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The impact of Cost of Poor Quality on Project Management

By

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September 2014

A dissertation submitted in partial fulfilment of the award of the degree of Master of Science in Engineering Management.

Abstract

This project evaluates current literature on project management philosophy, in particular the Iron Triangle that is commonly used to describe the relationship of the three restrictive forces in project management, namely Resources, Schedule and Scope.

Current literature has a rich source of information on quality approaches that are used in intensively competitive industries (particularly automotive manufacturing) where commercial need has driven innovation of quality approaches to develop leading quality philosophies such as TPS (Toyota Production System), lean, six sigma and so forth. These methods and philosophies enable companies to develop highly competitive delivery strategies that enable them to deliver high value with maximum efficiency and a minimum of waste. The same appreciation for the value of quality has yet to percolate to the construction industry. The perception appears to exist within the construction industry that increases in quality would result in additional expense and schedule impacts and not that increases in quality (meaning an investment in the wider tools and benefits of quality management) would introduce significant opportunities for benefits realisation for large project stakeholders.

This dissertation evaluates the current standing of quality within the construction industry and proposes means by which the success of project management might be enhanced by the adoption of more rigorous quality methods.

CONTENTS

1. AIMS AND OBJECTIVES

1.1 Aim

This dissertation's main aim is to critically evaluate current project thinking around the Cost of Poor Quality (COPQ) on large construction projects. This project will consider the potential benefits that can be realised to project and construction management organisation if they were to adopt a rigorous approach to the reduction of the Cost of Poor Quality on the large projects that they run. This dissertation will evaluate current thinking on COPQ on large construction projects as well as consider how other industries, in particular the automotive industry, have reacted to initiatives to reduce the impacts of COPQ.

In addition this dissertation will consider what projects may gain with regard to cost and schedule benefits. In addition this dissertation will evaluate whether improved project performance in other areas could be gained with a re-evaluation of the quality strategy deployed on projects.

The "Iron Triangle" of Cost-Time-Quality constraints that is popularly associated with project management will come under scrutiny. Popular literature on the subject (within the context of the construction industry) appears to describe a linear relationship between the three different factors in that an increase in quality necessitates a corresponding increase in schedule and cost to accommodate this. This is borne out by the anecdotal experience of the researcher within the construction industry. Does an increase in quality result in increases in cost and schedule? Evidence from the automotive industry would point at an inverse relationship, namely that increases in quality reduce the schedule and cost of a product. Would the same not apply to project management? This dissertation will evaluate whether a new approach to quality within project management will lead to better schedule (and cost) performance of large projects.

A reticence to invest in quality processes in techniques "to keep costs down" has been observed, though this appears to be done without consideration (or apparent understanding) of the potential benefits that this may deliver.

This dissertation explores the identification and analysis of poor quality on projects and aims

to identify poor project quality - and its associated impacts to the construction industry - through the Cost of Poor Quality (COPQ) methods proposed by Juran.

The dissertation describes the drivers for schedule performance of large construction projects. (For the purposes of this dissertation large construction projects are those that are considered to be in excess of £500 million).

Objectives:

1) Question the fundamental approach to construction project management – particularly in relation to the understanding of Quality with the "Iron Triangle" of Time-Cost-Quality. I.e. is the relationship a linear one in that an increase in quality results in an increase in cost and schedule, or is there an inverse relationship between quality and cost-schedule where an increase in quality results in a decrease to the cost and schedule? (It should be noted that there is considerable uncertainty in what "quality" means in regard to the iron triangle – this will be examined through further research in this dissertation).
2) Evaluate whether an investment in a quality approach within project management will deliver increased schedule performance.
3) Describe other possible "side-benefits" that a quality approach may have on projects such as potential increases in safety, morale and prestige.
4) Investigate whether project management in the construction and petrochemical sectors can benefit from a greater understanding and adoption of lean quality techniques as commonly used in the automotive industry.
5) Gain a better understanding of what impacts particular drivers have in project management.
6) Examine current industry best practice and further research currently being done elsewhere
7) Provide suggestions for further research in the field of construction project management

1.2 Significance (Technical and Functional)

The construction sector is a significant contributor to the UK economy and contributes in excess of £83 billion annually to UK GDP. The construction skillset in the UK is also

globally respected and the UK is a leading project management services provider to the rest of the world. In addition the UK is host to a number is very large engineering consultancies that deliver services to the construction and petrochemical industries across the globe. The value of construction project management to the UK is thus well over £100 billion annually.
For many of these locally executed projects, and certainly for the greater majority of the internationally executed projects there is stiff competition from similar engineering companies in other parts of the world. To maintain Britain's competitive edge it is critical that the industry evaluates any means necessary to gain and maintain the differentiators that drive clients to choose British firms and British execution centres to deliver their projects.

As such any initiatives that can further develop the state of the art of project management can have a significant positive effect on this sector of the economy.
Through anecdotal observation the researcher is of the opinion that the infrastructure project management techniques are some way behind those of other industries and significant step-change advances may be possible if some of the techniques and philosophies of other industry sectors are adopted within construction project management. An example of this would be the lean processes adopted within the automotive industry that has led to significant advances in the productivity of the automotive sector. The construction industry by comparison has not adopted this rigorous approach to eliminating wastes and it is perceived that significant opportunities to leverage learning from other industries exists within the construction industry.
While a substantial amount of research has been done on the Cost of Poor Quality (COPQ) in the manufacturing industries there appears to be little in the way of similar work for the construction field. The "Iceberg" diagram of hidden costs is often described as the hidden costs of poor quality related to manufacturing. However the presumption (to be borne out by further research) is that this situation is at least as bad in the construction sector.
The understanding of COPQ in other industries has led to greater understanding of the benefits of investing in quality upfront to prevent issues occurring versus those of dealing with the disruption of quality failures once they have occurred. Estimates vary between eight and twenty times that the COPQ amount exceeds the investment that might have prevented (or mitigated) it. (This investment cost being known as Cost of Good Quality or COGQ).

Why is this relevant?

There are many large projects that are successful, however there are also many large projects that fail. Merrow (2011) states that megaprojects (those worth over $1 billion) tend to be either very successful or abject failures with little in-between. Relating to the samples of megaprojects that he was analysing (over 300 projects classified as megaprojects) Merrow goes on to state that *the 35 percent of projects that succeeded were genuinely excellent projects. On average they underran their budgets by 2 percent while delivering highly competitive (96% of industry average) cost.* Merrow contrasts this with the failures where failed projects had a 40 percent constant currency overrun, slipped execution schedules by an average of 28 percent and averaged only 60 percent production in their first year.

Figure 1.2 is useful in understanding just how wrong a project can go. It should also be noted that some recent projects that have experienced funding and completion challenges (such as the Sakhalin 2, Kashagan and Sochi Olympics projects) are not included in this list and would likely dwarf many of the projects listed here.

Project	Cost Overrun (%)
Suez Canal, Egypt	1,900
Scottish Parliament Building, Scotland	1,600
Sydney Opera House, Australia	1,400
Montreal Summer Olympics, Canada	1,300
Concorde Supersonic Aeroplane, UK, France	1,100
Troy and Greenfield Railroad, USA	900
Excalibur Smart Projectile, USA, Sweden	650
Canadian Firearms Registry, Canada	590
Lake Placid Winter Olympics, USA	560
Medicare transaction system, USA	560
Bank of Norway headquarters, Norway	440
Furka Base Tunnel, Switzerland	300
Verrazano Narrow Bridge, USA	280
Boston's Big Dig Artery/Tunnel project, USA	220
Denver International Airport, USA	200
Panama Canal, Panama	200
Minneapolis Hiawatha light rail line, USA	190
Humber Bridge, UK	180

Figure 1.2. Sample of large project cost overruns - Flyvberg (2014)

Flyvberg (2014) states that Measured by value, the size of infrastructure projects has grown by 1.5% to 2.5% annually in real terms over the past century. Merrow (2011) in turn states that a number of factors (such as competition, required economies of scale for project viability and the resource demands of rapidly growing eastern economies) have converged to ensure that megaprojects will be far more common now than what they once were. It would thus appear as if megaprojects are here to stay, and that they are getting ever larger, more common, complex and expensive. Given the spectacular failure rate of big projects, and the fact that big projects are getting larger and more commonplace it is important to understand what factors might be contributing to the success (or failure) or projects and what could be done to mitigate for the factors that affect poor project delivery.

There are several "critical success factors" that contribute to project success or failure. Khan and Spang (2011) list four categories of critical success factors that affect project outcomes. The group these as a) Organisational Factors, b) Project Factors, c) People Factors and d) National Factors. Whilst all of these factors cannot be controlled by project management companies the organisation factors certainly can be. These are listed below, and are matched to the relevant excerpts from the ISO 9001:2008 standard for a comparison against the quality elements in a project organisation setup.

Critical Success Factor	**ISO 9001:2008 Quality Standard Equivalent**
Risk Management	7.1 Planning of Product Realisation (implied)*
Communication	5.5.3 Internal Communication 7.2.3 Customer Communication
Sufficient Resources	5.4 Planning 6 Resource Management
Organisation Structure	5.5 Responsibility, authority and communication
Top Management Support	5.1 Management Commitment 5.6 Management Review
Effective Monitoring and Control	8.2 Monitoring and measurement
Effective Change Management	5.6 Management review
Organisation Maturity	5.4 Planning 6 Resource Management 7 Product Realisation

Figure 1.2.1 - Organisational Critical Success Factors compared to elements of the International Quality Standard. (Adapted from Khan and Spang (2011)).
** It should be noted that the new ISO 9001:2015 will be a risk based quality management standard.*

It is against this understanding of quality within organisations that the concept of the Costs of Poor Quality can be introduced. If these factors are not controlled well and quality failures result then how do we understand the impacts of those Costs of Poor Quality. It would also help to quantify what the actual COPQ values are in large projects. If the impacts are less than one percent of TIC then they may well be deemed negligible in the greater scheme of the project. This information for project management companies is sparse however, and the nearest approximations can be made for companies in the manufacturing sector where this phenomenon has been studied extensively.
Estimates on the impact of COPQ on company bottom line profits vary with common figures shown as being around ten percent of costs being poor quality related.

Quality impacts:

1) Schedule – increased productivity through better coordination and active waste elimination will allow better schedule performance to be achieved. This in turn impacts:
2) Profits – through reduction in project expenses and elimination of COPQ costs. This in turn impacts:
3) Company sustainability – as the company will be able to offer more competitive bids than its competition. This in turn impacts:
4) Stakeholders (Society, clients, investors, employees, general public) – who get the benefit of better value delivered for their money and reduced disruption due to projects being delivered faster.

<u>Those who will benefit:</u>

The parties that will benefit from this research are:

Project Managers – will gain insight into the effects that robust quality management may have on their projects.

Quality Managers – will gain a new appreciation for their responsibilities and potential impacts within the world of large project management.

British Industry – Britain is a world leader in large project consultancy. Improvements in the management of projects will further enhance Britain's reputation as a project management centre of excellence.

Project Management clients – will gain benefits from projects that are better run, deliver increased value for money and are completed sooner.

British society – If Britain's project execution skills are further enhanced it would be reasonable to expect that the industry would benefit from increased work as a result. This would lead to further job opportunities as well as a growing number of persons contributing revenue through tax receipts to Her Majesty's government. Increases in contributions to the national fiscus would have positive benefits to UK society as a whole as the government would have additional funds to deliver better services to the British public.

Consideration for the novelty of different projects

Wembley football stadium is different to Heathrow Terminal 2 which again is wholly different to Heathrow Terminal 5, and these projects again are different again to the Kashagan petrochemical project in Kazakhstan or the Gorgon LNG (Liquefied Natural Gas) project in Australia. It is the nature of projects to be different, so much so that Oisen in Atkinson (2003) describes a project as *a unique, one-off, complex task.*

However, if we were to dismantle these "unique, one-off complex tasks" and compare the elements that make up their work breakdown structure then there will be significant similarities in the component parts of each of the projects. All of the projects, for example, require piling, and all of the projects are dependent on getting concrete mixes right, the correct material shipped from supplier yards in the correct order and made to the correct specification. All of these projects, as diverse as they are, need to have taken heed of the customer requirements and the particular challenges that can be faced in executing the projects as well as the lessons and pitfalls that previous, similar projects have encountered. All of these projects will need to have effective delivery strategies in place, be aware of what is required to commission and bring into use their projects as well as manage project challenges such as managing change and delivering the projects within complex, resource constrained budgets. As such there are significant elements within project management and execution that are common to large projects.

What this dissertation proposes is a greater understanding of some of pitfalls that occur on large projects as well as the tools that should be employed in managing the "unique, one-off complex tasks". In so doing this dissertation will discuss elements and propose solutions to provide a more robust method for delivering projects with better efficiency, less disruption and increased success.

a. Delimitations of this dissertation

This dissertation thesis is limited to the study of the Cost of Poor Quality impacts on project management for large and super-large construction projects in the construction and petrochemical sectors that are executed in the UK (note that this may mean that the project is physically located either in the UK, or abroad, but the execution centre for the construction (or construction management) is in the United Kingdom). For the purposes of this dissertation a large construction project (also referred to as a megaproject in some literature) is deemed to be a project where the TIC (Total Installed Cost) is over £500 million.

Projects within other fields, such as the development of a new motor vehicle model or roll out of an IT system are not included in this dissertation, although work related to those fields and tools developed for them are referenced in this dissertation.

2. RESEARCH METHODOLOGY

Cresswell in Thomasson (2013) describes Quantitative research as “transferring information into numbers and amounts and then conducting statistical analysis”.

Andersen in Thomasson (2013) describes Qualitative research as “methods words and the researcher’s interpretation and perception of them is in focus”.

This dissertation will make use of both quantitative and qualitative research.

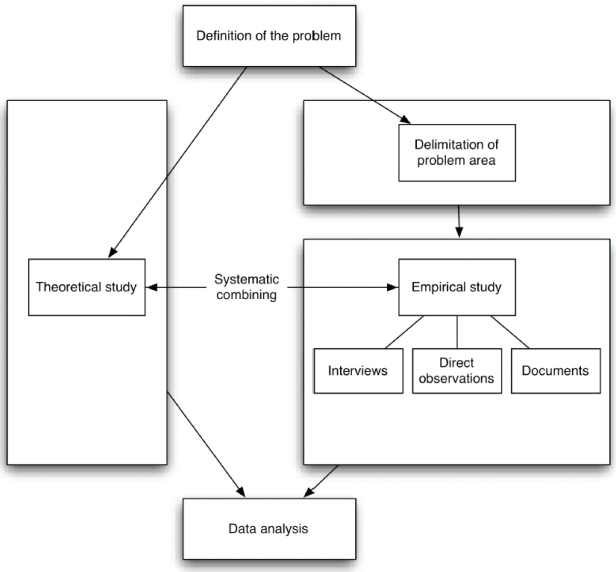


Figure 2.1 – The performed research process (Thomasson et al 2013).

Thomason et al (2013) above describes the research process as a parallel activity where the theoretical study (the literature review) is conducted in parallel with the empirical research. The theoretical study informs what the empirical study should target. It may be that some aspect of an issue is covered in detail in the literature, and that there is scant (or outdated) information on another aspect and this then, if it follows the premise of the research, may provide a good direction for the empirical research to follow. Initial research should be based on the existing information available and later on in the dissertation, once the extent of knowledge in literature is clear, that the theoretical analysis and the empirical study should be done in conjunction with one another. This will help ensure that the empirical study questions are best directed to investigate gaps in the common understanding.

This dissertation will make use of both theoretical (Qualitative) and empirical (Quantitative) study as described in Figure 2.1. Theoretical study will help shape the direction of the empirical study with data analysis performed at the end for the projects to examine whether there is support demonstrated for the dissertation hypotheses.

The literature review will examine current information that is available in;

- The Brunel University library,
- Industry journals (those not available on the library website),
- Publications by industry specific bodies such as the CIRIA and CII,
- Company internal information such as procedures, databases and go-bys and
- Previous studies done at other education institutions

At this stage it is envisaged that the qualitative study will include:

- Analysis of current literature on "Cost of Quality", in particular with reference to the construction industry, and with the view to equate cost of poor quality with impacts to schedule performance.
- Analysis of current literature on lean efforts in construction - so called "lean construction".
- Analysis of current literature on quality initiatives in industries where quality is perceived to have a higher level of uptake (such as the automotive industry).
- Analysis of the tools available to the construction management industry to reduce or mitigate for quality failures, and thus to enable projects to be better run.

The qualitative study will be done by means of questionnaires issued to construction industry professionals through an online survey tool. The questions posed will be determined through literature review and intended to support the examination of information that will demonstrate support for, or against the research's stated hypotheses.
The research will also gauge the responses between levels of construction industry professionals so that responses between those in senior posts can be compared to those in lower organisational posts. This may reveal whether there is any disconnect between senior management and the rank-and-file of construction company staff.

2.1 Problem Statement

Based on observation and initial review of literature the following problem statement has been developed for this dissertation.

Problem:

The understanding of Cost of Poor Quality (COPQ) as it relates to Project Management in large construction projects is poor. The Cost of Poor Quality (COPQ) impacts on large construction projects are significant. (Significant impacts are considered those that have the potential to put one or more of the completion parameters of the project in jeopardy – these parameters being one or more of scheduled finish date, functionality, profit, safety record etc). A better understanding of how the Cost of Poor Quality impacts the project management of large construction projects will lead to better project management and more robust delivery of projects.

Impact

If knowledge of the COPQ is poor then knowledge of its impacts and the actions required to reduce it are also poor. This would result in unnecessary wastage in projects that result in delay, poor project delivery, and negative impacts to project clients, project employees, wider project stakeholders and project management companies. These negative impacts could be any or all of; loss of revenue, loss of prestige, safety incidents (through unsafe situations arising as a result of poor project management) and cancellation and delay to projects that might otherwise have been successfully delivered.

3. LITERATURE REVIEW – COPQ

3.1 The definition of the word “quality”.

The ISO 8402-1986 standard defines quality as "*the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs*."

Wiezel et al (2013) describe project management as; “*the discipline of planning, organising and allocating resources to bring about successful completion of project goals and objectives while honouring project constraints*”. Understanding these two definitions then demonstrate support for Wiezel et al (2013) who also define project success as; “the satisfaction of stakeholder needs measured by the success criteria being identified and agreed upon at the start of the project”. (It should be noted that the term “stakeholder” is a broad term and thereby includes the project delivery company).

Project management literature describes the “iron triangle” where three factors are presented at the corners of triangles and these three commonly being either cost, time and scope (with quality in the centre of the circle); or as variation cost, time and quality.

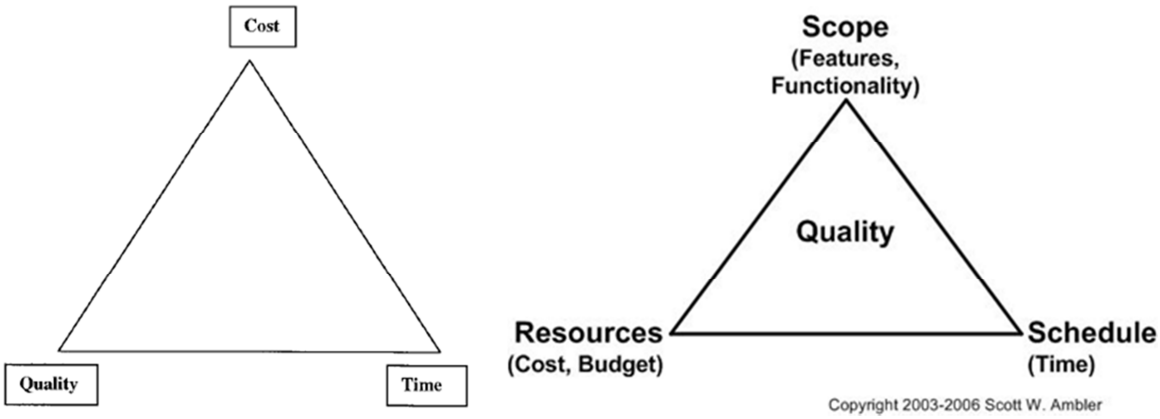


Figure 3a - Different interpretations of “Iron Triangle” from left Atkinson (1999) and Ambler (2005).

When considered as part of either triangle variant however there may be confusion as to what interpretation should be assigned to the word "quality". The inference with the triangle demonstrations are that there is a restriction on quality in that increases in time, cost, schedule or scope are required for an increase in quality. This is at odds with the definitions described at the beginning of this chapter in that quality is described as "fulfilling the stated or implied needs" of its stakeholders. Projects should thus, at their outset, be set up to deliver the stated or implied needs of their stakeholders and the necessary resources (including personnel, knowledge and other investment required) made available to facilitate project success.

Quality, whilst being understood as the discrete (or implied) specification that a project should meet, should also be understood as a set of tools, techniques and philosophies that enable companies to better meet their stakeholders requirements. This may require a paradigm shift in project management understanding of what quality is and what it has to offer.

Seawright (1996) describes different facets of quality (shown in figure 3.1) and these have been adapted by the researcher for possible application to the construction industry.

Seawright et al (1996) describe seven major categories of definitions of quality: transcendent, manufacturing-based, product-based, user based, value-based, multidimensional, and strategic.

No	Quality Category (from Seawright)	Definitions from Seawright (1996)	Application to construction
1	Transcendent	Condition of overall excellence	Condition of overall excellence, including the delivery techniques used in the project
2	Manufacturing Based	Production (in a factory) in conformance with objective design specifications	Production (in a factory) in conformance with objective design specifications, as well as on—site delivery of manufactured and assembled product.
3	Product based	Various definitions related to durability, reliability serviceability.	Quality of components manufactured offsite such as bolts, concrete mix and structural steel elements.
4	User based	"Fitness for use" in general this term refers to the user experience of the product supplied.	In construction – the experience/ perception of construction staff of a product, process or service. After construction – the building user's

			experience of the project as executed by the construction company – i.e. how well the building meets its stated or implied requirements.
5	Value based	Customer satisfaction (user based quality) considered in conjunction with price.	Customer satisfaction (user based quality) considered in conjunction with price. Price may include the operational expenses (Opex) of a finished building – a well designed and built building would tend to have lower Opex than a poorly built one.
6	Multidimensional	Where multiple aspects of quality are considered – (e.g. Parasurnam (et al) in Seawright (1996) describe 5 aspects of service quality: tangibles, reliability responsiveness, assurance, empathy).	Delivery of a construction project that meets both the objective quality requirements (such as conformance to delivery requirements, operability, maintainability etc), as well as the subjective quality requirements (such as aesthetic appeal and client experience)
7	Strategic	Where a company gains a competitive advantage through the robust application of quality methods, as described by Porter in Seawright (1996) as; "one way to differentiate a product from its competitors, potentially providing the producing firm with a sustainable competitive advantage that allows it to earn above average profits"	Where a company gains a competitive advantage through the robust application of quality methods, including the use of quality techniques to deliver projects ahead of the schedule that its competitors may be able to provide.

Figure 3.1 Adapted from Seawright (1996)

3.2 Cost of Quality (COQ) as applied to the Construction Industry

Tumala (2002) states that Juran introduced the concept of Cost of Poor Quality (COPQ) as a means for quality departments to highlight their quality programs to management. Whilst this is an admirable initiative it does imply that this (COPQ) is something that management are entirely unaware of. It may well be the case that management's understanding of quality, it's benefits and the impacts of not managing and resourcing it properly is misunderstood. It is

beyond the remit of this dissertation to evaluate why that might be the case. It would appear from popular literature however, that the value of a well-managed quality program has been recognised and fully adopted by the world's leading automotive companies, not just as a means to reduce defects, but as a means for the company to differentiate itself from their competition through the strategic application of quality techniques in their organisations to drive real delivery value. The Toyota Company is the classic example where a company is using quality techniques - the "TPS" (Toyota Production System) - to gain significant advantage (in terms of operational leverage as an efficient business entity) over its peers. The TPS system is now well studied and its techniques are applied to a broad range of industries well beyond the original automotive intent. Its application to the world of construction project management has, hitherto, been limited however.

Crosby (1979, 1984) in Tummala et al (2002) states that: COPQ is *"everything that would not have to be done if everything were done right".* Tummala goes on to state that COPQ is *the price of non-conformance, and sees non-conformance as a bacteria that must be treated with antibodies to prevent problems from recurring.*

Whilst treating causes of non-conformance is certainly one way to reduce costs Crosby does not imply that prevention is better than cure, but appears to endorse the belief that the nonconformities that constitute the COPQ should first occur before they are mitigated for. A far more efficient approach would be to assess the risks of non-conformance occurring (i.e. attempt to anticipate their occurrence ahead of the issues arising) and then implementing measures to ensure that they don't occur. This would be moving from a reactive quality mentality where a COPQ arises and is then fixed, to one of where risks are judged ahead of events occurring and then measures are implemented to prevent the COPQ arising in the first place.

This approach of risk-based quality management would be in keeping with the soon to be released version of the ISO 9001 quality management system standard. The major change with ISO 9001:2015 is that it will adopt a risk based approach and it would thus be in keeping with anticipating the issues that may affect a business and have the business mitigate them before they occur.

The CQI – Chartered Quality Institute - (2014) has published some guidance on the new 2015 Quality Management System (QMS) standard. The CQI state that "Risk-based thinking is

about demonstrating that you understand the risks to your QMS and its constituent processes which might affect your ability to achieve your intended outcomes". It would appear as if the CQI's greater focus is on managing risks to a company's quality management system rather than the risks to project delivery and stakeholder satisfaction. (Stakeholder satisfaction is used here rather than "customer satisfaction" as stakeholders would include customers, but also all of the company's other stakeholders such as the shareholders, employees, governments and so forth. By looking at all stakeholder interests it implies a more sustainable approach to business management rather than just purely focussing on customer satisfaction). Thus, to manage risks fully it would appear as if two separate risk approaches are required, one to manage the specific risks to a particular project and the other to manage the corporate risks of a company's management system.

Why is COPQ important?

Naidish (2000) states that: *"Quality Authorities" estimate that COPQ to 20-40% of gross sales for manufacturing and service companies* - though no reference to these studies is given. He goes on to state that: *Independent studies made over the last 30 years have verified this loss… yet two-thirds of executives believed that that company COPQ was less than 5%, or just don't know what it is.*

Naidish goes on to state that companies that reduce COPQ to 10% of sales would double profits for most companies without additional investment from the company. This is due to the fact that COPQ detract directly from the company bottom line, and if margins are tight then the profit margin could be very small compared to the percentage margin lost to COPQ. Given that COPQ directly affects the company bottom line, any means to reduce it will have a direct effect on company business results.

This alludes to a powerful differentiator that astute companies can employ on their behalf when bidding for new project works. With ever increasing competition for large projects, and with securing work being contingent on submitting competitive bids, it is becoming increasingly important for project management companies to be able to submit competitive bids to secure future work. The companies that have efficient means of project delivery and who look for innovative ways to improve their delivery through understanding, managing and reducing the impacts of wastage are the companies that are more likely to make a success of the work that they win.

Juran's research into "Cost of Quality" stated that quality will cost either through the investment required to prevent quality failures occurring (cost of good quality), or through accepting the cost of poor quality (COPQ) when failures occur.

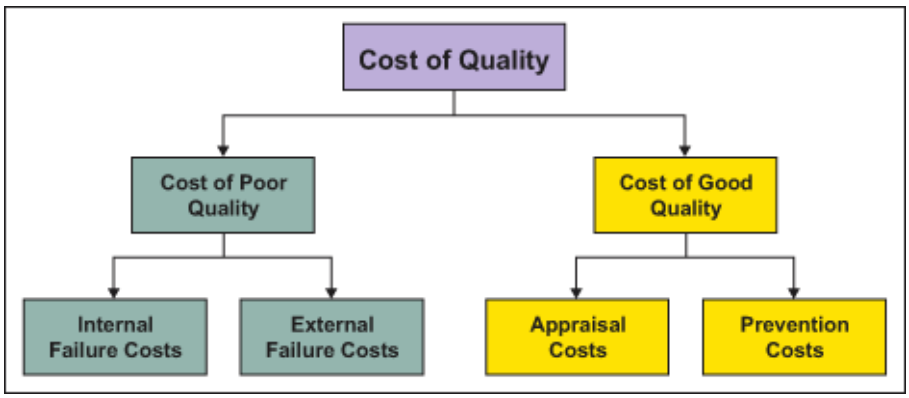


Figure 3.2 - Juran's cost of quality model (1988).

Goble et al (1993) quote the American quality guru Philip Crosby's statement that "Quality is free". Juran's model above where he spells out two types of costs of quality appears at first to conflict with Crosby's statement. Crosby however, is referring to the notion that an investment in the costs of good quality (i.e. the willingness to pay for prevention and appraisal costs) will be far more worthwhile than not making the investment and thus living with the expenses that will occur due to the costs of poor quality.

Juran also introduced the concept of having an optimum level of quality investment, namely that where the there is an intersection of the cost of poor quality and the cost of good quality. There would thus be a point of intersection where any increase in prevention costs may result in an increase in overall costs again as per figure 3.3 below.

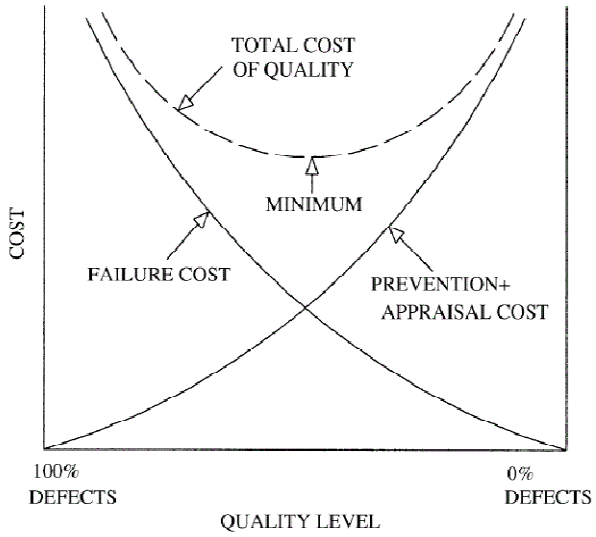


Figure 3.3 – Juran's Optimum Quality Costs Model

This model, however, does not take into account;

- The transient nature of projects with the introduction of new scope within a construction project (such as moving from piling works to assembling precast concrete columns). The introduction of these new situations may result in a period of flux while the control systems (persons, methods and machinery controls) become familiar with the new scope of work. There may thus be a greater occurrence of defective works in the early part of a particular scope delivery but the consistent application of preventive cost will reduce this over time. (i.e. COPQ may reduce with a steady application of preventive cost over time).
- The nature of projects where the critical path is in place. Within the narrow work scope for an element it may be that the cost of prevention is seen as an increase but for the overall scope the extra investment may be worthwhile – particularly if critical path pressure is reduced. The application of prevention and appraisal cost should thus be seen in the big picture of the finished project as a whole, not just individual narrow work scopes.
- Learning in subsequent projects. Should a company be a learning organisation – where it takes on board knowledge and turns it into wisdom (see figure 6.1) then it should not be encountering the same issue on project after project. It may be that a high cost of prevention and appraisal should be applied – where an element of organisational learning cost is incurred as part of prevention – so that subsequent

projects benefit from the lesson learnt.

- The COPQ initiatives should also be seen from the perspective of the wider business benefits that could accrue with having sustained higher quality due to positive impacts on downstream project elements. These benefits in turn could include winning more work and the business being financially more stable. Thus, the "optimum" point for cost of poor quality from a business point of view may well be with a higher prevention cost in place than the optimum that Juran describes in Figure 3.3.

The challenge with the construction industry is that large projects often have a lifecycle of around five years, and sometimes more. With companies submitting annual budgets and annual profit and loss statements there would appear to be the tendency to look at business costs on an annual cycle, rather than considering the whole project lifecycle. The "cost of good quality" is most often associated with the costs of assuring that early design work, supplier selection and rigorous construction methods are agreed and in place ahead the bulk of major construction works. The costs of poor quality however, typically arise late in the project lifecycle when the issues that were not resolved early in the project manifest themselves as defects that require management (either through concession or rework). Projects nearing completion typically have significant cost and schedule pressure so the tendency may be that further cuts are made and that the appetite to facilitate quality in the remaining delivery is reduced leading to a spiralling issue with poorer quality as the completion schedule looms. The cost of good quality then, is an early cost in the project and highly visible in the form of resource costs and the cost of poor quality largely arise later in the project lifecycle and are, at first glance not as visible and may well be "hidden" costs that require investigation to quantify.
It may be that the short term view is what focuses management attention due to its visibility, however it is the long term view that most affects bottom line.

Costs of poor quality can further be broken down into "visible" and "less visible" costs as described by the so called iceberg model shown in Figure 3.

Figure 3.4. Visible and Less visible quality failure costs. Costs above the line are easily quantifiable whilst those below the line are severe impacts but less visibly tied to the actual failure event.(Lulla 2014).

Tummala (2002) states a traditional challenge with quantifying COPQ is the "difficulty of tracing the root causes of resource consumption from the reported cost data by employing the traditional costing systems". This can be evidenced by the typical setup of project reporting where the Work Breakdown Structure (WBS) is set up so that COPQ events are not shown as discrete elements but are included in the WBS costs. Thus, for COPQ to be managed robustly a cost management system that allows for COPQ costing should be implemented on projects – as well as the willingness of individuals to use the data in an open and honest manner. Only once this is fully in place (this may well be a culture shock for many in project management) will COPQ be more accurately quantified. In the meantime however, much can be done to ensure that the major elements that inflate COPQ are addressed.

What is clear from the construction process is that COPQ has a significant knock-on effect to follow-on works as the construction programme typically does not have much flexibility beyond the critical path. This means that a relatively small hold-up can have a disproportionately large effect on follow-on works that the full impact of COPQ can be particularly hard to quantify. (The contractual nature of construction projects can also mean that these disruptions end up in expensive and protracted disputes requiring arbitration and litigation to resolve).

There appears to be little appreciation of "Cost of Quality" in the construction sector, quality failures are seen as part of the job costs and little emphasis is given on preventing quality failures occurring as the only numbers considered are the investment costs of prevention without considering the returns of the programme. There is also a tendency in some construction companies to deliver a project "to the rile" against what a contract stipulates and if any specific measures regarding quality are not included then it is simply omitted as a "cost-saving feature" rather than considering whether the company would benefit from the quality initiative.

COPQ constitutes a significant impact on bottom line income and estimates vary on how much this actually is.

Source	COPQ Estimate (% of sales)
Baatz, E.D. "What is Return on Quality, and Why You Should Care," *Electronic Business,* Oct. 1992, p. 61.	• 20-30% for manufacturing firms • 30-50% for service firms
Band, William. "Marketers Need to Understand the High Cost of Poor Quality." *Sales and Marketing Management in Canada.* Nov. 1989: 56-59.	• 25% for U.S. companies • 5% for Japanese companies
Bell, D., et al. *Managing Quality.* Oxford: Butterworth-Heinemann, 1994.	• 5-25% for manufacturing firms • 30-40% for service firms
Campanella, Jack. *Principles of Quality Costs: Principles, Implementation and Use.* Milwaukee: ASQ Quality Press, 1999.	• 20% is common • 2-4% is possible

Figure 3.5 – COPQ as estimate of sales (Defeo 2005)

4.3 Cost of Poor Quality (COPQ) in construction

The Cost of Poor Quality in Construction could be divided into two main areas;

a) The COPQ associated with the resolution of a defect (i.e. rework).
b) The COPQ associated with poor project management (i.e. inefficiencies).

Whilst inefficiencies are routinely described as quality failures within the automotive industry (Gao and Low (2014)) they are not recognised as quality failures within the

construction industry. The recognition of this as an issue for construction project management is key to the development of techniques to prevent or mitigate the issues.

COPQ related to construction defects

Managing COPQ requires understanding and recognition of what the potential COPQ issues are that occur. Costs and delays that are routinely incurred on construction projects may not be recognised as costs of poor quality and may thus not be addressed as such. Recognition of these costs is an important step in understanding;

a) That elimination (or at the very least mitigation) for them is possible
b) What actions can be taken to mitigate for them.

It should be noted that the list described below are the on-site cost impacts to the project and does not consider the root cause(s) of what these costs may be. The list below is not exhaustive but is a list of COPQ that the researcher has witnessed on recent large construction sites.

The costs of poor quality (COPQ) in construction could include any of or multiples of the costs listed below. The assumption has been made that costs of delays as a result of quality failures are also included in the COPQ estimates below (in essence, the "opportunity cost" of a COPQ event).

1) Hire of construction plant – for longer than is planned. A defined budget for hire of construction plant would have been established for a given project. If the project overruns its schedule then the cost of the hire of the plant would be a direct overhead that was unbudgeted. There would be additional hidden costs with the requirement for management to negotiate longer leases on certain plant, as well as the site enabling teams (those responsible for the provision and maintenance of construction plant) to determine what equipment is required for the remainder of the project.
2) Overtime rates staff to fix works. When a project is running late, or has an issue that needs to be reworked - particularly if this issue is on the critical path - then the project may need to spend extra hours on having the personnel present on the project to do the works. This is often at an overtime rate where time over the normal contracted hours is at 1.5 times the normal staff hourly rate, or even 2x if it falls on certain days like Sundays and Bank holidays. In Hanna et al (2004) productivity is defined as "the ratio of total input of resources to total output of product". The project may also suffer

additional cost in that the productivity of workers tails off the longer that they work. Hanna et al (2004) in a study of overtime productivity for mechanical and electrical fit-out contractors on construction projects in the United States – trades typically affected by rework - state that the contractors lose between one to sixty percent productivity depending on the type and extent of overtime worked. The extent to which productivity is affected by overtime in the European Union may be curtailed to some extent by EU regulations such as the Working Time Directive that can apply limits to how many hours may be worked on average per week over a given number of weeks (The Health and Safety Executive (HSE) 2014).

The project may need to pay for additional welfare elements such as providing meals for overtime staff and accommodation and other welfare arrangements.

3) Material required to complete works – this cost would include the building material required as well as the management time to procure the material and the logistics elements of handling, transporting and storing the material.
4) Professional support costs such as Health and Safety management to do bespoke risk assessments. As rework can often be beyond the scope of the standard works process there may be the requirement for bespoke activities to be performed by an organisation to satisfy the requirements of the defect resolution event. (An example could be the method-statement and risk assessment required for the replacement of a reactor in a petrochemical plant, which would not have been necessary if the works were done to satisfaction in the first place).
5) Undoing of completed works to access rework. Good projects should have a workflow process laid out so that as much of the work as possible is standardised. Koskela (1992) in Pheng (2005) describes the value in the reduction of variability as simplifying the number of parts and steps. Standardised works should be easier to adopt as the company systems would then be better equipped to deal with any particular issue that arises. In rework however, the works are very often non-standard works. As an example a section of construction scope, such as the installation of glazing panels would have a defined method statement and risk assessment (RAMS) for the installation of their works. If a defect with the installation is found that requires replacement then a new RAMS would be required for the elements that need to be replaced.

   It is likely that no method-statement/risk assessment would likely be written for the

rework when it occurs. As rework can be very tricky a project manager would need to ensure that the works are specifically assessed to ensure that the planned works are safe and that the rework is feasible (i.e. that the works planned will fix the defect without creating greater problems). This assessment may require the specific assessment of suitability by engineers to determine if the rework can be conducted safely and whether the proposed solutions are feasible. The perception is often that rework is twice the amount of normal work, however the reality is often far in excess of this. (As an example - rework often entails; that the work is done (incorrectly), it then needs to be undone, and then redone correctly. This is thus clearly more than twice the amount of work required to do it correctly the first time). As the works are often in complex already built up areas it often entails the unproductive occupation of a company's more experienced persons in the resolution of the particular issue. (Management around rework is often complex too as the Health and Safety requirements are often non-standard – see point 4 above).

6) Logistics costs such as transport and storage would increase. Large construction sites often require complex logistics arrangements such as lay-down areas and the administration of material to keep construction on track. Building a large and complex project often entails keeping track of the logistics of material being sourced from around the globe with varying lead times and surety of delivery times (i.ee. the confidence that the project may have in its timely arrival). If a project is delayed – or if rework is required – then the additional work would put further burden on the logistics arrangements of the project.
7) Supervision costs – on site supervision will be required for extended periods of time as the works are ongoing. Supervisors tend to be significant cost burdens on their project as they are expensive compared to labour, and the nature of the work that they are involved in (supervision) often means that they are not as productive as what an actively operating tradesperson might be. (i.e. their work is supervision, not construction).
8) Management time (from the construction company) used to investigate what went wrong and what should be done in remediation. Where a significant defect occurs it would be expected that a Root Cause Analysis (RCA) into the event is conducted to determine how the issue came to occur in the first place. This investigation will require further assessment of the events that led to the defect occurring, and this

entails further delay and non-productive use of construction team members' time. The evaluation of the proposed "corrective action" may need to be done by competent engineers and involve further time in amending the factors that contributed to the defect occurring.

9) Management time (from the construction company) used to manage client expectations with regard to the rework completion. Company leaders that would normally be busy winning new work for the company or improving a company's management systems would find themselves tied up in "fighting fires" with the client. This time would be spent largely providing reassurance of what the construction activities are that are that will be remediating the issue that has gone wrong. This is highly unproductive time for company leadership, and apart from affecting morale for the individuals concerned it is negating senior leadership from moving the company forward. This time is not often considered in the project makeup, it would often be considered "part of the job" for a company manager to get involved in and so this cost to the company (and its associated opportunity cost) would be lost.
10) Impacts in COCE (cost of capital employed) as working capital is tied up in building projects longer and milestone payments – or final settlement is delayed. In many contracts there are payment events tied to achieving certain construction milestones. These milestone are typically set by the client and may stipulate that a certain payment if due when a particular system comes on line or operates for a period of time at a specified rated capacity. When defects occur and these milestones are not met then the contractor is saddled with the ongoing expense of resolving what the particular issue is, as well as potentially missing out on payment milestones (especially if the payment milestones are contingent on achieving a specified element of satisfactorily completed construction scope by a given date.
11) Support works such as administrative/canteen/security to keep site operational,
12) Loss to client of having building availability (such as delayed income from rents as tenants moving in is delayed). This is a classic manifestation of a "loss to society" as described by Taguchi in Lofthouse (1999). Lofthouse states that *Taguchi defines quality in a negative manner as "the loss imparted to society from the time the product is shipped".* In the case of construction the researcher proposes that could be understood to mean "the loss imparted to society until the project is complete".
13) Loss of client goodwill – resulting in possible loss of future works

14) Liability insurance costs to fix difficult works. Insurers would have schedules and tables for standard work rates and they would be able to develop a cost quote for standard works without too much further assessment required. If a large defect event occurs however, the insurers may need to do a detailed engineering assessment of the proposed works, something that the contractor would have to pay for.
15) Assessment costs such as having Quantity Surveyors survey required works,
16) Damage to existing good works during remediation works of other defects (e.g. completed ceilings that need to be taken down to repair defective services).
17) Loss of goodwill to society (societal impacts) such as the blight of having hoardings up and dump trucks using roads for longer than they might have needed to. Societal impacts would also include the unavailability of employment in the local community that unfinished projects lead to. In some cases (such as late completion of schools and hospitals) the societal impacts may be significant on the service users of those facilities.
18) Rent of temporary spaces such as construction site offices that continue for longer than what was necessary with timeous project completion.
19) Loss of income through legal implications of finishing late. A project that over-runs may face litigation costs for over-running planned finish dates. The litigation could be for the loss of use to its owner (such as missed profits to the operator of the asset). The contractor doing the building work may also lose any completion bonuses that
20) Societal loss of not having facilities available to use on time (or impacts from having rework ongoing behind hoardings in opened but partially completed facilities),
21) Loss to industry of having competent construction staff held back to finish over-running projects (i.e. the next projects suffer due to lack of staff availability)
22) Safety impacts may arise (and subsequent costs) as rework in construction is done out of sequence of normal assessed method statements. The nature of rework also means that sometimes it is impossible to replicate the works in situ that would have been done in a controlled environment in a factory (e.g. paint touch up on steel), Manuele (1997) in Rajendran 2012 *"concluded that the word quality is interchangeable with the word safety".* Whilst Manuele was writing in relation to the construction industry it would be worth considering an automotive example to underline the point; the quality of a motor vehicle's brakes has a direct bearing on the safe operation of that vehicle. Quality then, could be considered as Operational Safety. Manuele's example

though, requires further clarification. Should a person be injured during the installation of an element of work then that matter is primarily an Occupational Health and Safety issue – during investigation it may be found that the root cause is a quality failure, such as poor installation method, poor design or faulty component. Occupational health and Safety deals primarily with the human behavioural aspects of the construction activity.

Should a person be injured after completion of the work (such as when a ceiling collapses on a member of the public) then that is wholly a quality issue.

This matter can be further examined by considering the health and safety impacts to the maintenance of a poorly constructed building to that of a well-constructed one. It could be assumed that the lifetime "human cost" (that being the total injury toll sustained during the maintenance of the building during its useful lifetime would be far less for a quality building than that building which isn't a "quality" building. Poor quality building in essence, could expose maintenance persons to higher risk than what a quality project might have done. (The Construction and Design Management (CDM) Regulations are intended to force building designed to consider the maintenance and operational needs of the buildings and to quantify – and mitigate – the "residual risks" that are left in the building).

In Rajendran (2012) Zurich Corp (2011) state that;

"Similar to safety management, it is critical to convince upper management and other stakeholders of the benefits of quality management, which are many;

- Better safety performance;
- Reduces project costs and time to complete
- Reduces potential for construction defect claims and warranty call backs
- Increases owner satisfaction
- Reinforces positive behaviours and accomplishment for project team members
- Creates a high-performance team atmosphere
- Promotes a zero-rework goal
- Minimises rework and punch lists
- Promotes a culture of continuous improvement
- Reduces the cost of the contractor or owner's insurance resulting in a competitive advantage over their competitors"

23) Reduction in warranty periods – increasing liability for the construction company. (e.g. construction companies are liable for system warranties from the time of handover/acceptance of the works. Product warranties however, start when these products arrive on site during construction phase. The bigger the delta between installation (start of product warranty period) and construction handover (system warranty period) the greater the liability for the construction company. Some building types (such as power plants and oil refineries) require a period of sustained productive running with a minimum output level and strict limits to what downtime the plant can experience in that time. This has to be achieved before the project is deemed complete and handed over to the client. Should there be failures in this cycle then (depending on the contract) the time resets to zero and the contracting company has to start the trial run period again – all the while incurring warranty liabilities for the components that have been installed that might have been the client's responsibility to manage.
24) Waiting time – as rework is done out of sequence there is inevitable disruption to a construction programme and certain works that would have been planned for a time are suspended while the rework is done. This results in planned resource not being able to be utilised productively and needless waiting occurring. The potential scale of waiting time impacts is significant. Flyvberg (2014) states if the London Crossrail project would lose £3.3 million per day that if any delays were to be incurred (a figure of £1.2 billion for each year should it overrun its planned completion date by that length of time).
25) Increased insurance costs for defect claims. Rajendran (2012) states that

A construction defect claim is any claim for property damage that is progressive in nature, and arises out of the construction of any project and occurs after construction operations have been completed. Defect claims are expensive. The U.S. insurance industry pays more than $5 billion annually to settle construction defect claims (Zurich Corp., 2011). This is approximately 0.5% of the value of the U.S. construction market, which was estimated to be slightly less than $1 trillion in 2010 (USCB, 2011). To put this into perspective, the average owner pays an additional ½ percent of every construction dollar to pay for construction defect claims and to bring their projects into conformance with project requirements.

As insurers often pick up the financial brunt of poor workmanship claims there is a rising interest from underwriters in reducing the likelihood of serious construction

defects occurring. An additional point of revenue for a construction company would be the savings over time in cheaper insurance premiums if the company manages to reduce its number of claims.

26) Staff turnover – Staff working on a project may be disillusioned with a project that is seen to be failing and may seek alternate work rather than stay and work through what would be seen as a failure. Staff on projects – particularly contract staff – would likely have other roles up in accordance with the project's contracted finish date. If the date slips beyond this then the contract staff would be inclined to leave their current works to move onto a new project that offers longer term employment, and a greater sense of reward (as the new project may not be in the defect resolution stage). The project that has the issues to deal with would then also face the challenge of losing the staff that would have been best placed to resolve the issue as they would have been most likely to have the best level of detail on the causes of the issue.

    Staff morale may also suffer if the project is seen to be in delay and a large number of issues to resolve. This may in turn affect morale and productivity may be jeopardised as a result.

27) Business value impacts. Significant delays to mega projects, particularly those that have media coverage or where stock market updates are required can have a significant impact on the stock price of a company (and hence the market capitalisation) of a company. Huband (2014) reported that a large oilfield engineering services firm announced delays to a key project. This announcement resulted in a share price drop of over fifteen percent in one day for the company. At time of writing this dissertation the share price had not yet recovered to its pre-announcement levels. (For a multi-billion pound company this is a significant loss of market value).

Understanding the Cost of Quality and the significant impacts that COPQ can have on a project presents an opportunity for construction firms to deliver projects faster, cheaper and with increased profit and this dissertation will evaluate whether a new approach to quality within project management will lead to better schedule (and cost) performance of large projects.

COPQ related to inefficiencies in the Project management process

The Oxford dictionary of business and management describes Shingo's seven wastes as:

1) Defects
2) Overproduction – make only what is needed now
3) Transportation
4) Waiting
5) Inventory
6) Motion
7) Processing (Over-processing)

Based on the researcher's experience with the construction industry the primary use for quality in construction currently appears to be the resolution of defect management, and not as an aid in driving efficiency. Related to Shingo's wastes above the first, namely "Defects" would thus be seen by most construction professionals as a quality issue, however wastes 2 - 7 above may not necessarily be seen as quality issues (or indeed as wastes at all) within the construction industry.

4.4 Further work proposed regarding "quality" in this dissertation:

Further work in this dissertation will include the evaluation of the understanding of the word "quality" and how it applies to construction. The current use of the term can often be used in a somewhat nebulous context and further definition, through the evaluation of current literature on the topic, will help develop the understanding of the different facets of quality through the delivery stages of a project. This will also include the competencies and toolsets required to leverage the different quality aspects properly. As an example, the competencies and toolset required for manufacturing quality (such as Statistical Process Control (SPC), Measurement Systems Analysis (MSA) and Root Cause Analysis (RCA) would be different to the application of quality in the strategic sense where project leaders would be required to have a greater sense of Management Systems, industrial psychology and organisational dynamics).

Mikkelsen (1990) in *Quality of Project Work and Project Management* describes a "Quality Pathway" where quality is applied to the different stages and facets of a project.

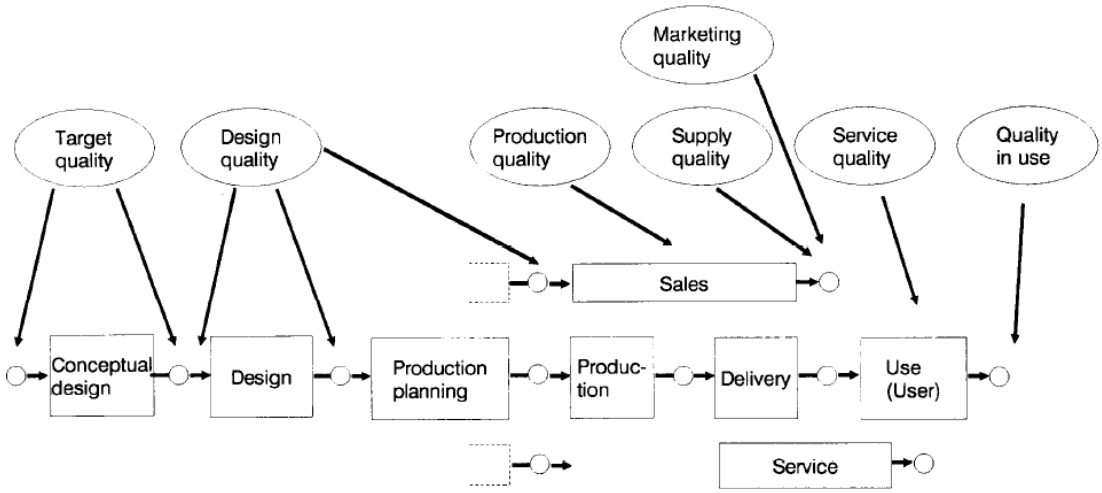


Figure 4.4 Mikkelsen (1990) – Quality Pathway in projects

Mikkelsen describes the different aspects of quality as applied to different elements of the project, and whilst an understanding of the different aspects of assurance across the project lifecycle is key to the understanding of the delivery of an assured project, the diagram does not explain how quality would be applied as a strategic driver in the project. This approach is symptomatic of quality having a "siloed approach" where different approaches are used in different aspects of the project but there is no coordinated and pro-active approach from the project leadership to use quality as a delivery strategy. Some twenty five years on from Mikkelsen's work the methods and approach to quality on large construction projects appear to still be much the same.

The detailed evaluation of the understanding of quality is required to properly support the premise of the research. Without the full view of quality and the varying ways in which it is applied at the different stages of a project the potential benefits of a quality investment - and the means as to how this could be achieved - may be lost.

4. RESEARCH – EMPIRICAL FINDINGS

Questionnaire design, questions and target audience

The survey was conducted using the online survey tool www.surveymonkey.com. This facility allowed the compilation of questions in a variety of ways with a flexible approach to question design. The SurveyMonkey website also allows the compilation of the responses and display of the results in a variety of available methods. The website provides full anonymisation of responses and also allows each respondents answer sheet to be evaluated individually. It maintains anonymisation by recording individual respondents as "Respondent 1", "Respondent 2" and so forth. This is useful in the further comparison of, for instance, the response of directors against a certain question versus those by engineers. In this way any difference in trend could be analysed.

Question design

The questions were designed to with the problem statement in mind. Questions were formulated to test the different aspects of the problem statement and also to provide some sense of calibration of the questions themselves (within the questionnaire some questions may be asked more than once to test responses). The questions themselves were drawn up from elements within quality and project management and covered the "Seven wastes of Lean", the "Quality Maturity Model", Lessons Learned as well as the general understanding and approach to cost of poor quality in the construction industry.

Target audience and response

The target audience is senior managers and knowledge workers (particularly those with technical and technically oriented management roles) such as project managers and project directors, construction managers, engineers and project oriented quality managers. Only persons who have worked (or who are still working on) large construction projects were be polled.

As the responses to the questions could be seen to be inflammatory if read out of context it was stressed that the responses would be anonymised. The responses given would be

confidential and that no reference to individuals, companies or specific projects would be made.

A concern with shaping the questions was that individuals might need to state what they thought the answer should be, rather than what the actual situation is. Persons may not be willing to effectively either admit to failures or running their company or project down by stating that the situation at their company or project was not ideal. Some error in response was thus anticipated, although it may be offset by having a response pool as large as possible.

Another aspect to guard against this was to frame, in the initial request for the response, that the responses would help shape the future of the industry and that their matter-of-fact response would be key to support this initiative.

The questions were designed with the website's freely provided templates and a hyperlink was generated by the website that could be used to email the target audience. The greater majority of the target audience was contacted individually through the linkedin.com website (A website for professional networking). It was felt that a professional social media platform would allow;

- Credible contact for the response (i.e. not appear as spam)
- More realistic chances of being viewed (as there is little chance for the message to go to a spam box and LinkedIn messages tend to be fewer in number than email)
- The questionnaire's website hyperlink was embedded in the LinkedIn message and thus allowed convenient access off a mobile handheld device (i.e. the questionnaire did not require paper hand-outs, printing, postage or faxing)

The questionnaire was submitted on the 28th August 2014 and closed for responses on the 6th September 2014

In that time 67 responses were received from 102 requests.

Questions asked – and responses.

In support of the research dissertation questions the following questions were used in the survey. For the benefit of future research, recommendations for improved questions for future research are also included based on this research experience.

Question 1

Respondents were asked to pick one entry from four which were Director, Manager, Engineer or Administrator/Commercial.

Which title best describes your role?

Question Rationale:

The options given were high level, but should have covered all of the roles of the target audience. The intent with this question was;

- Firstly to present an easy introduction to the questionnaire that would hopefully have driven further completion of the questionnaire.
- To identify whether there may be grouping of responses by the seniority of the responders (i.e. those who identify themselves as "directors" may have a wholly different view to the success of an initiative than those at lower levels within the organisation).

Question 1 Response:

Answer Choices	Responses	
Director	13.43%	9
Manager	70.15%	47
Engineer	10.45%	7
Administrator / Commercial	5.97%	4
Total		67

Question 2

This question concentrated on Lessons learned questions and had a subset of 9 sub-questions where respondents were asked to tick a box where five options were given. These were Strongly disagree, Disagree, Neither Disagree nor Agree, Agree and Strongly Agree. Only one option could be picked for each sub-question. The nine sub-questions were:

2.1 The Lessons Learned process adds value to the company

2.2 The Lessons Learnt process is implemented properly where I work

2.3 Lessons are routinely learned – as an organisation we genuinely look to learn from our past mistakes and failures.

2.4 I find that I don't encounter the same mistake on project after project.

2.5 I see the Lessons Learned process as adding real value to the company

2.6 I actively look to add lessons to the company database

2.7 I see lessons being applied actively, and people keen to not repeat past mistakes

2.8 The lessons learned process is a key part of my organisation's strategic improvement activities

2.9 The lessons learnt process delivers key strategic and competitive benefit for my organisation.

Question 2 Rationale:

Within a project Management Company the corrective action process within the Quality management System often is the means through which issues of a minor nature are corrected. The Lessons Learned however, have in the researcher's experience, tended to be at a higher, more strategic level and thus has the potential to have a higher impact on future project outcomes. Issues raised within the quality management system are typically done so through a non-conformance report system and addressed within the lifetime of the project.

Issues raised as lessons learned are often recorded for the benefit of future projects as they may not be rectifiable within the project lifecycle. It was thus deemed important to understand what the perceptions of construction industry professionals was with regard to the effectiveness of the lessons learned system at their respective companies and projects.

Question 2 Response:

The results are shown in tabular form below. Each respondent could pick only one answer per question. For each question the top number is the percentage respondents and the bottom number is the number of respondents.

Question	Strongly Disagree	Disagree	Neither Agree / Disagree	Agree	Strongly Agree	Average Rating
2.1 The Lessons Learned process adds value to the company	1.49%	2.99%	2.99%	41.79%	50.75%	4.37
	1	2	2	28	34	
2.2 The Lessons Learnt process is implemented properly where I work	4.48%	47.76%	22.39%	22.39%	2.99%	2.72
	3	32	15	15	2	
2.3 Lessons are routinely learned – as an organisation we genuinely look to learn from our past mistakes and failures.	2.99%	28.36%	34.33%	22.39%	11.94%	3.12
	2	19	23	15	8	
2.4 I find that I don't encounter the same mistake on project after project.	22.88%	38.81%	17.91%	14.93%	4.49%	2.37
	16	26	12	10	3	
2.5 I see the Lessons Learned process as adding real value to the company	0.00%	10.45%	13.43%	31.34%	44.78%	4.10
	0	7	9	21	30	
2.6 I actively look to add lessons to the company database	3.03%	19.7%	13.64%	45.45%	18.18%	3.56
	2	13	9	30	12	
2.7 I see lessons being applied actively, and people keen to not repeat past mistakes	4.48%	40.30%	25.37%	26.87%	2.99%	2.84
	3	27	17	18	2	
2.8 The lessons learned process is a key part of my organisation's strategic improvement activities	4.48%	26.87%	25.37%	37.31%	5.97%	3.13
	3	18	17	25	4	
2.9 The lessons learnt process delivers key strategic and competitive benefit for my organisation.	2.99%	23.88%	35.82%	20.90%	16.42%	3.24
	2	16	24	14	11	

Analysis of the results

2.1 The Lessons Learned process adds value to the company.

The greater majority of respondents (92.54%) either agreed or agreed strongly that the lessons learnt process adds value to their company. This is positive as it demonstrates strongly that people value the process within their companies.

2.2 The Lessons Learnt process is implemented properly where I work.

Only 25 % of the respondents agreed that the process was properly implemented at their place of work. This is an interesting contrast with the response above, whilst people value the process the perception exists that it is not properly implemented.

2.3 Lessons are routinely learned – as an organisation we genuinely look to learn from our past mistakes and failures.

Less than 35% of the respondents felt positively that lessons are genuinely learnt. This is reflected in the poor response to question 2.4.

2.4 I find that I don't encounter the same mistake on project after project.

Less than 20% of respondents stated that they do not see the same mistakes repeated on project after project. Whilst the question should have been better worded it does highlight that issues repeat themselves on large projects. This does call into question the effectiveness of the current lessons learned programmes. (The question could have been stated with reference to "major" mistakes that would have focussed on major things going wrong rather than minor issues occurring, although it could be argued that if the issues are memorable between major projects then perhaps they were major issues).

2.5 I see the Lessons Learned process as adding real value to the company.

More than three quarters of the respondents felt that the Lessons Learned process adds real value to the company, despite a clear sentiment earlier that the process is not properly implemented and appears to be ineffectual in that some mistakes are repeated.

2.6 I actively look to add lessons to the company database.

More than 64% of the respondents in the survey state that they actively seek to add lessons to the company database. The nature of the answers does reveal what appears to be an element of bias in the responses in that persons give a generally more affirmative response when the question is directed at them as individuals and a generally lower response when the question is directed at the organisation that they work for.

2.7 I see lessons being applied actively, and people keen to not repeat past mistakes.

Less than 30% of respondents gave a positive response to this question and this raises real concern about the importance that people within project management organisation apply to the lessons learned process. The researcher's expectation was that the phrase "people keen to not repeat mistakes" should have resulted in a high response for this question. This is another question where the difference between questions directed at the respondent's own perception and those of the wider organisation that they work in has resulted in a skewed response.

2.8 The lessons learned process is a key part of my organisation's strategic improvement activities.

Nearly of third of respondents (31.35%) of respondents disagreed with this statement – a very high number. It may well be that the lessons learned process is viewed as a strategically important element of the organisation but then there is clear disconnect between what the organisations strategic views are and what the respondents have stated. It should be noted here that the greater majority of the respondents (over 94%) are professionals in their organisations and as such the numbers disagreeing is a surprisingly high number.

2.9 The lessons learnt process delivers key strategic and competitive benefit for my organisation.

This question garnered a slightly higher average rating (3.24) to the previous question and demonstrates the sentiment that whilst the lessons learnt process is not viewed as

a strategic initiative by companies it can (and appears to) deliver strategic benefit to those companies.

Overall summary of question 2.

It would appear as if people value what the lessons learnt process can add to their organisation and they see it as an element that adds real value to the organisations that they work for.

Individuals also gave higher responses for questions that were directed at their own contribution to the system – as an example the average rating for question 2.6 was 3.56 when asked about their own contribution and for question 2.7 it was 2.84 when asked about the effectiveness of the programme as a whole.

From the results one can surmise that people are keen to contribute to lessons learned programmes and that there is real value to be gained from them. However, the programmes as they currently stand within organisations are not seen to be as effectual as what they could be.

Question 3

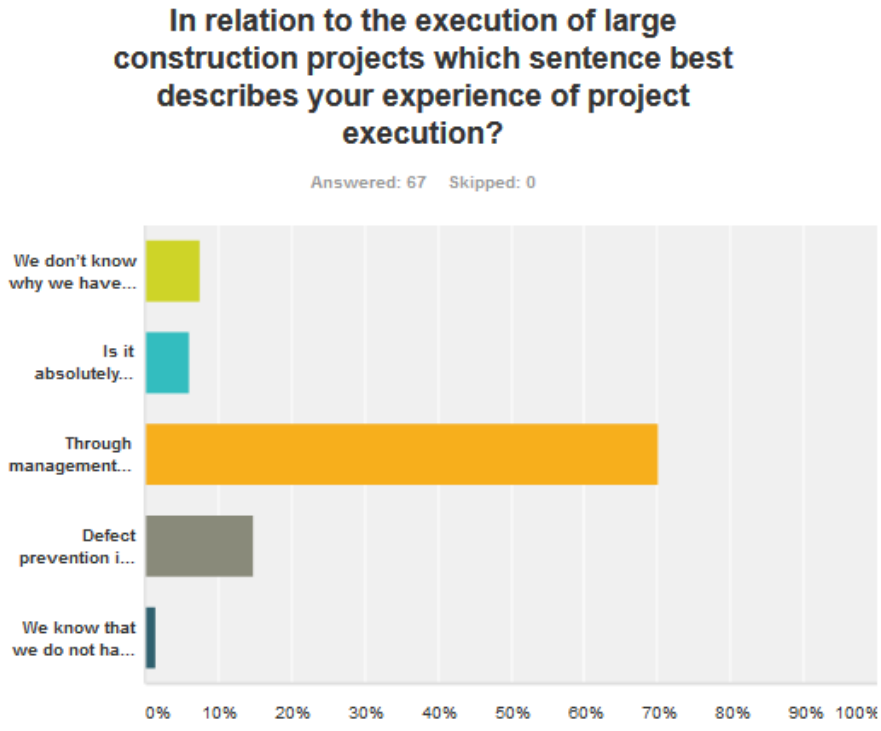
In relation to the execution of large construction projects which sentence best describes your experience of project execution?

a) **We don't know why we have problems with quality**
b) **Is it absolutely necessary to always have problems with quality?**
c) **Through management commitment and quality improvements we are identifying and addressing our problems**
d) **Defect prevention is a routine part of our operations**
e) **We know that we do not have quality problems**

Question 3 Rationale:

This question was one of two taken from the Quality management maturity grid and is attempting to gauge the quality management maturity of projects. A consistent response to this and the other Quality Management maturity grid question may indicate what people's perception of quality management in large construction companies is.

Question Response:



Answer Choices	Responses	
We don't know why we have problems with quality	7.46%	5
Is it absolutely necessary to always have problems with quality?	5.97%	4
Through management commitment and quality improvements we are identifying and addressing our problems	70.15%	47
Defect prevention is a routine part of our operations	14.93%	10
We know that we do not have quality problems	1.49%	1
Total		67

Analysis

The answer option that garnered the highest response was overwhelmingly point 3 – "Through management commitment and quality improvements we are identifying and addressing our problems". This option received 70.15% of the vote.

This indicates clearly that the perception amongst people working in construction and project management is that the quality management systems are not yet at a fully mature state as this response indicates that quality maturity within Project Management is at a level of 3 out of 5. The statement that most of the respondents identified with is one where a management system exists that functions well with identifying and resolving problems but not one where problems are routinely prevented, or indeed where there is sufficient knowledge of the project that the company knows that it does not have problems (the highest level on the quality maturity index for this question).

(See 6.4 for further reference on the quality maturity grid).

Question 4

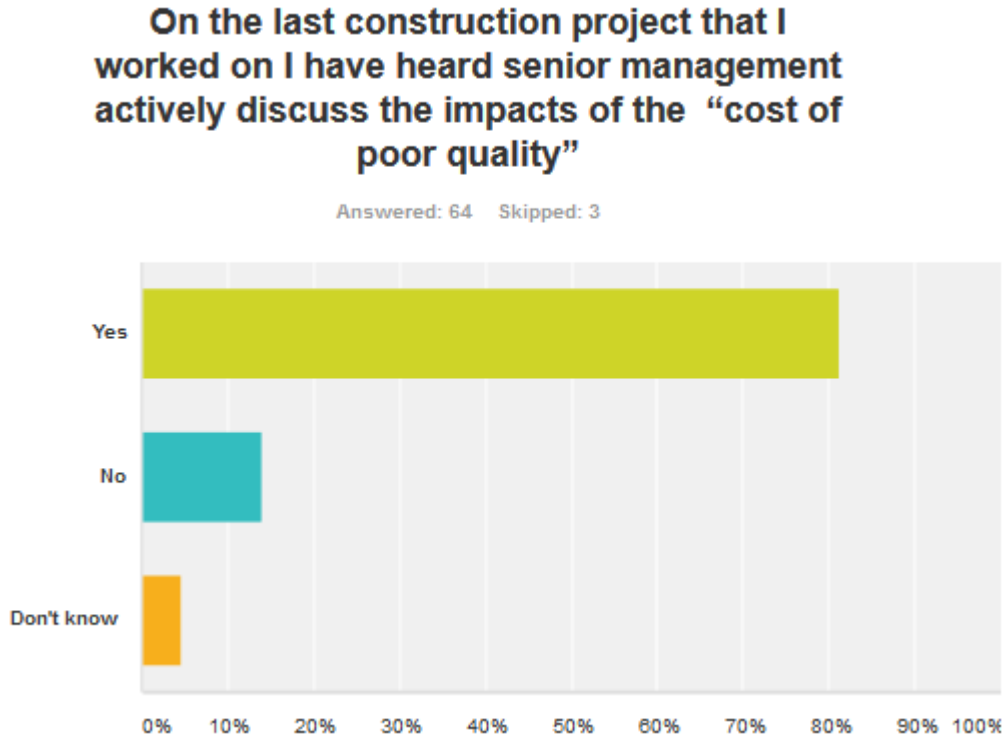
In the last 2 year period I have heard senior management actively discuss the impacts of the phrase "cost of poor quality"

This question is presented with a "yes" or "no" discrete option.

Question 4 Rationale:

The intent with this question is to gauge the understanding (within a project environment) of how often senior delivery managers engage with this topic. It could be that this is something that senior managers across a variety of companies do discuss, and this would inform that the company leadership are aware of the wider (hidden) impacts that COPQ often entails. It was decided to use the particular phrase of "Cost of Poor Quality" in the research exactly for this purpose, namely that it is an insight into the wider understanding of the phrase, rather than just a narrow view of the singular cost of a defect. This question also tests the main hypothesis of this research, namely that COPQ is poorly understood in the management of large construction projects.

Question 4 Response:



Answer Choices	Responses	
Yes	81.25%	52
No	14.06%	9
Don't know	4.69%	3
Total		64

Analysis

The respondents overwhelmingly identified yes – with 81.25% of respondents identifying with this question. The question was intended to clarify whether this was specifically in the context of Juran's "Cost of poor quality" understanding. The question was not clear in this regard, though it was still clear that the cost of poor quality is discussed in a lot of construction project companies, though it is not known what this context was (i.e. it may have been in a cost of resolution of defects scenario or it may have been in a prevention scenario).

It should be noted that 14.06% of respondents had not heard management discuss the cost of poor quality and this is perhaps the most noteworthy element from this question. All of the individuals in the target audience for the questionnaire have worked on mega projects for longer than five years (some on the same project for that long) and it is surprising that a percentage of the respondents did not hear management discuss the impacts of poor quality. This is indicative of opportunities within the construction project management profession to broaden the impacts of discussion.

Question 5

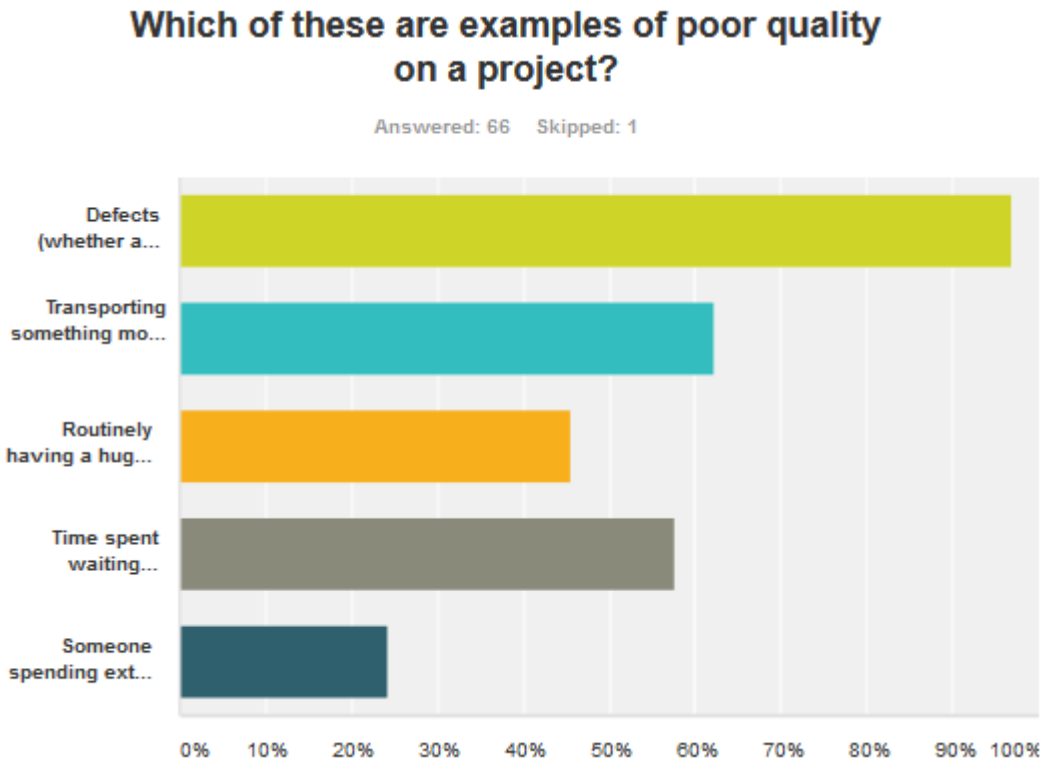
Which of these are directly related to poor quality on a project?

a) **Defects (whether a component fault or poor workmanship)**
b) **Transporting something more than it needs**
c) **Routinely having a huge stockpile in the stores**
d) **Time spent waiting (whether for people, information, material etc.)**
e) **Someone spending extra time on something to make sure that it is right.**

Question 5 Rationale:

The intent with this question is to gauge the understanding of Shingo's classic "seven wastes". The responses to this question will describe whether the construction industry in general understand quality in the broader sense of lean management and as a potential means to improve project effectiveness through delivering robust delivery mechanisms through using quality as a strategic approach.

Question 5 Response:



Answer Choices	Responses	
Defects (whether a component fault of poor workmanship)	96.97%	64
Transporting something more times than it needs	62.12%	41
Routinely having a huge stockpile of supplies in the stores	45.45%	30
Time spent waiting (whether for people, information, material etc)	57.58%	38
Someone spending extra time on something to make sure that it is right	24.24%	16
Total Respondents: 66		

Analysis of the responses

a) Defects (whether a component fault of poor workmanship)

Two of the respondents did not note defects being a quality issue on projects. This is surprising as defects (also referred to as snags) are discussed in great detail on a project and is the one element where the researcher expected a 100% score. This may be an error in the response or it could be that there is further work to do to clarify quality matters.

b) Transporting something more than it needs

Nearly 38% of the respondents did not see excessive movement (explicitly stated as transport in the research question) as being a quality issue. It should be noted that construction material such as steel, concrete, glass, paving and so forth is typically of an extremely heavy nature. Thus losses direct to the construction industry would be any or all of:

- Fuel cost as any movement incurs a significant carbon cost (and associated financial cost) due to the fuel required to move the material.
- Excessive movement would also take its toll on construction machinery as they would be in service for longer than is necessary. A reduction in transport of material would thus have capital expenditure benefits for construction companies as they would be able to get more productive use out of their plant.
- Losses to material due to movement – whenever product is moved (particularly "finished" product such as premanufactured façade panels) then some loss is due to be incurred as a result of movement damage

- Safety – The HSE (2013) records demonstrate that approximately ten percent of construction industry fatalities are as a result of vehicle impacts on construction sites. Thus, it would appear as if construction worker safety could be improved by having a reduction in transport and vehicle movements on site.

c) Routinely having a huge stockpile in the stores

Whilst waiting (delays by another term) are a significant impact on projects it does also appear as if projects carry huge inventories and that this is not seen as a quality problem on construction sites. Over 54% of respondents did not feel that it was a quality issue. Whilst not having supplies is a greater impact it does identify that there are opportunities for simplifying the system and improving the project logistics process. (Just-in-time and KANBAN may be of benefit in this regard but are beyond the scope of this dissertation to explore). It is recommended that projects understand the nature of delays on construction sites and remedy those before making wholesale changes to the logistics plan. not understanding (and mitigating for delays) and having a poor understanding for the resource profile of the project may lead to further delays and a reduction in the appetite for project directors to examine further project improvement measures.

d) Time spent waiting (whether for people, information, material etc.)

42.52% of respondents did not feel that waiting is a quality issue. Whilst this is not a defect as such it is a waste and therefore, within the wider understanding of quality by taking the seven wastes of lean into account, it is a quality issue.

e) Someone spending extra time on something to make sure that it is right.

The key with this question are the words “extra time”. A person should have enough time to make sure that the work is right, and any extra time required is effectively rework, or at the very least the use of resource that should be engaged on a different part of the project. This “extra time” would be time taken away from other aspects that the project requires and is thus unproductive time. A clear majority of respondents – 75.76% - did not feel that this was a quality issue. This presents a significant opportunity to improve the efficiency of project delivery.

There may be the tendency among some companies to force personnel to only spend a certain amount of time on specific tasks before moving them on. This would likely have the detrimental effect of leaving incomplete work behind, which may be progressively more difficult to remedy as the project moves on. It would be far better to understand fully ("Study" in Deming parlance) the issue at hand and ensure that sufficient means are in place to support the project tasks being completed in their allotted time.

Question 6

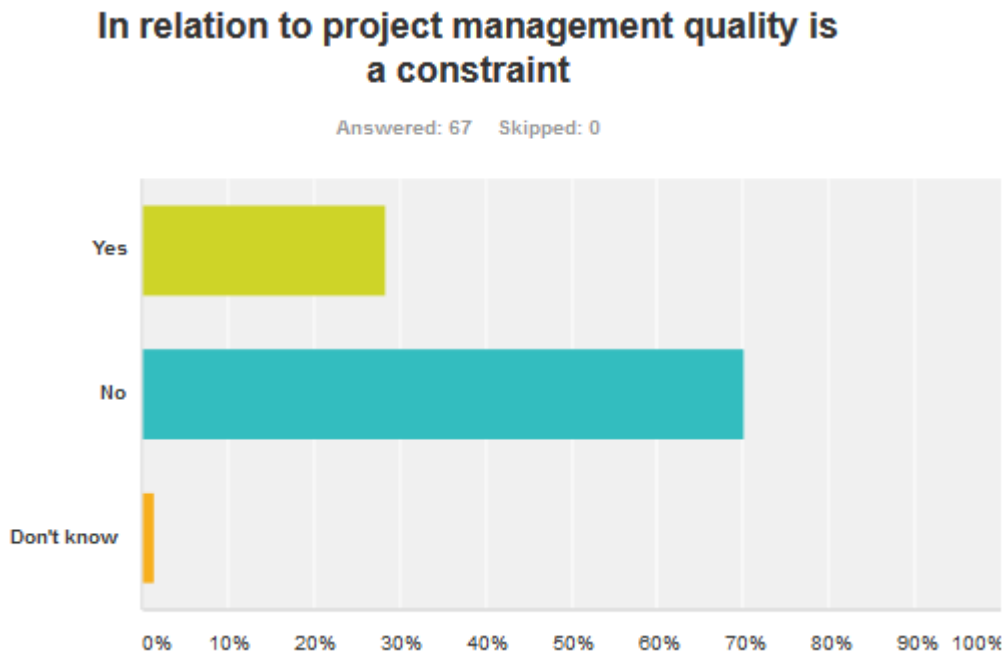
In relation to project management, Quality is a constraint. (Yes/no)

Question 6 Rationale:

A voluntary comment field has been added to this question without a request for responses. It was anticipated that some responders may have wished to add further clarity to their answer and these answers may thus be of interest to the dissertation.

This question is designed to test the perceptions of personnel within the construction industry on what their perception of what quality is. The response would be indicative, but not absolute and may point to a trend developing that could indicate directions for future research. (It would be preferable to baseline this test with the questionnaires being sent to persons within the construction industry against a similar sized sample of persons within the automotive industry – this would then allow a comparison of trends between industries. It is beyond the scope of this dissertation).

Question 6 Response:



Answer Choices	Responses	
Yes	28.36%	19
No	70.15%	47
Don't know	1.49%	1
Total		67

Analysis of the response

Given that the major project management literature (PMI, APM) describe quality as a constraint it was interesting to note that only 28.36% of respondents gave a yes response. Question 7 was given as a text box so that respondents could clarify what their perception of the quality / constraint situation is and this question needs to be understood in the context of the responses given in question 7. (The text box had to be formulated as a question as the software package used did not have the text box functionality for insertion after a question, only on its own.)

Question 7 (related to question 6 above)

Whilst this is worded as a question, question 7's intent was to give an optional text box so that survey respondents could add some detail if they so wished to their responses in question 6 (about whether quality was a constraint or not).

Some of the text responses are given as follows (responses in *italics*, analysis in "normal" text)

"Project management around my organisation is still focused upon time and cost - Quality is not as easy to identify and measure."
The response above implies the understanding of quality as a standard (in essence a completion specification) and not also in the means to deliver a project.

"Competition between time, cost and quality nearly always means quality loses."
This is a classic response where the "iron-triangle" comes into play. The "old school" philosophy within construction implies that if there is a trade-off (possibly as a result of "iron triangle" drawings) and if one aspect needs acceleration then there must be a loser. This philosophy does not consider the schedule and cost benefits that a quality approach may bring to a project.

"Quality management is an intrinsic component of project management, as failure to deliver to quality targets is a failure to deliver the brief. Importantly, quality targets/aspirations etc need to be established at brief stage"
This respondent raises a valuable point in that quality needs to be understood at brief stage and the client has a critical role to play in delivering a good quality project. Khan et al (2011) state the same in describing the "People" grouping of critical success factors. These specific factors that relate to client factors are End user, Project Owner and Stakeholders Influence.

People talk about quality as being a (the) key driver and is set up properly at the start of a project but programme always seem to get in the way of delivering 'right first time'.
Some projects appear to get into a situation where the works are rushed to meet the programme and that "quality" is seen as an opportunity where cuts can be made (to the

quality process) rather than using quality techniques to provide the acceleration to the schedule.

If tasks are planned correctly staff will have the time, tools, skills, and materials to achieve a right first time solution.

Agreed, the investment need to be made into the project to provide this, as well as the leadership, guidance and support that quality-centric decisions will be supported. Getting the job done is not as important as getting the job done right and the precedent needs to be set early in the project that only compliant works will be accepted. If the construction managers can undermine the quality managers by complaining that an adherence to quality is costing schedule time then there will not be a great deal of respect for quality. What can occur then is that works are rushed to meet schedule and then an extensive rework period may be required as a result of not completing compliant works. This element of rework is where the COPQ can manifest itself in a big way. The most efficient use of project time then, is to do things properly the first time so that rework is minimised, the COPQ is minimal and therefore no schedule time needs to be spent to recover poor quality works. Chasing schedule at the expense of quality then can result in the project failing on both schedule and quality (and cost). This should be contrast against concentrating on quality which result in compliant works being completed without a heavy rework bill that will affect the schedule (and cost). "Chasing quality" (in a measured and informed manner) can thus deliver both schedule and cost savings.

Above Yes response based on my last major construction project. But, quality should not be a constraint, it should be an enabler.

This respondent has clearly had the experience of quality being applied in a narrow means, in essence the narrow "old school" understanding of quality – presumably as part of the iron triangle – was applied.

Quality is not a constraint it is a benefit on safety, cost and time, as long as the quality management tools and philosophy are incorporated into the contract. It must be discussed and understood at award of contract. Both parties then start with the same intent for success.

This respondent has summarised the intent of this dissertation.

Question 8

In working on large construction projects I have found that projects are generally

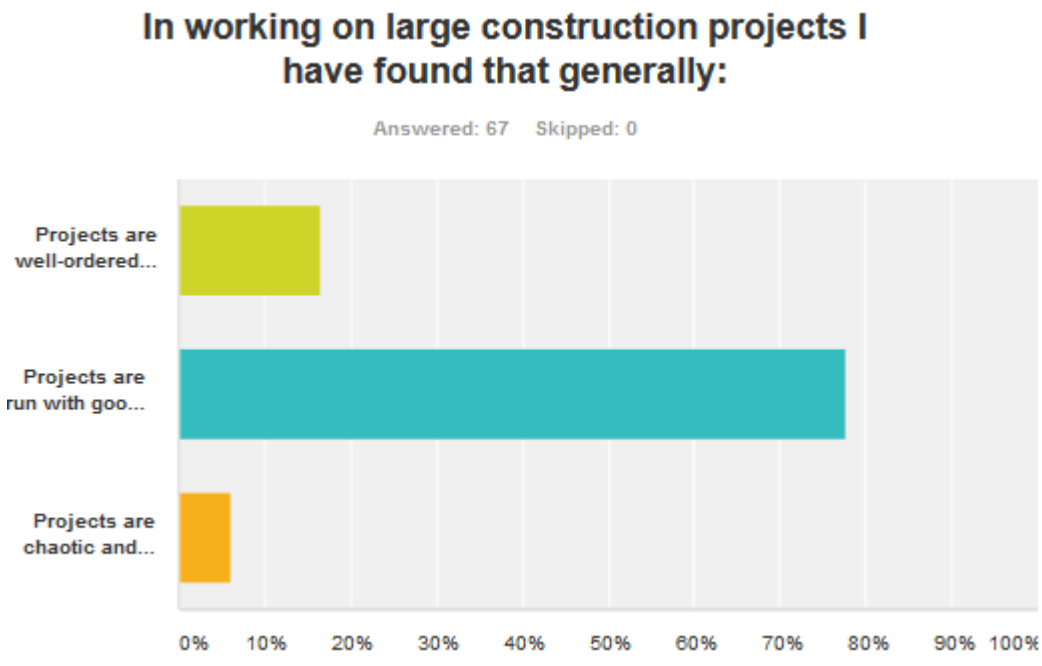
a) **Projects are well-ordered with clear communication channels and it is an environment where generally where people are working efficiently and know what they are doing.**
b) **Projects are run with good intentions but poor understanding of delivery and waste in the process leads to unnecessary wastage, delays and projects end up being more difficult that what they may need to be. Projects are delivered but not as well as what could have been.**
c) **Projects are chaotic and plans (where available) were either ignored or not necessarily followed. People were not clear about what was required and why their work was important.**

Question 8 Rationale

This question was designed to test people's perception of how projects are managed.

This question relates to the overall status of a project, not just the particular elements of lessons learnt of waiting.

Question 8 Response:



Answer Choices	Responses
Projects are well-ordered with clear communication channels and it is an environment where generally people are working efficiently and know what they are doing.	16.42% 11
Projects are run with good intentions but poor understanding of delivery and waste in the process leads to unnecessary wastage and delays. As a result projects end up being more difficult that what they could have been.	77.61% 52
Projects are chaotic and plans (where available) were either ignored or not necessarily followed. People were not clear about what was required and why their work was important.	5.97% 4
Total	67

Question 8 Response Analysis

Only 6% of respondents stated that their projects always ran well and a large proportion (77.61%) stated that their projects were run with good intentions but ultimately were not delivered as well as what they might have been. The response to this question has a very similar profile to the response to question 3 (albeit that question 3 has five options to choose from). In both questions there was a strong response for the middle option.

This indicates that personnel working on projects have the perception that things could be a lot better. The option chosen is explicit in saying that "poor understanding of delivery and waste in the process leads to unnecessary wastage, delays and projects end up being more difficult that what they may need to be". This would indicate that there is significant opportunity for improvement in the delivery of large projects.

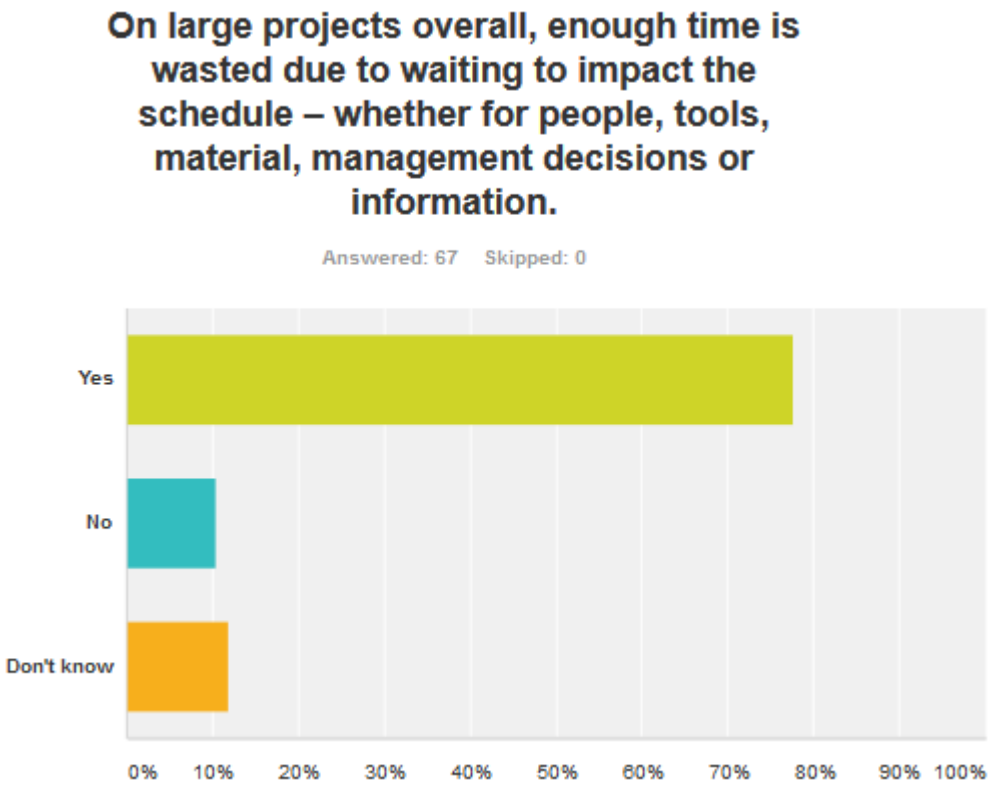
Question 9

On large projects overall, enough time is wasted due to waiting to impact the schedule – whether for people, tools, material, management decisions or information. *(This question was offered with a yes/no response option).*

Question 9 Rationale

Whilst defects are routinely seen as a quality issue in construction it was decided to evaluate the response to a question about efficiency. Waiting is one of Shingo's classic 7 lean wastes and this question was designed to determine person's perception of whether this was a factor on construction projects.

Question 9 Response:



Answer Choices	Responses	
Yes	77.61%	52
No	10.45%	7
Don't know	11.94%	8
Total		67

Question 9 Response:

Over 77% of respondents stated that enough time is wasted on construction projects to affect the schedule. The question did not attempt to quantify what the impact is (in terms of actual time lost) however this is quantified in other research such as Merrow (2011).
This response should be seen in the context of the response to question 5d) where 42.52% of respondents did not feel that waiting is a quality issue.

It would appear then that there is a significant opportunity for projects to gain advantage through the reduction of waiting time. The list of COPQ impacts in 4.3 of this dissertation is significant and many have to do with cost impacts of waiting time and schedules that have overrun.

Research conclusion on Problem Statement

In relation to the problem statement made in chapter 2.1 the following research results have been determined.

The research demonstrated that the understanding of Cost of Poor Quality, as described by Juran, is poor within the construction industry.
Literature review demonstrates that large construction projects in general suffer from the impacts of Cost of Poor Quality. This was borne out by the research where, in the opinion of over 77% of the respondents, enough time is wasted on projects to impact on the project schedule. Further research of an empirical nature is advised (particularly where the Schedule and cost Performance Index information for projects can be analysed. This would allow the quantification of the impacts of COPQ on large projects to be established).

The impacts of the COPQ have been explored in this dissertation, and its understanding quantified to an extent within a sample of the construction professional community. Further empirical research is required to adequately demonstrate that better understanding of COPQ.
This is inferred in the research, and it is assumed that a better understanding of COPQ (and means to mitigate for it) will lead to better project delivery.

6. STRATEGIES FOR COPQ REDUCTION

The Cost of Poor Quality has a significant effect on project management and the delivery or construction projects. This cost is often very difficult to quantify and for the most part goes unrecognised as "business as usual" in the construction management world.
The "cost" element is also far more than just financial. Impacts relate directly to the profit that a company makes, the usability of the space, the feasibility of the companies involved (and as a result the job security of its employees) and at its most poignant, the safety impacts that occur when individuals feel the brunt of quality failures – either directly as a result of failures or during the work to remediate the issues.
This dissertation will make some recommendations as to how the COPQ and its associated impacts can be reduced. This is by no means a comprehensive list and there are a myriad of techniques and methods that may still be employed in the pursuit of flawless project delivery. Further research on this topic is very much required.

Suggestions for the improved delivery of projects, where the perception exists that their proper implementation will result in a net reduction of project expenditure are detailed below;

- Lessons Learnt
- Manufacturing in Construction
- Quality as an enabler
- Quality as a strategy
- Lean Construction
- BIM (Building Information Modelling)

6.1 Lessons Learnt

The Lessons Learnt" process is a standard procedure within project management and construction companies where a formalised activity is held to ensure that "lessons" from what has gone badly, as well as what has gone well, are captured for future the reference. There are

several terms used to address the "lessons learnt" process, and Jugdev (2001), states that these could be any of; knowledge management, after –action reviews, post-implementation review, post mortem and project debriefing.

Jugdev (2012) states;

"The project management literature describes lessons learned as practices that:

- Is quality improvement oriented and help correct process efficiency and effectiveness problems in a timely manner (Schindler, 2003; Kotnour, 1999; Kamara et al., 2002; Koners and Goffin, 2007).
- Help deliver more successful project, improve customer satisfaction (Kotnour, 1999) and help participants learn about successful and unsuccessful practices (Busby, 1999)
- Involve dissemination and sharing functions (Busby, 1999).
- Involve both inter- and intra-project learnings (Kotnour, 1999) because they assist with externalizing implicit knowledge (Disterer, 2002)."

The published research on the topic appears to be wholly qualitative in nature, and somewhat aspirational in its statements in that it makes claims that lessons "help deliver improved projects" but does not state how this is achieved with the very narrow aspect of the lessons process that is addressed – namely the recording of lessons
. It is recommended that a future study be conducted that compares the performance of multiple projects that have a robust lessons learned process in place against those that do not would be useful. (Comparisons could include client satisfaction surveys, project performance against forecast baseline, rework rate, COPQ (if quantified in a standardised manner across projects).
A study of this nature would quantify the outcome on an objective scale, rather than the subjective nature of feedback from questionnaires.

The PMI (Project Management Institute) is a leading think-tank on project management matters.
PMI (2010) in Jugdev (2012) states that:
PMI's PMBOK® (Project Management Body of Knowledge) Guide defines lessons learnt as "the learning gained from the process of performing the project. Lessons learned may be

identified at any point. Also considered a project record, to be included in the lessons learned knowledge base. Jugdev goes on to say that; *lessons learned then, are one set of important project outputs delivered at the end of the project.*

Jugdev and the PMI both fail to identify that only recording of lessons has occurred at this stage, and that lessons learned are only *learned* once;

- The detail around the occurrence has been fully analysed
- The causes behind the lessons (whether positive or negative) identified
- Knowledge of how the system should be changed is determined
- A measured change is enacted robustly that addresses the issue

Only once this has been implemented will the environment be created where the desired situation will occur.

Both Jugdev and the PMI refer to lessons learned as an after the fact event near the end of a project life cycle and don't state how the recorded lessons will be learnt, nor that the lessons learned process should form part of the inputs to risk management of current and future projects. Jugdev and the PMI also only describe the lessons approach as it applies to in-company lessons and they make no consideration to where else lessons may be collated from.

Buttler et al (2012) also state means by which lessons are "captured" but not how they might be disseminated effectively to be learnt – rather than just recorded. Herein lies the key, whilst these lessons are extracted at the end of the project management process – with the intent of use for future projects, there appears to be little described in the literature in the way of driving the uptake of lessons within the project management organisation. The "Lessons Learned" process thus appears to be largely based on recording, and some consideration should be given to "Lessons Implementation".

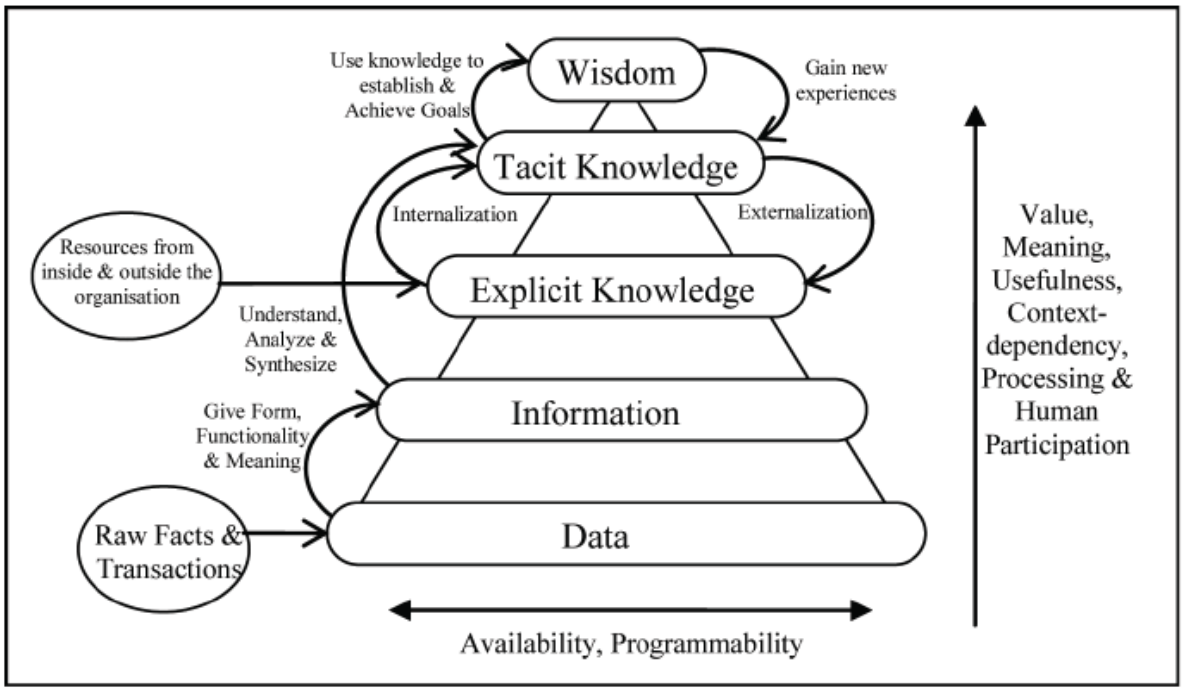


Figure 6.1. Data, information, explicit knowledge, tacit knowledge and wisdom. (An et al 2010)

It could be argued that according to figure 6.1 above, that lessons, once codified are only in the data (or the information stage).

This means that the lessons have been recorded and perhaps given some contextual reference and entered into a system – typically an online archive or spreadsheet – though they seldom make their way from the recording mechanism to being part of a knowledge uptake for future projects. In other words, information in an organisation seldom makes the transition from being explicit to being tacit knowledge and ultimately, becoming wisdom for future projects.

Using Figure 6.1 An (2010) describes the uptake of knowledge in different stages where raw data is collected first, and then translated into information. This information is then moderated before being turned into explicit knowledge. It is at this point that the knowledge is in some form of company database where it is typically accepted that "lessons have been learnt". The key consideration should be that this has not yet been taken into cognisance by people and this process (described as internalisation in Figure 6.1) is where the knowledge crosses into employee awareness. When this knowledge is fully understood and it is applied to improve an element of works then it is deemed to be "wisdom".

Caldas et al (2007) state that only 8% of respondents in a survey of construction companies

state that their lessons learned program is very effective and also notes that all of these companies have a formal lessons learned program in place. It should be noted that this is a subjective response to the question stated and further research – such as the evaluation of how often an issue reoccurs on successive projects – may give a clearer picture of how effective a lessons learned program really is.

Why is the lessons learnt process important?

W. Edwards Deming was an American quality pioneer whose Plan-Do-Check-Act work was instrumental in the development of modern quality management systems. The current ISO 9001 Quality Management system is still based on his quality philosophy.

Lessons Learnt are a key element of the Deming PDCA cycle, and impact heavily on the Check and Act elements of those cycles. Without the active application of the learning in place, key opportunities to eliminate causes of non-conformance in the future are lost.

Moen et al (2010) describe how the original "check" element in Deming's wheel was misconstrued and that the word "study" was deemed by Deming to be a better description of what was required. Moen et al (2010) go on to describe how Deming felt that "the English word "check" means to hold back". The word check could be misunderstood in the sense of "inspection" rather than having a detailed ongoing study and analysis of the process.

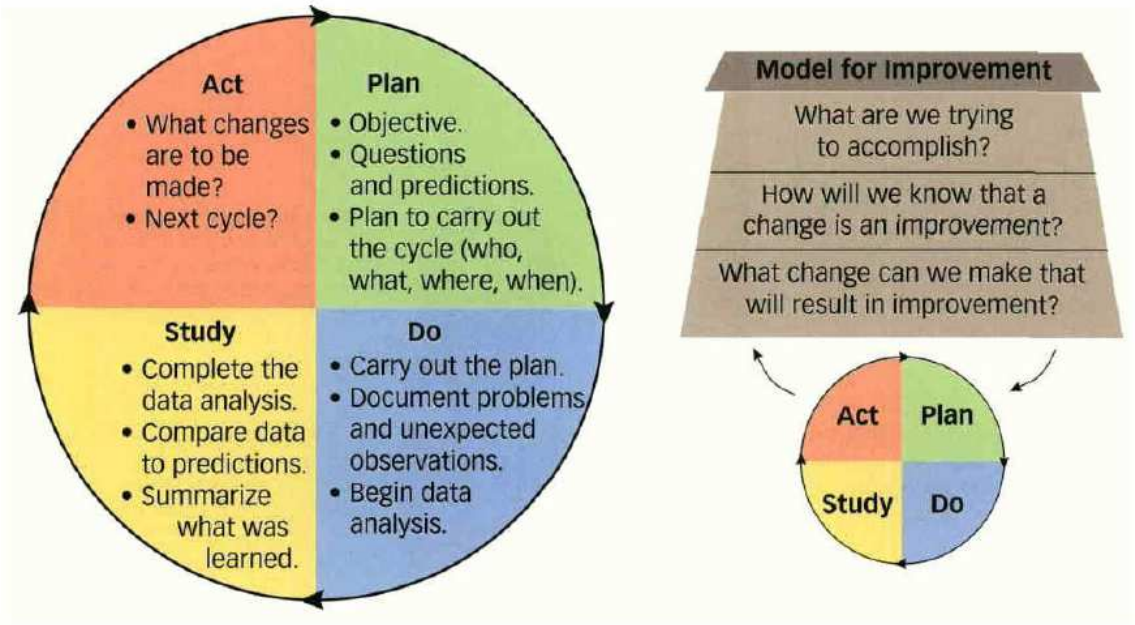


Figure 6.2 Deming's PDSA cycle. From Moen et al (2010)

What is clear that Deming is clear that any changes that should be made to a system should be made as an informed and measured response. The model for improvement described in figure 6.2 above askes “How will we know that a change is an improvement?”. This is a valid point, any change where the impacts are not fully understood might well end up in a worse situation than what the original issue was.

Suggestions for lessons implementation

A mechanism for ensuring that the lessons in a company database are considered when a new project is initiated is to ensure that a deliverable is created in the early phases of a project that requires a lessons learned study and implementation exercise to be conducted. A four part process could entail:

1) (Plan) Investigation/assimilation of lessons learned
2) (Do) Sorting and codifying of the lessons
3) (Check) Checking that the lessons would be effective
4) (Act) Implementing the lessons
5) (Review) Review the effectiveness of the actions taken

This can be further expanded below:

1) (Plan) Research of lessons

This would entail that research is conducted into any sources of relevant lessons and these can be:

- In-company lessons from a company lessons learned repository
- Client based lessons learned repositories (Client may sometimes enforce the consideration of their lessons onto a contracting business to ensure that issues encountered on previous jobs do not arise again)
- Academic articles, these may be from academic sources or from industry bodies such as regulators or insurers.
- Media reports into incidents
- Government initiatives

2) (Do) Sorting of lessons

It is usual that the lessons should be sanitised and checked for veracity by a senior person within the company who would authorise the lessons for use. This "moderator" would check that the lesson is recorded in suitable details so that the persons who would use the lesson have enough information to work with. The moderator would also check that the lesson is correct in its wording and that the lesson's deductions and recommendations are suitable for use. The moderator would make use of a suitably competent person to verify the lesson content, if they themselves are not sufficiently competent on the nature of the lesson being described.

The person sorting the lessons should also attempt to present them in a usable way, so that persons who need to make use of the lessons can find the list of lessons, but also be able to find the lesson relevant to a particular discipline. (i.e. Lessons Learnt registers can be large, and an individual may only be looking for - as an example – lessons related to low voltage storage. The main register of lessons should be sufficiently well sorted and catalogued so that the relevant lessons can be found in a user friendly manner.

3) (Check) Checking that the lessons have been effective

Central again to the quality ethos, is the ability to gauge the effectiveness of a measure taken. A review on a regular basis would be advised so that the effectiveness of the lessons implemented can be determined. This could be done through;

- Audit
- Customer satisfaction survey
- Engineering review

4) (Do) Implementing the lessons

The implementation of lessons is the crux of the matter. Until such times that the lessons have been taken up, reviewed and something has been done to mitigate for the lesson, the lesson is not learnt. Ideally the register of lessons should have a field in each for each lesson where a description could be written of how the lesson has been learnt. The responses could then state the applicable response such as; procedure amended, training given, system simplified –as appropriate. As the lessons learned may have a significant effect on the execution of certain aspect of project work it is

advisable that full details of the implementation plan are included in the description of how the lesson has been learnt. This should be done so that future reviewers may judge whether the lesson has been productive.

5) (Review) Review the effectiveness of the actions taken
   In this step the effectiveness should be evaluated. Deming advocated the "study" element with regard to the understanding of product realisation processes so the inference is that this would not but a cursory once off check but an ongoing detailed analysis of the whole process to monitor its effectiveness.

6.2 Manufacturing in construction

Manufacture (from www.dictionary.com)
Manufacture: *the making of goods or wares by manual labour or by machinery, especially on a large scale*.
Manufacturing relates to the transformation of raw materials into a different discrete component or end product. (As an example steel beams are cut to size and welded together and then painted to form a ready-made component that requires no further work other than its connection in situ – essentially "making stuff").

Assembly (from www.dictionary.com)
Assembly: *The putting together of complex machinery, from interchangeable parts of standard dimensions.*
Assembly relates to the connection of various discrete manufactured components into a final product (As an example manufactured and treated steel beams would be connected together according to a pre-determined design to form a steel structure – essentially "connecting stuff").

Transformation of Automotive manufacturing – a forebear for Construction?
The manufacturing industry has been transformed from having large plants that make the bulk of their components in-house into assembly lines where off-site manufactured components are fed into a production line in a systematic manner where assembly of the different components takes place to deliver the final product.

The construction industry has been largely confined to the on-site manufacture of the building (essentially craft style manufacture) rather than leveraging the capability of off-site manufacture and having an assembly mentality for on-site works.

Many would balk at the principle saying that the manufacture analogy is inappropriate for construction as there is only one "Gherkin" and only one Crossrail Project and that these are construction projects that will never be repeated. This is true, however one should consider that the micro aspects of the construction project (such as piling, glazing, tiling, cabling and so forth – essentially the production aspects of a project) will be repeated on the next project and that there are definite manufacturing techniques from the automotive industry that could be utilised. (The comparison with the automotive interest may be more apt when considering the development of a new model of car as well as the manufacturing processes required for an individual car - e.g. the current BMW 5 series model is the "F10" designation and required significant development before being put into production).

	Automotive equivalents	**Construction equivalents**
Off-site manufacture	Tyres and rubber fittings, seats, electrical components such as alternators and other motors, automotive glass	Drywall, raw cement, building services modules
On-site manufacture	Chassis panels (in some cases), body panel treatment such as spray-painting and gluing	Wall building (including so-called "wet trades" such as plastering and painting), fire-stopping, piling, concrete pouring, insulating.
Off-site assembly	In some cases engine assembly is done offsite from final assembly.	Triple glazing units (glass and extruded aluminium assembly), valves and motors
On-site assembly	Final assembly of parts into finished automobile.	Steelwork assembly (where bought as components), fitting of glazing panels within assembled frames, connection of pre-manufactured modules.

Figure 6.2.1 Manufacturing – a comparison between automotive and construction industries.

Whilst it will be exceptionally difficult to remove on-site manufacture totally in large construction projects it can nevertheless be drastically minimised from the current status quo.

Presumed advantages of manufacturing approach:

1) Reduction of personnel working on site – this will have immediate benefits in the reduction of liability and insurance costs and in the provision of welfare and security facilities.
2) Reduction in congestion of personnel – work sites can be congested with work crews in the way of other work crews. A reduction of personnel numbers will result in a subsequent reduction of the risk of congestion occurring.
3) Reduction of complexity of works – with offsite manufacture occurring the onsite works should be limited in large part to assembly of parts rather than craft style manufacture.
4) Reduction in transport costs – a reduction may be possible as currently everything for construction manufacture is transported to site, the works are manufactured and then the waste is transported off-site again. Potential transport saving may be realised by eliminating the transport to site and removal of waste. This may be offset somewhat by the fact that pre-assembled modular may take up more space on transport vehicles than the individual components.
5) Reduction of co-dependent works – (e.g. reducing the need to wait for the paint to dry or concrete to cure for follow on works to proceed)
6) Reduction of works in uncontrolled environments – work done in controlled environments (such as factories) should be more likely to be conform to requirements as the conditions that the components are made in will be better controlled. (i.e. painting or concreting in cold temperatures will be reduced)
7) Safety – eliminating safety hazards such as working from height – an example may be the insulation of ducting in a factory rather than installing the ducting at height and then insulating it in situ. Insulation off-site would eliminate the working at height hazard.

Further research in this dissertation will evaluate what benefits the modular approach to construction may have to large construction projects.

6.3 Quality as an enabler

Quality is often seen as the inevitable output of the combination of time, scope and cost, rather than as a proactive driver in achieving benefits to the other factors in the Iron Triangle.

Oisen 1973 (in Atkinson, 1999) describes Project Management as:

> *Project Management is the application of a collection of tools and techniques (such as CPM and matrix organisation) to direct the use of a unique, complex, one-time task within time, cost and quality constraints.*

It is clear from this definition that Oisen considers quality as a constraint, and not as an enabler. Perhaps Oisen is referring to quality in the narrow sense of "standard of workmanship" in which case a better description for the constraint might be "scope". Scope would describe the limitations of the contracted deliverables for the project as well as the standard of the project (in terms of its functionality and finishes) that are required of the project. The Oisen constraint for quality is shown in the "typical" iron triangle below:

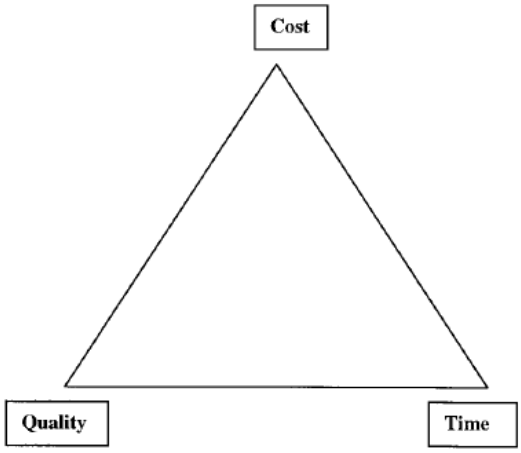


Figure 6.3.1 – Iron triangle (Figure 1 in Atkinson (1999)).

The Alternate "Iron Triangle" is shown below using Resources, Schedule and Scope as the three parameters on the triangle.

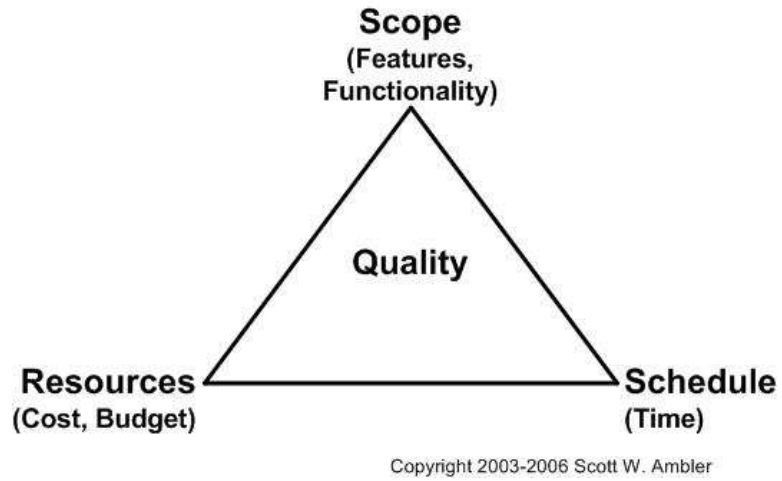


Figure 6.3.2 – "Alternate" Iron Triangle Ambler (2012)

The alternate Iron Triangle is that proposed by Ambler (2012) where Scope, Resources and Budget form a triangle with Quality contained inside the triangle. Again the inference is that increases in quality are only gained with an increase in resources and time (the scope presumably remains constant in this case as it should be contractually bound).

Rather it is proposed in this dissertation that quality should be seen as an enabler to project delivery in that the means to deliver a project with greater efficiency of resources (and elimination of the causes of project wastage) will be enabled by the robust and early application of broad-based quality techniques. A broad based application of quality would entail the adoption of quality as a strategic driver in project delivery with rigorous application of the quality strategies mentioned above, in the same manner as has already been achieved (for some decades already) in the automotive industry. Quality in the automotive industry is seen as a strategic business technique to both reduce the number of defects occurring in the production process but also to eliminate the waste of process inefficiencies in the manufacturing process.

This is in stark contrast with the current minimalist and reactive use of quality in current projects where quality is seen as an overhead that is to be minimised with only the bare minimum of quality tools applied on a project (often the quality tools applied are only done to comply with contractual requirements and arguably less - or even no quality management - would have been applied on the project without the contractual requirements in place).

6.4 Quality as a strategy

Naidish (2000) states that: *Success requires a CEO who remains actively supportive, with continued high visibility for the effort* (of maintaining focus of the reduction of COPQ).

The dependence of the support of top management for the success of quality initiatives is further evidence by the number of times that "Top Management" is mentioned in the ISO 9001:2008 standard. The phrase is mentioned no fewer than throughout the ISO 9001:2008 standard and is indicative of the requirement that quality should be driven by an organisation's most senior leadership. Juran in Titch (1991) stated that "CEOs should make themselves responsible for establishing quality goals, making sure quality expectations are included as part of job descriptions and compensation plans, and should personally serve on company quality councils".

All companies can be evaluated on the "Quality Maturation Grid" - companies in the construction sector are no different. The grid describes five different stages in the order of Uncertainty, Awakening, Enlightenment, Wisdom and finally, certainty against a number of measurement categories. These categories could be further developed for a company to their specific requirements, and may be particularly useful if an initiative has been developed that needs tracking.

Quality Management Maturity Grid (Crosby)	Assessor:			Department:	
Measurement Categories	**Stage 1: *Uncertainty***	**Stage 2: *Awakening***	**Stage 3: *Enlightenment***	**Stage 4: *Wisdom***	**Stage 5: *Certainty***
Management understanding and attitude	No comprehension of quality as a management tool. Tend to blame quality department for "quality problems".	Recognising that quality management may be of value but not willing to provide money or time to make it all happen.	While going through quality improvement programme learn more about quality management; becoming supportive and helpful.	Participating. Understand absolutes of quality management. Recognise their personal role in continuing emphasis.	Consider quality management as an essential part of company system.
Quality organisation status	Quality is hidden in manufacturing or engineering departments. Inspection probably not part of organisation. Emphasis on appraisal and sorting.	A stronger quality leader is appointed but main emphasis is still on appraisal and moving the product. Still part of manufacturing or other.	Quality department reports to top management, all appraisal is incorporated and manager has role in management of company.	Quality manager is an officer of company; effective status reporting and preventive action. Involved with customer affairs and special assignments.	Quality manager on board of directors. Prevention is main concern. Quality is a thought leader.
Problem handling	Problems are fought as they occur; no resolution; inadequate definition; lots of yelling and accusations.	Teams are set up to attack major problems. Long-range solutions are not solicited.	Corrective action communication established. Problems are faced openly and resolved in an orderly way.	Problems are identified early in their development. All functions are open to suggestion and improvement.	Except in the most unusual cases, problems are prevented.
Cost of quality as % of sales	Reported: Unknown Actual: 20%	Reported: 3% Actual: 18%	Reported: 8% Actual: 12%	Reported: 6.5% Actual: 8%	Reported: 2.5% Actual: 2.5%
Quality improvement actions	No organised activities. No understanding of such activities	Trying obvious "motivational" short-range efforts.	Implementation of a multi-step programme (e.g. Crosby's 14-step) with thorough understanding and establishment of each step.	Continuing the multi-step programme and starting other pro-active / preventive product quality initiatives.	Quality improvement is a normal and continued activity.
Summary of company quality posture	"We don't know why we have problems with quality".	"Is it absolutely necessary to always have problems with quality?"	"Through management commitment and quality improvement we are identifying and resolving our problems."	"Defect prevention is a routine part of our operation."	"We know why we do not have problems with quality."

Figure 6.4 - Quality Management Maturity Grid. Crosby (1980).

The research done in this dissertation demonstrated that Quality Maturity within the construction industry probably falls in the “Enlightenment” category – effectively stage 3 of 5 in the maturity grid. The assumption can thus be drawn that the COPQ in construction projects could be as high as 12% (based on the “Cost of quality as % of sales” entry from Figure 6.4 above.

Suggested further steps to enable quality as a strategy would be to;

1) Consolidate the current position of quality within large projects. In particular the need that problems should be “faced openly and resolved in an orderly way” as described in Figure 6.4 above.
2) It is suggested that active steps to move to defect prevention be made, this would be moving to stage 4 where “Defect prevention is a routine part of our operation”. Some strategies on how this might be achieved are described in the rest of chapter 6.

6.5 "Lean" Construction

Gao and Low (2014) state that in the UK; *the term 'lean construction' has become an established theme, and is promoted as a means to achieve operational improvement (i.e. quality and productivity) through elimination of waste and maximising value.*

Lean construction does promise significant advantages to companies that properly understand and implement it, and the BIM (Building Information Modelling) approach favoured by large clients should go some way to ensuring that lean is adopted to some extent within the wider construction industry.

As suggested by Jørgensen (2008) in Gao (2014) however, Lean Construction is still in its infancy and has yet to achieve the maturity of other quality philosophy models such as TQM and Six Sigma.

Lean Construction also, whilst promising to be a powerful driver in better value projects, does not address all of the quality factors that a company may employ if they were to adopt a wider view of quality.

Terry et al (2011) describes Lean as:

"a way of thinking and delivering value, innovation and growth by: doing more with less – less human effort, less equipment, less materials, less time and less space aligning effort closer to meet customers value expectations at the heart of Lean are flexible, motivated team members, continuously solving problems."

Whilst Lean principles have been in use in the wider manufacturing industry for decades it is still a relatively new concept in construction. Miller et al. (2009) in Thais (2012) state that: "Lean (in construction) is still in its early adopter phase".

Gao and Low (2014) suggest how lean construction could be modelled much more closely on the Toyota Production System (TPS), in particular with aligning the 14 points of the TPS to lean construction equivalents.

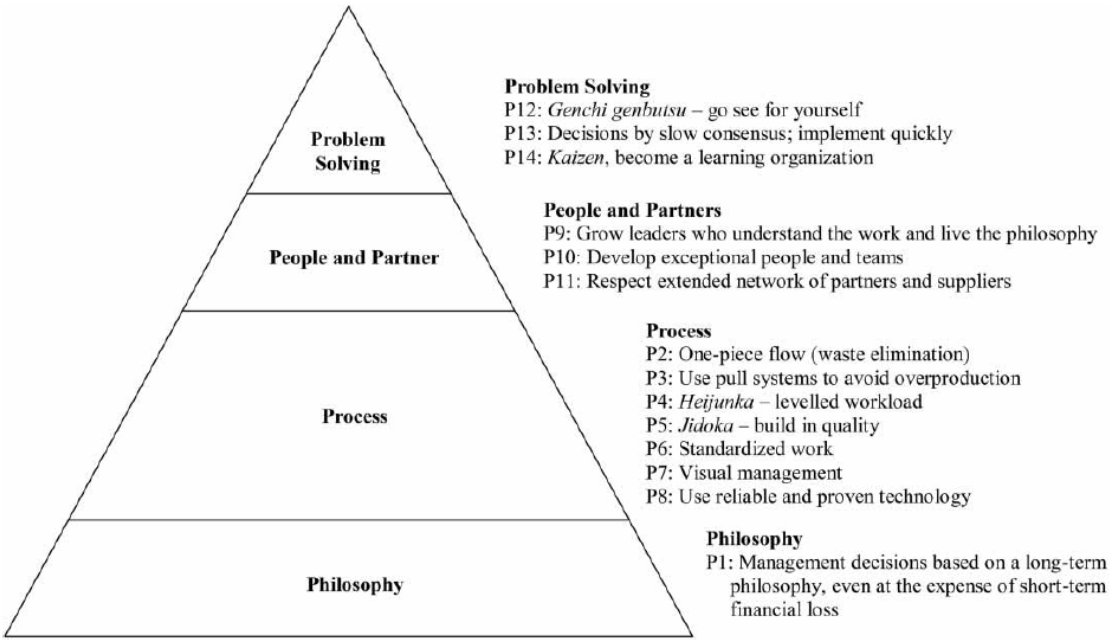


Figure 6.5 – The "Toyota Way". (Liker (2004) in Gao (2014)).

As a measure of the uptake of lean within the construction industry a survey was done on the current leading internet job hunting sites (including, www.jobsite,co.uk, www.monster.com and www.totaljobs.com). The survey looked for how many UK based roles were advertised that had "lean" in their title and then attempted to identify the industry that the role was being hired for. This could then give some indication of the uptake within construction. The results were as per table 6.5.1 below.

Industry Sector Hiring	**Number of roles**
Manufacturing/FMCG	23
IT/Commerce	10
Automotive	8
Unknown (not identified)	7
Utilities	4
Healthcare	2
Construction	0

Figure 6.5.1 Lean related roles hired by UK industry

The results described in the table are an indication that lean is not understood and adopted widely within the UK construction industry. This may present significant opportunities to

those companies who are early adopters of the lean construction. Relating the status of lean construction uptake in the USA Lukowski (2010) states that it has benefitted “construction firms looking for ways to be more competitive in the wake of the 2008 U.S. economic crisis are attracted to lean construction as a new model for conducting business”.

6.6 BIM (Building Information Modelling)

The Contractor's Business Management Report 2008 describes BIM as:
“Building information modelling” is not a software product but an approach to designing and building. BIM also is sometimes referred to as “parametric building modelling” or “virtual design and construction.”
It allows for a building to be seen as a 4-D or 5-D model with all components included. 4-D building models would be those where the 3 dimensions of the building are built up progressively over time, and 5-D would be the same with the added benefit of resource use (manpower as well as material added). Thus a building model would show construction sequencing in detail that would allow for planning and error proofing taking place. The claimed benefits for contractors are that a project model in BIM should enable computerized take-offs, allow easier drafting of shop drawings, enhance scheduling and sequencing of tasks, facilitate value-engineering, and provide for identifying design inconsistencies”. BIM gives the project the ability to deploy Simultaneous Engineering (SE). Tennant et al (1999) states that the SE approach *encourages downstream activities to be pulled forward as long lead activities within the project plan* in essence shortening the critical path as previously sequential activities can now be done in parallel.

Dave et al (2013) describe four mechanisms for how Lean and BIM interact:

1) BIM contributes directly to Lean goals – Dave et al give the example of clash detection with 3D building simulation. Clashes can be detected in the design stages and therefore eliminate rework on site once clashes manifest themselves in the fabric of the built environment.
2) BIM enables Lean processes and contributes indirectly to Lean goals – Linking the designed 3D model to time and creating a 4D model empowers collaborative planning

and certain processes such as scheduling have a much more transparent information source to work from.

3) Auxiliary Information Systems enabled by BIM – examples of these stated by Dave et al may be where a carbon footprint analysis model enables planning of the building sequence – or at least informed decisions that could improve sustainability.
4) Lean processes facilitate the introduction for BIM. Dave et al state that having Lean as an objective on the project would lead to greater appetite for the introduction and understanding of tools such as BIM, leading in turn to the betterment of the Lean execution.

7. CONCLUSION

Conclusions of the research

Large projects fail, and they fail more often than what they are successful. The nature of their failure is often catastrophic to their holding companies (and possibly even governments) and as such there is a real need to understand what means can be applied to wrest success from what otherwise may be failed projects.

There are several contributory factors to this (most of which are beyond the bounds of this dissertation), however one contributory factor is the understanding, application and leveraging of quality philosophies and techniques within the project management profession. As the research in this dissertation demonstrated, quality within the project management environment remains poorly understood and at best, partially applied. Several of the quality techniques and philosophies discussed in this dissertation (such as Cost of Poor Quality, Lean, Taguchi Cost of Quality and Deming principles) are decades old yet have still not gained traction within the quality industry.

For this reason the researcher proposes the adoption of "enhanced quality" on large projects where quality management techniques, philosophies and tools are applied to leverage the best practice within project management and gain better outcomes for large construction projects. Some of these tools were described in some detail in this dissertation but there are many more that the project management profession could avail itself of if it so chooses.

As ever challenges exist with introducing new methods into industry and, like any industry that is not keen on change, some pushback is expected. There will be those who state that these techniques aren't really for the construction industry, or that they don't see the benefit, or indeed that things have always been done in a particular way and there is no reason for further change.

On the subject of Lessons Learnt the responses described a respect for the process and the appreciation that it can offer significant benefits to the companies that employ it. However the research response described the situation where the respondents generally viewed their own contributions to the process as high but not the overall contribution of the company (effectively their peers). Companies can do more to ensure that lessons are learnt and that a greater level of support is given to this process within companies.

On the measure of quality maturity within the construction industry the respondents scored the industry at 3 out of 5. In essence this demonstrates that there is still much that the construction industry can learn from other industries and apply. It should also be noted that the maturity model is nearly 35 years old, and one can assume that much has moved on in other industries as far as what enhanced delivery mechanisms go. It would appear then, that there is much that the industry can avail itself in the pursuit of improved project outcomes.

In short a large measure of quality techniques and process efficiency measures in use in other industries have not yet been taken up by the construction industry. This presents a significant opportunity to those companies and individuals who gain an understanding for the advantages that this has to offer and apply those to the construction industry.

There is evidence such as the recruitment profile for different industries (figure 6.5.1) that industries beyond manufacturing are picking up lean principles and employing them – utilities, healthcare and IT are key examples. It was notable that there were no construction project hires in this group and as such it would appear as if the potential benefits to the construction industry are being lost as a result.

The benefits will not just be felt by the project management fraternity but will benefit society as a whole. An adoption of enhanced quality systems on construction projects promises that;

- Project disruption will be minimised,
- projects will be completed sooner
- Companies and jobs will be protected as companies don't suffer crippling costs associated with poor quality
- Society will benefit as facilities are ready and morale of those working on the sites and the general public will be improved.
- More poignantly it has promise to make a difference to the approximately thirty families every year who lose a loved one on British construction sites. For this reason alone, enhanced construction quality is worth considering.

Suggestions for further research

An empirical study that compares projects that have had an "enhanced" quality approach taken could be compared against those where the status quo is the order of the day. (The status quo here referring to projects where the normal level of quality is utilised on the project). These projects can then be compared using empirical data (such as the Cost Performance Index and Schedule performance Index) to see how the projects performed against plan. This study could also be expanded to evaluate what the customer perceptions of the buildings or projects were to see how the planned operational expenditure and facility uptime were in reality to that which was planned.

The safety statistics for projects with an enhanced quality approach could be compared to those where the status quo is in use. The assumption – to be borne out by empirical testing – would be that projects where an enhanced quality system is in use may be safer as a result of more work being done in a controlled, systematic way and the complexities of rework are reduced or eliminated.

CIRIA, the Construction Industry Research and Information Association champions the uptake of lean principles within the UK and wider construction industry and have published a number of guides at www.ciria.org.

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9. APPENDIX 1 – QUESTIONNAIRE

Question 1

Which title best describes your role?

Respondents could pick one only from the predefined titles; Director, Manager, Engineer or Administrator / Commercial.

Question 2

This question concentrated on Lessons learned questions and had a subset of 9 sub-questions where respondents were asked to tick a box where five options were given. These were Strongly disagree, Disagree, Neither Disagree nor Agree, Agree and Strongly Agree. Only one option could be picked for each sub-question. The nine sub-questions were:

2.1 The Lessons Learned process adds value to the company

2.2 The Lessons Learnt process is implemented properly where I work

2.3 Lessons are routinely learned – as an organisation we genuinely look to learn from our past mistakes and failures.

2.4 I find that I don't encounter the same mistake on project after project.

2.5 I see the Lessons Learned process as adding real value to the company

2.6 I actively look to add lessons to the company database

2.7 I see lessons being applied actively, and people keen to not repeat past mistakes

2.8 The lessons learned process is a key part of my organisation's strategic improvement activities

2.9 The lessons learnt process delivers key strategic and competitive benefit for my organisation.

Question 3

In relation to the execution of large construction projects which sentence best describes your experience of project execution? *(Respondents could pick one only).*

a) We don't know why we have problems with quality

b) Is it absolutely necessary to always have problems with quality?

c) Through management commitment and quality improvements we are identifying and addressing our problems

d) Defect prevention is a routine part of our operations

e) We know that we do not have quality problems

Question 4

In the last 2 year period I have heard senior management actively discuss the impacts of the phrase "cost of poor quality"

This question is presented with a "yes" or "no" discrete option.

Question 5

Which of these are directly related to poor quality on a project? *(Respondents were asked to pick all of those that apply).*

d) Defects (whether a component fault or poor workmanship)
e) Transporting something more than it needs
f) Routinely having a huge stockpile in the stores
g) Time spent waiting (whether for people, information, material etc.)
h) Someone spending extra time on something to make sure that it is right.

Question 6

In relation to project management, Quality is a constraint. (Yes/no)

Question 7

Comments (optional) about whether quality is a constraint.

Question 8

In working on large construction projects I have found that projects are generally; *(Respondents could pick one).*

a) Projects are well-ordered with clear communication channels and it is an environment where generally where people are working efficiently and know what they are doing.
b) Projects are run with good intentions but poor understanding of delivery and waste in the process leads to unnecessary wastage, delays and projects end up being more difficult that what they may need to be. Projects are delivered but not as well as what could have been.

c) **Projects are chaotic and plans (where available) were either ignored or not necessarily followed. People were not clear about what was required and why their work was important.**

Question 9

On large projects overall, enough time is wasted due to waiting to impact the schedule – whether for people, tools, material, management decisions or information. *(This question was offered with a yes/no response option).*

10. LIST OF ABBREVIATIONS

APM	-	Association of Project Management
ASQ	-	American Society for Quality
BIM	-	Building Information Modelling
CDM	-	Construction and Design Management (The CDM Regulations 2007)
CIRIA	-	Construction Industry Research and Information Association
CPM	-	Critical Path Method
CQI	-	Chartered Quality Institute
COCE	-	Cost of Capital Employed
COPQ	-	Cost of Poor Quality
COGQ	-	Cost of Good Quality
COQ	-	Cost of Quality
GDP	-	Gross Domestic Product
HSE	-	Health and Safety Executive
JIT	-	Just In Time
PDCA	-	Plan, Do, Check, Act (Deming Cycle)
PMI	-	Project Management Institute
QMS	-	Quality Management System
RCA	-	Root Cause Analysis
SE	-	Simultaneous Engineering
TIC	-	Total Installed Cost
TPS	-	Toyota Production System
UK	-	United Kingdom
WBS	-	Work Breakdown Structure