EXTERNAL FAILURE COST IN CONSTRUCTION SUPPLY CHAINS

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The effective measurement of cost of quality has an important role to play in driving quality. A handful of studies on the implementation of cost of quality in the construction industry have been undertaken with a good deal more published in other sectors. Cost of quality definitions, methods, and models are reviewed. The aim of this research is to understand how the complex interrelationships of construction supply chain members may influence the existence of external failure cost. A new study that focuses on the measurement of external failure cost during the post-handover stage of construction is proposed. An expert workshop and a trial questionnaire involving construction industry experts (both owners and their supply chains) show the various categorisations of external failure quality cost elements and the involved and compound nature of their measurement through the construction supply chain. Further research is proposed to appraise, quantify and align incentives and ultimately reduce the occurrences of failure.

Keywords: cost of quality, external failure cost, supply chain

INTRODUCTION

Cost of quality (COQ) was first introduced in the early 1950s in Juran's Quality Control Handbook (Yang, 2008) and has become part of the business strategy of many firms (Tye *et al*., 2011) to benchmark, drive continuous improvement and increase profit (Jaju *et al*., 2009). The application of COQ is well established in the manufacturing industries, but not in construction (Aoieong *et al*., 2002). While various theoretical forms of studies have defined and described the need to measure COQ failure, none have explored it against the complexity of the construction supply chain.

Various applications of the COQ in the construction industry have demonstrated tangible savings. For example, Abdul-Rahman (1996) found that tender value could be reduced by 5.6% through the prevention of non-conformance cost. While Hall and Tomkins (2001) found 5.48% failure cost savings and 12.68% prevention and appraisal cost savings. Tang *et al*., (2004) showed significant increases in COQ savings could be made when learning was applied between consecutive projects. There appears to be no construction specific approach to COQ and the complexity of the construction sector makes it difficult to translate practices from elsewhere (Jaafari and Rodchua, 2014). Instead, construction enterprises best existing project costing systems or perform bespoke investigations of specific quality failures that are dyadic

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in their relationship between two parties and so closed to wider learning, There is still significant work to be done to classify and spread good COQ practices.

Failure cost is highly recurrent in construction projects (Avendano Castillo *et al*., 2010), albeit rarely empirically investigated. According to Basu (2014) projects delivering on time and within budget, often fail to meet the end users' expectations in operation. Recent research by the Standish Group found that 98.9% of the projects in their database failed (*ca.* 49,450 projects) against one of cost, time, value, scope, customer satisfaction and strategic objective criteria. Examples of post-project failures are widespread. In the UK an air traffic control centre was ten years over schedule and still required reworks a year after opening (BBC, 2002). Berlin's Brandenburg airport was not functionally fit for purpose resulting in significant cost overruns and time delays from its 2011 opening. The significance of this work is that although there are definitions, methods, and categorisation of COQ, there has been little elaboration of the quantifying failure cost relationships post-handover. This article will thus address this gap and appraise the existence of external failure cost against a complex construction supply chain.

Defintion of Cost of Quality (COQ)

The COQ is known as the price of not creating a quality product or services. According to Krishanan *et al*., (2000), quality costs are the costs incurred to prevent shortfall in quality and failure to meet customer requirements. Accordingly, the COQ is simply a cost absorbed due to the work requisite in achieving targeted quality in a project. It is either cost to achieve the quality or a cost due to quality failure. As such, it cannot be ignored.

Quality cost was first propounded by Juran (1951) and later developed by Crosby (1979, 1983 and 1984). Quality was known as the conformance to requirement, but it was Crosby (1979) who elaborated quality cost to see it as both the price of conformance (cost invest to comply with requirement) and price of non-conformance (cost of poor quality). Feigenbaum (1991) later redefined these categorisations as the cost of control (cost of conformance) and costs of failure of controls (costs of non-conformance). Schiffauerova and Thomson (2006) included the additional cost due to the failure in achieving customer requirements (such as correcting, reworking or scrapping). All are simply the total costs that are avoidable (Al-Tameemy *et al*., 2012). Ali *et al*., (2010) differentiated between internal failure cost (the costs incurred before delivery to the owner) and external failure cost (after delivery to the owner).

COQ has previously been consistently classified into three main categories: Prevention, Appraisal, and Failure (Feigenbaum, 1956), according to the timing of its occurrence. Better known as the "Prevention-Appraisal-Failure" (PAF) model (Abdul-Rahman, 1996; Aoieong *et al*., 2002; Jaafari and Rodchua; 2014). The relationship between quality cost elements for construction has been depicted in a new model developed in collaboration with the Chartered Quality Institute (Figure 1), and being trialled by the authors.

Despite the general classifications model of COQ being implemented, some have expressed scepticism on the overall coverage of this traditional categorisation (Yang, 2008; Dahlgaard *et al*., 1992), with those such as Yang (2008) and Krishan (2006) referring to the "hidden" nature failure costs. While there are sceptics, however, no better alternative exists. Quantification will almost certainly help to benchmark and see the causality between costs. The increased and controlled cost of prevention and appraisal will lead to the decrease in internal and external failure costs (Kiani *et al*.,

2009). So the central tenant of the P-A-F model is an investment in prevention and appraisal activities which will reduce failure costs, and further investment in prevention activities accordingly will reduce appraisal costs (Roden and Dale, 2001).

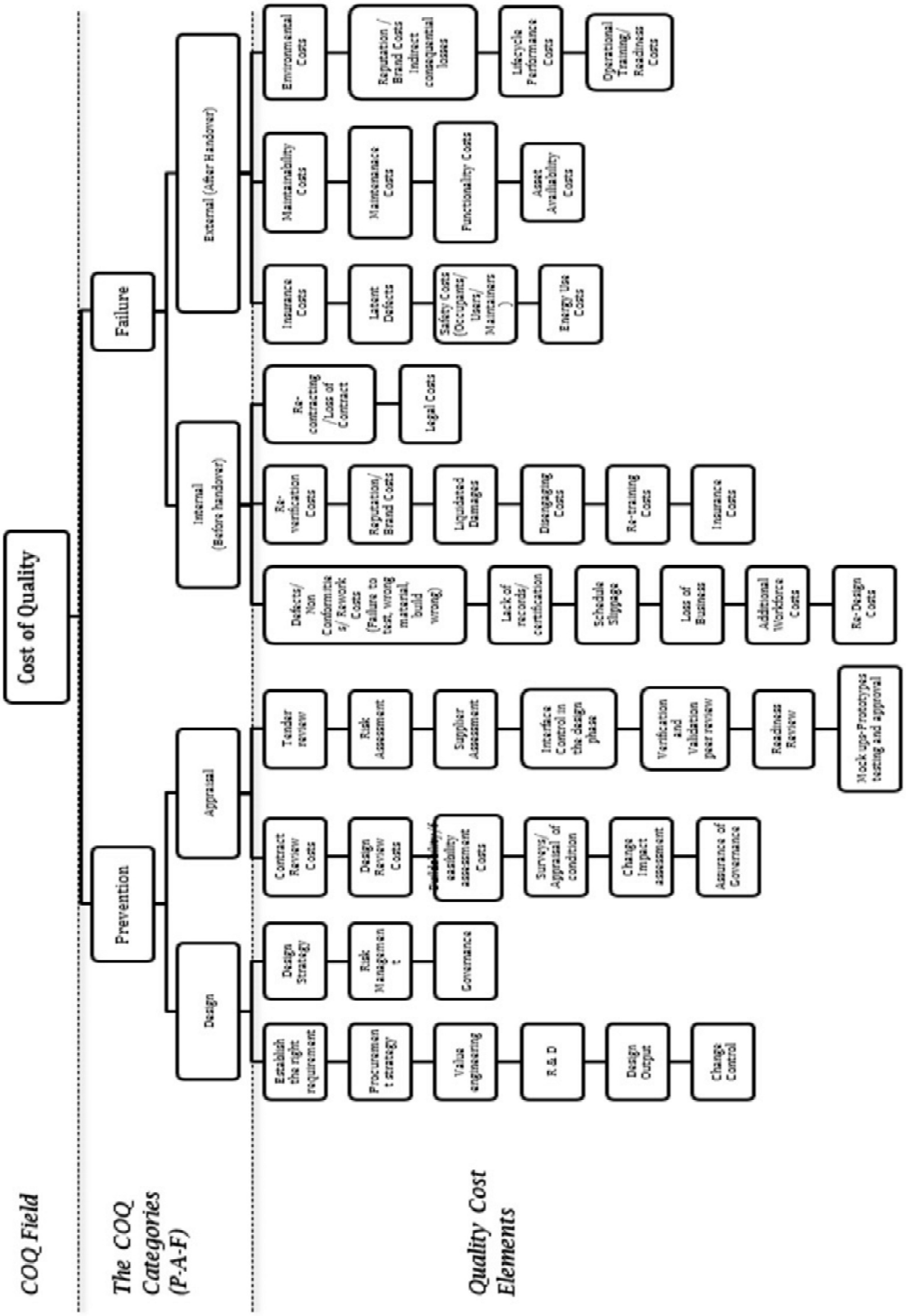

Figure 1: The COQ field and classification of quality cost elements

Focus on Cost of Quality failure

Failure is a lack of success, falling short, or omission of some persons, processes or products. Many academic authors associate insufficient planning and control with project failure (e.g. Dvir *et al*., 2003b and Lechler *et al*., 2015), although projects are

complex, time restricted and unique endeavours that have often not been implemented before; consequently changing plans are inevitable to accommodate for the uncertainties (Andersen, 1996).

While there are consensuses in the literature on measuring COQ, research on failure cost is fragmented. Models have been suggested to measure failure, but none are developed for construction (Taggart, 2014), however specific quality costs have been investigated, for example defective works (Mukhopadhyay, 2004), deficient work (Freiesleben and Freiesleben, 2005) or the consequence of rework (Castilo and Helman, 2010).

Yang (2008) defined failure as "visible" and "hidden" cost. Typically, external failure costs are hidden costs - comprising such elements as insurance, maintainability and environment costs. External failure costs are considered to be the most significant quality cost and more difficult to evaluate than other categories (Snieska *et al*., 2013). Love and Irani (2002) believes that costs could be 25% of the total construction process. While Taggart *et al*., (2014) suggested rework cost range from 2% to 6% during construction and additionally 3% to 6% during maintenance period. Prevention and appraising external failure cost has yet to be empirically investigated in construction.

Application of measures

Ozkan and Karaibrahimoglu (2012) have identified classification and measurement steps, although accuracy and information misreporting can be a problem (Omar and Murgan, 2014, Yang, 2008), with traditional cost accounting systems known to fail (Ozkan and Karaibrahimoglu, 2012; Yang, 2008; Tsai, 1998). There is huge variability in standards and guidelines for measuring quality costing, and skills and training in measuring COQ are needed (Jafari and Rodchua, 2014) to avoid error (Barber, 2000).

Some believe there must be a dynamic and constantly changing measure of COQ and the measures must be organisationally specific (Srivastava, 2008, Hwang and Aspinwall, 2010) and cover the breadth of an organisations operation and the needs and requirements of customers (Dale *et al*., 2007). However, standardisation is needed to facilitate benchmarking and continuous improvement (Miguel and Pontel, 2003).

Miguel and Pontel (2003) state quality failure is due to ineffective and unsystematic capture of quality costs, with external failure costs absorbed by one party or shared among the supply chain. While, most studies only indicate basic guideline in failure cost (Dror, 2009; Snieska, 2013), there is little consistent and credible quality cost data (Kumar *et al*., 1998) and mechanisms are judged by some to be ineffective (Miguel and Pontel, 2003). Research on how owners and their construction supply chain form relational and technical systems to measure and address external failure cost are therefore imperative.

METHODOLOGY

Two studies investigated the status of failure cost during post-handover. Study 1 was a workshop held to categorise external failure cost elements. The participants were construction industry experts (a quality manager, quality consultant, two contractors, and owner) within different sectors of project-based firms (n=5). A card sorting

methodology (Jahrami 2012) was used to classify the quality cost elements (e.g. to show dependence and interrelatedness). Participants were first asked to indicate through sorting) which organisation positions accrued costs related to each external failure cost element (based on their experience), then think about how groups could be categorised.

Study 2 was a survey that investigated the respondent experience of external failure cost issues, enterprise maturity in COQ and to understand various owner and supplier influences on external failure. Data were collected from 15 respondents with advisors (*n*=2), suppliers (*n*=3) main contractors (*n*=2) and owners (*n*=7) in UK construction industry who mostly had responsibility multiple assets (rather than a single one off project) and the value of these assets ranged from £400m to £5billion per annum.

FINDINGS

Study 1 finding from an expert workshop to categorise failure cost

The analysis of the card sorting showed two key findings for the nature of external failure cost within the supply chain.

All external failure cost elements are partially incurred by the owners / operator followed by integrator / main contractor and advisor/ consultant/designer. One outlying expert perceived cost shared throughout the supply chain. Discussion of this fact between the experts showed that the difficulties in quantifying external failure costs during the operation of the assets. This shows that most cost is absorbed as part of day-to-day operational costs. Each organisation may not be aware of the occurrences of these costs, as it is assumed to be only incurred by the owners. Thus, the total amounts of external failure cost are anonymous or only suffered by one party.

The external failure costs were categorised and incurred differently by various members of the owner and supply chain. For example Insurance cost was most frequently incurred by the whole supply chain, while obsolescence cost was the least frequently incurred. Each expert (who had a different role) produced different categorisation of external failure cost elements, according to when they are identified or occur in time, or according to the risk owner or who they are incurred by (e.g. to the owner, supply chain or shared). This was otherwise described as those that are impacted.

Study 2 findings from the application of a trial COQ questionnaire

The results show that the maturity of enterprises in dealing with these external failure cost elements differed significantly. Measurement and management of quality cost element was judged by respondents to be insufficient, with relatively low maturity expressed. The results in table 1 show how owners (O) and their supply chain (S) judge their own maturity. There were limited expressions of maturity (at a level of "managed" or "optimised" experience. Most elements were at best understood (e.g. at a "defined" level or lower). Perhaps most interesting was "insurance" where there was significant misalignment within and between owners and suppliers. However, it was also judged to have the highest level of maturity, which may illustrate its management. This shows variances between owners and supply chain maturity may be due to insufficient information upon the element. There is some variation between suppliers on the maturity of "safety", "asset availability" and "energy use" (with scores ranging from unaware to managed), perhaps more than between owners. It is difficult to say why this may be, and so why suppliers vary more significantly in their maturity should be further investigated. There is strong alignment between both

owners and suppliers, with most aligned maturity on "operational training", "environmental", and "lifecycle performance". There was owner and supplier alignment on some elements with least maturity (including "adaptability", and "Early obsolescence"). There was a moderate level of awareness on "latent defects" and "maintenance".

Table 1: Owner (O) and supply chain (SC) level of maturity in measuring external failure cost elements

Level of maturity	Failure cost elements: Insurance		Latent Defect		Safety		Asset availability		Energy use		Maintenance		Environmental		Lifecycle performance		Functionality		Unadaptable		Early obsolescence		Reputation		Operational Training	
	O	S	**O**	S	**O**	S	**O**	S	**O**	S	**O**	S	**O**	S	**O**	S	**O**	S	**O**	S	**O**	S	**O**	S	**O**	S
Unaware	**4**	1	**1**		**3**	2	**2**	3	**2**	1	**2**	2	**2**	1	**1**	1	**4**	2	**4**	3	**4**	3	**3**		**2**	1
Aware	**1**	2	**4**	5		2	**2**	2	**2**	2	**3**	4	**2**	3	**4**	3	**1**	2	**2**	1	**2**		**2**	3	**1**	3
Defined		2	**1**	2	**2**	2	**1**	2	**3**	2	**1**	2	**2**	3	**1**	3	**1**	3	**1**	2		3		2	**3**	3
Managed	**2**	3		1	**2**	2	**1**	1		3	**1**		**1**		**1**		**1**			1	**1**	1	**1**	2	**1**	
Optimising			**1**				**1**																			

Respondents frequently differed on how they rated their own maturity versus that of others with the maturity of the supply chain judged to be the lowest. Both owners and supply chain saw their own level of maturity as above fair (e.g. fair, good or very good). When judging the customer, there is an agreement on the level of maturity to influence operational failure as good, but few say it is below fair (either very low, low or fair). In judging suppliers, most owners and supply chain indicates moderate maturity (ranging from fair, low or very low), although the supply chain score themselves and other suppliers as good. In judging the ability to influence, owners and supply chain both agreed they are beyond fair (fair, good and very good). Table 1 and 2 shows that the level of maturity of the owner and supply chain in dealings with quality cost elements is understood but not managed, however there are great confidence in the ability to influence operational failure. Thus, increments in the maturity towards quality cost elements help greater managerial and measurement of the quality cost. It is believed to depreciate the occurrences of external failure cost with more integrated system of quality costing.

Table 2: The level of maturity in influencing operational failure ascribed to the Owner (O) and supply chain (S)

Level of maturity	Own Enterprise		Customers		Suppliers		Overall ability to influence	
	O	SC	**O**	SC	**O**	SC	**O**	SC
Very Low			**1**	1	**1**			
Low		2		1	**2**	2		
Fair	**4**	2	**2**	1	**2**	3	**3**	5
Good	**1**	2	**3**	4	**1**	2	**1**	2
Very good	**1**	1					**2**	

These findings may be explained by participants' qualitative comments. There was a belief that the owner role was unclear in dealing with failure cost, and that there was a need for strong owner leadership. There was perceived to be poor standards in place and a lack of knowledge on what defines value. Also there was weak understanding of a projects context, and some acceptance to acceptance of non-performance. There was also a need for rigorous assurance during design and construction, change and

scope control and clear definition of operational requirement pre-project to reduce the failure cost during operational. These require greater investigation.

DISCUSSION

Most organisations have different ways to capture the COQ (Yasamis *et al*., 2001), thus there is a need to align and standardise measurement through the supply chain. There is a need to understand the contextual and organisational differences between projects with regards to COQ measures (Shiffauerova and Thomson, 2006), and this initial study indicates that maturity within industry is relatively low. Quality cost is believe as an exchange/transition cost, although more research is needed to understand the relationships and shared responsibility that will contribute to learning. External failure cost may be classified in different ways in different projects and sectors and there are variations in owner and supply chain maturity and influence.

Snieska *et al*., (2015) recommend steps in order to reduce external failure cost through quantification and observation during the process. There are variations in COQ models (Omar and Murgan, 2014), although no existing models are suitable. Most of the research effort has focused on identifying quality cost elements, calculating COQ, reducing the costs and the relationship between cost component during the prevention and appraisal. This paper contributes to the field of quality cost management by looking into the relationship of construction supply chain in appraising external failure cost.

There is a known benefit in visualising hidden costs, and in monitoring and quantifying (in financial terms) the effects of poor quality (Hwang and Aspinwall, 1996 and Jafari and Rodchua, 2014). Studies 1 and 2 have shown the need for industry measurement and management of failure costs because there is a lack of full maturity and uncertainty on owner and supplier influence. As in Porter and Ryner (1992) it is hoped that this work will facilitate quality management improvement and help to eliminate waste, and point out the strengths and weaknesses of a quality system (Srivastava, 2008). It is hoped that understanding COQ deficiencies will help to define the quality programme (Yang, 2008), lead to time and costs savings (Love and Li, 2002, Tang *et al*., 2004), enhance profit sustainability (Paleneshwaarran, 2006), reduce customer dissatisfaction and reduce lost reputation during the period of maintenance and operation (Devi and Chitra, 2013), and allow for immediate corrective actions (Love and Irani, 2002).

CONCLUSIONS AND RECOMMENDATIONS

External failure cost is recognised as the cost incurred after the asset is handed over to the owner. Due to the complexity of project handover there are still costs accrued by the supply chain. Many costs are either recognised, found lost in the process or ignored or absorbed as an overhead by one party or another, who is willing to take the responsibility. This shows the difficulties in measuring COQ in construction.

The measurement of the external failure cost has not been well explored in the academic literature and within the sample of construction industry owners and supply chain representatives, there was seen to be a low or at best a moderate levels of maturity. Ability to influence operational failure appears very clear; that operational failure is not a result of an independent parties but it is the result of interaction between many interrelated supply chains represented by different failure factors.

This paper has combined existing literature with an initial research trial to show that further research is needed to underpin knowledge of external failure costs. This initial step shows the complexity in understanding quality costs and the limited maturity in capturing data due to the distribution of responsibilities throughout the supply chain. This raises important questions, such as in what proportions are these costs shared? How can relationships and technical systems be managed to reduce quality failure? And how can improvements in external failure cost measured? Action research in one major infrastructure organisation is undertaken to elaborate on these findings.

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