



**Prifysgol Cymru**

Y Drindod Dewi Sant

**University of Wales**

Trinity Saint David

Wales Institute for Science and Art (WISA)

**BEng (Hons) Mechanical Engineering**

**Group Project (ACMA5009)**

**Reflective Project Report for Product  
Automation**

**Joshua Craig Thorngate**

**2008670**

## Disclaimer

“The information or images referenced within this report is the property of Sony UK Tec and shared in good faith.

Under no circumstances should this information be published without the permission of Sony UK Tec”

“It should be further noted that the information within this report may not be fact, it may have been generated to show how to analyse a project, thus, one should use this report for academic purposes only”.

# Table of Contents

|                                                            |           |
|------------------------------------------------------------|-----------|
| <b>1.0. Introduction.....</b>                              | <b>5</b>  |
| 1.1. Project Background .....                              | 5         |
| <b>2.0. Project Plan and Techniques .....</b>              | <b>7</b>  |
| 2.1. Planning Techniques.....                              | 7         |
| 2.1.1. Gantt Charts .....                                  | 7         |
| 2.1.2. Critical Path Analysis .....                        | 7         |
| 2.2. Project Plan .....                                    | 8         |
| <b>3.0. Project Reflection Aims and Expectations .....</b> | <b>11</b> |
| 3.1. Project Reflection Aims.....                          | 11        |
| 3.2. Project Reflection Expectations .....                 | 11        |
| <b>4.0. Project Reflection and Analysis.....</b>           | <b>12</b> |
| 4.1. Project Management Techniques and Methods .....       | 12        |
| 4.1.1. Initiation Phase.....                               | 13        |
| 4.1.2. Planning Phase .....                                | 14        |
| 4.1.3. Execution Phase .....                               | 17        |
| 4.1.4. Closing Phase.....                                  | 20        |
| 4.1.5. Summary .....                                       | 21        |
| 4.2. Project Analysis .....                                | 22        |
| 4.2.1. Project Initiation Analysis.....                    | 22        |
| 4.2.2. Project Planning Analysis .....                     | 22        |
| 4.2.3. Project Execution and Control Analysis .....        | 26        |
| 4.2.4. Project Closing Analysis.....                       | 30        |
| 4.3. Reflection and Analysis Summary.....                  | 30        |
| <b>5.0 Conclusion &amp; Future Recommendations.....</b>    | <b>33</b> |
| 5.1. Conclusion .....                                      | 33        |
| 5.2. Future Project Analysis Recommendations .....         | 33        |

|                                                    |           |
|----------------------------------------------------|-----------|
| <b>References.....</b>                             | <b>35</b> |
| <b>Figure References.....</b>                      | <b>38</b> |
| <b>Appendix One – Design Brief .....</b>           | <b>40</b> |
| <b>Appendix Two – Design Solution .....</b>        | <b>43</b> |
| <b>Appendix Three – Design Specification .....</b> | <b>47</b> |
| <b>Appendix Four – Cost Analysis .....</b>         | <b>50</b> |

## Table of Figures

|                                                                                                                                                                   |    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Figure 1. Shows the RCP Panel with its' Button Variations .....                                                                                                   | 5  |
| Figure 2. Shows the entire design of the Automation System on SolidWorks.....                                                                                     | 6  |
| Figure 3. Shows an Example Gantt Chart (What is a Gantt Chart?, 2021) .....                                                                                       | 7  |
| Figure 4. Shows the Critical Path Highlighted in Red (Eby, 2015).....                                                                                             | 8  |
| Figure 5 Shows the first set of tasks for the project and their CPA.....                                                                                          | 9  |
| Figure 6 Shows the second set of tasks for the project and their CPA .....                                                                                        | 9  |
| Figure 7 Shows the final set of tasks and their CPA.....                                                                                                          | 10 |
| Figure 8 Illustrates QTC (Riggie, 2017) .....                                                                                                                     | 11 |
| Figure 9. Shows the Project Process (Petersen, 2013).....                                                                                                         | 13 |
| Figure 10. Shows a Work Breakdown Structure for an Aircraft System (Cohen, 2018) .....                                                                            | 15 |
| Figure 11 Shows a Network Diagram (Petersen, 2013) .....                                                                                                          | 15 |
| Figure 12. Risk Management Assessment Table (Goth, 2017) .....                                                                                                    | 16 |
| Figure 13 Shows the phases of Team Development (Graffius, 2021).....                                                                                              | 17 |
| Figure 14 Thomas-Kilmann Conflict Mode Instrument .....                                                                                                           | 18 |
| Figure 15 Shows a Typical Commitment Curve (Petersen, 2013) .....                                                                                                 | 20 |
| Figure 16 Shows a Project Management Process WBS (Peterson, 2013) .....                                                                                           | 21 |
| Figure 17 Shows the roles within Belbin's Theory of Team Dynamics (Belbin's Team Roles:<br>How Understanding Team Roles Can Improve Team Performance, 2021) ..... | 27 |
| Figure 18. Shows the FMEA process (Forrest, 2021) .....                                                                                                           | 28 |

---

## 1.0. Introduction

---

This report will reflect on a previously completed project. It will use qualitative analytical approaches to compare the project with typical project management techniques and processes to understand the root cause of its' outcomes.

### 1.1. Project Background

Sony UK Technology Centre, a Manufacturing Company, discovered their high-end Remote-Control Panel (RCP) assembly process was inefficient.

RCP's control camera systems, thus, are crucial to business sales. The total manual build time for an RCP should be 17 minutes. However, operators took 5 minutes to insert 40 buttons of different colours and shapes into a front panel instead of 2 minutes, increasing assembly time to 20 minutes.

Quality issues also arose, with button damage and misplacement, contributing to rebuilds, thus, profit losses.

The project's purpose was to increase the process by 15% efficiency, increasing profitability, thus, project feasibility. An automation machine was designed and developed for this process. Figure 1 shows an RCP panel and figure 2 shows the automation machine design. The full design brief is shown in Appendix One and the solution in Appendix Two.



*Figure 1. Shows the RCP Panel with its' Button Variations*

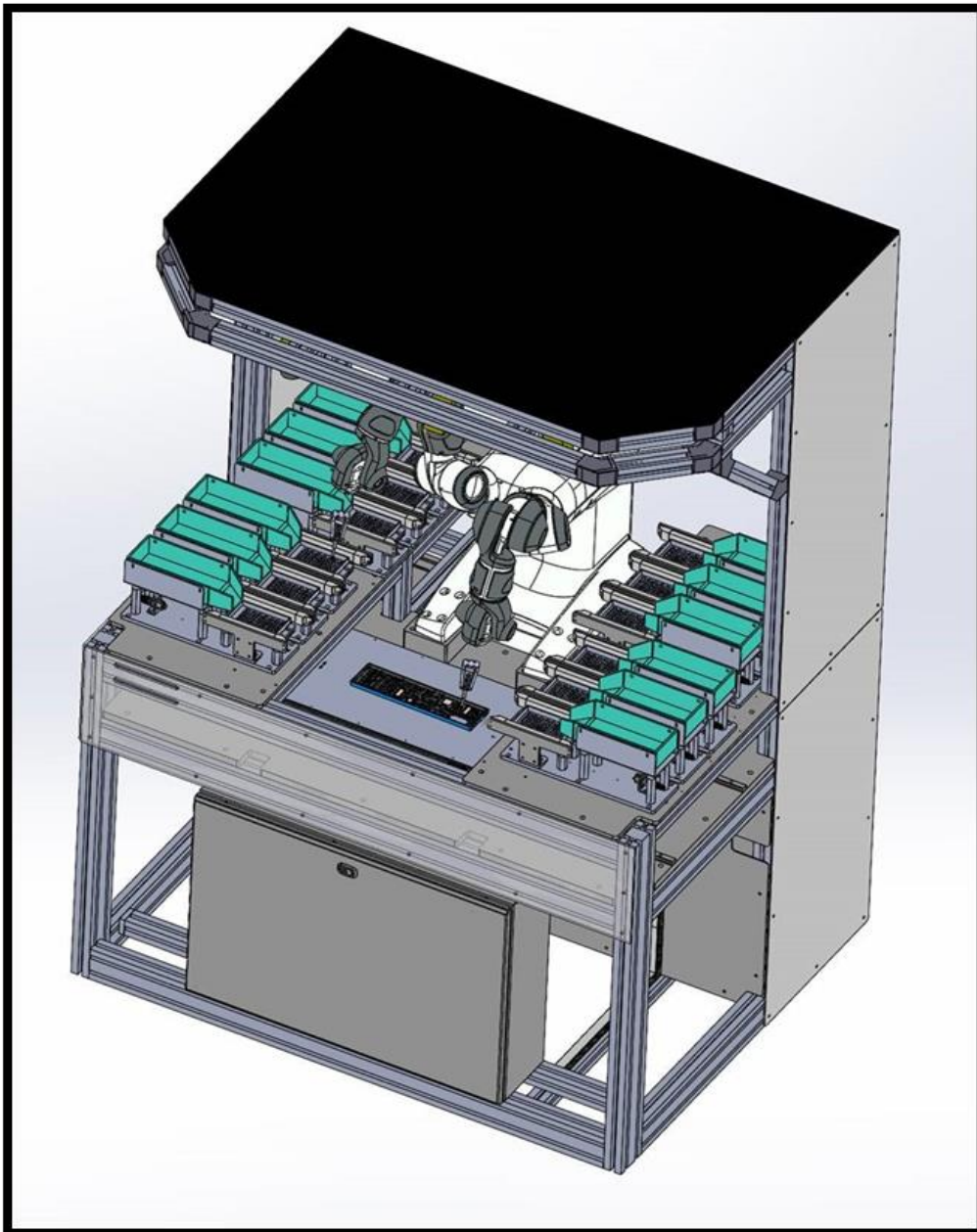


*Figure 2. Shows the entire design of the Automation System on SolidWorks*

Design Specifications were met, however, setbacks occurred. **Budgeting** was set at £40,000, however, it went over by £17,721. A cost breakdown can be found in Appendix Four.

The project was **delayed** by 3 months. A fully documented machine was set to be online by the end of June, however, it was installed online at the end of July, and documented at the end of September. Also, increased maintenance and modification were required due to the decreased machine **quality** before the final handover.

## 2.0. Project Plan and Techniques

This section of the report will outline the project plan and techniques used to carry out the project.

### 2.1. Planning Techniques

To ensure the project was completed on time, two project management techniques were utilised. Gantt Charts were used to manage the timeline, and Critical Path Analysis (CPA) to determine the prerequisite tasks.

#### 2.1.1. Gantt Charts

To obtain the desired results, Gantt Charts were used for project planning, scheduling and task monitoring. Tasks were broken down individually and assigned to rows, each having their duration (Advantages & Disadvantages of Gantt Charts, n.d.). An example is shown in figure 3.

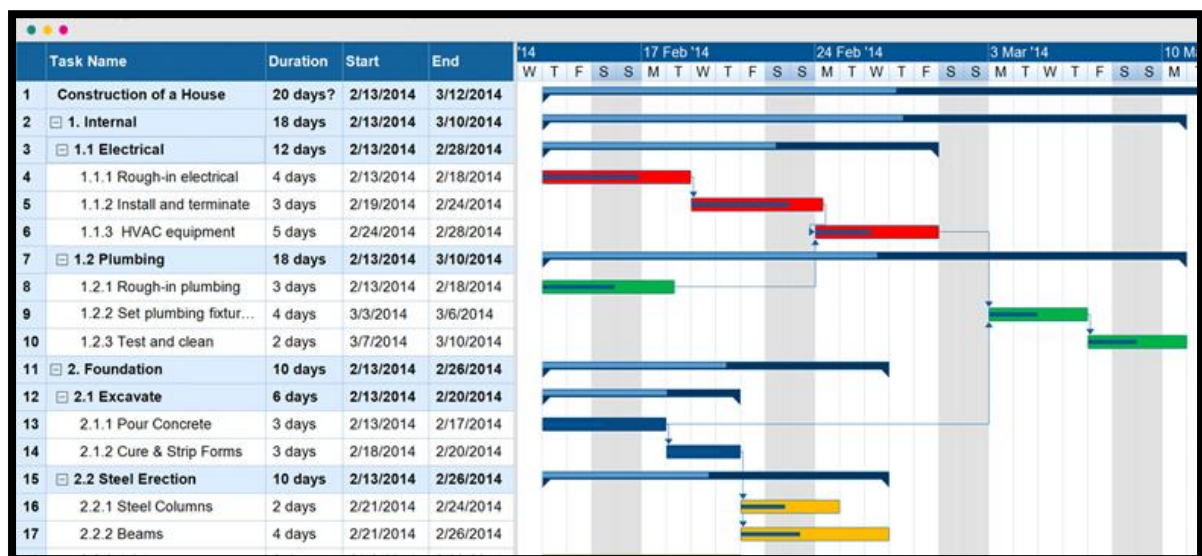


Figure 3. Shows an Example Gantt Chart (What is a Gantt Chart?, 2021)

#### 2.1.2. Critical Path Analysis

CPA determines the order in which tasks are completed to move to the next. For example, house walls must be completed before a roof can be fitted. If the critical path isn't followed, delays occur. CPA identified prerequisites and dependencies as shown in figure 4 (Eby, 2015).

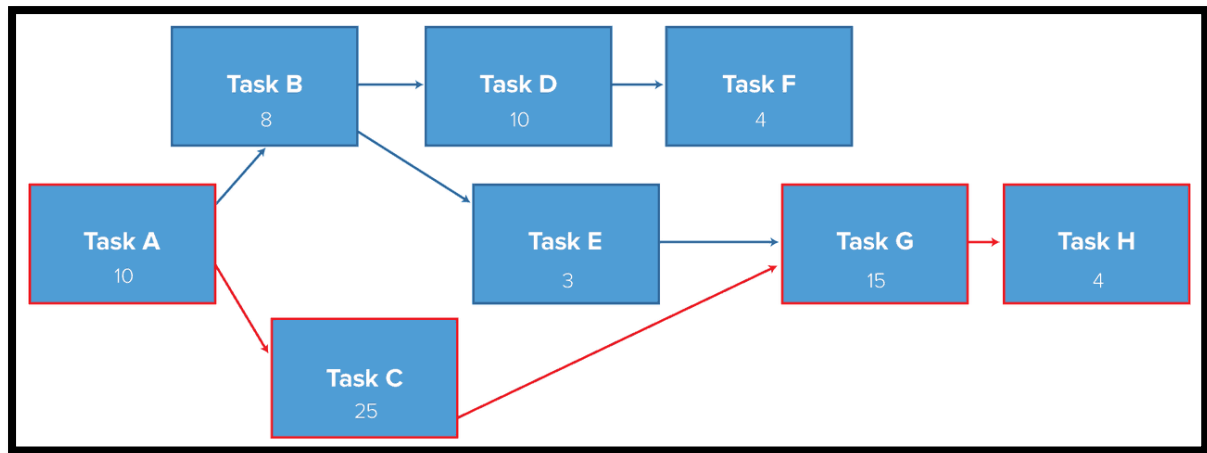


Figure 4. Shows the Critical Path Highlighted in Red (Eby, 2015)

## 2.2. Project Plan

The proposed start date for the project was the end of March 2020, with a fully tested and documented machine online by the end of June 2020, thus, before Sony UK Tech's Summer holiday break.

Deadlines were set due to customer demands, ensuring process efficiency increased by 15%, decreasing human error, thus, meeting product demand before the summer break.

A design plan was created, ensuring deadlines were met, whilst complying with design specifications shown in Appendix Three. The projects' Gantt Chart and CPA can be seen in figures 5, 6 and 7 in retrospective order.

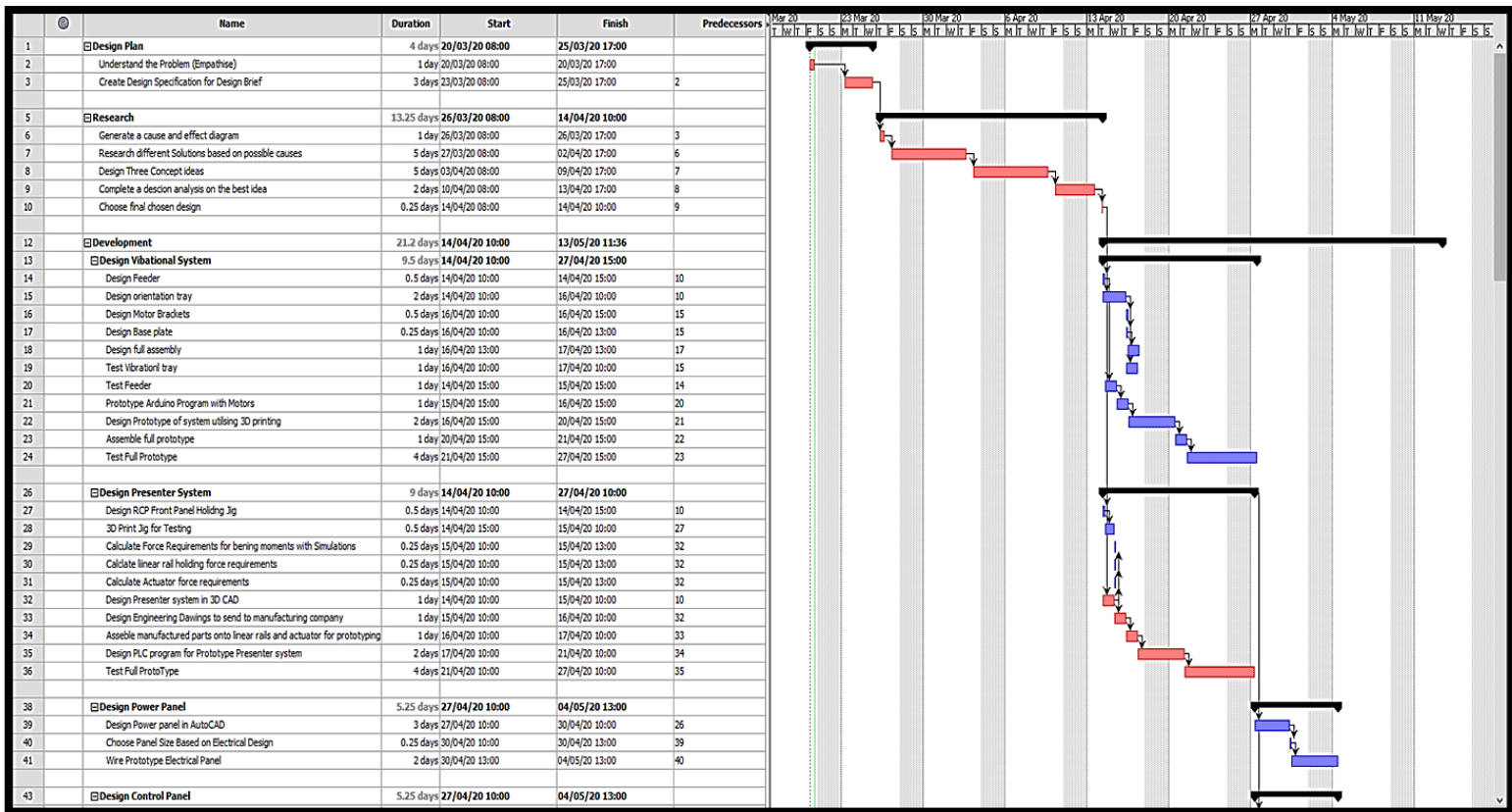


Figure 5 Shows the first set of tasks for the project and their CPA

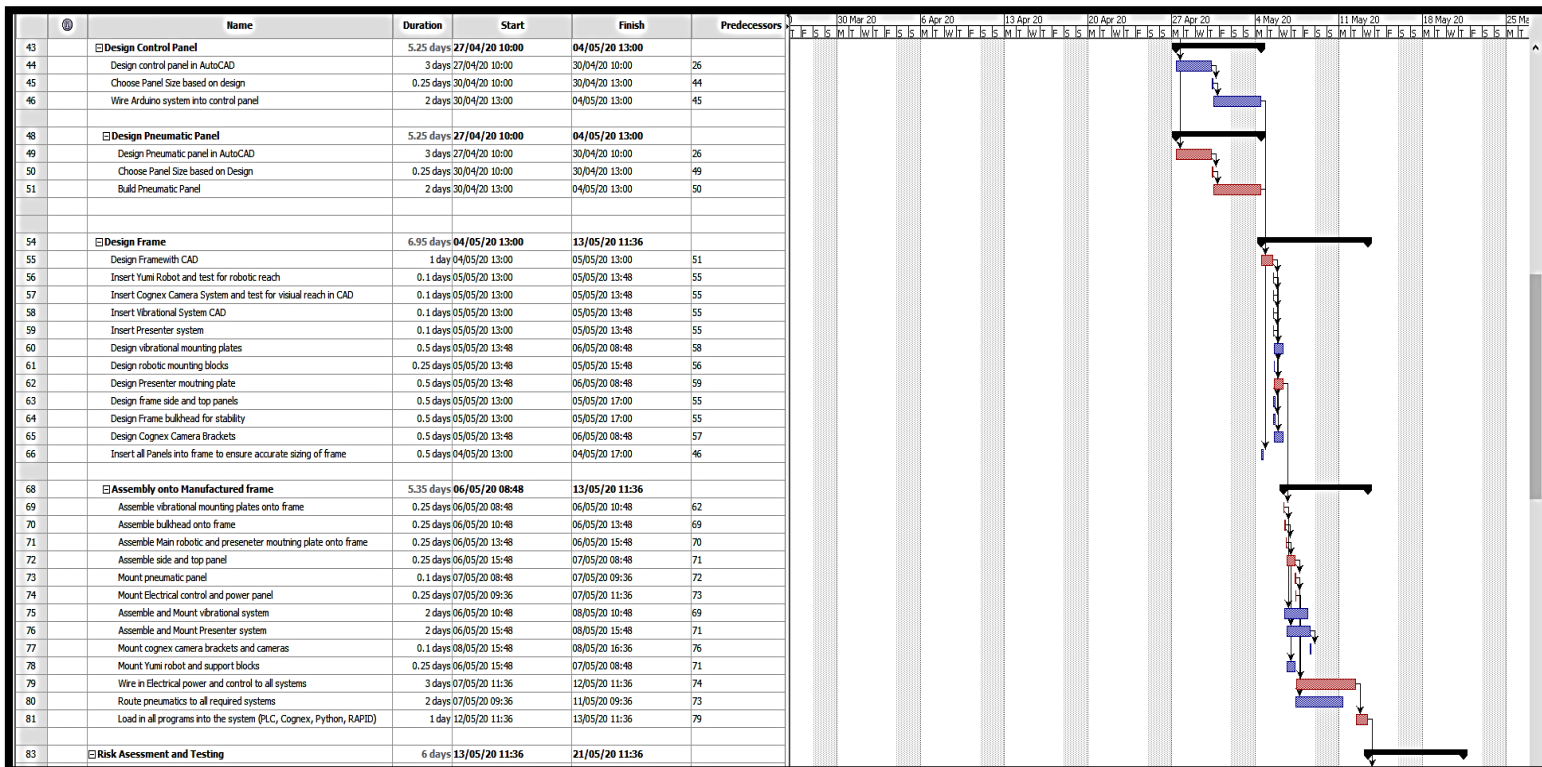


Figure 6 Shows the second set of tasks for the project and their CPA

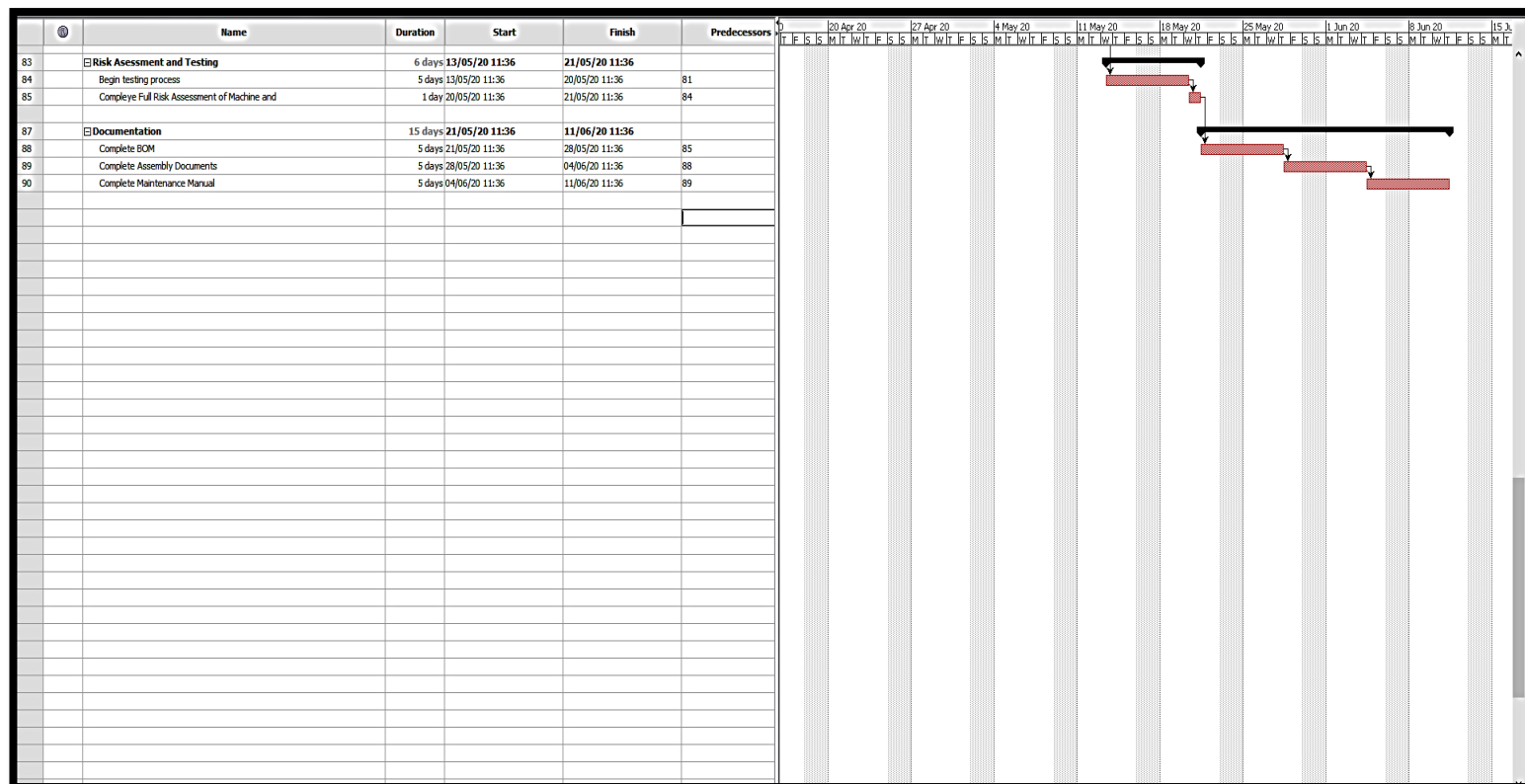


Figure 7 Shows the final set of tasks and their CPA

The Gantt Chart shows a 96.5-day duration time. However, some tasks are shown to be completed concurrently which normally requires more people allocated to that task, hence the project completion for mid-June. Each task is broken down into sub-tasks with their allocated duration, feeding into their main task, contributing to the overall duration of each main task and the project duration. Each task including main tasks, have prerequisites, thus, indicating the CPA.

---

### 3.0. Project Reflection Aims and Expectations

---

This section will outline the project reflection aims and expectations.

#### 3.1. Project Reflection Aims

The project reflections' purpose is to compare and contrast typical project management techniques with the ones used in the automation project, to find a root cause analysis of the time delays, increased budget requirements and quality issues, thus, providing suggestions on how one can improve this type of project with a managerial approach.

#### 3.2. Project Reflection Expectations

One expects many possible root cause contributions instead of one overall root cause, which may be found whilst comparing and contrasting the management techniques and strategies used with current literature, thus, one can put these techniques in place for future mitigation, thus, with many possible causes, no one method can eradicate the problem, only mitigate it. Quality, Time and Cost (QTC) must be analysed, which dictates that not all three can be achieved, one must sacrifice one for another, such as reducing time may cause an increase in cost, or cause quality issues as figure 7 shows (Riggie, 2017).

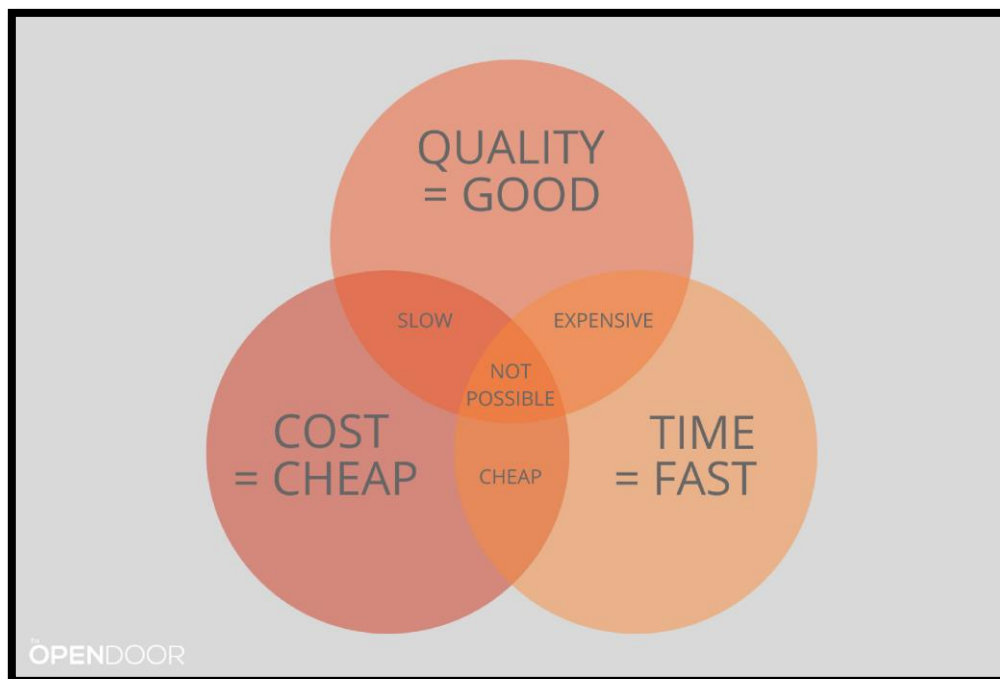


Figure 8 Illustrates QTC (Riggie, 2017)

---

## 4.0. Project Reflection and Analysis

---

The automation project met the design specification, however, to achieve it, increased duration and resources occurred, such as working overtime, carrying out rework and creating further maintenance manuals.

This section will analyse project management techniques, indicating the theories of success, thus, comparing the techniques with the automation project to discover the causes of the setbacks, whilst providing suggestions for future automation project management plans.

### 4.1. Project Management Techniques and Methods

The key to any successful project is careful planning. Creating a project plan, although initially time-consuming, can save time and money in the future, without which, problems may occur down the line, creating setbacks.

*“Those who plan do better than those who do not plan, even though they rarely stick to their plan.”* – Winston Churchill

Researching into project management, one came across the Project Management Body of Knowledge (PMBOK), which set the standard for project management.

Projects should have a five-stage process, **Initiation, Planning, Execution, Control and Close** as figure 9 shows, indicating that control should occur throughout, with planning and executing adapting based on project change which allows for successful closure (Petersen, 2013 p9).

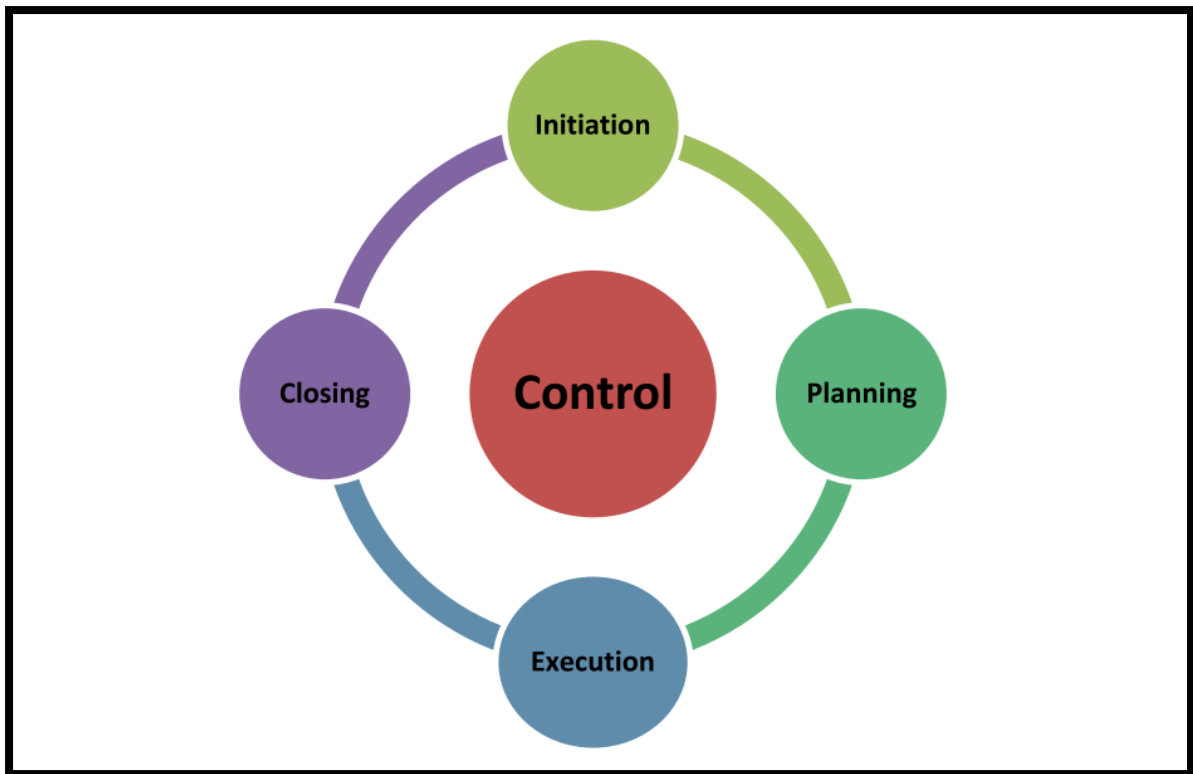


*Figure 9. Shows the Project Process (Petersen, 2013)*

Heerkens (2001, p12) also states the same process, however, leaves out the control segment. This indicates that this process is common practice, whereby controlling throughout is assumed.

#### 4.1.1. Initiation Phase

Heerkens (2001, p12) further states the initiation stage is to understand the project objective. This is where a team should be identified and formed. Petersen (2013, p12) elaborates on this and states what the steps of the project are, the reasons behind it, and identifies the stakeholders, thus, one needs to create **Specific, Measurable, Attainable, Relevant and Time-Bound** (SMART) objectives.

Therefore, the project plan needs to be specific enough to meet the problem, enabling the project to have set targets, thus measurable. It needs to be attainable, meaning setting realistic goals, whilst being relevant to meet business needs, and should be time-bound thus having a deadline (Herridge, 2021).

### 4.1.2. Planning Phase

Once initiation is set and analysed, project feasibility is undertaken, determining the Return on Investment (ROI). If feasible, one can move onto project planning within the process cycle.

The project planning stage follows on from the design brief as shown in Appendix One, as one can create a design specification from the brief as shown in Appendix Three.

Key deliverables are common practice, as Petersen (2013, p24) states they are as follows:

- Work Breakdown Structure (WBS)
- Set a budget
- Deadlines and Milestones
- Task Responsibility and Project Organisation Chart
- A list of Resources
- A Risk Management Plan
- A list of Pending Issues and Decisions
- Team Performance Measurement Baseline

At the project start, a **Kick-off Meeting** should occur, allowing teams to work together more effectively, ensuring project presentations occur, allowing everyone to understand the design brief and specification, whilst contributing to key deliverables (Cohen, 2018).

(Cohen, 2018) further states to utilise a **DACI** framework used in Six Sigma, whereby a **Driver** moves the project forward, interfacing with the team and stakeholders, obtaining information about decisions. An **Approver** makes key decisions, signing off deliverables. A **Contributor** offers their services such as advice or task completion. Finally, the **Informed** are the people such as stakeholders, who receive the project status.

Many techniques can be used within project planning, such as **Gantt Charts** and **CPA** as discussed previously. However, other techniques such as **Work Breakdown Structures (WBS)** as shown in figure 10 can be utilised.

Cohen (2018) mentions a WBS is all the project tasks that are broken down into subtasks with as many levels as one likes, set up like a hierarchical structure. Level 1 is the project objective, and level 2 would be the main tasks leading into the objective. Level 3 are the tasks that lead into the level 2 tasks. Thus, the subtasks are the deliverables. One must ensure not to overcomplicate the WBS with too many levels.

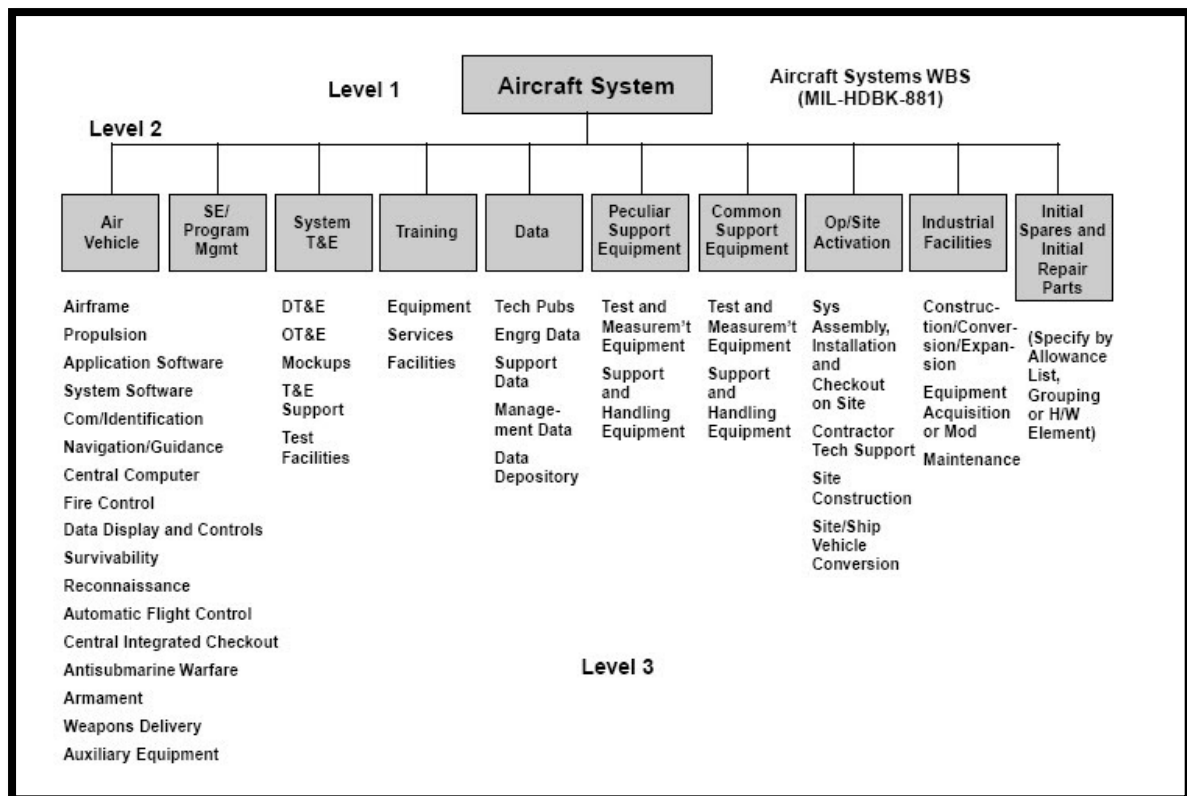


Figure 10. Shows a Work Breakdown Structure for an Aircraft System (Cohen, 2018)

**Network Diagrams** are another technique, which are project workflows, presented visually. Tasks and responsibilities are notes in boxes with arrows mapping the sequence and project schedule as figure 11 shows. These can be known as CPA, however, some techniques have alternative names and normally CPA is developed after Network Diagrams (Malsam, 2020).

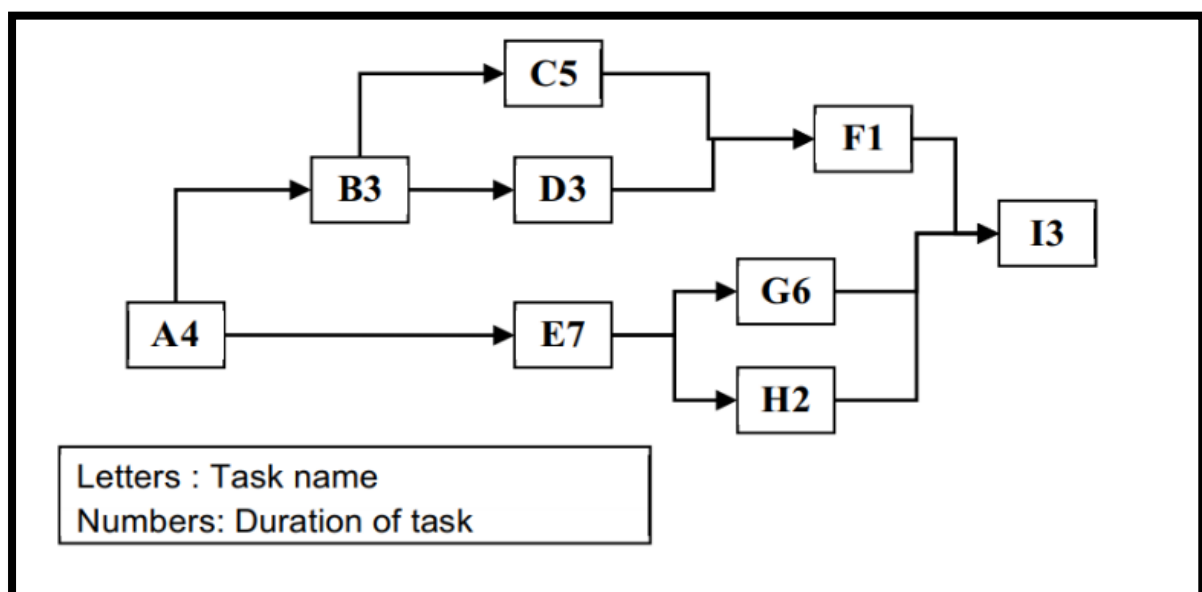


Figure 11 Shows a Network Diagram (Petersen, 2013)

One can also use **Float** alongside CPA, which are tasks non-dependant on others, thus, more flexible (Petersen, 2013 p.31).

**Managing Risk** is highly critical to any projects' success. One must define all possible risks, managing them by way of elimination, acceptance or mitigation to which can save time and money (Ray, 2021).

Risks can be negative but also positive, such as an early project finish. Once risks are identified, one must evaluate the impact and probability, document the risk, then define a risk action and contingency plan thus, reducing the risk rating as shown in figure 12.

|                                                   | Probability & Impact Risk Ranking |        |         |          |
|---------------------------------------------------|-----------------------------------|--------|---------|----------|
| Probability<br>(of occurrence of the harm/threat) | Negligible                        | Minor  | Serious | Critical |
| Frequent                                          | Low                               | Medium | High    | High     |
| Probable                                          | Low                               | Medium | Medium  | High     |
| Remote                                            | Low                               | Low    | Medium  | Medium   |
| Improbable                                        | Low                               | Low    | Low     | Low      |

Figure 12. Risk Management Assessment Table (Goth, 2017)

Figure 12 shows the correlation between impact and probability on risk rating. For example, a frequent probability with a negligible impact will be low risk. However, with a minor impact, it becomes a medium risk and so on. Actions can reduce probability or impact, thus reducing the rating. Negligible is acceptable, Minor can be accepted or mitigated, but Serious and Critical must be mitigated or eliminated (Petersen, 2013, pp.35-36).

Finally, one must organise a **Team**. A project manager should choose the type of team dynamics required for the project, which will meet expectations and reduce barriers, whilst embracing any changes that occur throughout. A successful team will have ground rules, be good at communication to prevent errors and loss of information. They should take mutual accountability and make joint decisions for beneficial risk. Their collaboration should provoke creativity and innovation (Petersen, 2013, p.38).

One could use Tuckman's Model of team development, as shown in figure 13.

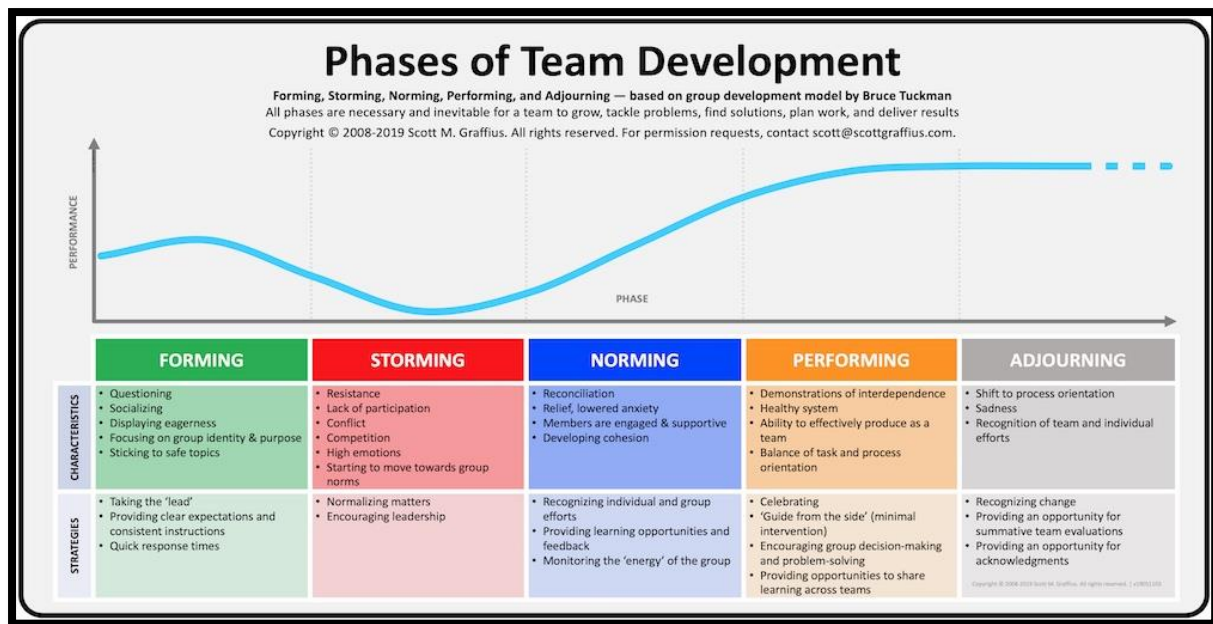


Figure 13 Shows the phases of Team Development (Graffius, 2021)

In Tuckman's model, one can see the different stages a team goes through. A new team will have a **Forming** stage, whereby eagerness and politeness occur, therefore, a leader is required, ensuring expectations are understood. When time passes, **Storming** begins whereby resistance causes competition or a lack of participation, thus, the leader must encourage feedback, identify issues, and normalise the situation to build trust. When **Norming** occurs, team purpose emerges, with goal and role understanding, thus, the leader must show appreciation and support to ensure high motivation continues with cohesion development.

Increased productivity occurs within **Performing** with self-management and consistent performance; thus, the leader must guide from the side and encourage decision making.

Finally, **Adjourning** occurs whereby the phase shifts to process orientation, teams' collective efforts are recognised and accomplishments are celebrated (Graffius, 2021).

#### 4.1.3. Execution Phase

This phase is the actual execution of the project and can be the most critical. With a good plan in place, this stage should flow, with task allocation being delegated based on one's skill. The project manager must coordinate the team, whereby involving the right technical people (Breesam and Ali, 2017).

Following the plan, a project leader should leave the technical work and concentrate on management, such as **Risk Management** utilising risk management tables discussed previously. One can further **Manage Change** as it is an inevitable occurrence, which may affect the timescale, team or target. One must understand the impact on QTC and project scope, thus, one must decide within QTC which is the priority. A project manager should decide to accept or reject change, whereby, threats and opportunities can be both seen as negative or positive, as threats can lead to good change. For example, a threat could be a competitor having cheaper products, thus, an opportunity arises to increase process efficiency to produce cheaper products (Alexander, 2019).

**Conflicts** need to be managed by the project manager turning them into collaboration, thus, utilising words like “us” instead of “you”. This allows for joint responsibility. A Kilmann Conflict Mode Instrument Questionnaire allows one to decide a goal phase to be in as shown in figure 14.



Figure 14 Thomas-Kilmann Conflict Mode Instrument

*(Can brief training improve managers' ability to deal with conflict? | Nursing Times, 2019)*

One must also ensure change management occurs which utilises different techniques that enable the guidance of teams or individuals to prepare for change, allowing them to be supported to adapt and adopt the change which will then lead to desirable circumstances, leading to success (Perkins, 2018).

Execution mainly consists of managing the project tasks and managing change to prevent the team from resisting change. One must communicate the benefits of change to all stakeholders, ensuring that buy-in is achieved (Perkins, 2018).

A priority on the QTC must be set. For example, if the quality is more important than cost. One must ensure a project plan is followed incorporating change throughout, therefore, executing **Control and Reporting**. Control is done throughout the five-stage process whereby communications occur to stakeholders routinely, ensuring they know where in the process the project is. The more routinely this is done, the more one prevents going off-track and not completing tasks that would now require change. Therefore, within control and reporting, risk assessments and change management should occur along with team dynamic management utilising Belbin's Theory of Team Dynamics.

One can also manage re-work if there are any problems such as a mechanical failure that requires modification due to an incorrectly designed component. This should be carried out before project closure.

Controlling means the project manager must ensure quality throughout before completion, managing the risks, raising issues, whilst keeping within budget and timescales. Intertwining this with communication allows for a transparent project. Consistency is key as commitment from the team and stakeholders increase over time as figure 15 shows.

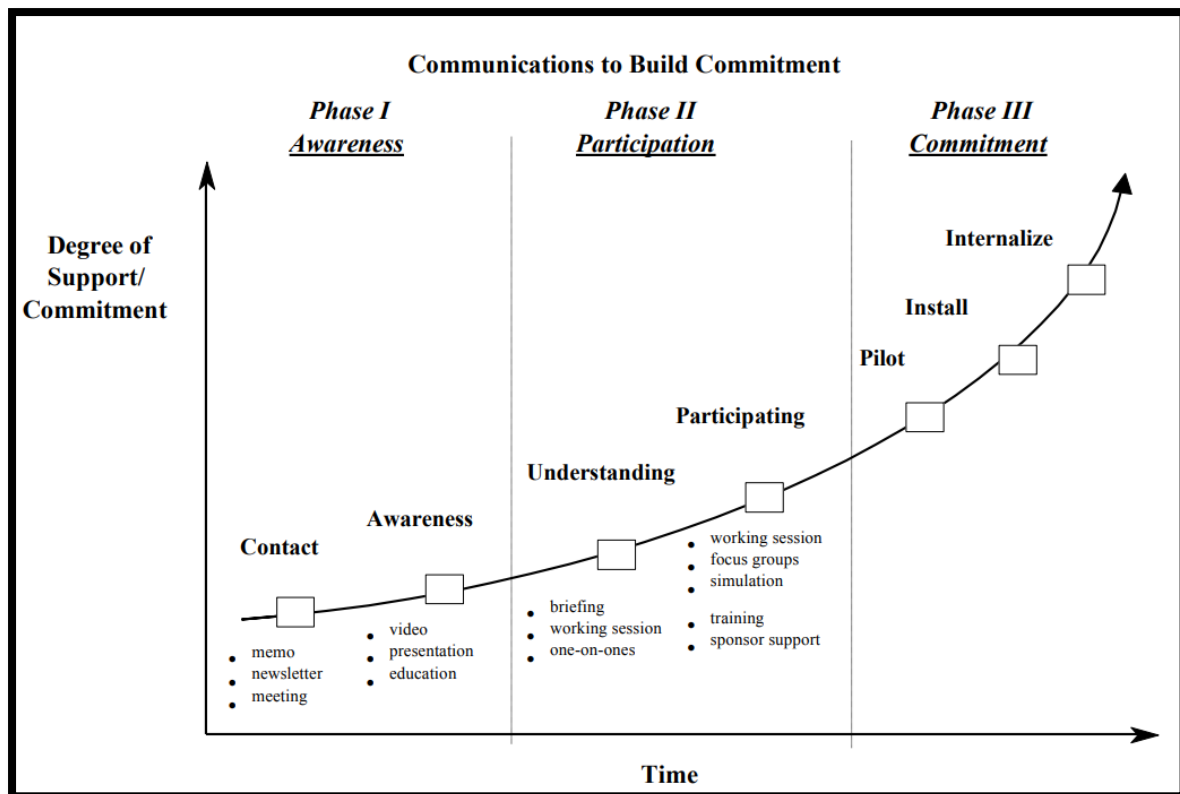


Figure 15 Shows a Typical Commitment Curve (Petersen, 2013)

Therefore, the control phase is mainly about ensuring transparency and involvement with stakeholders. Weekly presentations, email updates and informal talks can be a good method to ensure this transparency occurs, whilst utilising the correct method based on the person one wants to communicate with (Petersen 2013, pp.61-66).

#### 4.1.4. Closing Phase

The final phase of the process is the closing phase. This is the formal acceptance of the finished project by the client or sponsor. All tasks are closed, full documentation is completed and signoffs are achieved. Signoffs, normally by the project manager, can also occur throughout the project when milestones or tasks are completed. This ensures the project is on track, whilst noticing any change requirements needed and further ensuring the end closure is a smoother process.

Team evaluations also occur in this phase, praising them for their efforts. Finalising budgets and evaluating results that aid in the learning and development for future projects also occur within this phase. One will further review all risk and change management action plans

ensuring the project was not negatively affected in any way and if there are any reoccurring action requirements.

One will then complete full documentation before celebrating project closure, uplifting team spirits to encourage future project motivation (Petersen 2013, pp.77-79).

#### 4.1.5. Summary

In summary, a successful project has a project manager who follows a set process as shown in figure 16. Feasibility studies are completed within initiation whilst setting SMART objectives. Planning is key, breaking the project down into subtasks and allocating work logically. Execution must ensure risk and change management occurs whilst following the critical path to carry out tasks, utilising resource to complete some tasks concurrently. Communication is key for transparency, limiting risks, therefore, ensuring the closure runs smoothly with full documentation and ensuring feedback is achieved, encouraging learning.

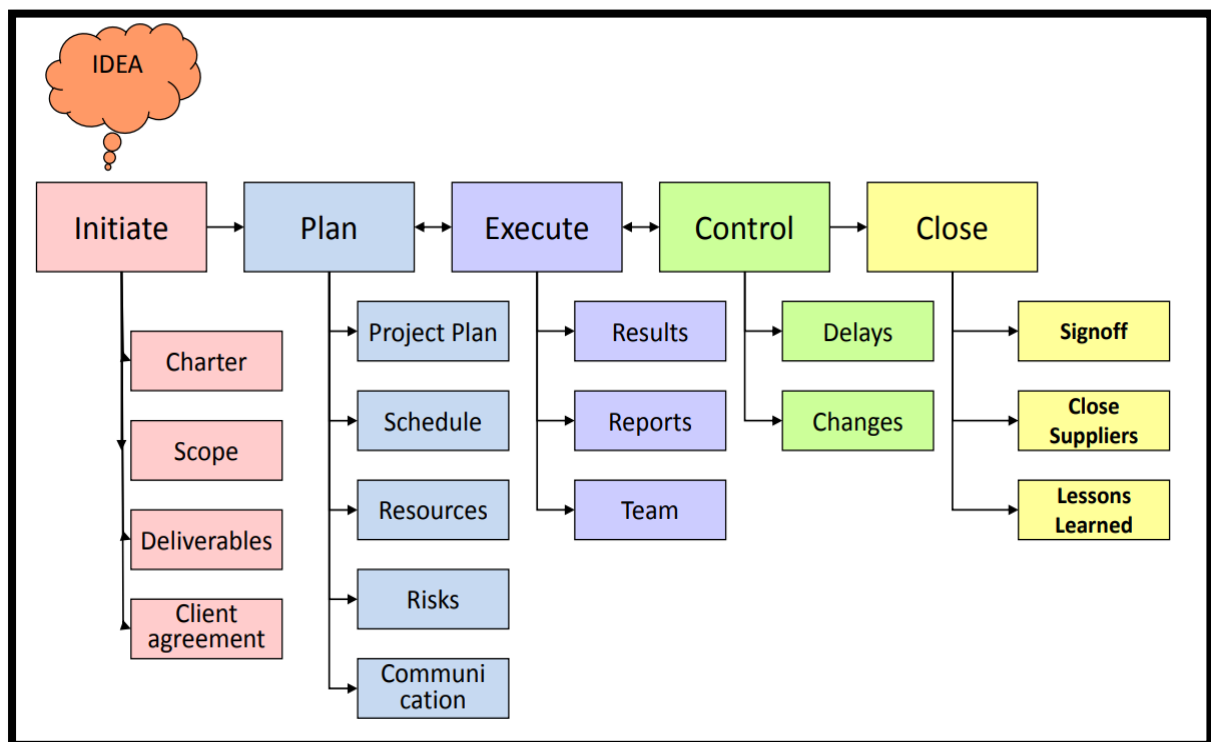


Figure 16 Shows a Project Management Process WBS (Peterson, 2013)

## 4.2. Project Analysis

This section describes how the RCP automation project was carried out compared to the PMBOK process, discovering similarities and differences to understand how QTC may be affected. Although the RCP automation project did not follow a process, it will be analysed utilising the PMBOK five-stage process.

### 4.2.1. Project Initiation Analysis

The RCP automation project did not have an effective initiation stage. A quick description was given to oneself who was new to mechanical design. This shows concerns, as stated previously, project management should be carried out separately from the technicality to gain an outside perspective.

No SMART objectives were set due to the lack of a project manager and one being new to the role of mechanical design engineer, thus, no clear vision could be obtained.

To gain a specific idea of what the project objectives were, communication was required, although this took weeks due to the lack of initiation and project management. This led to a delay in obtaining a design brief which was created by oneself to then create a late design specification. Furthermore, project feasibility was not carried out before the project began, thus, increasing risks of failure.

The project was given a deadline before the factory summer shutdown, therefore, approximately 3 months. This was given before a project timeline was set, such as understanding what was required, thus, understanding if it was realistic. Therefore, before it began, one did not understand if the project was feasible or realistic, which possesses many problems.

### 4.2.2. Project Planning Analysis

Similarly compared to the PMBOK style, the automation project used two similar techniques within project planning, such as **Gantt Charts** and **CPA**. This would have led to easier management of tasks, understanding what was required and by when. However, Petersen (2013, p24) states there are many techniques to utilise within planning. Planning is an important phase as it can limit risks throughout.

Although one utilised a Gantt Chart, one created it based around the deadline, not setting realistic task durations but, changing task times to suit the deadline. This was done after logically setting out the tasks and CPA, then altering them based on the fact that it originally exceeded the deadline.

In doing so, false completion times were created, on top of already committing to an unrealistic deadline. If one was to allocate work hours next to the real task duration, one would be working above 100% capacity, thus, time-bound aspects to QTC will suffer, which would be opposing SMART objectives. Having no project manager to recognise this risk early on, led the project to early complications.

One did, however, create a CPA for the project, which Eby (2015) states, aids one to identify task prerequisites and dependencies to understand the critical path and critical tasks within the Gantt Chart to plan time more effectively.

Nevertheless, due to the lack of a team, one had to carry out the majority of the tasks oneself, such as project management tasks which are hidden, designing, developing and so on.

CPA has to be followed as stated in the previous literature, however, some tasks as figure 5, 6 and 7 show, can be carried out concurrently with more resource. Thus, due to the lack of a team, this could not be achieved, causing tasks to take longer. On top of that, no contingencies were allowed for, which would be managed within change management according to the previous literature.

To prevent risks and delays, one should have done what Eby (2015) stated, listing the dependencies to set tasks and allocated them to a person of which had the right skillset. Thus, to do so, a team should have been formulated utilising **Belbin's Theory of Team Dynamics** to understand what skills were required, whilst carrying out tasks concurrently, reducing time. For example, two tasks with a week duration time each would take one person two weeks to complete. However, it would take one week with two people completing them concurrently with no prerequisites.

Cohen (2018) states that a **WBS** is important. The automation project had a WBS, but it was built in with the Gantt Chart as figures 5, 6 and 7 shows. This was useful to see what subtasks completed the main tasks. However, a visual WBS was not created, therefore, preventing an easy visualisation of the project scope and structure, which would have aided in better

organisation and highlighted achievability and which team members would be required, therefore, one could have used this to further breakdown costs and human resource.

The most important element of the planning stage is **Team formation**. This is extremely critical. The purpose of a team is to work together as a unit, having a common objective, of which to perform well, to take pride in their team whilst sharing responsibility, and having trust and above all, good communication.

Wehbe (2017) has stated that teams are extremely important when carrying out a project. With the lack of a team at the start of the automation project, one missed out on the following:

- Teams learning skills from one another
- Faster innovation
- Team self-monitoring
- Increased efficiency
- Different perspectives and feedback
- Motivational unity

It is starting to become apparent that a team is critical for any large project. The lack of a team during the planning stage of the automation project created many risks and initial errors. Referring to the information by Cohen (2018), with a team, one could have created a kick-off meeting, gaining a better objective understanding, thus, creating SMART objectives. Furthermore, due to the lack of a team, **DACI** was not utilised decreasing project efficiency, thus, affecting QTC.

Furthermore, forming a team at the planning stage would allow for the SMART objectives to be set, intertwining them with Belbin's Theory to understand what skillset was required for each task, understanding the achievability and thus, saving time and money. Adding to this with the increased experience and knowledge, more innovative ideas could have been created, which not only increases design and time management efficiency but also increases the teams' skillset from them learning from one another, thus, further increasing motivation whilst promoting shared responsibility (The Importance of Teamwork in the Workplace | BrightHR, 2021).

**Cost Analysis** is also an important section within the planning stage to ensure one stays within budget or applies for the correct budget. It can be seen from Appendix Four, that a cost

breakdown has been completed. However, in this cost analysis, the budget of £40,000 was exceeded by £17,721.

Petersen (2013, p24) has stated an important factor was to set a budget. The budget for this project was completed by oneself, with no prior machine design experience. Therefore, a number was generated based on one's perspective of what **may** be needed. The cost analysis in Appendix Four was completed within the Execution phase of the project. Therefore, this would further tie in with the team development and kick-off meeting mentioned. If one developed a team from the start, one would then use the kick-off meeting to understand the cost of the project, utilising many skills and experiences to decide on a more accurate price, thus, putting together a more accurate cost analysis. This would have been one of the reasons for going over the budget. This also falls within the WBS and understanding the duration and cost of each task. Furthermore, allowing for more experience would mean a reduction in manufacturing costs, reducing the overall cost of the project.

Petersen (2013, p24) further states one should also have a **Risk Management Plan**, which the automation project did not. The Gantt Charts had no room for contingencies and was forged to the deadline, thus, inaccurate. However, the Gantt Chart did have a **Testing** stage, allowing one to place the machine online and complete the testing to ensure the machine met specifications.

Risk management should have been incorporated into this phase by the project leader, allowing the team to contribute their knowledge, therefore, allowing opportunities to be seized and risks to be eliminated, accepted or mitigated. For example, within this automation project, there was a lot of pushback and non-acceptance from the operators which will be discussed further on. This pushback should have been highlighted as a potential risk, therefore, eliminating the risk from the start, as this risk caused a lot of delays and operator negotiations, which were made very late in the project.

Additionally, risk management would highlight opportunities, such as gaining operators' understanding of product assembly which not only gets their buy-in as they feel involved, but one gets their understanding of how the product is built and any potential causes for concern with the build, mitigating risks, thus, preventing time delays or increased costs or quality issues later on.

### 4.2.3. Project Execution and Control Analysis

Within Execution, one designed three mechanical concepts and chose the best solution for automating the RCP project by **oneself**.

Once the mechanical design was finalised as shown in Appendix Two, the engineering drawings were sent off for manufacture. However, with limited knowledge and experience, one designed the components too complicated, and chose the least efficient manufacturing methods, increasing time and cost.

**Team Formation** was performed within execution and not within planning. Due to the lack of electrical and software engineering knowledge, one had to gather a team at this late stage to fill those roles. late team formation eliminates early team formation benefits as previously mentioned. Additionally, it caused a knock-on effect due to the Tuckman Model, whereby, the team underwent the phases at a later point in the project, causing the execution to be delayed due to conflicts, which require additional management before a norming and performing stage can be accomplished.

Therefore, eventually after the delays with these conflicts, the team benefits started to occur, and the electrical and software design was completed as shown in Appendix Two

After the team was performing and the building of the machine progressed more efficiently, the project was still behind as the commitment and benefits of early team formation were lost. Full commitment such as being in phase 3 of the commitment curve shown in figure 15, could have been achieved if early team formation occurred, however, as this was not the case, the team found themselves in phase 2 of this curve, thus, planning and early team formation would have allowed for easier execution and control at later stages.

Therefore, due to delays, the machine was built after the deadline. Once installed, there were many arising issues whereby the machine did not perform to its required function. There may have been many causes for this. The first was possibly due to the lack of specialist knowledge at the early stages, thus, causing simple design and manufacturing errors. This could have been avoided with specialist team knowledge, whereby one could utilise Belbin's Theory of Team Dynamics mentioned previously and shown in figure 17, to gain the required knowledge for the machine.

This can be related to DACI whereby a successful team requires a mix of skills and characteristics of which each has an important role best suited to their skillset and personality. It can be seen from figure 17 that there are many roles to fill, although not all need to be filled, one would require as many as possible to eliminate weaknesses. The main roles required are the coordinator and shaper. Project management and the critical roles were lacking within the automation project.

A project manager is important due to the previously mentioned reasons. Additionally, it can be seen in figure 17, a shaper challenges a team to improve. This is the role of someone who motivates the team and allows them to move and remain in the performing stage. The coordinator acts as the chairperson. This is important due to conflict resolution, risk management, project planning, and communication with various departments which increases transparency. Having these roles filled from the start would have allowed the project to have a clear vision. (Belbin's Team Roles: How Understanding Team Roles Can Improve Team Performance, 2021).

|                        |                       |                                      |
|------------------------|-----------------------|--------------------------------------|
| Action Oriented Roles  | Shaper                | Challenges the team to improve.      |
|                        | Implementer           | Puts ideas into action.              |
|                        | Completer Finisher    | Ensures thorough, timely completion. |
| People Oriented Roles  | Coordinator           | Acts as a chairperson.               |
|                        | Team Worker           | Encourages cooperation.              |
|                        | Resource Investigator | Explores outside opportunities.      |
| Thought Oriented Roles | Plant                 | Presents new ideas and approaches.   |
|                        | Monitor-Evaluator     | Analyzes the options.                |
|                        | Specialist            | Provides specialized skills.         |

Figure 17 Shows the roles within Belbin's Theory of Team Dynamics (Belbin's Team Roles: How Understanding Team Roles Can Improve Team Performance, 2021)

One way in which a coordinator could utilise project management techniques is to use a risk management tool which could have also been utilised by oneself for the design. The tool is **Failure Mode and Effects Analysis (FMEA)**. This could have been used for instances to understand the severity of different tasks, as well as design tasks. It is a qualitative tool that anticipates what may fail with a product or process. It identifies possible failures, how they

may fail and the effect of the failure, as well as possible causes, and how likely it can be detected (Lolli et al., 2015, p6342).

The methods and processes used to carry out an FMEA can be seen in figure 18. One could have utilised this technique to understand what the potential failures were with the design, such as not selecting the correct material for the vibration system, which may have caused the vibration system to fail. The occurrence could have been high due to this, and the severity would have been a hard failure as it would stop the machine from performing its primary function. This could have then been analysed to ensure how one could detect this and choose the correct material by following a standard and completing a friction analysis and so on.

Furthermore, the project manager could have applied this method to the building of the machine. Not having the correct specialist could cause a failure of the electrical build for example, again, causing a hard failure due to loss of function and so on.

| Process Step           | Potential Failure Mode                | Potential Failure Effect                                                                                           | SEV <sup>1</sup>                          | Potential Causes                                                                                               | OCC <sup>2</sup>                             | Current Process Controls                                                                                         | DET <sup>3</sup>                                            | RPN <sup>4</sup>                                   | Action Recommended                                                                                                                                                 |
|------------------------|---------------------------------------|--------------------------------------------------------------------------------------------------------------------|-------------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| What is the step?      | In what ways can the step go wrong?   | What is the impact on the customer if the failure mode is not prevented or corrected?                              | How severe is the effect on the customer? | What causes the step to go wrong (i.e., how could the failure mode occur)?                                     | How frequently is the cause likely to occur? | What are the existing controls that either prevent the failure mode from occurring or detect it should it occur? | How probable is detection of the failure mode or its cause? | Risk priority number calculated as SEV x OCC x DET | What are the actions for reducing the occurrence of the cause or for improving its detection? Provide actions on all high RPNs and on severity ratings of 9 or 10. |
| ATM Pin Authentication | Unauthorized access                   | <ul style="list-style-type: none"> <li>Unauthorized cash withdrawal</li> <li>Very dissatisfied customer</li> </ul> | 8                                         | Lost or stolen ATM card                                                                                        | 3                                            | Block ATM card after three failed authentication attempts                                                        | 3                                                           | 72                                                 |                                                                                                                                                                    |
|                        | Authentication failure                | Annoyed customer                                                                                                   | 3                                         | Network failure                                                                                                | 5                                            | Install load balancer to distribute work-load across network links                                               | 5                                                           | 75                                                 |                                                                                                                                                                    |
| Dispense Cash          | Cash not disbursed                    | Dissatisfied customer                                                                                              | 7                                         | ATM out of cash                                                                                                | 7                                            | Internal alert of low cash in ATM                                                                                | 4                                                           | 196                                                | Increase minimum cash threshold limit of heavily used ATMs to prevent out-of-cash instances                                                                        |
|                        | Account debited but no cash disbursed | Very dissatisfied customer                                                                                         | 8                                         | <ul style="list-style-type: none"> <li>Transaction failure</li> <li>Network issue</li> </ul>                   | 3                                            | Install load balancer to distribute work-load across network links                                               | 4                                                           | 96                                                 |                                                                                                                                                                    |
|                        | Extra cash dispensed                  | Bank loses money                                                                                                   | 8                                         | <ul style="list-style-type: none"> <li>Bills stuck to each other</li> <li>Bills stacked incorrectly</li> </ul> | 2                                            | Verification while loading cash in ATM                                                                           | 3                                                           | 48                                                 |                                                                                                                                                                    |

- Severity:** Severity of impact of failure event. It is scored on a scale of 1 to 10. A high score is assigned to high-impact events while a low score is assigned to low-impact events.
- Occurrence:** Frequency of occurrence of failure event. It is scored on a scale of 1 to 10. A high score is assigned to frequently occurring events while events with low occurrence are assigned a low score.
- Detection:** Ability of process control to detect the occurrence of failure events. It is scored on a scale of 1 to 10. A failure event that can be easily detected by the process control is assigned a low score while a high score is assigned to an inconspicuous event.
- Risk priority number:** The overall risk score of an event. It is calculated by multiplying the scores for severity, occurrence and detection. An event with a high RPN demands immediate attention while events with lower RPNs are less risky.

Figure 18. Shows the FMEA process (Forrest, 2021)

Finally, after the team were in the performing stage and the machine was being built, it was found that one had to work overtime to reduce the overall project duration. However, following QTC, this caused the cost to increase. It was found that when the machine was built, failures were occurring. Analysing the project and typical methods indicates that at the start of any project, communication of the project to key stakeholders is key.

As stated, with the lack of filled roles within Belbin's Theory, one did not organise the project to its' utmost efficiency. The first stage should have been initiation as stated, of which one should have not only communicated the project throughout engineering but to other departments.

One can mention **Frederick Winslow Taylor**, who created **Scientific Management**, also known as Industrial Engineering (Mee, 2021). This is the science behind how to do something better. For example, an industrial engineer will look at the RCP build station, and calculate the best operational areas for the operator, to optimise the process and the most efficient order to build the RCP in. Therefore, this method could have been applied to this project. One could have understood the current process better, which would have been the role of the coordinator, whom of which would speak to the industrial engineer. Not only that, it would have been **Vital** to speak with the operators themselves.

Getting an operator's feedback, could be crucial. For one, an experienced operator understands the process fully and secondly, they will be involved in the project, giving them buy-in, letting them understand what is going on, thus, preventing pushback from the operator. Having them involved will allow one to understand the best methods to use and typical assembly problems the operator encounters. It will likely further prevent them from rejecting the project due to the communication.

It can therefore be stated that this management method is critical, the lack of may have been the reason for the machine modification requirements when the machine was first put on the production line. Not only did problems occur with the actual machine, but also with inefficiencies matching with the operator. This could have been due to the rejection by the operator, rejecting the project, due to the lack of communication, which further leads to last-minute training with the machine.

Therefore, for a successful execution phase, one must manage the risks, conflicts and operations of the execution. The best way to do so is to have the roles filled with a coordinator, whilst this is being done, the coordinator or project manager should be documenting

everything, allowing for easy traceability and communication. This was one of the biggest flaws in the RCP automation project, as not having the right people completing the right tasks whilst documenting and communicating them, would therefore create many setbacks, from time to quality and cost.

Ultimately, control and communication are key, which the project lacked, thus, theoretically contributing to the complications in all three QTC areas.

#### 4.2.4. Project Closing Analysis

This section of the automation project was completed promptly. It must be stated that although it was late being released to production, this was due to the CPA. That being, the full documentation was not set to be started until the machine build and implementation was completed. Therefore, the documentation not being completed during the other phases caused pushback of the documentation. This may have been due to the lack of project management, and thus, a technical author who could carry out this task alongside the design engineer would be required to ensure time durations were met.

However, the closing phase, although delayed, was successful and followed the standard phase in what should be expected. It had a full sign off by production and it had a full maintenance list, as well as a predictive maintenance list.

As stated, the project required some modifications. In the closing phase, these modifications were included in the documentation. Furthermore, operational manuals were also included.

However, one thing that was not included, which may cause problems with future projects was a project appraisal. The project did not undergo an evaluation, such as what went well, not so well and so on. It also did not praise the people involved or evaluate how to improve. Doing so would prevent these errors from future projects.

#### 4.3. Reflection and Analysis Summary

This section will summarise the analysis and what was found.

It can be stated that the RCP automation project had the following summary:

- Time delay of 3 months

- A quality decrease occurred at first introduction, but after modifications were added, the machine increased productivity by more than 15% specified in the design specification
- Over budget by £17,721

Many factors contributed to the lower initial **Quality**, the over-budget **Cost**, and the delay in **Time**.

All aspects of QTC cannot be perfect, one must sacrifice one for another. For example, spending more money to increase the quality. However, many factors contributed to the reduction in all three.

It can be stated that the most important contributions that reduced quality, and increased time and cost would be that of the following:

- Lack of clear **Initiation and Project Management** – Kick-off meetings, scope, SMART objectives, deliverables, and lack of key stakeholders.
- Unrealistic **Project Plans and Schedules**
- Lack of **Resources** – Team formation and team commitments (Following Belbin's Theory, Tuckman Model and the DACI framework)
- Lack of **Risk and Change Management**
- Lack of overall **Communication**, from within engineering and to the wider stakeholders such as operators.
- Lack of allocated specialist **Skillsets**
- Lack of project **Control and Mitigation** methods throughout
- Lack of final **Appraisals**

Therefore, having a project manager who is not involved in the technical tasks, the project outcome may have been more organised and successful. Project initiation would have taken place with clear team formation, allowing for SMART objectives to be set and allowing the correct stakeholders to be involved, whilst ensuring accurate resource allocation. Additionally, an accurate budget estimate would have been set from the outset due to the increased engineering knowledge and experience. Risk management could be completed, ensuring mitigation of risks throughout, whilst ensuring transparency through communication. Therefore, planning being a key element would ensure all key processes and techniques are utilised through the correct project phases, ensuring the appropriate individuals and departments are involved, thus, positively impacting QTC.

---

## 5.0 Conclusion & Future Recommendations

---

### 5.1. Conclusion

An RCP automation project was proposed to increase the RCP assembly efficiency by 15% by removing human error, thus, making the product profitable, therefore, feasible to continue future manufacture.

The project met the design specification developed from the design brief, however, it had many setbacks including a 3-month time delay, an overspend of the budget, and many modifications were required whilst online to meet the design specification before the official handover.

There were many reasons why the Quality, Time and Cost were all negatively affected. The causes can be said to be intertwined with one another, which lead to other complications. For example, it was stated that the project did not follow standard project phases, which led to a lack of techniques typically utilised within these phases, such as within initiation and planning, whereby no project manager was set, no SMART objectives were developed and no team was formed.

Therefore, although many causes were found to negatively affect QTC, it all begins within the initiation of the project, whereby if a project manager is not set, an appropriate team is not formed, clear objectives are not set and planning is not fully achieved, then a snowball effect occurs throughout the project, negatively affecting all other aspects, leading to higher risks and a lack of other benefits from the techniques and processes.

### 5.2. Future Project Analysis Recommendations

One could continue with this project analysis to increase one's knowledge and support the findings within this qualitative analysis report. To do so, one firstly recommends utilising a quantitative analysis, obtaining data from multiple engineering projects with various techniques and processes, comparing the data to understand which techniques and processes have the biggest impact on project success. This allows for a data-driven visualisation of the most critical methods, whilst understanding how each project management process and technique are intertwined and affect one another.

Additionally, one could research further techniques and processes, comparing them with those in this analysis, to understand their effect on project success, further defining a correlation between all techniques and project success.

---

## References

---

Alexander, M., 2019. *What is a project manager? The lead role for project success*. [online] CIO. Available at: <<https://www.cio.com/article/3224865/what-is-a-project-manager-the-lead-role-for-project-success.html>> [Accessed 30 April 2021].

Analysistabs.com. (n.d.). *Advantages & Disadvantages of Gantt Charts*. [online] Available at: <https://analysistabs.com/gantt-chart/advantages-disadvantages/> [Accessed 07 Feb. 2021].

Apm.org.uk. 2020. *What Does A Project Manager Do? | Role & Responsibilities | APM*. [online] Available at: <<https://www.apm.org.uk/jobs-and-careers/career-path/what-does-a-project-manager-do/>> [Accessed 17 February 2021].

Breesam, H and Ali, J., 2017. *Mismanagement Reasons of the Projects Execution Phase*. 23. pp. 15-29.

Brighthr.com. 2021. *The Importance of Teamwork in the Workplace | BrightHR*. [online] Available at: <<https://www.brighthr.com/articles/culture-and-performance/teamwork/the-importance-of-teamwork-in-the-workplace/>> [Accessed 13 March 2021].

Cohen, E., 2018. *How to Run Exceptionally Effective Project Kickoff Meetings*. [online] Workamajig.com. Available at: <<https://www.workamajig.com/blog/project-kickoff-meetings>> [Accessed 24 February 2021].

Cohen, E., 2018. *What is WBS (Work Breakdown Structure) in Project Management?*. [online] Workamajig.com. Available at: <<https://www.workamajig.com/blog/guide-to-work-breakdown-structures-wbs>> [Accessed 24 February 2021].

Dininni, J., 2011. *Management Theory of Douglas McGregor*. [online] Business.com. Available at: <<https://www.business.com/articles/management-theory-of-douglas-mcgregor/>> [Accessed 25 April 2021].

Eby, K., 2015. *The Ultimate Guide to the Critical Path Method (CPM) | Smartsheet*. [online] Smartsheet. Available at: <<https://www.smartsheet.com/critical-path-method>> [Accessed 7 February 2021].

Graffius, S., 2021. *Five Stages of Team Development | ScottGraffius.com | Blog | Intersection of Project Leadership with Business and Technology*. [online] Scottgraffius.com. Available at:

<<https://www.scottgraffius.com/blog/files/tag-five-stages-of-team-development.html>>  
[Accessed 2 March 2021].

Heerkens, G., 2001. *Project management*. 1st ed. New York: McGraw-Hill, pp.9-227.

Herridge, D., 2021. *What are SMART objectives and how do I apply them?*. [online] Professionalacademy.com. Available at: <<https://www.professionalacademy.com/blogs-and-advice/what-are-smart-objectives-and-how-do-i-apply-them>> [Accessed 21 February 2021].

Lolli, F., Ishizaka, A., Gamberini, R., Rimini, B. and Messori, M., 2015. FlowSort-GDSS – A novel group multi-criteria decision support system for sorting problems with application to FMEA. *Expert Systems with Applications*, 42(17-18), pp.6342-6349.

Malsam, W., 2020. *3 Free Tools for Making Network Diagrams* [online] ProjectManager.com. Available at: <<https://www.projectmanager.com/blog/network-diagrams-free-tools>> [Accessed 25 February 2021].

Mee, J., 2021. Frederick W. Taylor | *Biography & Scientific Management*. [online] Encyclopedia Britannica. Available at: <<https://www.britannica.com/biography/Frederick-W-Taylor>> [Accessed 18 March 2021].

Mindtools.com. 2021. *Belbin's Team Roles: How Understanding Team Roles Can Improve Team Performance*. [online] Available at: <[https://www.mindtools.com/pages/article/newLDR\\_83.htm#:~:text=Belbin%20suggests%20that%2C%20by%20understanding,help%20create%20more%20balanced%20teams.>](https://www.mindtools.com/pages/article/newLDR_83.htm#:~:text=Belbin%20suggests%20that%2C%20by%20understanding,help%20create%20more%20balanced%20teams.>)> [Accessed 13 March 2021].

Petersen, C., 2013. *The Practical Guide to Project Management*. 1st ed. [ebook] BookBoon (2013), pp.8-80. Available at: <<http://projektkvalitet.dk/wp-content/uploads/the-practical-guide-to-project-management.pdf>> [Accessed 20 February 2021].

Ray, S., 2021. *The Risk Management Process in Project Management..* [online] ProjectManager.com. Available at: <<https://www.projectmanager.com/blog/risk-management-process-steps>> [Accessed 27 February 2021].

Riggie, Y., 2017. *Quality, Cost & Time: How To Choose Between Project Constraints*. [online] the Open Door. Available at: <<https://the-opendoor.net/how-to-choose-between-competing-project-constraints/>> [Accessed 17 February 2021].

Wehbe, S., 2017. *5 Important Reasons Why Teamwork Matters* [online] The Online Learning Platform. Available at: <<https://www.potential.com/articles/5-important-reasons-why-teamwork-matters/>> [Accessed 13 March 2021].

---

## Figure References

---

**Figure 3** - Gantt.com. 2021. *What is a Gantt Chart?*. [online] Available at: <<https://www.gantt.com/>> [Accessed 25 April 2021].

**Figure 4** - Eby, K., 2015. *The Ultimate Guide to the Critical Path Method (CPM)* | Smartsheet. [online] Smartsheet. Available at: <<https://www.smartsheet.com/critical-path-method>> [Accessed 7 February 2021].

**Figure 8** - Riggie, Y., 2017. *Quality, Cost & Time: How To Choose Between Project Constraints*. [online] the Open Door. Available at: <<https://the-opendoor.net/how-to-choose-between-competing-project-constraints/>> [Accessed 17 February 2021].

**Figure 9** - Petersen, C., 2013. *The Practical Guide to Project Management*. 1st ed. [ebook] BookBoon (2013), p.9. Available at: <<http://projektkvalitet.dk/wp-content/uploads/the-practical-guide-to-project-management.pdf>> [Accessed 20 February 2021].

**Figure 10** - Cohen, E., 2018. *What is WBS (Work Breakdown Structure) in Project Management?*. [online] Workamajig.com. Available at: <<https://www.workamajig.com/blog/guide-to-work-breakdown-structures-wbs>> [Accessed 24 February 2021].

**Figure 11** - Petersen, C., 2013. *The Practical Guide to Project Management*. 1st ed. [ebook] BookBoon (2013), p.29. Available at: <<http://projektkvalitet.dk/wp-content/uploads/the-practical-guide-to-project-management.pdf>> [Accessed 25 February 2021].

**Figure 12** - Goth, G., 2017. *Alignment of Risk Management Processes for Medical Device Products and Projects*. [online] mddionline.com. Available at: <<https://www.mddionline.com/testing/alignment-risk-management-processes-medical-device-products-and-projects>> [Accessed 27 February 2021].

**Figure 13** - Graffius, S., 2021. *Five Stages of Team Development* | ScottGraffius.com | Blog | Intersection of Project Leadership with Business and Technology. [online] Scottgraffius.com. Available at: <<https://www.scottgraffius.com/blog/files/tag-five-stages-of-team-development.html>> [Accessed 2 March 2021].

**Figure 14** - Nursing Times. 2019. *Can brief training improve managers' ability to deal with conflict?* | Nursing Times. [online] Available at: <<https://www.nursingtimes.net/roles/nurse->

managers/can-brief-training-improve-managers-ability-to-deal-with-conflict-25-02-2019/>  
[Accessed 6 March 2021].

**Figure 15** - Petersen, C., 2013. *The Practical Guide to Project Management*. 1st ed. [ebook] BookBoon (2013), p.65. Available at: <<http://projektkvalitet.dk/wp-content/uploads/the-practical-guide-to-project-management.pdf>> [Accessed 06 March 2021].

**Figure 16** -Petersen, C., 2013. *The Practical Guide to Project Management*. 1st ed. [ebook] BookBoon (2013), p.79. Available at: <<http://projektkvalitet.dk/wp-content/uploads/the-practical-guide-to-project-management.pdf>> [Accessed 06 March 2021].

**Figure 17** - Mindtools.com. 2021. *Belbin's Team Roles: How Understanding Team Roles Can Improve Team Performance*. [online] Available at: <[https://www.mindtools.com/pages/article/newLDR\\_83.htm#:~:text=Belbin%20suggests%20that%2C%20by%20understanding,help%20create%20more%20balanced%20teams.](https://www.mindtools.com/pages/article/newLDR_83.htm#:~:text=Belbin%20suggests%20that%2C%20by%20understanding,help%20create%20more%20balanced%20teams.)> [Accessed 13 March 2021].

**Figure 18** - Forrest, G., 2021. *FMEA (Failure Mode and Effects Analysis) Quick Guide*. [online] iSixSigma. Available at: <<https://www.isixsigma.com/tools-templates/fmea/fmea-quick-guide/>> [Accessed 17 March 2021].

---

## Appendix One – Design Brief

---

SONY which is a manufacturing company is responsible for the Manufacture of high-end Broadcasting equipment. They produce many camera products one of which can be seen in the figure below.



This type of camera product is typically used in broadcasting, thus, is high in quality. The cameras come with their own control system, such as a Remote-Control Panel (RCP), as seen in the figure below.



The RCP controls all the visual and sound aspects of the camera, from the contrast to the picture quality.

The RCP built by SONY UK Tec has a current assembly time of 20 minutes per RCP, per operator. It has been stated that the industrial engineering study has suggested 17 minutes per RCP, and it was found that the individual buttons of different colours and shapes placed in the front panel of the RCP should take 2 minutes in total, however, it currently takes 5 minutes. It was also found that the majority of quality issues arise from the buttons, whereby they are placed in the wrong locations whilst also having visual damage on the buttons.

Therefore, with the slow build times and quality issues with the button insertion, it has been decided that an automated build cell is required to place the buttons into the front panel of the RCP, the buttons can be seen in the figure below.



The buttons indicated by a yellow circle shows some of the many buttons of which need to be individually inserted into the RCP.

The automated cell must insert all the buttons in the RCP front panel in the correct locations based on their colour and shape, without any cosmetic damage. The fully assembled RCP front panel must be delivered to the operator within their 1-metre diameter operational area.

The automated machine must be able to reduce the overall build time to 17 minutes, therefore, the button placement is the final stage of the RCP builds. Therefore, after the operator finishes the rest of the build after 15 minutes, the button insertion must be completed, tested and delivered to the operator within 2 minutes. Therefore, having a total build time of 17 minutes. When the RCP front panel has all the buttons inserted, it weighs a total of 0.5kg.

Therefore, for this project to be viable, the Return of Investment must be within a year, thus, saving 3 minutes per build and therefore having a 15% productivity increase, which will be around £40,000. Therefore, the maximum budget is £40,000.

The machine must be easy to maintain, limiting downtimes. Furthermore, the machine must be able to cope with various models, there are three RCP models currently.

Therefore, the machine must be able to cope with these various models, by also accommodating the size and variations in numbers, colours and shapes of the buttons.

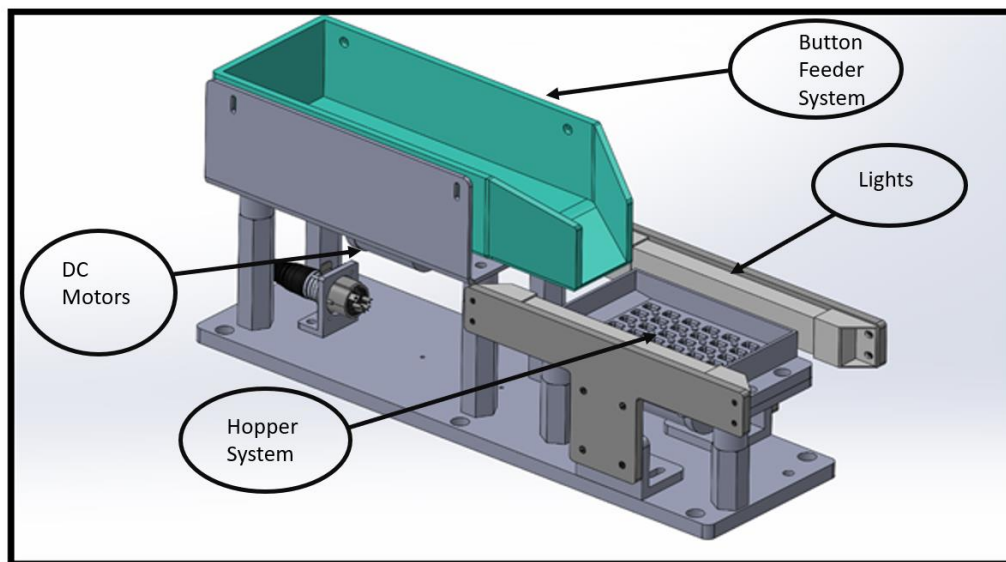
The machine will be placed in the main factory, working around the operators in the RCP assembly area. There is currently a limited space for the machine, being 2m in length, 2m in width and 2.5m in height. The mass of the machine must be below 500kg to be moved around the factory with the current equipment. The lifespan of the machine must be able to cope with operating for 40 hours per week, over 52 weeks, for at least 3 years.

---

## Appendix Two – Design Solution

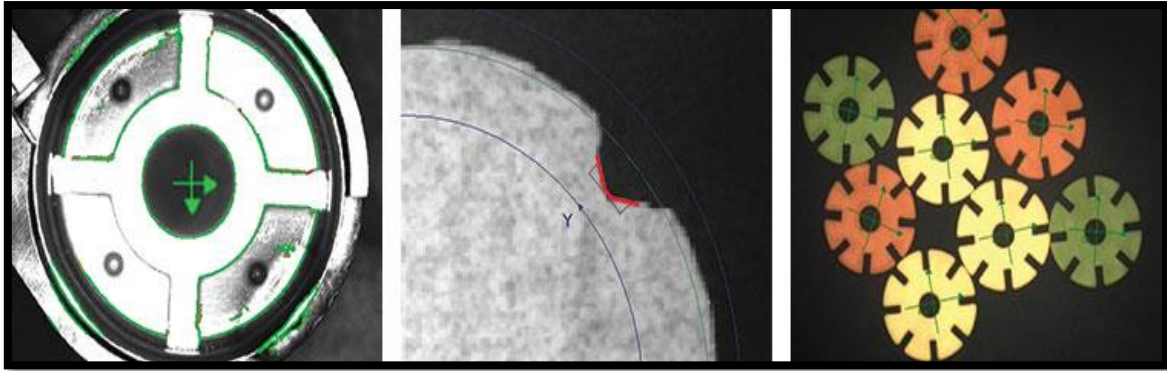
---

A vibration system was developed to orientate the buttons for the RCP in order to be picked up and placed into the RCP. The vibration system vibrates, and the buttons fall into the correct orientation. This can be seen in the figure below. It can be seen an offset weight attached to a DC motor, created the vibration from the feeder to the hopper, which orientates to components.



Once the parts are orientated, a vision system was utilised to pick the correct button in terms of shape and colour to place it in the correct location on the RCP. The vision system used can be seen in the figures below.

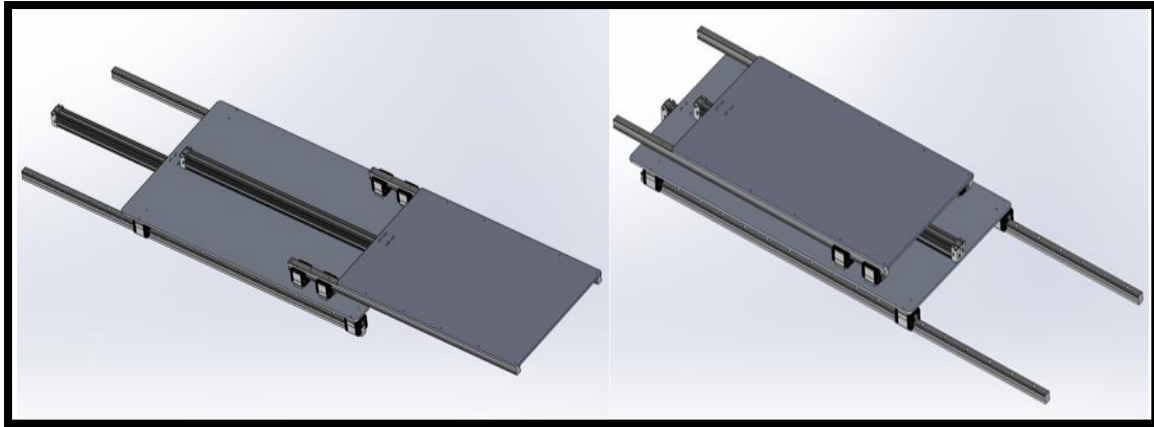




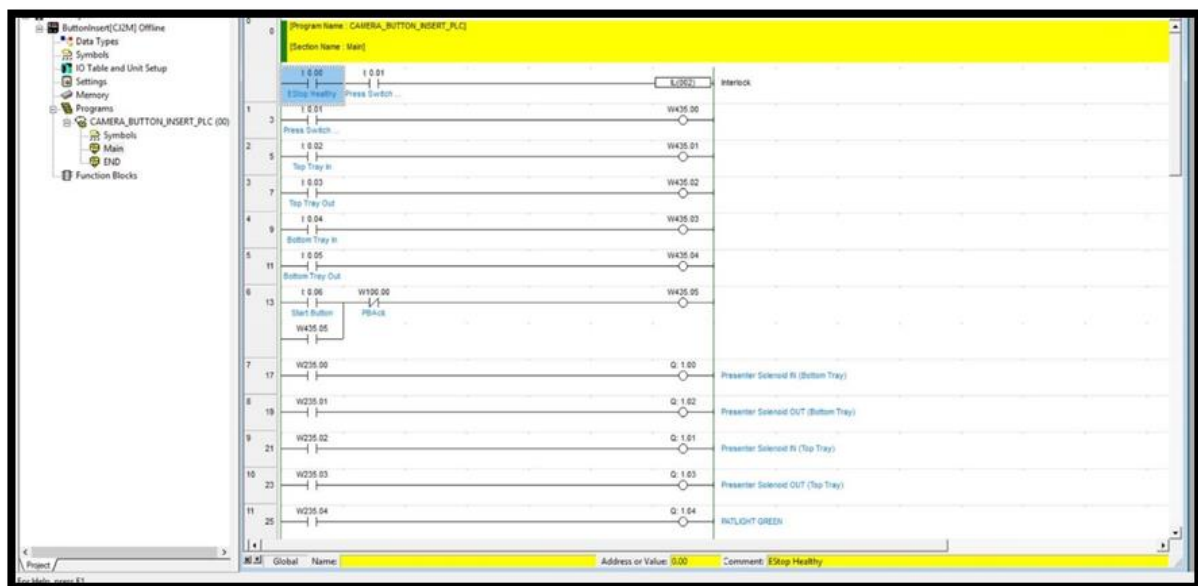
To pick and place the buttons, one utilised a collaborative robotic system with vacuum grippers to pick and place the buttons, with the integration of the vision system and shown in the figure below.



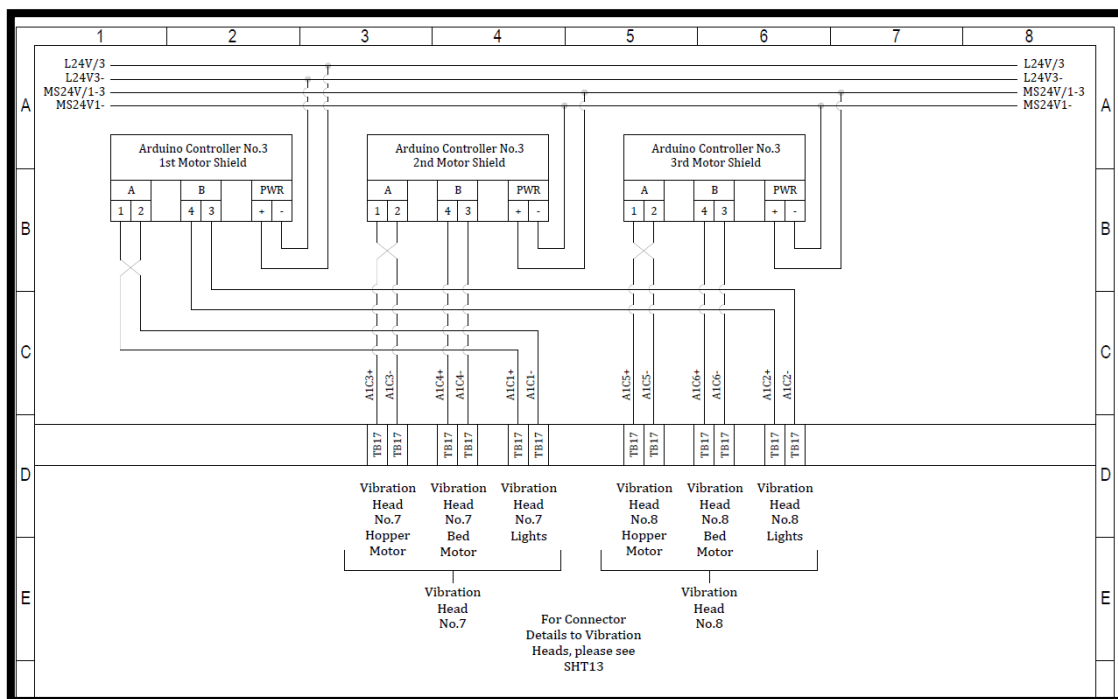
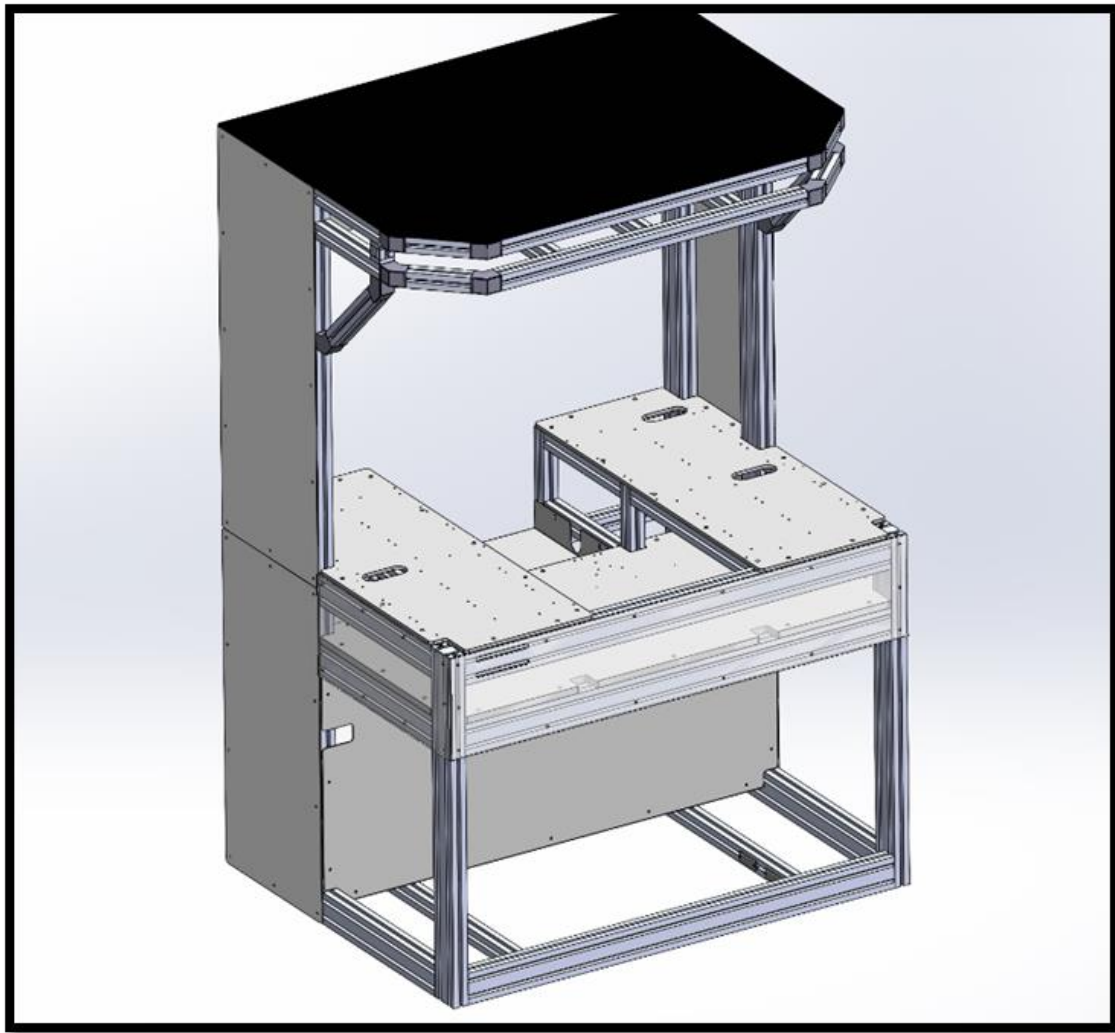
Once the buttons have been placed in the RCP by the Cobot. The finished RCP is checked by the vision system and delivered to the operator on a presenter system as shown in the figure below.



To integrate the entire system, a Programmable Logic Controller was programmed to integrate all aspects of the design, of which it was programmed in ladder logic as shown below.



Furthermore, to enclose all the systems, a frame was designed along with an electrical panel to give power and control to the entire system as shown in the figures below.



---

## Appendix Three – Design Specification

---

The Engineering Design Brief for this project can be found in **Appendix One**. This section will describe how the design brief in Appendix One will influence the design specification.

### **Design Briefs' Influence on the Design Specification**

To achieve a 15% efficiency increase, the specification must ensure the Remote Control Panel (RCP) has its' varied coloured and shaped buttons inserted into the correct location, prevent damage and check for the quality of the buttons, and deliver the assembled product to the operator within a 500mm radius operational area, all within 2 minutes.

The brief fails to see that the machine could work simultaneously with the operator, therefore, if loaded before the end of the operator build, the machine has the potential for a 25% efficiency increase, as it would finish before the operator finishes their 15-minute build. However, the specification will still mention a 2-minute time for any contingencies.

It fails to mention the 7 different button variants with an average button count across models of 40 buttons, thus, affecting speed requirements. Safety is overlooked; thus, ISO standards should be followed, limiting forces in the delivery and insertion systems.

It is also constrained by various models and must cope with the various types. Also, maintenance is important, therefore, the specification would include modular designs, for easy maintenance and minimum downtimes. Size and mass are also important due to the footprint requirements. Furthermore, this is constrained by a £40,000 budget.

## **Design Specification - Automated Button Insertion Machine**

### **Performance**

- Maximum 2-minute assembly time
- Product retrieval and delivery to the operator within their 500mm radius operational area
- Support and transport 0.5kg minimum (Product weight)
- Various model range integration capability (Three model types)
- Fully insert all seven variations of buttons into the front panel within the 2 minute build time
- Transportation time must be within the 2-minute build time
- Must complete button orientation for efficient placement
- Must complete all quality checks within the 2-minute build time

### **Size and Weight**

- Less than 500 kg
- Less than 2.5m Height
- Less than 2m Width
- Less than 2m Length
- Build table must be 0.9m high (+- 100mm)

### **Power & Supply**

- Operate with the factory air supply of 6 bar (87.0226 PSI)
- Operate with factory power supply (230 V AC)

### **Safety**

- Have a Machine Risk Assessment - Provision and Use of Work Equipment Regulations (PUWER)
- Moving components must comply with ISO-15066 Human-Robot-Collaboration (HRC) standards - Maximum impact and clamping force of 65N

### **Maintenance and Life Cycle**

- Minimum lifecycle of 6240 hours
- Modular design for easy repair and part replacement

- The machine must have full assembly documentation, maintenance manuals, and Bill of Materials

### **Budget and Cost**

- Return on Investment of one year or less (£40,000 budget).

## Appendix Four – Cost Analysis

| Yumi Robot                                                                   |         |     |         |
|------------------------------------------------------------------------------|---------|-----|---------|
| Component or System                                                          | Price   | Qty | Total   |
| Cost of Yumi Robot and Programming Software – Along with Maintenance Package | £30,000 | 1   | £30,000 |
| Presenter system                                                             |         |     |         |
| 600mm Pneumatic Actuators                                                    | £150    | 2   | £300    |
| Presenter support plates                                                     | £40     | 2   | £80     |
| Pneumatic tubing and fittings                                                | £50     | 1   | £50     |
| Pneumatic Regulator Valve                                                    | £100    | 1   | £100    |
| Linear rails including Two Blocks                                            | £160    | 2   | £320    |
| Vibrational System                                                           |         |     |         |
| 3D Printed Tray                                                              | £5      | 7   | £35     |
| Base Plate Machining and material cost                                       | £150    | 7   | £1050   |
| Arduino and connectors                                                       | £75     | 7   | £525    |
| Feeder System Plates                                                         | £70     | 7   | £490    |
| Feeder System injection moulded tray                                         | £120    | 7   | £840    |
| Tray Lights                                                                  | £50     | 14  | £700    |
| Vibration Damper Posts                                                       | £11     | 56  | £616    |
| DC motors                                                                    | £25     | 14  | £350    |
| DC Feeder motor Bracket                                                      | £160    | 14  | £2240   |
| DC Hopper motor bracket                                                      | £150    | 14  | £2100   |
| Cognex Camera System                                                         |         |     |         |

|                                                                      |          |   |        |
|----------------------------------------------------------------------|----------|---|--------|
| Cognex Cameras, Cables and Software                                  | £4000    | 3 | £12000 |
| Machine Cell (Frame & Plates)                                        |          |   |        |
| Main Cell Plate (Material and machining)                             | £400     | 1 | £400   |
| Vibrational system support plate left side (Material and machining)  | £250     |   | £250   |
| Vibrational system support plate right side (Material and machining) | £250     | 1 | £250   |
| Main bulkhead (Material and machining)                               | £200     | 1 | £200   |
| Side Panels top half (Material and machining)                        | £55      | 2 | £110   |
| Side Panels bottom half (Material and machining)                     | £45      | 2 | £90    |
| Aluminium Extrusion frame and fittings including assembly            | £1700    | 1 | £1700  |
| Electrical Power Panel                                               |          |   |        |
| Transformer                                                          | £200     | 2 | £400   |
| Safety Relay and E-Stop                                              | £150     | 2 | £300   |
| Electrical Wiring                                                    | £100     | 1 | £100   |
| Isolator Circuit                                                     | £100     | 2 | £200   |
| Circuit Trips                                                        | £5       | 5 | £25    |
| Electrical Control Panel                                             |          |   |        |
| PLC and I/O Banks                                                    | £700     | 1 | £700   |
| Transformer                                                          | £200     | 2 | £400   |
| Electrical Wiring                                                    | £100     | 1 | £100   |
| Isolator Circuit                                                     | £100     | 2 | £200   |
| Safety Relay and E-Stop                                              | £150     | 2 | £300   |
| Arduino and Connectors                                               | As Above | - | -      |

| Pneumatic Panel  |          |         |      |
|------------------|----------|---------|------|
| Solenoid Bank    | £200     | 1       | £200 |
| Pneumatic Tubing | As Above | -       | -    |
| Regulator Valve  | As Above | -       | -    |
| Total            |          | £57,721 |      |