



The Implications and Management of Inefficiencies Within Engineering Projects that Contribute to Delay

Major Project (ACFA7003)

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Executive Summary

This work seeks to develop a methodology for achieving the desired outcome for engineering projects. The report is partially in the form of a case study, with specific focussing on three programmes within an organisation. The organisation designs and manufactures bespoke business and first class seats and suite, for the commercial aircraft industry. Two of the programmes under consideration are business class seats, and one being a first class suite. There are differences between business and first class, the latter being incredibly low volume, from three to nine suites per aircraft, and the former being between thirty to sixty seats per aircraft. There are a multitude of inherent difficulties within each programme, many of which correlate in terms of similarity and identically replicate across every programme, others are isolated. The important finding is that they could all benefit from change, reducing inefficiencies and proceeding to create a better future state.

Research has been conducted into key areas of project management in general, including forecasting, planning, and finally EVM (Earned Value Management). These provide the foundations of any project, and span across both public and private sector projects of engineering, construction, financial and medical to name but a few. EVM is of particular interest, as this consists of a vast array of considerations, leading to focus in particular on change itself and on value balance management. The concept of value balance management is a by-product of this research, and quickly became an area of significant interest.

The report discovers several key factors, the first being the volume of inefficiencies and difficulties, there is an incredibly high number of difficulties within the programmes being analysed. The second factor being that of change management, where change is often implemented with a view to solve a particular problem. This is not news, however consideration to the wider impact is not necessarily given sufficient attention. It is sometimes the case that when one solution is found, it has an adverse effect on other areas. An example of this is when a permanent corrective action is discovered that has an associated cost, it may be rejected by management or finance for being too costly to implement, or there may be insufficient resource to perform the change. Regardless of the nature of the opposition to the

change, there are always considerations to be made, and often valid reasons not to implement the specific change without rethinking the solution.

Collating a set of considerations, identified as Cost, Quality, Time and People, in order to make better and more informed decisions when finding solutions to problems. This methodology is not necessarily a new process in itself, at least not in the conventional form. Its intent is to provoke a more critical thinking mind-set, thereby leading to better and more robust solutions to moderate and complex issues. The overarching principles of Lean, 6σ, 8D etc are not challenged by this methodology, on the contrary, this work seeks to enhance those methodologies, by implementing the correct solution.

It is worth noting from the outset, this report does not conclude with a specific tool or a definitive result. However, consideration as to how this will eventually be created is present in the form of a discussion on future work. This work is the first and important step in defining the problem, it unearths important factors for consideration, thereby establishing the foundation for future work to come.

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1. Introduction

The aim of this project is to identify and consider the disruptive factors preventing the delivery of a project, on time, on cost, and with consideration to quality. Businesses depend on the delivery of projects against the aforementioned three factors, it is important for achieving customer satisfaction, business reputation, and security for the future of the business itself and all employees. All project experience difficulties, and there will always be issues to hinder success. This project will seek to analyse several case studies within a single organisation based in the UK, who design and manufacture business class seats and first class suites for the commercial aircraft industry. The organisation has experienced difficulties over the past several years due to the COVID-19 pandemic, as have many organisations.

Inefficiencies need to be reduced or ideally eliminated, this report will look to identify factors across different projects, and draw similarities between them. Identification of issues is however is only the first step, the main objective is to create a methodology of choosing the best action to improve on an issue. Lean methodologies consist of fantastic tools for identifying the root cause of problems, and then corrective actions can be established accordingly. However the way a corrective action itself is chosen, is arguably often lacking somewhat in terms of methodology. Each corrective action may have the desired effect, but it may also bring about issues elsewhere. This is similar to the difficulties of a project, having already established that a project's main goals are to be delivered on time, on cost and at the right quality. Every task in general should be completed on time, on cost and at the right quality, and therefore these may arguable be factors of consideration for any action taken.

An outcome of this report should be to create a robust set of criteria for managing projects in terms of process selection, created from a critical review of common issues within projects. A measurable system for establishing which solutions are worthwhile perusing should be considered. This may be in the form of a tool for calculating or grading each action in terms of the impact, and the tool may be either manual or automated in nature. But first a grading or scoring system should be established, in order to make better and more informed decisions.

2. Literature review

2.1. Introduction to Review

Accurate forecasting is fundamental to the success of a project, this is especially true when considering the prioritisation of resources, which is often limited and requires prior authorisation (Kerzner, 2017). A project manager is accountable and responsible for achieving specific objectives of a project (Lester, 2017), and to achieve this they must consider a wide array of project management techniques in order to succeed. Forecasting is important as it is common to forecast in terms of hours (resource), and due to the direct link between hours and cost, forecasting is highly important (Kerzner, 2017).

The term 'project' can be summarised as a task with a desired end point, and the term is generally attributed to a task with a degree of complexity (Newton, 2016). There are four pertinent areas for consideration when planning a project, one is to establish a clear understanding for the purpose of the project (Newton, 2016). Another consideration is to plan the cost and timeline, there are several means of doing this, and will need to consider the other steps (Newton, 2016). Consideration to how the project will be managed, in terms of governance and KPIs to ensure tasks remain on track and are completed correctly (Newton, 2016) (Kerzner, 2017) (Parmenter, 2020). Part of this is to consider different gates, where a set criteria must be met at each project phase in order to progress (Newton, 2016). There should be careful consideration of the criteria, as well as establishing how it will be governed, with consideration to meeting frequency and action tracking (Newton, 2016). This overlaps in part with the fourth area, which is to ensure the project is completed properly (Newton, 2016). This in itself may appear an obvious goal, however alignment of expectations is fundamental to success (CMA, 2011), and links to the previous three areas, all are considered to be of equal importance. Some key drivers for achieving the above is to establish visibility of what is actually being done, both by the project team and the project manager (Robertson, 2016). Understanding other's viewpoints is a consideration, this is why the project plan should be clear and free of ambiguity (PMI, 2011) (Newton, 2016).

2.2. Forecasting

A robust forecast on a project considers the management of risks, it sets out what needs to happen, therefore one could argue that a critical component of a project is a reliable forecast (Kim, 2007) (APM, 2019). An accurate forecast is fundamental in terms of preparedness for the plan when in practice (Sankaran, et al., 2019). If done correctly, forecasting can support the success of a project in terms of cost and on time delivery (Moustafaev, 2015). It is claimed that “Forecasting is the art and science of making predictions about the future” (Sankaran, et al., 2019). This statement is based on the requirement for rigorous quantitative extrapolations of mainly historical data in order to create a robust forecast (Sankaran, et al., 2019). There is a fair to high probability of a forecast failing if it does not consider a wide range of possibilities or risks (Thomopoulos, 2015). The risks associated with a forecast can again be obtained through thorough investigation of historical data, this is why data is so important (Sankaran, et al., 2019). The reflection phase of Kolb’s ‘Experimental Learning Cycle’ is a key element of learning and improving (Kolb, 2005), without reflecting on what has past, it is difficult to contextualise and understand the successes and failures of what has been (Martinelli & Milosensevic, 2016). Reflection is important to obtain data used for forecasting as the lessons learnt are incredibly helpful for future projects, one may argue that it is one of the most important factors. This is regarded as a quantitative approach for gathering data, a more qualitative approach is to speak with those involved in historical projects and understand what, from their perspectives, went well and what did not go so well (Leavy, 2017). Possibly, merging both approaches would result in a sound paradigm of past failures and successes.

Forecasting techniques may fall into two categories, those are Quantitative & Qualitative (Thorn, 2020). It is worth noting that some models used for forecasting may be specific to sales or demand for products, and may not necessarily be compatible with engineering projects in general. Therefore the models deemed to be non-applicable have been discounted for the purpose of this research. Quantitative methods are mathematical in nature, and are categorised as ‘Casual’ and ‘Time Series’ models, all of which fall into the category of orders, and therefore all ‘Quantitative’ models as a category may be discounted completely from this analysis. ‘Qualitative’ models consist of ‘Market Research’, ‘Executive Opinion’ & the ‘Delphi Method’ (Thorn, 2020). ‘Market Research’ is as the term suggests, it is about understanding

what customers want, in this instance, the customers may be internal to the business, or the downstream functions. For example, the time planned for the engineering phase of a project will need to consider the time required by the downstream function, such as procurement, manufacturing and production, therefore if a deadline is in place, the forecast would need to work from right to left. 'Executive Opinion' is often applied, whereby the executive team will agree a start and end date, then the project will need to be contained within that timeline. The 'Delphi Method' is arguable the most sensible means of forecasting, it includes the input of the relevant experts. An example of this would be to include all relevant functions of a project, from design and engineering, industrialisation and development, procurement, manufacturing and build. This is time consuming and it is difficult to ensure all plans align.

2.3. Planning and Scheduling

A project manager's key responsibilities are planning, integration and execution of plans (Kerzner, 2017). There are said to be three types of planning, these are 'Operational', 'Tactical' and 'Long-term' planning (Sankaran, et al., 2019). 'Operational' planning generally has a horizon of 4-12 weeks generally and provides a very granular level of detail, this is measured in weeks or days (Sankaran, et al., 2019). 'Long-term' planning, as the name suggests, covers a long period of time, accounting for generally 3-10 years, measured in years, quarters and possibly months (Sankaran, et al., 2019). 'Tactical' planning has a horizon of 12-36 months, measured at a granularity level of months (Sankaran, et al., 2019), and therefore is the best method for this application given that the engineering projects in question generally last 18-32 months.

The importance of reflection is not to be underestimated (Kolb, 2005), projecting forward whilst looking back is a good approach to have with regards to planning (Tracy, 2013). This may be interpreted as the need to regularly reflect on what has been in order to learn and progress, making a stronger plan for the future (Martinelli & Milosensevic, 2016). Tracy (Tracy, 2013) speaks specifically of time management, and lies down considerations for the best use of time with regards to individuals and their general planning, these practices could be used also for project planning. Thinking is the most important thing an individual can do in any field or

profession (Tracy, 2013), the ability to stand back and understand what exactly needs to be achieved will help prioritise tasks and should produce a better plan. The most successful managers of time are all said to be good planners (Tracy, 2013), the reason for this is that a good plan will help uncover potential risks, and help prioritise accordingly. Plans take time to create, and a good plan takes a great deal of time as more factors may be considered. Lack of time for planning however is not a valid reason to avoid creating a plan, it is said that for every 1 minutes spent on planning will likely save 10 minutes executing the given tasks (Tracy, 2013).

In terms of creating a robust plan that considers all risks, honesty, openness and transparency amongst all business partners and stakeholders of a project promotes an accurate means of planning (Lynch, 2009) (Ross, 2015). This is particularly important when there are constraints such as deadlines as it is often common to work backwards from those deadlines, this is known as planning from right to left. The difficulty however with planning from right to left, is that there may be a disconnect in this method as the timeline may be too compressed to complete the given tasks.

2.4. EVM (Earned Value Management)

The EVM system is intended to manage the somewhat complicated task of having to control and modify the baseline schedule of a project throughout the project's duration (Vanhoucke, 2009). The PMI (Project Management Institute) describe EVM as "a management methodology for integrated scope, schedule and resource; for objectively measuring project performance and progress; and for forecasting project outcome" (PMI, 2011). In order to describe a project as a success, one should consider several conditions, these being: (i) Achieving what was set out to do, (ii) Delivering on time, (iii) Delivering on cost. The role of earned value management would be to ask the question: Was the result worth the cost and time that went into it, or in other words, is the output worth the input. This not only applies to an entire project necessarily, it can apply to several areas phases, gates or tasks within a project or programme. To simplify this, one may use the term "*What we are getting . . . for what we are spending*" (Fleming & Koppelman, 2010).

The application of EVM may be an expectation for most if not all projects, however it is not, for three clearly identifiable reasons:

1. **Visibility and Transparency** – Often a difficult and inconvenient truth is how much a project will cost and how long it will take to complete (Fleming & Koppelman, 2010). This is not necessarily to suggest that management are wilfully ignoring the facts, it is a more optimistic approach to proceed with confidence, and under the assumption that the plan is robust and will succeed without any issues.
2. **Terminology and Measurement** – The application of EVM was introduced by Frederick W Taylor to American Factories over a century ago, this was a simple but seemingly effective method of measure (Fleming & Koppelman, 2010). At the time, EVM consisted of three main factors: (i) “Planned standards” referred to the initial plan, (ii) Earned standards” being the resultant performance, (iii) “Actual hours” is the time spent to achieve the “earned standards” (Fleming & Koppelman, 2010). The model of EVM was practically unused, until the Minuteman missile project of the early 1960s decided to measure the performance of the project (Fleming & Koppelman, 2010). At this time, more complex terminology and acronyms emerged which arguably made it less interesting for organisations and senior management to buy into (Fleming & Koppelman, 2010). This was complicated further when the DoD (Department of Defence) adopted the three dimensional EVM method with different terminology leading to even more acronyms (Fleming & Koppelman, 2010).
3. **Adaptability** – Since EVM was adopted for use on military projects in the 1960s, the methods and measures were applicable to those particular type of large-scale projects. For example, the Minuteman missile project was an incredibly costly project, running for multiple years, highly complicated and innovative venture, these types of projects are uncommon (Fleming & Koppelman, 2010). The EVM for this project was named the Cost/Schedule Control System Criteria (C/SCSC). For a practitioner of the method, they must adhere to a 35 element criteria which translated into a >150 question checklist, this made it incredibly difficult and time consuming to employ and eligible person for the role (Fleming & Koppelman, 2010). It is arguable why this overly complicated and

bureaucratic requirement by the DoD made EVM very unattractive to adopt. Working with private industries, the DoD later improved on the method by reducing the 35 elements to 32, however this was still regarded as too precise for most projects. In 1996 the PMI incorporated EVM into their book PMBOK (Project Management Body Of Knowledge) which includes the minimal EVM standards to be used on any project (Fleming & Koppelman, 2010).

In an attempt to improve on the monitoring of progress within the construction industry, a system named SMAC (Site Man-hours and Cost) was created, with the view to provide better visibility of critical path activities (Lester, 2017). A significant benefit of EVA (Earned Value Analysis) is that it not only measures performance, but it may also be used to evaluate trends, and therefore it may be a very effective instrument enabling further action (Lester, 2017). This system may be used within construction, manufacturing and engineering projects, to categorise a few (Lester, 2017). Criteria was established as the foundation of the system in order to maximise the probability of success:

1. **Minimum Input** – Staff should be managing the contract instead of completing unnecessary admin tasks such as paperwork (Lester, 2017).
2. **Speed** – In terms of reacting to the analysed results, in terms of lean this may be considered a form of ‘containment action’ (Lester, 2017).
3. **Accuracy** – The hours spent on a specific activity should be recorded accurately in order to provide visibility (Lester, 2017). The importance of this is not only to capture the effort that went into the task for costing purposes, but the data may also be used to more accurately cost future such work. To take this one step further, if the cost of a specific task has overrun, then a route cause analysis may be required in order to improve for future.
4. **VFM (Value for Money)** – Comparison of the ‘value added’ hours spent on a task against the actual expended hours (Lester, 2017).

5. **Economy** – Cost of the system to operate, in this sense, it must be inexpensive (Lester, 2017).
6. **Forward Looking** – Analysis of trends should lead to swift action when necessary (Lester, 2017).

This particular system provided a percent complete which was used to feed back into the network plan (Lester, 2017). Using a percent complete is an effective way of monitoring progression especially in tasks that may be quantitative, qualitative tasks however may be more difficult to measure. An example of this is on a typical engineering design project, where a safety critical article such as a passenger seat may be subject to certain dynamic test criteria. Through analysis using FEA, CAE and simulation, the product appears to be meeting the criteria, however, on the physical test it may not perform as expected. This does in turn take a design that according to task as being 95% complete back down to 50%. However, this may be attributed more towards risk management as opposed to the estimating the completion level of qualitative tasks (Wibowo & Sundermeier, 2020).

Using the 'Value hours' (earned value) system:

1	2	3	4	5	6
Activity No.	Activity	Budget × 100	% Complete	Value Hours × 100	Actual Hours × 100
1	A	1000	100	1000	1400
2	B	800	50	400	600
3	C	600	60	360	300
4	D	1200	40	480	850
5	E	300	70	210	250
6	F	400	80	320	600
<i>Total</i>		4300		2770	4000
Overall % complete = $\frac{2770}{4300} = 64.4$ Predicted final hours = $\frac{4000}{0.644} = 6211 \times 100$ hours Efficiency = $\frac{2770}{4000} = 69.25$					

Figure 1 - Value Hours Table (Lester, 2017)

The table above shows how an activity has associated 'Budget' hours allocated (column 3), and has the total number of 'Actual Hours' spent to date (column 6). The '% Complete' (column 4) is indicative of progression for each task. The 'Value Hours' (column 5) indicates how many

hours were spent directly on that task in terms of value added activities, which may be subjective. What the basic calculation indicates is the total overall progression in terms of percentage complete (64.4%), the efficiency of the operation (69.25%), and the predicted sum of the final hours when the project completes (6211 hours). Efficiency may be obtained by dividing the 'Value Hours' by 'Actual Hours', this provides the CPI (Cost Performance Indicator) (Lester, 2017). The data obtained above may be used to considerably enhance the forecasted final hours, this is done by either dividing the 'Budget' hours by the 'Efficiency', or by dividing the 'Actual Hours' by the '% complete' (Lester, 2017).

2.5. Cost, Time, Quality & People

2.4.1. Cost, Time & Quality

When working There is a great deal of focus within organisations and projects on cost, time and quality, and specific focus has been placed on 'trade-offs' between these factors (Kannimuthu, et al., 2018). Some work differs and includes additional factors for consideration, in this model there are said to be five categories of all projects, these are Quality, Cost, Time, Scope, and Risk (Newton, 2016). Project management bodies of both PMI and APM have principles that define a project as being centred around four considerations of Time, Cost & Quality performance, and Safety (Lester, 2017).

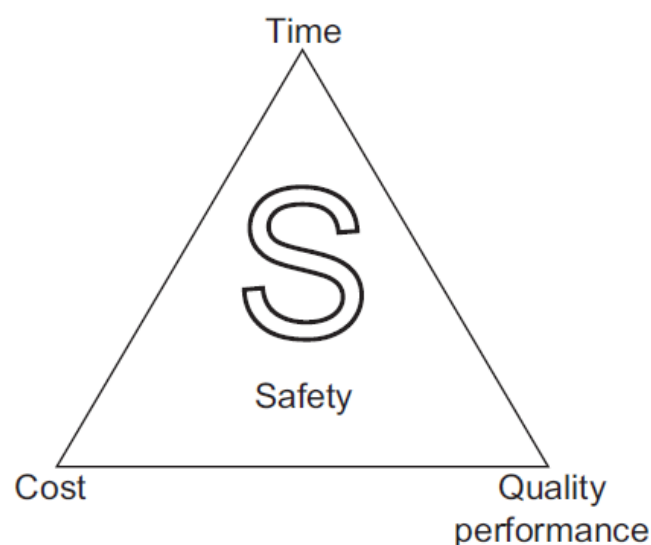


Figure 2 - Cost, Time, Quality Performance & Safety (Lester, 2017)

The common factors in the sources analysed are that of Cost, Time & Quality. Considering the relevance of the non-common factors, being that of Scope and Risk: Scope may be attributed specifically to planning and is not a factor that can be traded against Time, Quality & Cost, neither is risk. In terms of optimising the project for Time, Cost & Quality, four key elements should be considered:

1. Develop a methodology of utilising existing data from past projects to create more accurate predictions of outcomes in terms of quality, cost and time (Kannimuthu, et al., 2018).
2. The need for formulating models to calculate for optimisation of multi-objective outcomes (Kannimuthu, et al., 2018). This is effectively a form of trade-offs between the 3 key factors.
3. Clear identification of significant tasks that must be included within the project (Kannimuthu, et al., 2018), this provides focus on what is relevant and key in terms of outcomes.
4. Measure and adjust resource allocation throughout the project to ensure all objectives are met in a balanced and fair way (Kannimuthu, et al., 2018), thereby not neglecting any particular task.

Other models consider other factors within the framework of cost, time and quality, where in terms of projects, the outlying factors could be Cost, Time & Scope (Kerzner, 2017). The factors to consider will be somewhat different on projects, depending on their levels of complexity (Kerzner, 2017).

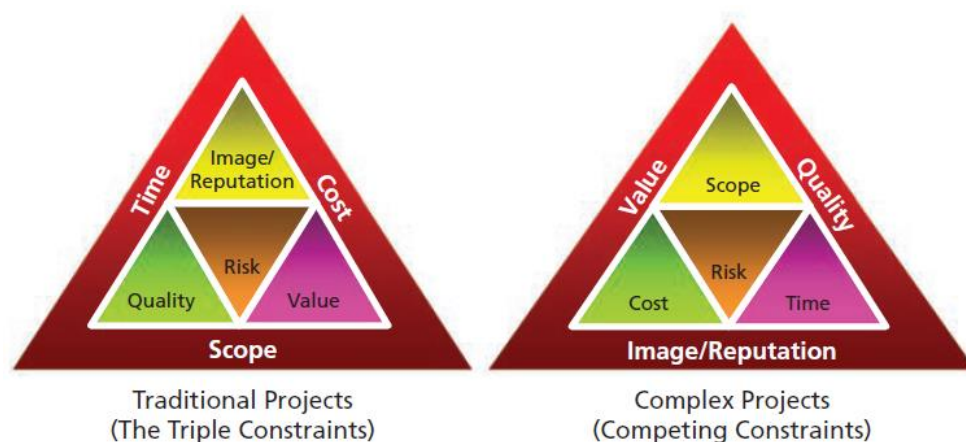


Figure 3 - Competing Constraints (Kerzner, 2017)

2.4.2. People

Change Management is an important factor of any project as projects must change and adapt to risks. Considering a key element of change management, being that of people, moreover people are what make a business, organisations focus on Cost, Time, and Quality, although very little consideration is given to the aspect of people in general, but people are perform the activities of a project (Kerzner, 2017) (Lester, 2017). In the book on change management (Baca, 2005), people are referred to 55 times, with very few positive references to how people contribute to the success of a project. People do arguably fall into the categories of Cost, Time, and Quality, as it is people who generate the quality product that brings in revenue at a cost, and to achieve that it often takes a great deal of time and investment in people. A happy workforce is said to be a productive one (APM, 2019), as identified in a study in 2019 by Oxford University, who found that people were generally 13% more productive in a happy environment (Univesity of Oxford News & Events 2019, 2019). The result by Oxford University correlates with another study conducted by Google, whereby the outcome of being happier increased productivity by 12% (Oswald, et al., 2021). The values of productivity being increased to 12% and 13% are good in terms of accuracy, however a larger sample group would be required to validate the results. The Google study also showed that employees were 37% happier following a focus on addressing happiness (Oswald, et al., 2021). Happiness will undoubtedly contribute in a positive way towards staff retention as it provides a balance in life in general, and work can impact personal life (Uhereczky & Vadkerti, 2018). For this reason, it is a valid argument to make that People should also be included in Cost, Quality & Time.

2.6. Risk Management

Risk is defined as “an uncertain event or condition that, if it occurs, has a positive or negative effect on a project’s objectives” (PMI, 2011). Some research is critical of the approach of project managers, stating that risk is often perceived to be a task at the beginning of a project only, and the remainder of the project is perceived to be executing the real work (Wysocki,

2019). The task is not only to identify and log the risk as is often believed to be the case, there are indeed four main areas when considering risk management (Wysocki, 2019):

1. Risk Identification
2. Risk Assessment
3. Risk Mitigation
4. Risk Monitoring

(Wysocki, 2019)

Considerations should also be made when contemplating the potential occurrence of a risk, asking questions such as ‘what would be the impact of a worst case scenario?’, ‘what alternatives are there to be had?’, ‘will the alternatives produce different risks?’ and so on (Wysocki, 2019) (Wysocki, et al., 2016).

Some traditional techniques for planning and scheduling, such as methods that identify critical path, will generally assume unlimited resource availability (Kannimuthu, et al., 2018) (Goncalves, et al., 2008), whereas in reality this is certainly not the case as resource is finite (Hartman & Briskorn, 2010). Resource is often a challenging topic for projects at times, as demand may fluctuate throughout the course of the project, and the risks need to be identified and managed carefully (Stern, 2017). Methods for managing resource utilisation are often transaction based, relying on observation and KPIs (Stern, 2017). The effectivity of utilisation of resource is dependent upon having the correct type of set up, whether the resource structure is lean or agile (Stern, 2017). A project where the goal is to deliver on an existing product may be regarded as relatively low risk (Teller, et al., 2014) (Killen, et al., 2008), whereas a new developmental project have greater risk due to the associated unknown factors (Raz, et al., 2002) (Kerzner, 2017) and will therefore require a more agile resource approach (Stern, 2017).

Project risk tracking and performance should be managed using relevant KPIs, dashboards and metrics (Kerzner, 2017). Governance is important within all projects (Lewis, 2011) (PMI, 2011) (APM, 2019), and should form part of the overarching framework to govern success (Kerzner, 2017). Figure 4 illustrates the importance of all factors to manage and control risks associated with any given project.



Figure 4 - 'New' Developments in Project management (Kerzner, 2017)

The methodology of lean and 6σ regard risk as something that be controlled via a process (Voehl, et al., 2014). Similar to other work on identifying factors for risk management (Wysocki, 2019), lean and 6σ also identify four areas of management when dealing with risk:

1. Risk Identification
2. Risk Qualification
3. Risk Response Development
4. Risk Response Control

(Voehl, et al., 2014)

Upon comparison with the previous four factors, the first step is the same, as it is important to firstly identify the risk. The second step differs only by wording, where assessment and qualification means to categorise the risk in terms of a rating, severity and likelihood of occurrence (Voehl, et al., 2014) (Wysocki, 2019). The third step is somewhat differs between the two models, where 'Risk Mitigation' seeks to completely avoid the given risk (Wysocki, 2019), 'Response Development' seeks to manage it (Voehl, et al., 2014). The term 'Control' differs significantly from 'Monitor', due to the fact that 'Control' suggests the action is fluid and reactive, adapting to the risk as necessary and when the situation changes. Whereas the term 'Monitor' suggests the risk will be watched and simply measured for success.

3. Analysis

3.1. External Factors

At the beginning of a programme, the engineering project team will create a resource plan, this is to cover the demand on the programme. The resource plan considers several factors, from complexity of the product to be developed through to the method used for obtaining the end result. There are a multitude of contributory factors to consider when estimating the engineering NRC (Non Recurring Cost) required to deliver a successful project on budget and on time. Most of these are relating to the wider business decisions and methods of working, therefore should be regarded as external factors.

2.4.3. Complexity

Programmes are categorised in complexity from 1 to 5. Generally, most modern programmes hold a complexity rating of 3 to 5, business class seats holding a complexity level of 3, with a first class suite holding a complexity level of 5. The rating considers complexity such any new technology which may hold a low TRL (Technology Readiness Level) rating, areas that are known to be difficult to certify, and perceived challenging design features or configurations. In addition to complexity, the scale of the task is a consideration, whereas a business class seat may contain approximately 2,500 bespoke designed parts, a first class suite may contain approximately 4,000 bespoke parts requiring design, not including standard fixings and fasteners.

2.4.4. Outsourcing Strategy

The business will look to outsource elements of the engineering to different parts of the business, this is generally done when the main site has too much work, or when other sites have too little work. The other sites include Santa Maria in the USA, Bangalore in India, two sites in France and recently Tunis in Tunisia. These sites all fall under the umbrella of the organisation and work to similar standards, however some working practices are undefined or

ill-defined at best, and the misalignment of expectations has proven to be incredibly problematic in recent years. The additional effort required to deliver a successful collaborative programme is generated in several forms:

- **Skill** – The required skill set in India is difficult to retain, there is a high turnover of staff, meaning that when a person gains experience, they often leave the business, meaning there is a constantly recurring learning curve. The skill set in France and the USA is good, the staff retention is believed to be a strong contributory factor in this.
- **Collaboration** – Not all sites are equal in managing the work collaboratively, some provide a very granular level of visibility, where others are less compliant in providing visibility. The term ‘visibility’ in this instance refers to the sharing of timelines, providing updates on targets, the sharing of risks, and reporting on general product maturity.
- **Governance** – Whereas collaboration is key to the success of programme, especially within a modern, complex, and multinational network, the way in which it is managed should consider the effort required to manage it. The model lacks what could be regarded as a clear process or framework of which to operate within. Some sites prefer to micromanage everything, utilising documentation and lengthy processes to manage the smallest of detail. Other sites work on a macromanagement model, promoting autonomy and very little governance. Neither model is necessarily incorrect, both have positive and negative impacts on the programme. Micromanagement provides a great deal of visibility and control, reducing and controlling risk, however the negative impact of which is that it consumes a great deal of time, an element that programmes always fall victims to, leading to late delivery. A macromanagement approach enables the task to be completed much faster, it allows quick reaction to changes and enables freedom to rectify issues immediately as they arise. The negative impact of this approach is that it creates breaks in the communication chain, with a department’s actions potentially having a negative impact on other departments. Due to the lack of change control and documentation, the work’s history may not be documented, meaning there is little learning to draw from for future programmes.

2.4.5. Purchasing Strategy

There is a vast network of supply chain within modern businesses, and the aircraft commercial seating industry is certainly no exception. Suppliers should not necessarily impact the delivery, because they should be selected based on their ability to deliver on time and to the correct quality. However, some suppliers have lengthier timelines compared with others, this can impact the milestones of a programme such as shortening the timeline for design in order to procure on time. Another negative impact of the supplier may be the service they offer, e.g. some latch suppliers will work to provide a solution to a problematic application, whereas some will only work to provide an off the shelf product. There is risk associated with working collaboratively with such suppliers as there is a risk of certification failure of the new product, leading to potential delay if not certain increased cost. The purchasing strategy may be to procure from within the business group, again leading back to the aforementioned collaborative working difficulties.

2.4.6. Change in scope

When working with a customer to develop a bespoke, luxury, innovative new product that needs to stand out from the competition, change in scope is an expected and inevitable element of the programme. The business controls change via a CCB (Change Control Board), this board has a core team consisting of programmes management, engineering, purchasing and quality. The functions of each role is as follows:

- **Programme Manager** – Budget holder, managing the commercial aspect of the change and will present the cost in the form of an MCP (Major Change Plan) to the customer if required.
- **Engineering** – All aspects of engineering, feasibility of the change, including NRE (Non-Recurring Engineering) effort to complete the task.
- **Purchasing** – To determine if the change may impact the supply chain or the purchasing strategy. For example, if a change in material is required to something more obscure, then only a finite group of suppliers if not a single supplier may be able to provide the parts.

Polystone produce moulded and machined components which have the appearance of stone such as marble, they feel like stone to the touch, however they are incredibly light, which is an important factor for the aerospace industry. If a simple cocktail table was to have a laminate inlay with a machined surround, now has Polystone, the number of available suppliers may be reduced from 10 to only 1, this obviously removes the bargaining power to control the cost as the supplier can within reason charge what they want.

- **Quality** – The quality department will be present mainly to update their inspection records and to provide input such as the prevention of historical potential issues reoccurring.

Focusing on the Engineering element of the change, as mentioned, NRE (Non Recurring Engineering) will be provided as part of the change, the outcome will be simply 'Approved' or 'Rejected'. If the outcome is to 'Reject', the hours will be challenged and a request will be made to amend accordingly. If the outcome will be to 'Approve', it will be included within the MCP for the customer. The way in which the business operates, the actual budget for engineering does not change, there is no additional resource available to complete the task, often due to the lack of resource availability, therefore a change will most often directly contribute to the overspend on hours.

3.2. Internal Factors

Internal factors refer to what the programme team directly have autonomy over, and how that specific team can control how the programme is managed throughout its duration. Sometimes a process or working practice may be forced upon a programme team by the business as a new way of working. The programme team has limited ability to deviate from the processes, however there is autonomy over how they manage the processes.

3.2.1. Engineering Reviews

Engineering reviews, commonly known as design reviews, would traditionally review the specific module under design with a small engineering team, this team would include design, stress, certification and industrialisation. The engineering review would capture all pickups and produce subsequent actions to be undertaken, including action owner and a date of completion, this is a relatively simple way of managing the design evolution. The 'new' method as released on recent projects include the use of a master engineering checklist, consisting of incredibly detailed criteria that must be adhered to. Furthermore, it is no longer accepted to simply review the live design CAD data during the review, the expectation is that a presentation is created. The presentation will include every single element of the criteria, detailing how the requirement is met, and this is presented during the engineering review. Each review has an extended engineering team compared with previously, consisting now of the abovementioned representatives, with the addition of purchasing, after market engineer, weights engineer, systems engineer, technical integrator, technical audit, and quality to name but a few. The issue with having a wider team from a wider background is that each individual has their own agenda, and can bring valuable input to the event, or an exponential increase in additional activity in the form of actions and interruptions.

This process has several deliverables, it's primary objective is to provide confidence that all aspect of the design meets the requirements, and that there is a good robust product. This is qualitative in nature due to the high level of subjectivity surrounding what is actually mature and what is not. The final evidence record is in the form of the master check sheet, therefore the time consuming presentation may not necessarily need to be produced, it is an expectation of the business, but not a mandatory deliverable. For this reason, the programme team may balance the time wisely by differentiating between what may be regarded as mandatory, and what may be regarded as optional.

3.2.2. Systems

The system used for storing the design work such CAD models and drawings is a system named Enovia SmarTeam, or more specifically, a customised version of this software named 'C+'. The customised version intends to manage more within the system, such as materials, BoM (Bill of Materials) report including trim, finish and colour of each part. The intent of the software is good, it aims to consolidate everything into a single location, therefore downstream users may access everything relating to a single component. Behind the user interface, a complex network of links to all relevant information lives, in principle this is certainly beneficial. The negative elements of this system include that requires significantly more effort and time from a design engineer to create and add data. An example of this is that previously, a single MS Word document containing every colour, material, trim and finish relating to colour sensitive components would exist for every programme/product. This has been replaced with an Excel document containing the same information, but linked separately to every single part. Considering a typical first class suite, whereas previously there would be one MS Word document, there would now be ~6,000 MS Excel documents, one for each part. That is an astronomical increase in terms of effort and time to create the documentation. These documents, known as e-item reports will include the following information:

- **Part number** – Entered as per the part number of the master model.
- **Drawing number** – Entered as per the drawing number, which has no relation to the part number.
- **Material** – Entered as per the desired material grade, considering stress requirements, manufacturability and colour. This was previously applied to the CAD model in the model structure without a need to linking externally.
- **Finish** – Any specific finish must be added to the report, this will include specifying anodise, paint or natural.
- **Revision** – The revision of both part and drawing must be added to the report.

The addition of this amount of information on to every e-item report, for every item has proven to be problematic, the reason for this is that it allows room for human error, not to mention the significant time it takes to create. When the drawing, part and e-item enter what is known as the 'Release Workflow' to release the data, it must be checked by another design engineer, then a Senior Design Engineer, then by the Manufacturing engineer, Stress Engineer, Certification Engineer, Flammability Engineer, BoM (Bill of Materials) Controller, only to be approved or rejected by the Lead Design Engineer at the end of the release process. That is not an insignificant number of checks, especially given that this process may repeat itself as previously mentioned for ~6,000 times.

Upon evaluation of the 'C+' system, a recent program estimated it would cost approximately £1,000,000 in additional effort to adopt the system on a new programme. This was requested as a contingency by a recent programme team, which was subsequently rejected by the business, in a display of unwillingness to accept the failings of the system. The significance of this is that the particular system was implemented 10 months in to a 36 month live programme, and given the factors already discussed, it is evident that it was a significant contributory factor in the overspend in engineering hours for that particular project. Furthermore, a smaller business class programme was running in parallel to the above, with a different however equally skilled and experienced engineering team, and that programme had a very similar outcome. For this reason, there is data to compare and contrast if the 'C+' system did indeed contribute as expected to the difficulties in delivering the programmes on time and on cost.

3.3. Programme Comparison

Due to the number of potential contributory factors leading to overspend, it is a worthwhile activity to compare programmes, in an attempt to identify commonalities between them. Whereas a single programme may hold a wealth of information, that project in itself is not necessarily likely to be a large enough sample group in order to determine the route of the problem.

3.3.1. Down-Selection of Factors

Three programmes have been selected, each is unique however there are similarities between them:

- **Programme 'JU'** – This is a business class seat, consisting of 2,800 parts. It was subjected to the most significant disruption in terms of the new C+ system, and in terms of outsourcing the work to three different sites.
- **Programme 'RL'** – This is identical in terms of the condition expressed for project 'JU', with the exception that this is a first class suite, consisting of 6,000 parts.
- **Programme 'FT'** – This programme is for a business class seat consisting of 3,100 parts, but unlike the above two, it outsourced only to one other site in France for a short period of time.

Determining fair comparable factors is important in order to obtain an unbiased outcome, therefore consideration have been made from the previously stated factors. 'Outsourcing' as a factor has been broken down into different categories, providing a more granular level of detail in an attempt to focus the investigation further. The CAD data management system has been disruptive, but comparing to a programme that did not adopt it, this method should help determine if it was as disruptive as it is believed to be, again in an attempt to remove bias. Programme team retention is important as it provides stability and knowledge retention throughout the duration of the programme. Differentiation has been made between cost and

hours, this is due to the fact that different sites charge different hourly rate, therefore a programme may be on target on hours and significantly over budget on cost, and vice versa.

The table displays that all programmes have common factors, and some polar opposites. The term 'partial' requires further explanation:

Possible Contributory Factors	JU	RL	FT
1. <i>Outsource Seat Design (France)</i>	Yes	Yes	Partial
2. <i>Outsource Composites Design (France)</i>	Yes	Yes	Partial
3. <i>Outsource Mechanical Design (India)</i>	Yes	Yes	Yes
4. <i>C+ CAD Data Management System</i>	Yes	Yes	No
5. <i>Change in scope</i>	No	Yes	No
6. <i>Core Engineering Team Retention</i>	No	Yes	Yes
7. <i>Wider Engineering Team Retention</i>	No	Partial	No
8. <i>Overspend on Engineering Hours</i>	Yes	Yes	Yes
9. <i>Overspend on Engineering Cost</i>	Yes	Yes	Yes

Figure 5 - Contributory Factors Table (Kilbane, 2023)

- **Outsource Seat Design (France)** – Programme 'FT' began working with this strategy, but the work was quickly pulled back 'in house' when flaws were identified in the form of inefficiencies and lack of clear process/agreement.
- **Outsource Composite Design (France)** – Programme 'FT' replicated what was done on the seat design, for the same reasons.
- **Wider Engineering Team Retention** – This was maintained partially on programme 'RL' as some contract staff did come and go, the permanent staff members did in large remain within the business and working on this programme for its duration.

Having tabulated the results, it is possible to determine what factors may be linked, and then investigate in terms of potential impact to the forecast of a programme.

Common Factors:

Possible Contributory Factors	JU	RL	FT
3. <i>Outsource Mechanical Design (India)</i>	Yes	Yes	Yes
8. <i>Overspend on Engineering Hours</i>	Yes	Yes	Yes
9. <i>Overspend on Engineering Cost</i>	Yes	Yes	Yes

Figure 6 - Common Factors Table (Kilbane, 2023)

The outsourcing of work is a common way of working, it has benefits and negatives, but what is obvious is that parameters should be established in order to manage the work effectively. Too excessive control and documentation leads to an admin-heavy environment where much NVA resides. Too little control and documentation leads to poor control of risk, it also leads to lack of visibility for all parties. Although both hours and cost are overspent on all three programmes, the hours overspend does not necessarily equal cost overspend, this is due to the hourly rate being different from site to site. Furthermore, a highly skilled and/or experienced engineer may complete a package of work much faster than a lesser skilled or experienced engineer. Unfortunately, despite the extraordinary work ethic and effort by the team in India, the department lacks experience which is mainly due to high turnover of staff leading to poor knowledge retention. Although this skill level is reflected in part in the hourly rate being far less than the other sites, and the geographical location means the basic wages are often less in this area of the world.

Similar Factors:

Possible Contributory Factors	JU	RL	FT
1. <i>Outsource Seat Design (France)</i>	Yes	Yes	Partial
2. <i>Outsource Composites Design (France)</i>	Yes	Yes	Partial
7. <i>Wider Engineering Team Retention</i>	No	Partial	No

Figure 7 - Similar Factors Table (Kilbane, 2023)

Further work is required into determining the impact poor control and governance has on a programme, both in terms of hours and quality. Although the latter is outside the scope of this

work, it will be considered as it is integral to delivering a successful good quality project, and there is believed to be a direct link between the level of governance and the delivering a good product at the end.

Dissimilar Factors:

Possible Contributory Factors	JU	RL	FT
3. C+ CAD Data Management System	Yes	Yes	No
4. Change in scope	No	Yes	No
5. Core Engineering Team Retention	No	Yes	Yes

Figure 8 - Dissimilar Factors Table (Kilbane, 2023)

These factors are regarded as dissimilar, and they could be disregarded altogether if it was not for the fact that each may have merit. Measuring the time added to a programme by the use of C+ is not a difficult task to complete, there is data readily available for analysis, therefore this is going to be taken further for analysis. The change in scope of a programme is generally when the customer may request a change, and the programme may issue an MCP to the customer billing for a change in NRC & RC. However, even though the company may receive additional revenue in terms of sales for this change, it is not necessarily always distributed back to the programme, which may be an issue in terms of management or process. The core engineering team is important as they manage the engineering sub-departments within the programme, and they interface with the customer. Although the leaving team member(s) will be replaced with someone who is likely to be equally as competent, the knowledge of the programme is lost at least in part, also is the working methodology and relationship which was built with the wider team. Change can be disruptive, and people act differently to it, therefore there may be an element of change management requiring further investigation.

3.3.2. Outsourcing Analysis

3.3.2.1. Composite Design France (CDF)

As discussed, outsourcing may be problematic due to a multitude of reasons, from over-governance to under-governance. Considering the implications of these factors further, with particular focus on time and risk.

- **Time** – Meetings are often necessary but also disruptive, it is not necessarily the time taken to achieve an outcome, but more a question of ‘does the outcome warrant the time taken to achieve it’. If the answer is ‘no’, then lessons must be learned, and improvements made in order to avoid future recurrences and NVA. Considering the CCE change method, the process map appears accordingly:

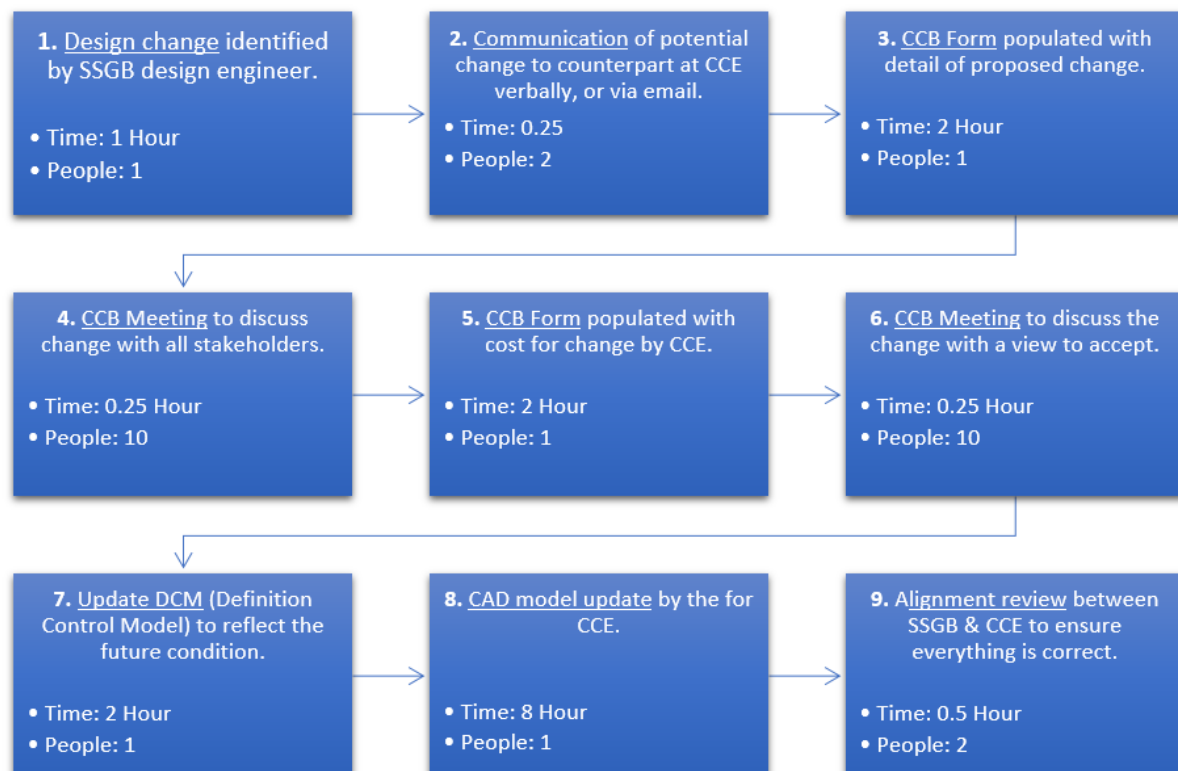


Figure 9 - Process Flow for Controlling Change (Kilbane, 2023)

Items 1, 2, 8 & 9 may vary in terms of hours, however the number of people involved may be regarded as a constant, and most importantly, these steps will always remain as they are fundamental to ensure the change takes place. Items 3 to 7 are additional steps established in

order to control and most importantly, record the change. Considering these hours the effort calculates thus:

$$(2 \times 1) + (0.25 \times 10) + (2 \times 1) + (0.25 \times 10) + (2 \times 1) = \underline{\underline{11 \text{ Hours}}}$$

The sum of these hours in and of themselves may not be significant, however the associated hidden delays may increase exponentially. The reason for the associated delays are due to two significant factor, the first being the weekly CCB meeting, and the second is the time to process the CCB form by applying the relevant information.

- CCB meetings are held once per week, therefore at best there is only hours delay, however there may be a 1 week delay.
- Proven to be a significant delay is that of obtaining a cost from the CCE, this at best will be reviewed at the following week's CCB meeting if the cost is provided, however the wait for the cost is often a month or more.

Given the aforementioned factors, the potential for delay may be significant, however one may argue that this does not necessarily prevent work from continuing as there are always other tasks to continue with. This is a reasonable argument, although this is not always the case, the delay may lead to uncertainty and delay in development of a given area, subsequently contributing to overall programme delay. Considering all factors relating to this topic, it is evident that this process is at best disruptive in terms of additional work. At worse it may be regarded as potential a major cause for delay, with added disgruntlement to those who are attempting to deliver a programme on time.

In addition to the process for creating a change, the CDF require recurring weekly meetings to discuss programme timeline, risks, design and product evolution. These meetings are largely beneficial and productive, they cover the main elements associated with the control of delivering a programme on time, on cost and adherence to quality expectations. The meetings

at times do become more frequent in their occurrence, it is known to have daily meetings at busy times and if there is hold up in the system.

3.3.2.2.Seat Design France (SDF)

The business department working on the seat design do not have rigid controls in place, there is little governance. The parallels between SDF & CDF are that they have regular weekly meetings, covering the same topics of timelines, cost & quality, however there is less functional support from SFD. The term 'less functional support' in this instance refers to two factors, the first being the number of people supporting the meetings from the SFR side is sparse, often only 1 or possibly 2 people supporting at a time. The second factor relates to the completion of tasks, all actions are recorded in an action tracker, consisting of detail or problem statement, the action detail, a due date, and the action owner. This is arguably action tracking in its simplest form, it is effective for recording detail, however due dates are regularly missed and/or modified to be further in the future. Another factor proving to be problematic is the visibility of the work done, the work may be identified as being complete at times although the detail lacks evidence of completion. SDF are not customer facing, they are however part of the supply chain, but they are not a supplier as such because they are a different section within the same company. They also have their own projects and are working to deliver them in parallel to the portion of this product, and given the workload inevitably fluctuates at times, it is deemed excusable to redistribute the resource internal tasks that are deemed to be more important. Task importance will vary from person to person, department to department, and indeed from site to site. If SDF priorities lie with delivering for their direct contracts, this is what will be prioritised, and has proven to be the case at times during all 3 of the programmes being analysed.

3.3.2.3.Design India (DI)

DI have a high turnover of staff, as stated previously, the amount of governance therefore requires additional effort. The time difference is a both a factor of disruption and acceleration.

Disruption being because the staff are not always available to support immediately due to their day ending 5.5 hours earlier to that of the UK, this is due to the time zone difference. The benefit of this time difference is that at the end of the UK working day, a work package or task may be sent out to India via email, and may be completed by the commencement of the UK working day upon the following morning. For this reason, it is important to plan and utilise the resource in India to accelerate the speed at which urgent task may be completed. Given the work ethic of always aiming to please, the manager(s) in India may redistribute resource briefly in order to ensure a task is always complete on time, and this does work well. Given the factors mentioned, this working relationship works well, with one significant issue, and that is the factor of quality.

The quality of the work is not necessarily rushed, nor careless, but lacks consideration of significant factors such as manufacturability which is one of the most important factors of any design. Manufacturing knowledge is gained through two paths, the first is that of having first hand prior manufacturing experienced such as coming from a skilled trade, the other is having a wealth of experience in design. Whereas the team in India are highly intelligent individuals, holding a minimum of one degree, but often several, they lack the design experience as they are often fresh from academia. Furthermore, most people who are of a skilled background do not have the ability of progressing to a formal higher qualification, this is usually due to their personal circumstances, needing to work to support their family and are unable to return to study. If a design cannot be manufactured, it often needs to be reworked, but this not identified until the work has been reviewed through a design review, and that often does not take place until the design has evolved somewhat, leading to significant wasted time. It is reasonable to argue that there should be frequent design reviews in order to capture issues arising and identifying items that cannot be manufactured. An argument against increasing the frequency of design reviews is that the reviews themselves take time, and can lead to further investigation if not managed well, therefore it is not an ideal solution to the issue.

3.4. Value Balance Management

3.4.1. Problem Definition

Overwhelming evidence exists identifying that there are significant factors contributing to the delay in programmes, many of these may be regarded as ‘noise factors’, whilst others may be deep-rooted systematic issues plagued by NVA activities. For this reason, it would be naïve to conclude there is a singular significant factor contributing to failure in the form of delay. Moreover, even if there was a single, or several factors contributing towards failure, those factors stated within this research may not necessarily be interchangeable with other projects. A more proactive way of managing would be to develop a means of managing time, cost & quality in balance. Therefore in terms of a problem statement, the issue would be: ‘Most processes, tools and methods, regardless of benefit actually hold significant adverse effects’. Most continuous improvement activities focus on a particular issue and seeks to determine what may be done to resolve that particular issue. The route cause analysis process is a powerful tool to find the heart of the issue, and subsequent countermeasures and corrective actions are generated in order to rectify the issue. Using this same principal, consider the issue of not having sufficient resource to complete a project, putting this into a 5-why process, the outcomes may be as such:

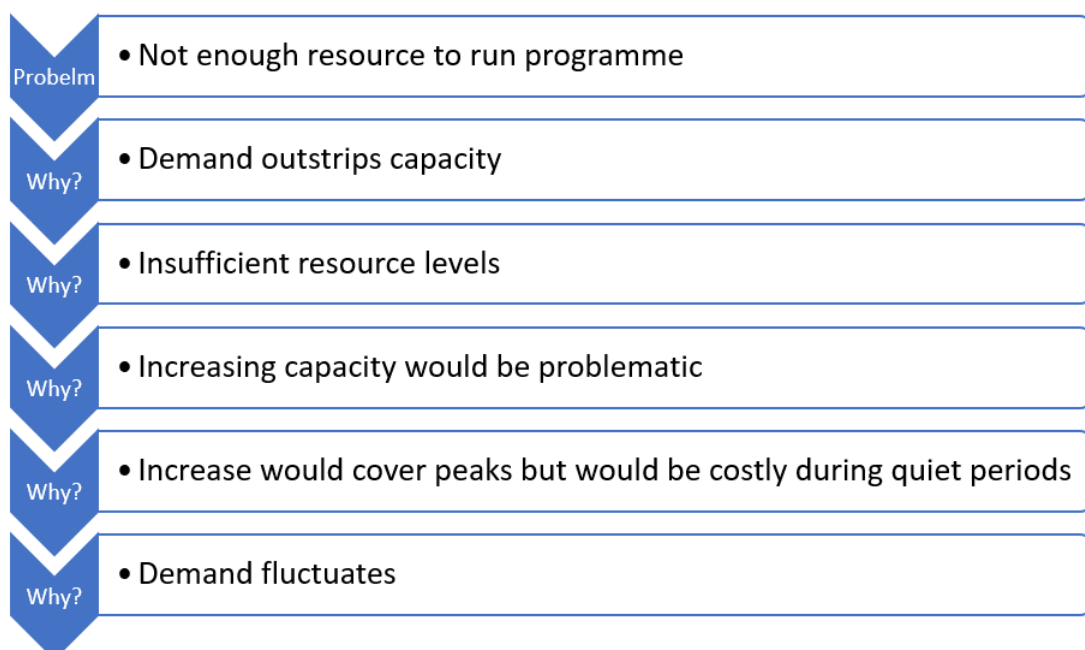


Figure 10 - 5-Why Analysis for Resource (Kilbane, 2023)

Possible outcomes to the above may result in the employment of temporary staff, which comes at a premium rate as professional contractors generally cost more than permanent staff. Another benefit of working within a large global organisation is the ability to distribute the work to different sites in other countries, this allows the business to adapt to fluctuations in workloads and absorb the 'peaks & troughs' accordingly. Undoubtedly, this makes good business acumen and is a modern way of working due to globalisation. Assuming the above led to the outcome to outsource work, the questions would be how to manage the work accordingly, and the 5-why process of this may look as such:

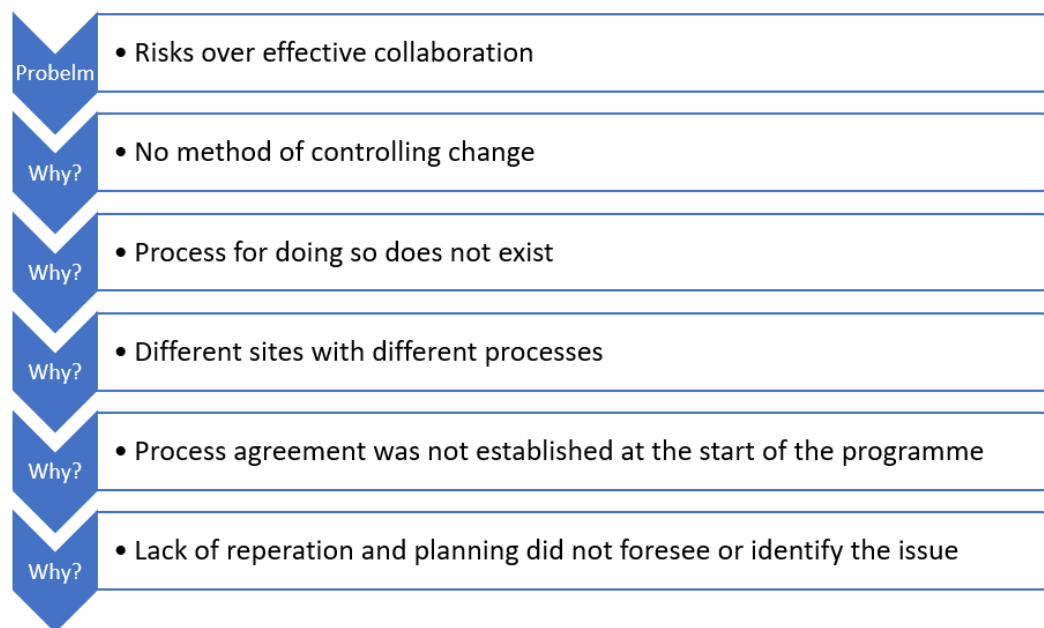


Figure 11 - 5-Why of Collaboration Risks (Kilbane, 2023)

As an outcome of this issue, the result would be to create a process for controlling interface and successful collaboration. However, due to the lack of prior planning and preparation on the side of the business owning the programme, the partner drove the process themselves. This in itself does not necessarily negate the aim of collaboration, however there is a vested interest of the partner which is in effect a supplier, to protect itself and its own timeline and cost. In this instance the partner should be commended as they do this very well, subsequently impacting the programme owner as the amount of additional work and admin increases cost and contributes to delay. Using the root cause analysis method, specifically the 5-why process, the issue of improving the above to improve on time may be done. Further to this, another root cause analysis may be done to improve on cost following the improvement on time. Therefore it may be regarded as reasonable to categorise the continuous improvement

method as a concurrent form of improvement, hence the word 'continuous' in the term continuous improvement. But what if there was a way of providing better foresight in to the potential negatives associated with an improvement? This work does not look to challenge the principle of continuous improvement, on the contrary, it looks to compliment and potentially improve on it.

3.4.2. Forming the Method

Considering factors of why an improvement may be implemented, the goals will always be one of the following:

- 1) **Cost** – Every organisation, with the exception of philanthropic research organisation, generally operate for the sole purpose of generating money, therefore cost is always a significant factor in considering any method or process.
- 2) **Quality** – This refers not only to a physical product, but may be associated to a service. Process effectivity improves on quality, there may be processes in place with the sole purpose of improving quality.
- 3) **Time** – The importance of time is that it is associated with everything, from completing a task to delivering a programme. The reduction time to achieve something is beneficial, also the increase of the need for time to achieve something will impact on the freedom to be agile in managing other activities. Time is finite, it is often the victim of quality, governance and certainly NVA activities, it is arguable significantly overlooked.
- 4) **People** – This is completely different to the abovementioned 3 factors, however it is people, employees, staff who make the above work. Not having enough time to complete work will bring about stress, increased governance and processes to improve quality will lead to discontent, and cost in the form of profitability may lead to a threat of unemployment.

Using the 4 factors, it is important to understand the relationship between them, and how one may have a negative impact on the other(s). Generally, an improvement in one area may result in a negative impact on the other. If quality had no associated cost implication, arguable everything around us would be of the highest quality, it may be regarded as unreasonable to suggest otherwise. A Dacia car may not be of the same quality as Mercedes, subsequently the Mercedes costs more to manufacture and therefore recuperates its additional costs through a higher sale price than the Dacia. In manufacturing, quality may be controlled via the use of additional checks within the process to ensure quality is maintained, this takes time and cost, therefore is another example of where an increase in quality contributes to increased time, and therefore cost. The relationship is evident, and may be visualised as such:

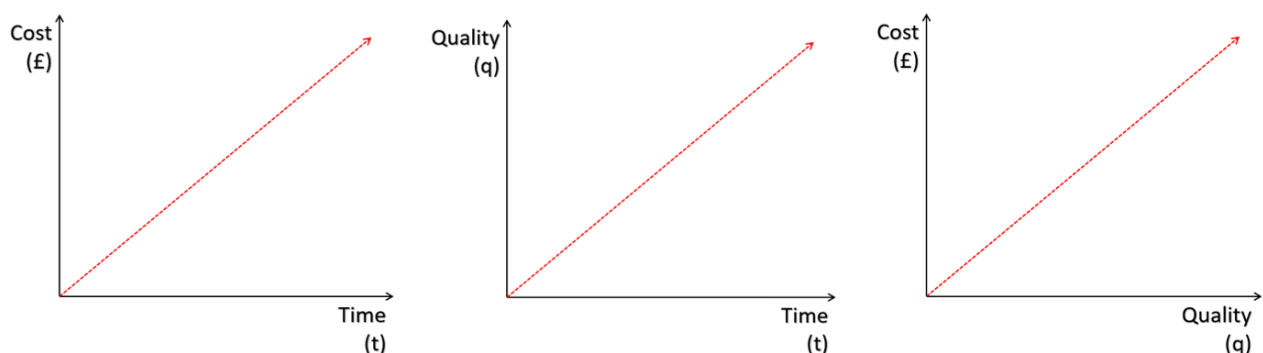


Figure 12 - Cost, Time & Quality Correlation (Kilbane, 2023)

The element that is more subjective is that of the fourth and final consideration, people. We as people, work to earn money in order to better ourselves and to provide for our families, we work truly for these reasons. Having established that work is an important part of our lives, it is important to accept that everyone wants to succeed and do their best, people do not go to work to do a bad job, therefore the impact on people is certainly not to be underestimated. Every employee wants to be happy in their work, and a happy workforce is generally a productive one (University of Oxford News & Events 2019, 2019) (Uhereczky & Vadkerti, 2018). Having the freedom of autonomy to be creative and flexible, having the tools to support in completing the work that has to be done, and having sufficient time in order to do so. Time, as discussed previously is finite, however when time cannot be extended accordingly, it is good to prioritise what has to be done, and the removal of NVA is key to succeeding in this. The ideal process will deliver on all 4; cost, quality, time & people, however in reality the probability of this is between slim and none. Therefore it may not be reasonable to achieve a perfect

outcome, what should be done is to identify the four factors and balance accordingly in order to maximise value. The term 'value' in this instance is a measure such as that used in EVM.

Similar to FMEA methodology, where an RPN (Risk Priority Number) is applied in the form of an index, identifying if a corrective action is required to take place, the same may be applied in this instance. Substituting the measures of Severity $\times$ Occurrence $\times$ detection, with Cost $\times$ Quality $\times$ Time $\times$ People, this adds a fourth element, but nonetheless should be consideration in modern ways of working as people are arguable an organisation's greatest asset (Fulmer & Ployhart, 2013). The issue with this methodology is that it is somewhat difficult to apply a scale to the four elements as they are not easily quantifiable factors, there is no precise science in this methodology. What is important is to rate in terms of the baseline and mark as zero, this is why it is important to identify the current condition. From this, it is possible to simply identify if one element will have a positive or negative impact on the other.

Cost										
-5	-4	-3	-2	-1	0	1	2	3	4	5

Quality										
-5	-4	-3	-2	-1	0	1	2	3	4	5

Time										
-5	-4	-3	-2	-1	0	1	2	3	4	5

People										
-5	-4	-3	-2	-1	0	1	2	3	4	5

Cost = 0 Quality = 0 Time = 0 People = 0	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr style="background-color: #d9e1f2;"> <th style="padding: 5px;">Change to current condition</th> </tr> <tr> <td style="background-color: #fff2cc; text-align: center; padding: 20px; font-size: 2em;">0%</td> </tr> </table>	Change to current condition	0%
Change to current condition			
0%			

Figure 13 - Value Balance Management Template (Kilbane, 2023)

For this phase of the analysis, it is purely a case of understanding how one factor impacts the other, and rating it accordingly. It should become apparent if something is either worse, better, or indifferent to the current condition. This in itself does not determine if a change should take

place, but it provides an early indication if effort should be placed into pursuing a potential change in the form of an improvement or otherwise.

This is an example of the table used for calculating if a worthwhile pursuing. Each element is marked individually, and then the large box named 'Change to current condition' will display the delta compared with if the change were not to be implemented. The sum of the values are divided by the maximum score ($5 \times 4 = 40$) and then multiplied by 100 to produce an overall rating. A positive value would indicate that pursuing the change would have a probability of being beneficial, whereas a negative value would indicate the opposite.

Consider a change of implementing the design storage system C+ (figure 14), the intent was to improve on quality in terms of working collaboratively across multiple sites, therefore the beneficiary target was that of 'Quality'. However the cost in terms of implementing the system via planning and set up, was a slight negative. Significantly greater negative factors were that of 'Time' and 'People', time because the user interface was very poor.

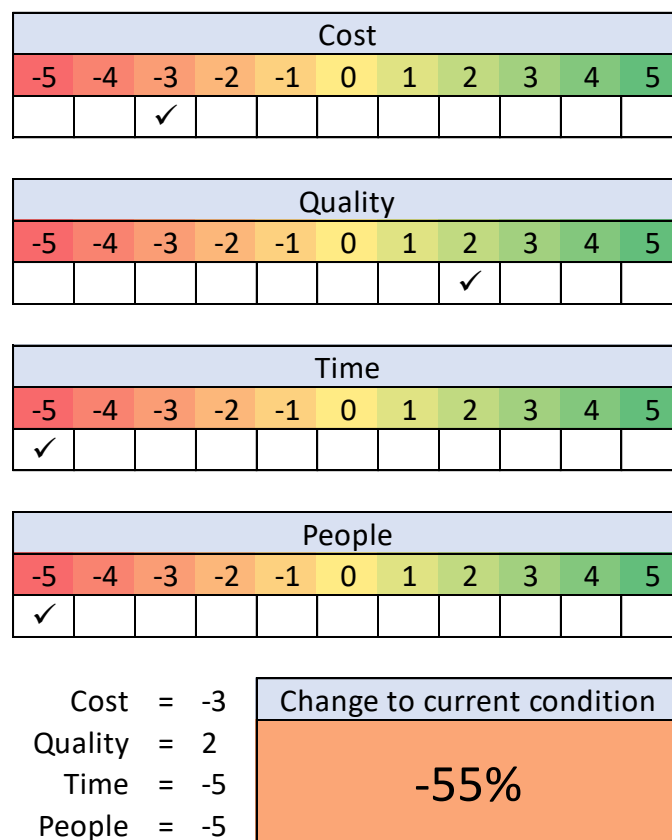


Figure 14 - Value Balance Management Results for C+ (Kilbane, 2023)

Compared with the previous system, the effort required to complete a task was exponentially slower due to the process, and the servers were incapable of managing the number of users across multiple sites around the world. People suffered through stress, brought about by increased pressure to deliver work in a timeframe that had not considered the new system. Furthermore, it was said to be incredibly unpleasant to use the system, and made people's work a misery, subsequently many people left because of it.

Upon investigating, a change that happened well across programmes at the time of this investigation was the introduction of 'Hybrid Working' (Figure 15), this was to allow staff members to work remotely for two days per week, and attend on site for three days per week.

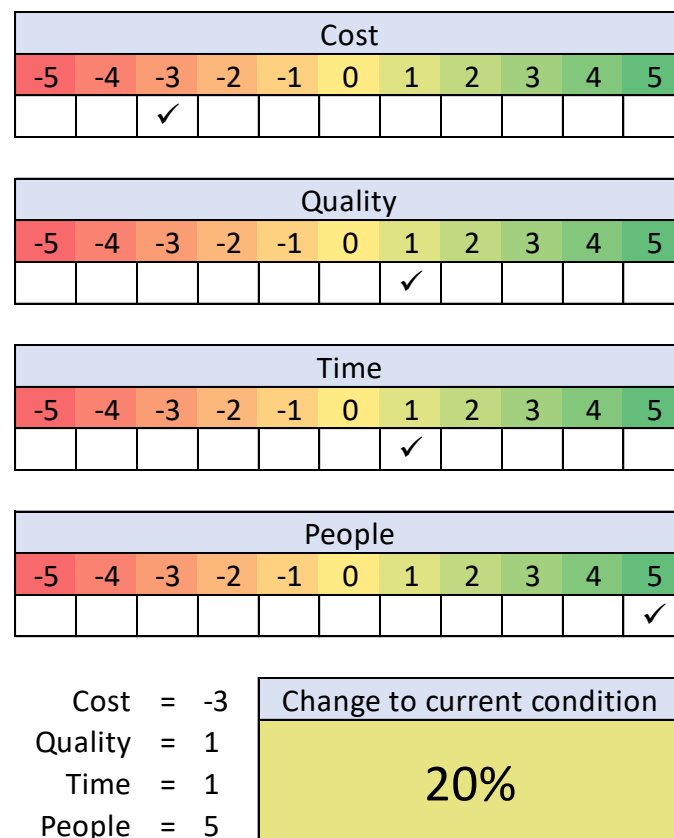


Figure 15 - Value Balance Management Results for Hybrid Working (Kilbane, 2023)

The process provided people with a better balance in the form of spending more time at home, especially for those who had lengthy commutes to the office. The time factor in this was a slight improvement, primarily due to not having the interruption of being in a busy office place, and time could be spent completing tasks when the daily commute would take place. This new working method had a slight positive impact on quality, work could be completed quicker in some instances due to fewer interruptions, therefore deliverables were less likely to be late.

Robust ways of working remotely were established in order to manage the impact of CIVD-19, this had provided the foundation for working practices, such as the use of collaborative tools like MS Teams for instant communication. Had it not been for COVID, the drive to introduce hybrid working may have never occurred.

The cost impact for the introduction of hybrid working was not insignificant, this was because many laptops needed to be procured in order to support the new structure. The sum of the new laptops totalled £96,000, although it is worth noting that this sum could not solely be placed against hybrid working, due to the fact that computers were nearing the end of their warranty periods and would require replacing in the very near future anyway. Therefore the introduction of hybrid working brought the cost forward by a year or two.

The tool is a good indicator to highlight the areas impacted by a given change, it enables people putting a change forward to consider the important factors. It does not conclude definitively if a change should or should not take place, it purely provides considerations in order to proceed if deemed necessary. The people involved in this process should be representative of the areas, and hold the interests of each factor as a priority. This method in and of itself will not improve the forecast on programmes, however it will aid with managing the risk associated with a given change, and then will be able to update the forecast accordingly. There is an evident direct correlation between all four of the factors, and should be considered as such when implementing any change. It is worth noting that not all factors are equal in their importance, e.g. a change quality in the form of delivering right first time on complex designs may increase cost and time, it may have a negative impact on people also, however the repercussions of not delivering right first time could lead to even further additional time in the form of having to redesign, and then obviously cost will increase also. For this reason, it is not always indicative of what the best way to proceed may be. Judgement is required, some factors may have a greater importance than others, this can be applied to the tool in the form of a weight factor and added into the overall calculation if needs be. This does add complexity and may not necessarily be of great benefit, therefore has been left out of this work and may be considered for future development if necessary.

This work seeks to manage the balance of value across multiple factors, it is a good general rule that may be applied for future changes. It is beneficial to use this to compliment the

process of continuous improvement, precisely at the phase where permanent corrective actions and containment measures are being considered for implementations. The reason being is that it could contribute to more robust countermeasures, meaning a greater probability of success, and could reduce the need for future 8D, 4D, A3, Kaizan, 6 σ etc. activities on the same topic area. Given the time constraint of this investigation, it is not possible to implement this theory into practice, however it will be developed and improved moving forward over time as programmes progress. Continuous improvement by nature seeks to evolve processes and practices, adapting to modern practices and ways of working, therefore the continuous improvement process itself can continue to improve. Continuous improvement is excellent at finding a root cause, implementing and measuring the results, however little focus has been applied to the actual corrective actions themselves, and this is an area for improvement.

3.4.3. Measurement and Control

The measurement model for balancing cost, quality, time and people is one that requires further research in terms of measuring results, as it is in early development. The results of which may be measured using several methods:

- **Cost (£)** – The baseline cost should be determined, and the cost of the change should be measured. This is a relatively simple measure that should be achieved without significant difficulty or ambiguity.
- **Quality (q)** – The measurement of quality should be apparent when considered in terms of the improvement to a physical object, such as a product in manufacturing where the defect rate has decreased. More ambiguous may be the improvement to the quality of a process or software, such as making it less problematic, more intuitive, or control of error proofing/Poka-Yoke. Quality in terms of perceived quality is a consideration for consumer good, within the aerospace first class seating industry, perceived quality is the consideration for feel, aesthetics and sound. For this reason, perceived quality is often subjective as it considers aesthetics, and what some people consider to be aesthetically pleasing, others may not.

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- **Time (t)** – This is a deceiving topic to measure, and falls into at least two categories. The first being the reduction of time to produce a product, which can be measured in terms of cycle time, or in terms of takt time from a production line consideration. The resultant of this measurement is often a definitive outcome in terms of time delta.

Example – Process for approving a production permit – A production permit is required as an official document, recording the permitting of a deviation from the baseline design intent of a product or component. The initiator of the permit will send the permit through the signatory loop. Historically, the person who raises the permit will walk the permit through all the 6 signatories in order to obtain their signature and a 'reject' or 'approve' status. This is time consuming as there are many people carrying permits, and attempting to track down all relevant signatories was difficult. It is relatively simple to apply a generic time to this process, and therefore a baseline to be measured against. An improvement was implemented, where a person was employed to gather all permits at a regular frequency, once every day, and take in batches to the allocated signatories. This was an obvious and measurable improvement in terms of time. During the impact of COVID-19 and subsequent hybrid/remote working, this method was replaced with simply emailing signatories for an electronic signature, and understandably this had a negative impact on the time it took to approve a permit. A proposed improvement would be to have a program or software such as a database that would notify individuals when they are required to sign a permit, and then they could action accordingly within the allocated timeframe. This is an example of how time can be measured accurately and definitively, a KPI could also be implemented within the software in order to continually measure the results.

The second category of time falls into what may be described as 'hidden time' or 'incremental time'. The terms 'hidden' and 'incremental' are pertinent as they describe how these time aspects are neither obvious or instantaneous, but nonetheless may be significant and arguably one of the biggest contributors to delay.

Example – Process (Obeya) for obtaining drawing release values – The result of this process is highly important as it is fundamental to measure the reality against the forecast for drawing release, the process is a non-value added but necessary activity. As already

discussed, the amount of time spent in the daily meeting to discuss this is disruptive and takes time away from actually progressing the task that is being reported on. Measuring this time from meetings can be done by simply multiplying the number of people involved in the meeting by the amount of time taken on average per meeting. What takes time is the need for individuals to record the work they do on a daily basis, the number of drawings checked, the number of drawings approved, the number of drawings rejected. Furthermore, the specific blockers and identified, along with reasons for why the target was met or missed. Considering this, it would take approximately 15 minutes per day to prepare the information/data per person. Which in itself is not significant, however this equates to 1¼ hours per week per person, and 37.5 hours per week based on a team of 30 people. Note that this is equivalent to one person full time gathering the data alone outside of the Obeya meeting.

- **People (p)** – Remaining with the last example first, people generally do not like to report in the said Obeya meeting, the reason being it is a form of micromanaging. Having to answer the following questions: “How many drawings did you process yesterday?” “Why did you fail to meet your target (if under target)?” “How will you recover today for yesterday’s shortfall?” “How many drawings do you plan to process today?” This, according to many managers is necessary for two reasons, the first is to gather the values and compare against the forecast. The second reason is to hold people accountable for achieving a target, and breeds discontent and anxiety, people have known to have left the business for this very reason. The relevance of this example is it illustrates how a process may have an adverse effect on people, which in turn could contribute to an increased turnover of staff, it could also impact the enthusiasm and commitment to succeed. For these reasons, the ‘People’ aspect of this model is difficult to measure without the obtainment of some feedback in the form of a survey or general discussion. In the words of John Lydgate: *“You can please some of the people all of the time, you can please all of the people some of the time, but you can’t please all of the people all of the time”*. This means that there may always be discontent amongst people in general, and therefore no ideal solution to every problem, however the ‘People’ aspect is something worth considering. Another consideration is the ability to view something from another person’s perspective, stopping to consider the person

that must work with the new method, tool or process, and would it have a positive or negative impact on them.

All these considerations should be collated and fed back into the original rating from the model, revisiting and validating if the results are as expected. If the results are not as expected, they should help identify what else can be done to address the issues, continually measuring and improving accordingly. The process, for this reason does not have an end, but it continually adapts and improves to achieve an optimal condition.

3.4.4. Management of Slack

Slack is a term used to describe the activities that may have some additional time to complete, in terms of a project plan, this would include activities that are outside of the critical path (Franceschini, et al., 2019). The pertinence of 'slack' for this discussion is that it may be used to improve a project's timeline, by redistribution of resource to accelerate critical path activities, or to bring tasks forward and have more time to control any issues that may arise. Project 'slack' is not often considered as a major issue, as it is generally good to have more time to complete work, however it is a form of waste. As a measurement of time, if it is not used for alternative tasks it may be viewed as additional cost spent on a particular task, and therefore poor in terms of EVM.

In terms of quality, 'slack' may be beneficial as it could allow more time to complete a task to a higher standard or a better outcome. Applying the 'people' aspect to the topic of 'slack' and one would consider this brings less stress, in the form of delivering to what may otherwise be challenging timelines. The additional time may allow for improvement activities, or better planning for the other tasks, therefore increasing work satisfaction from seeing the results of better work being produced. In reality most people thrive to achieve a high standard of work, and on time delivery, but it is important to balance what is necessary in order to deliver on time, and that may compromise quality somewhat. 'Slack' can be beneficial if utilised correctly, failure to do so will result in wasted time.

3.5. Cost Analysis

In order to understand cost in the context of this type of industry, it is first important to explain what the wider picture of cost is and the implications of not achieving the desired profit. The cost associated with the discussed factors may be significant, and contribute to delay in delivery, which translates to overspend and potential penalties for the delay. As all projects' main aim is to be profitable, with the exception of public or governmental projects, it is the single largest driver. Profitability of large projects may determine the future of an organisation, it does not only generate recurring revenue when the product is delivered, but there may be payment for achieving each milestone in the development. Considering a project has a NRC of £8M, the payments will be distributed thus:

Event – PDR (Preliminary Design Review)

Occurrence – 6 Months in to project

Revenue upon successful completion of event – 20% (£1.6M)

Event – CDR (Critical Design Review)

Occurrence – 12 to 15 Months in to project (6 to 9 months post PDR)

Revenue upon successful completion of event – 30% (£2.4M)

Event – FAI (First Article Inspection)

Occurrence – 21 to 24 Months in to project (6 to 9 months post CDR)

Revenue upon successful completion of event – 30% (£2.4M)

Event – ODD (On Dock Date)

Occurrence – End of project

Revenue upon successful completion of event – 20% (1.6M)

The significance of these milestone events is that they not only generate cash flow to fund the developmental phase of a project, but that cash flow is also used to fund wages of the wider business. This has not been more prominent as during the COVID-19 pandemic, where the shop floor workers' jobs were placed at risk due to a significant shortage of work, caused by

cancellation and postponement of existing orders. Developmental programmes, such as those in the phases mentioned above were key to job retention as they brought much needed revenue into the business. Some airlines did pause projects during the COVID-19 pandemic, others saw it as an opportunity to proceed to push to develop new and innovative projects in preparation for when the market would reopen.

In addition to the cost benefit of achieving each milestone event, there may be cost penalties written into the contractual agreement with both airline and integrator for on time delivery. There have been instances in the past, where the cost implication has been so significant, that the first 4 shipsets (~30 to 60 seats per ship set) have been delivered before a profit is made, and there is approximately a 50% profit margin on each seat generally. There may be cost penalties also for being overweight on the end product, where a cost per unit measure of weight may be applied and subtracted from the overall cost per seat, this has led to projects being cancelled by the organisation in the past for being too large a risk. A pessimistic view would be that airlines apply the penalties for late delivery and weight against short lead times and low weight limits purposely, in order to claw back some money. Knowing businesses will bid for work, some organisation may accept the work at risk, under the assumption that there will be penalties, but in order to secure the work and ensure it does not go to competitors this may be regarded as a necessary action.

Cost is relatively simple to summarise, $\text{budget} - \text{CTC (cost to complete)} = \text{cost delta}$, being under budget translates into profit, and over budget may be a loss. Every project has a factor of safety, and the hours allocated to a project will be broken down into multiple more granular tasks and risks which define the overall cost. To discuss specific costs, and to establish the potential opportunity for improvement, cost has two categories, measurable cost and subjective cost.

Measurable cost – This is when a task or activity has an allocated CTC, and the actual cost may be recorded and compared with the planned cost. Factors leading to waste and NVA could then be associated as contributors to the cost delta, and therefore analyzed further.

Subjective cost – A more difficult measure, this is the unrecorded or unseen disruption, factors such as ad-hock meetings, governance, and more significantly, the human impact. The human factor is very subjective, as when people are unhappy they generally do not perform to the best of their ability, and this is difficult to measure definitively. Contributors to this factor are constraints in the form of processes and tools that hinder autonomy, preventing the ability to move fast, and arguable the biggest factor of all is that of time constraints or unrealistic timeline expectations. Pressure may lead to stress, reduction in the quality of work and ironically it could lead to further delay. It is better to remove ‘noise factors’ in order to improve on time, again returning to having the correct balance of cost, time & quality.

Another cost type that could fall into both categories of ‘measurable cost’ and ‘subjective cost’ is that of delay, depending on the scale of the delayed impact and if it can be traced back definitively to the main activities. Examples of cost types are discussed below. Considering the design of a meal table for a first class suite, it will be planned for several iterations of development build, then cyclic (fatigue) testing and eventually abuse load testing. To put this into context, a meal table for a first class suite is either a single slab or bi-fold in nature, generally between 500 × 300mm to 650 × 450mm in size of the surface area. The table may be deployed manually, or sometimes actuated electronically. Often stowed adjacent to the passenger in a vertical condition within a stowage, it will translate towards the passenger from behind a small door, travel vertically from its cassette, and then rotate to a horizontal deployed condition, with the ability to further translate towards and away from the passenger for comfort. It is often an incredibly complex item, and the suite door is often more complex due to the need for an emergency egress mechanism if it were to fail in service. Here are some examples describing how the different types of cost may inhibit themselves within a product of this nature:

Example 1a – Meal Table (Measurable Cost)

If the release is late, then the development build may be late, and undetermined issues discovered too late to rectify within the budget. In this instance, additional resource will be required to modify the design in order to rectify the issues. Furthermore, an expedited build will have an increased cost compared with that of a standard lead time also, again contributing

to the cost. This is easily measurable during and immediately after the product has been developed.

Example 1b – Meal Table (Subjective Cost)

Change of staff is incredibly disruptive, this is unfortunately very common on lengthy projects, especially within an organisation who promotes opportunities for development & progression. When someone leaves one team, someone new will often need to continue the work, which is difficult considering that a meal table may have a complex mechanism, consisting of ~200 components. Unless the evolution or detailed intent has been accurately and unambiguously recorded, it is tremendously difficult to continue with someone else's design of complex products. The CAD filing or IT system may slow down the process of being able to open and save work, this is not recorded as a specific activity, it all falls under the task of design, and therefore is difficult to measure, hence its subjectivity.

Example 1c – Meal Table (Delayed Cost)

Delayed cost often comes from the aftermarket department, where an item has failed in service, leading to excessive costs to replace. Excessive in the fact that any fault must be rectified within a standard 20 minutes LRU (Line Replaceable Unit) timeframe, meaning if it cannot there will be a condition of AOG (Aircraft On Ground), and this will lead to significant penalties due to delay and lost revenue for the airline being placed back to the supplier. The largest contributor to a product failing in service is due to the lack of cyclic (fatigue) testing, and hardly ever abuse load related. The reason for this is simple, the regulatory body will mandate that items meet certain criteria for seating, in terms of physical testing these are primarily the ability to withstand a specified abuse load, depending on the location and nature of the product. At best the cyclic test being conducted late, and sometimes no until the product is being built production. The resultant of being late in development often results in cyclic testing however is not a regulatory requirement, it is conducted as a quality function to ensure the product meets the customer expectation. An issue in recent years with a dropping sidearm had significant costs, due to the volume in service, the cost was not dissimilar to that of the entire engineering for developing a new programme.

3.6. Results

The result of this study is not quantitative in nature, it does not conclude with a potential saving in terms of value, but seeks to result in something more fundamental. Granted, the identification of considerations within this work are specific to the case, but the discussed examples should provoke thought for other scenarios. Structured or arguable rigid methodologies, tools and processes are excellent for continuous improvement, but the corrective actions and subsequent solutions should be placed into context of the wider picture. This is an attempt of challenging one's own perspective, with a view to pause for thought, considering the adverse effect on other factors.

The ultimate goal is to create a robust set of standards, however there is a great deal of work to progress with in order to achieve this, and that will be the next step in this body of work. It is regretful that this was not concluded during this research, however it is important to first define the problem statement and identify the current state, which has concluded. The next phase was to progress on to a set of potential solutions through root cause analysis, and finally onto permanent corrective actions, with implementation of some containment actions along the way. This has not been completed as initially intended, and the reason being is that upon considering the factors, the wider picture is very complex. Complex problems do not necessarily require complex solutions, the solutions may be simple, and simple solutions are indeed often the best. However, this is the basis for the argument, the process for forming the solutions should be more intellectual. This is a mind-set, a 'better' way of thinking

The overall end result will seek to be more intelligent, thereby creating a more sustainable set of solutions, making a better future state. Of course what works for today's solutions may not necessarily work for the future, it is important to recognise this. A key factor, if not the key factor for success is the ability to adapt to change, and the better the adaptation the more powerful the organisation may become. Change management is often overlooked or poorly implemented, this work has provided the foundations in terms of considerations to make it more successful.

4. Conclusion

The management of engineering projects are often complex, balancing the difficult technical aspects of engineering using general project management tools and methodologies. This report does not focus on only a single issue, but has unearthed what may be regarded as a primary step in determining the difficulties within engineering projects in general. What has been discovered is the need to balance key attributes within a project, and a balance by nature should consider the wider contributory factors. The outcome of this is to invoke a different way of thinking, and what may be the beginning of a tool that could be used as a standard measure to determining balance. The best solution is not necessarily the most effective countermeasure or containment action for a given problem, moreover the best solution is one that looks to address the issue whilst ensuring all relating factors are respected and impacted to which is controlled to a minimum. Human nature dictates that our own perspective is what drives us to achieve a result, often pushing against other perspectives or disregarding them altogether. It is often the case that an argument is due to the lack of empathy or willingness to understand the other side of the argument, either due to one's deep-rooted beliefs in their own view, or simply due to not wanting to accept another perspective. The same is often true for solving problems, as one problem is solved, another is sometimes created, or as one factor such as time is improved, another such as quality may often be impacted.

Honesty and awareness are other important factors when determining a project plan or timeline, honesty in a sense of identifying and accepting how long a task actually takes to complete, an unbiased and realistic vision is a strong attribute to hold. Awareness of all factors again, cost, time, quality and people, it is not always wise to focus on one at the detriment of another. Honesty is the ability to stand back and view the wider picture, and accept that an idea or plan may harm another area. This will theoretically enable the project to run smoother, controlling the risk and potential issues, eliminating or controlling the risk prior to the potential occurrence.

There is a great deal of literature and work available on processes and tools in order to carry out a task effectively, documenting and creating tools from lessons learnt is how we as a

society prosper, it is fundamental to our ever evolving and continuous improvement mind-set. More subjective is what this work seeks to do, its intent is to provoke critical thinking and to consider the wider picture. This is by no means intended to challenge continuous improvement methodologies, but is intended to complement and enhance such tools, complex problems often require complex ways of thinking, the easiest option is not always the best.

There is not always a clear 'right' answer, the answer on the other hand may be 'right' to a given question, but perhaps we often ask the wrong question. Such as the emphasis on defining 'the problem statement' on an 8D analysis, failure to do so may result in solving the wrong problem. An example of this is how we treat the root cause of the symptoms, not the root cause of the correct problem. An example of this is that during the 3D & 2D data release phase of a project, rejections of the data during the release phase by checkers are often very high, picking up on drawing errors or DFM (Design For Manufacturing) errors. Multiple times have workshops taken place on attempting to reduce the number of rejections, often with a problem statement 'Drawing Rejection Rate is Too High', this is addressing the wrong problem. The result leads to more paperwork for checking thereby slowing the process down, and fewer checks so that more issues go undetected. A far more progressive and honest approach would be to have a problem statement 'Quality of Drawings does not meet expected standard'. This may result in better training, focus of having the right people in the right roles during the release phase, and not only would this make the process move faster but it may improve quality and even reduce cost. Of course the latter option is more of a long term solution, and is more difficult to achieve as training takes time, but it is undoubtedly the more progressive action that will reap benefits in the future.

5. Recommendations & Further Work

The next steps will be to work on the framework of Value Balance Management when considering solutions. The work to date has uncovered the complexity of the wider picture, and further work is required to investigate possible further considerations. When the next step has concluded, a clearer measurement system should be developed, this will include the following:

- **Definition of factors** – For each consideration of ‘Cost’, ‘Quality’, ‘Time’, and ‘People’, a clearer definition of what should be considered for each is required.
 - Example – Cost in terms of time may consider immediate cost, mid and long term cost. Measureable cost in terms of impact may consider the value of the potential saving against the baseline or current state. Set up cost may consider the cost in terms of effort and resource to implement the change. Abstract or qualitative cost may consider the potential given a scenario.
- **Scoring of factors** – This will feed into the overall rating system, and is important to ensure the results are fair and measured.
 - Example – Remaining on the topic of cost, with the more subjective qualitative cost factor to begin with. This could be rated not dissimilar to that of a risk assessment, whereby the severity and likelihood of occurrence may be rated accordingly. The impact of cost benefit may be measured as a percentage delta to the baseline or current state, with an agreed grading level applied. However, the problem with this method is that percentage alone may not necessarily be the best measure, the reason being that a small percentage change of a large cost may be significantly greater than a large percentage change of a small cost. For this reason, a factor in terms of actual value should be applied to the equation.

- **Tools and calculations** – The calculation for this will not be in the form of a manual calculation, the tool will be application based, with a first primitive version likely to being developed in Microsoft Excel, using a series of formulas, functions, data validation and conditional formatting. Possibly with a series of drop-down menus and values to enter into some fields. Importantly, the parameters can be set within the workbook, and then the required fields can be populated accordingly in order to obtain the result.
- **Results** – The results will be calculated automatically, in a visual display similar to the concept:



The result is measured against the baseline or current state, the importance of this is that it is indicative if the difference of the change or solution. A weight may be applied within the parameters for each given factor, if cost was significant than it may be deemed necessary to forego the other three factors somewhat. Similarly, if morale was incredibly low within a business, leading to a poor retention rate, then the 'People' factor may be of a higher weight than the other factors, and so on.

Figure 16 - Value Balance Management Template (Kilbane, 2023)

What is important is that this does not necessarily provide the final result, but provides a set of results for consideration, allowing for more informed decisions to be made accordingly.

- **Further action** – The results may be discussed by stakeholders or key members of the team, enabling decisive action to be taken. It is important to act upon the wider result as opposed to the final rating, the final result is an indication, and individuals should use their own intuition and intellect to interpret the results accordingly. Such as a 'Pugh Matrix' for concept selection, an 'FMEA' process, or 'FEA' software, the result (output) is only as good as the parameters and accuracy of data (input). For this reason, it may be important to formulate a set of rules or additional guides.

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- **Rules and guides** – This will ideally be a set of guidelines for using the new tool, these guidelines will be in two forms:
 - Input & parameters – An aid to understand how the tool works, including the setting of the parameters and descriptors of the fields of input data.
 - Results & considerations – The results in terms of the output will ideally be complemented by a set of considerations, possibly in a tabulated form such as a scoring rubric. Alternatively, with a view to automate and make the system more user friendly, a macro within the program could be used to generate the set of results with the given considerations when a button is pressed. This would not only provide a faster result, but would also be more user friendly, thereby reducing yet more time and effort. Taking a step further yet again, with a click of a button the document could output an automatically generated PowerPoint presentation of the results, thereby achieving an automated presentable format for whomever would need to view, such as management or any relevant stakeholders.

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