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A CONCEPTUAL FRAMEWORK FOR INTEGRATING COST OF QUALITY AND COST OF SAFETY IN CONSTRUCTION PROJECT

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Abstract

Project acceleration has been growing as a common demand construction projects. This creates challenges to project management in managing project budgets to ensure work quality and eliminate work accidents throughout the project. To address this issue, this study aims to offer a conceptual framework in integrating the cost of quality (COQ) with the cost of safety (COS) estimation method as a model that can be used by project management to optimize resource allocation by providing accident prevention measures and evaluating quality failures. This study conducts a qualitative method through systematic literature review about COQ and COS to formulate a conceptual framework for integrating COQ and COS using risk management framework. This paper found three major reason that integrating COS and COQ are feasible. (1) Quality failures and safety incidents have common precursor issues, (2) Quality and safety could be analyse using risk management perspective, and (3) Quality and safety cost are using similar estimation methods. This integrated COQ and COS model using risk management perspective would provide a conceptual framework for future research in integrating quality and safety management.

Keywords: cost of safety, cost of quality, integration, risk management, construction project

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INTRODUCTION

Construction projects have specific project specification demands specified in the contract related to labour, materials and equipment and have uncertainty challenges that have potential safety quality risks throughout the project (Silalahi et al., 2023). Construction industry always been known prone to high safety risk and quality failure. In US every year nearly \$5 billion dollars loss due to fatality cases in construction project for covering lost family income, post traumatic suffering cost, and quality of life improvement cost (Manzo, 2017). In Australia, per project , an average \$1.374,25 paid for a short absence due to accident to \$4058,42 for accident result in permanent incapacitation and worker replacement (Allison et al., 2019).

Work quality failures also have a major financial impact on project management. Rework caused by poor quality supervision is key reasons for time and cost overruns in construction project (Garg & Misra, 2022). Moreover, Love et al. (2018) suggested that human error proved as a significant root cause of the work accidents and quality failures, it also mentioned that injury rate tends to be equivalent to the nonconformance rate. The incidence of work accidents and work correction demands due to poor quality impacts 3.1% to 6% of the total project cost and extends the project schedule by approximately 5.1% to 10% (Yap et al., 2017).

Project management needs a solution to overcome quality failures and work accidents. These solutions require resources to be allocated specifically to allow management to manage the risk of quality failures and safety incidents. However, project management still have to handle the fact that to perform quality and safety management effectively requires cost, and managing tight project budget that includes quality and safety cost is not an easy task (Hoonakker et al., 2010). Inadequate financial support to control quality and safety risk in an integrated manner is one of the inhibiting factors (Apriyati & Latief, 2020).

Khaled Omar and Murgan (2014) stated that cost of quality (COQ) method has been proven as a prominent method to estimate quality budget also as a method to utilise project resource based on preventive and corrective plan. Allocating strategic resources for safety investments significantly influence safety outcomes in small and medium construction company (Bachar et al., 2025). On the other hand, developing an optimum safety investment for a construction project provide many benefits such as increased worker confidence and minimise near miss incident that undoubtedly be valuable assets to the contractor (Gurcanli et al., 2015) . An accident prevention cost (APC) method has proven to reduce unforeseen cost due to fatalities of injuries in the construction industry (Ikpe et al., 2012).

Unfortunately, to this date no research has been found that addresses the integration of quality and safety management in the context of quality and safety control, resource allocation and cost calculation. Therefore, the primary

objectives of this study is to determine a conceptual framework for integrating COQ and COS using systematic literature review and descriptive analysis. To guide this research, three primary research questions formulated to investigate the possibility to integrated COQ and COS using risk management perspective.

- **RQ1:** Do quality and safety issues have the same root cause?
- **RQ2:** Can quality risks and safety risks be analyzed using the same perspective?
- **RQ3:** Can quality cost and safety cost be calculated with the same estimation stages?

This research question is structured as a guide to provide comprehensive review in findings possibility of integrating COS and COQ as an integrated cost estimation method using risk management perspective.

LITERATURE REVIEW

A. Identifying COQ and COS Components

Previous studies (Garg & Misra, 2022; Shafiei et al., 2023; Sharma & Laishram, 2024; Thabet et al., 2024) generally categorize COQ components in two main groups as shown in Table 1, namely conformance cost (CC) and non-conformance cost (NCC). Conformance cost consist of preventive cost and appraisal cost. Preventive costs defined as all costs spent by management to prevent the occurrence of non-conformities before-in-after work (Garg & Misra, 2022). On the other hand, appraisal costs are the costs that are incurred to ensure that all work products are in compliance with the expected standards including testing costs, monitoring and evaluation costs, and material inspection costs as shown in Table 2.

Non-conformance cost mostly described as costs that must be paid by the service provider if there was non-conformity/failure in a product before it is handed over to the owner (internal failure costs) or after it is handed over to the owner (external failure costs) (Heravi & Jafari, 2014). Shafiei et al. (2023) found that there are 22 factors related to CC and NCC, for example, the addition of training costs to workers has the potential to reduce the cost of rework and reduce the overall quality cost allocation.

Several previous studies categorized COS components into two parts, namely accident prevention costs (APC) and accident costs as mentioned in Table 1. APC are cost paid by contractors to prevent accidents, normally it was not included in the project budget and considered as an additional cost for contractors (Lee et al., 2022). Accident cost are costs that arise due to accidents even though prevention measures are in place (Ikpe et al., 2012).

Meanwhile, some studies classified COS as fixed prevention cost or generic cost (GC), variable prevention cost or specific cost, and unexpected

prevention cost. GC are costs incurred by management to prevent work accidents and ensure that the work area, workforce, materials and equipment are in a safe condition and ready for use. Specific costs or variable prevention cost are costs associated with securing work areas or work methods that tend to be unique and cannot be generalized between projects, including the cost of protective equipment, safety signs, the cost of securing work methods and salaries for safety personnel (Fitriani, 2022). Security costs are example of unexpected costs which is incurred by the contractor to secure the project site, workers, materials and equipment from theft, vandalism, sabotage or disturbance of unauthorized individuals

Table 1. COQ Components

Components	Description	Reference
Prevention cost	Training of workers and staff	(Garg & Misra, 2022; Shafiei et al., 2023; Sin et al., 2024; Thabet et al., 2024)
	Suppliers quality surveys and review	
	Preparing quality system, procedures and standards	
	QC staff salaries	
	Design and specification review	
	New material storage/ inventory review	
	Equipment storage/ maintenance	
	Internal audit	
Appraisal cost	Third party audit	
	Material laboratory inspection and testing	
	Onsite inspection and testing	
	Product/ after build final testing	
	Documents review	
Internal failure costs	Defect identification	
	Scrap and demolition	
	Rework/ corrective actions	
	Re-testing	
	Re-inspection	
	Re-design/ review design	
	Materials wastage	
External failure costs	Penalties due to nonconformance	
	Warranty claims	
	Legal cost and compensations	

Table 2. COS Components

Components	Description	Reference
Generic costs	Safety training and orientation for workers and staff	(Fitriani, 2022; Ibarrondo-Dávila et al., 2015; Lee et al., 2022;
	Health and safety plan/ procedures	
	Personal protective equipment	
	Health and safety signs	
	Health and safety monitoring	
	Safety consultant/expert	

Components	Description	Reference
	General expense for health and safety inventory/supplies – first aid, hygiene related expense, fire extinguishers, emergency lighting, etc	Misnan et al., 2024; Rosmariyani Arifuddin, 2023; Teo & Feng, 2011)
	Safety promotion and incentive	
	Workers and staff insurance premiums	
Security costs	Security plan – permit, security personnel, security equipment (Sc)	
Specific costs	Health and safety staff salaries	
	Emergency response equipment/ supplies	
	Safety protection measures – fence, nets, railing, curtain, façade coating, etc	
	Traffic safety measures	
	Job/ material/ equipment/ worker permit	
Direct costs	Insurance cost	
	Uninsured medical expenses	
	Compensation for workers family	
	Fines/Claims due to safety procedure violations	
	Legal penalties and administrative cost	
Indirect costs	Work delay, productivity loss, cleanup and repair	
	Equipment failures, wasted material, raw material damages	
	Additional cost for new worker/operator recruitment	
	Accident investigation related cost	
	Penalties/ Fines due to handover delay	

B. COQ and COS Estimation Methods

Some previous studies clearly show the calculation model of quality costs and safety costs. one of the calculation models that both cost estimation methods use in common is the activity-based costing (ABC) model. The ABC could be used to identify, analyse and allocate quality costs in a detailed way, helps to manage quality costs more effectively (Schiffauerova & Thomson, 2006).

One of the most common methods of the ABC model is the preparation of work breakdown structures (WBS). WBS is used to describe each element of the project in stages into smaller items so that it is easy to manage and calculate the resource requirements for each item (Yılmaz & Kanit, 2018). As shown in Table 3 several previous studies illustrate some similarities in the stages of the COQ and COS estimation methods.

Table 3. Cost of Quality and Cost of Safety Estimation Phase

References	Phase 1	Phase 2	Phase 3	Phase 4	Result
(Heravi & Jafari, 2014)	Identifying and classifying quality-related activities	Collecting the cost of classified quality-related activities through survey study	Analyzing COQ data and developing the model for evaluating the COQ	Calculation of optimum level of COQ	COQ
(Rosenfeld, 2009)	Define quality failures cause and quality prevention elements	Identifying elements of quality cost (P-A-F elements)	Quantifying the cost of elements per unit		Total quality related budget
(Desai, 2008)	Identifying cost components and sub-components	Measuring and quantifying the elements	Determines quality cost scenario by analysing improvement area	Define prevention-appraisal and failures compensation measures based on quality cost scenario	COQ budget
(Fitriani, 2022)	Preparing WBS	Hazard identification and risk assessment	Determining OHS control measures	Calculating safety cost	OHS Cost
(Yılmaz & Kanit, 2018)	Establishment of work breakdown structures	Identify possible safety hazards	Determine the protection measures and proper risk respond procedure	OHS cost estimation	OHS Cost
(Gurcanli et al., 2015)	Preparation of WBS	Analyse risk value by identifying possible safety hazards	Determination of protection measures and risk mitigation techniques	Safety cost estimation	OHS cost

RESEARCH METHODOLOGY

This study conducts qualitative research and document analysis through literature search through databases such as Scopus and Web of Science. The research problem is broken into manageable keywords such as: “cost of quality”, “quality costs”, “cost of conformance”, “cost of nonconformance”, “construction industry”, “cost of safety”, “accident cost”, “accident prevention cost”, “integration”, “integration management”.

Searching process then proceed using snowballing and trial-and-error search methods. The search was conducted between March and June 2024. The last search was performed 15 June 2024, followed by descriptive analysis on the selected articles to provide a compilation of COQ and COS factors and estimation methods which is classified into different categories using inductive content analysis.

Furthermore, the findings of the categorisation analysis provide an in-depth perspective for proposing a conceptual framework for integrating COQ and

COS as an integrated cost estimation method. The results of the literature review were then used as a reference to develop theoretical framework about COQ and COS as shown in Figure 1. The results of the theoretical framework obtained from the literature analysis are then used to develop a conceptual framework in integrating COQ and COS using WBS based on a risk management perspective as illustrated in Figure 2.

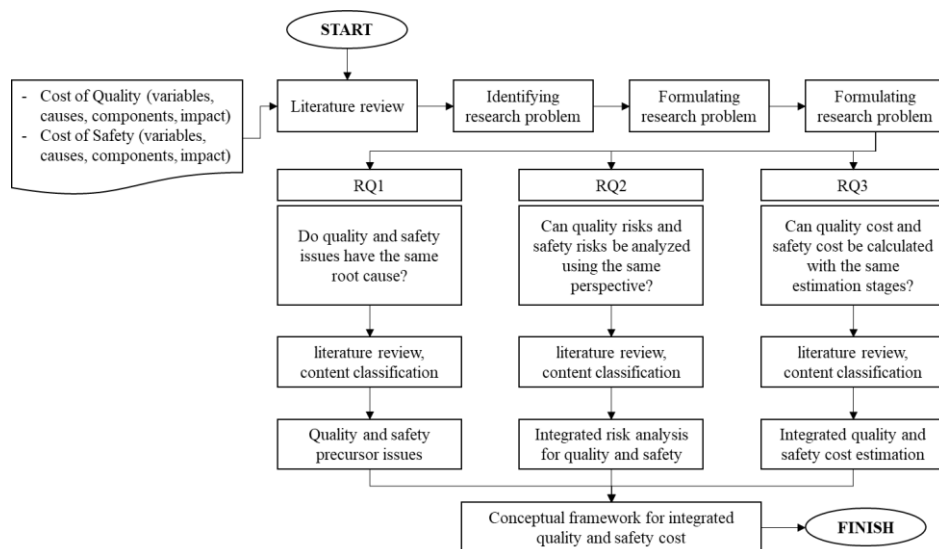


Figure 1: Research methodology

FINDINGS

A. Quality and Safety Failures Precursors Issues

Yarnold et al. (2023) state that quality control is closely related to safety control in project operations. Safety issues are often found as a consequence of poor quality. As shown in Figure 2, failure to meet specifications or requirements results in the issuance of a non-conformance report (NCR), which then requires corrective action such as rework (Love et al., 2019). Injury rate reports is positively correlated with the rework and defect rate, hence projects with poor quality performance have a higher probability to cause safety incidents (Wanberg et al., 2013). The consequence of rework is to increase safety incidents partly because rework increases working hours and increases the potential for worker fatigue (Wanberg et al., 2013).

Sadeghi et al. (2020) found that the increasing number of non-conformities found tends to lead to safety incidents or has a higher chance of potential new safety-related hazards in the work area. Prioritizing quality control in conjunction with safety control has been shown to provide significant benefits

to project management and project operations throughout the duration of the project.

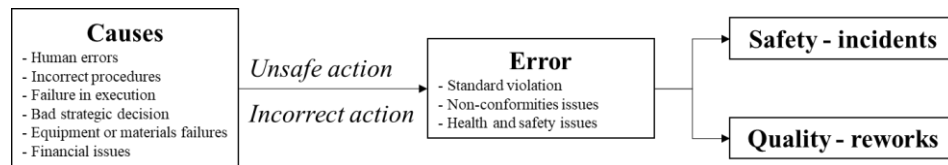


Figure 2: Quality and safety failures precursor issues
Source: Love et al. (2019)

B. Quality and Safety Risk Analysis

Previous research shows that the patterns of estimating quality costs and safety costs have some clear similarities, namely (1) determining the components or items involved; and (2) determining the potential factors that cause quality failures or safety hazards. This is relevant when associated with the stages of risk management in the construction project, namely (1) risk identification; (2) risk analysis and evaluation; (3) risk response (Fitriani, 2022).

Silalahi et al. (2023) shown that using risk management perspective proven highly relevant to provide detailed quality or safety plan. Quality and safety plan that comprise selected resources efficiently to ensure cost effective strategic decision as shown in Figure 3.

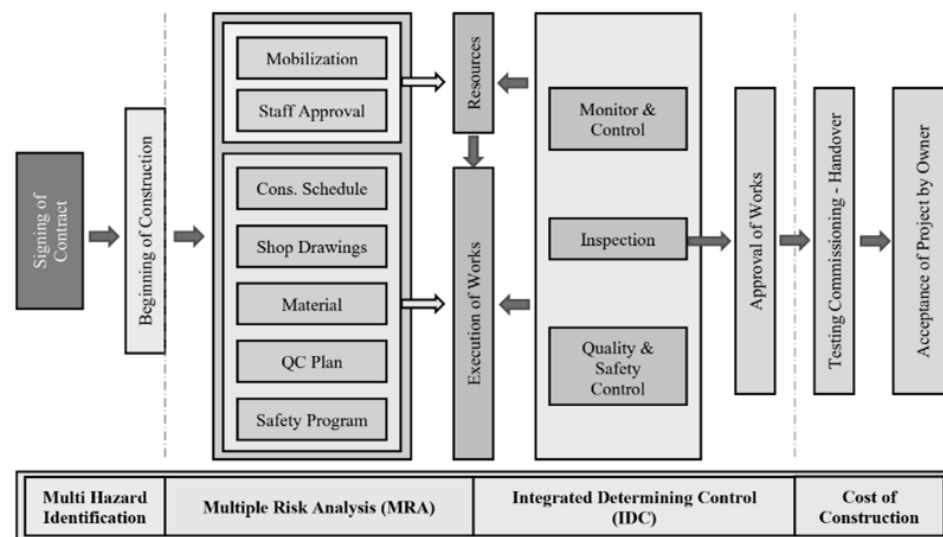


Figure 3: Quality and safety analysis model using risk
Source: Silalahi et al. (2023)

C. Quality and Safety Cost Estimation Method

Studies on OHS costs in the construction industry have been conducted since the 1990s. Tappura et al. (2015) introduced cost-benefit analysis of accident prevention method and incorporated the fatality factor as a critical risk into this model. Gurcanli et al. (2015) estimated COS contained in project costs and using the activity-based risk assessment method along with activity-based cost analysis to calculate COS. Fitriani (2022) included the element of security cost as a new variable in calculating the safety cost component.

On the other hand, Desai (2008) used the conventional method of quality costing approach on six construction companies in India from various levels (local, regional, national to multinational). Rosenfeld (2009) used the total quality related cost (TQRC) approach by comparing historical data of nine construction companies in Israel to serve as a basis for estimating COQ in percentage form. Heravi and Jafari (2014) used the method of decomposing all quality-related activities associated with the level of conformance to quality and the COQ elements.

From literature mentioned above that COQ and COS estimation method provide quite similar pattern and stages as shown in Figure 4.

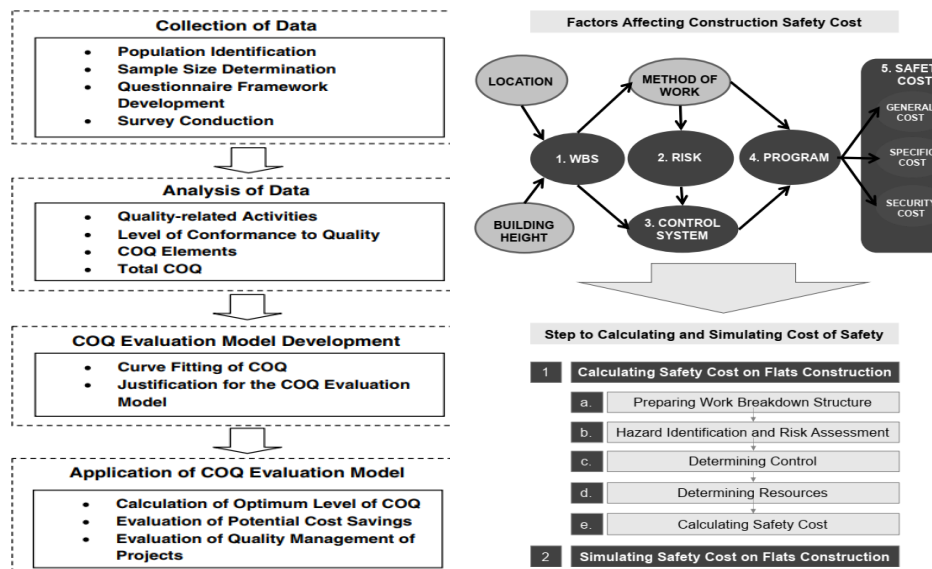


Figure 4: COQ and COS estimation method comparison

Source: (Fitriani, 2022; Heravi & Jafari, 2014)

ANALYSIS AND DISCUSSION

Using the risk management point of view as illustrated in Figure 5, the steps of integrating quality costs with safety costs can be described as follows,

1. Using systematic activities breakdown as a starting point followed by determining all activities in detail grouped by project stages (preparation, mobilization, implementation, testing and handover);
2. The next step is identifying the potential quality and safety hazards simultaneously in each activities;
3. Followed by analyze the probability and impact value of each potential hazard that has been determined using risk analysis (quality+safety) matrix;
4. After that proceed with establishing an integrated quality and safety control measures based on the risk value analysis results.
5. Lastly, determine quality and safety control measures to estimates integrated COQ and COS according to local/national cost standard.

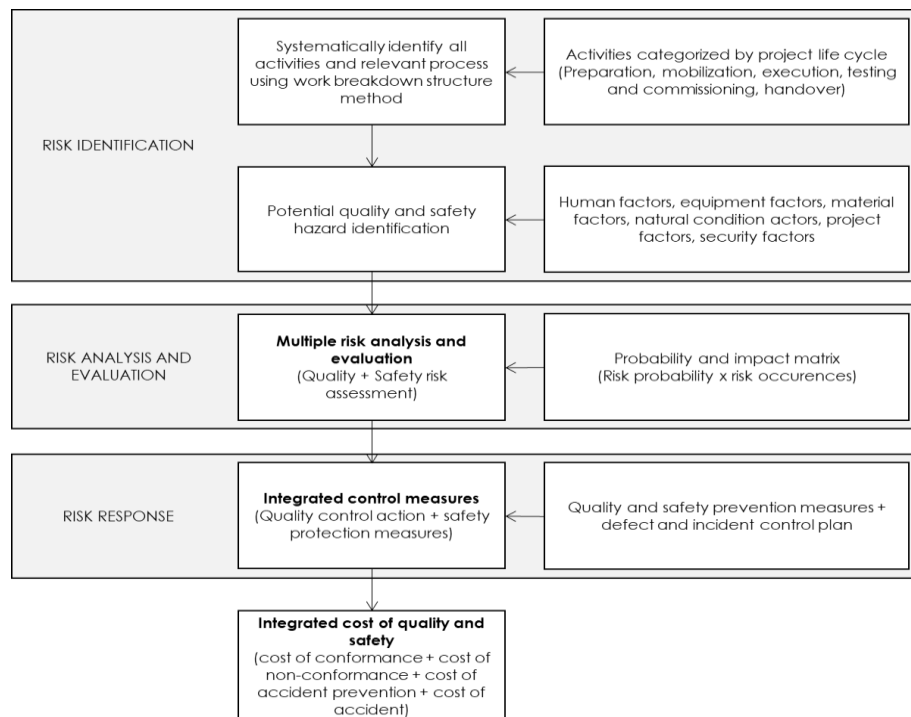


Figure 5: COQ and COS integration conceptual framework using risk management perspective

CONCLUSION

We found there are three major highlights that led us to conclude that the integration of COQ and COS is feasible using a risk management perspective. Those highlights are:

- (1). COQ and COS have common precursor causes such as human error, equipment and material failures, and incorrect procedures;
- (2). COQ and COS component that tend to be similar grouped into two main components as preventive components such as training for workers, providing safety/quality plan, scheduled quality and safety inspections and corrective components such as direct expenses for medical expenses, cost for rework-retest-reinspection; and
- (3). COQ and COS common estimation stages/method.

Estimating COQ and COS are proven relevant when associated with the risk management framework as stated by Love et al. (2018) that conducting risk assessment before project begins to anticipate potential errors that may cause NCR or safety incidents. Application of risk management framework in conducting integrated estimation of quality costs and safety costs expected to result in detailed breakdown of COQ and COS components, a better and comprehensive risk analysis because the probability level and impact value are calculated from the quality and safety perspectives simultaneously, and quality and safety risk control measures could be applied in effective and efficient manner resulting in optimum cost allocation (Silalahi et al., 2023).

LIMITATIONS AND FUTURE RESEARCH

While this research provides valuable insights in integrating COQ and COS. This research scope is still limited to a literature review with descriptive analysis so that it still needs further follow-up to prove the proposed conceptual framework. This conceptual framework can serve as a baseline for further research to validate each of step of risk analysis for COQ and COS integration. This integration process will be very efficient if assisted by information and communication technology (ICT) innovations such as Building Information Modelling (BIM) in its future research methods which could help to provide an efficient and better cost estimation methods.

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