Sharma, N., Sood, R. and Laishram, B., 2024. Mapping global trends in cost of quality dynamics: A bibliometric study. In: Sandanayake, Y.G., Waidyasekara, K.G.A.S., Ranadewa, K.A.T.O. and Chandanie, H. (eds). *Proceedings of the 12th World Construction Symposium*, 9-10 August 2024, Sri Lanka. pp. 755-768. DOI: https://doi.org/10.31705/WCS.2024.60. Available from: https://ciobwcs.com/papers/

MAPPING GLOBAL TRENDS IN COST OF QUALITY DYNAMICS: A BIBLIOMETRIC STUDY

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ABSTRACT

In the construction industry, unique projects and complex dynamics pose challenges for maintaining high-quality standards. An inadequate Quality Management System (QMS) can lead to extra costs and delays, highlighting the importance of methodologies such as the Cost of Quality (COQ). Despite extensive knowledge in manufacturing, the construction sector lags in adopting COQ. A systematic review is needed to understand COQ developments in construction, informing better practices and cost reduction strategies. A Systematic Literature Review (SLR) and bibliometric analysis were carried out utilising 27 peer-reviewed papers obtained from the Scopus database. The present study utilises a range of tools, including VOSviewer and Litmaps to facilitate descriptive analysis, bibliometric analysis, and network visualisation. The purpose of this study is to investigate different aspects of the COQ and analyse different patterns and models related to it in the context of the construction industry. The present study systematically presents potential avenues for future research that have been identified in the existing literature.

Keywords: *Construction Industry; Cost of Quality (COQ); Quality Management.*

1. INTRODUCTION

Traditional construction projects have been criticised for their significant challenges. These challenges can be methodically categorised into four cardinal domains i.e. (i) cost, (ii) time, (iii) scope, and (iv) quality, which support the iron triangle criteria for the success of the project. The first three positioned at the periphery of the triangle are comprehensively recognised however the understanding of quality, which occupies a central position inside this triangle, has limitations within the construction industry (Thekkoote, 2022). Accelerated quality issues in construction projects arise from the fact that different definitions of quality are used in literature, varying from one industry to another. In addressing the challenges pertaining to quality, different Quality Management Systems (QMS) such as Total Quality Management (TQM), Lean Six Sigma, the International Organization for Standardization (ISO), and Cost Of Quality (COQ), originally designed for the manufacturing industry are being progressively integrated into the construction industry. Despite the widespread implementation of QMS, construction

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industry stakeholders still lack objective and quantitative decision criteria. In this context, a recent surge was observed in the implementation of COQ (Psomas et al., 2022), primarily driven by its capability to measure and document project quality, essential for the proper functioning of QMS (Omar & Murgan, 2014). As interest in COQ increased, a number of researchers and practitioners have carried out significant work in different fields such as business, manufacturing, and construction, to explore the domain of COQ. For instance, Schiffauerova and Thomson (2006) attempted to review various COQ models and underlined their relevancy in the manufacturing industry. Similarly, Lopez and Love (2012) indicated that design-related costs range from 5% to 8% of the contract value. Moreover, the authors engaged in a critical discussion of COQ estimation, yet the research lacks coverage of recent developments, including the classification of COQ costs and breakthroughs in COQ models specific to the construction industry. Despite the growing interest in this field, comprehensive assessments and analyses of COQ study trends are scarce, leading to a lack of literature review studies pertaining to the in-depth practical implications of COQ for quality monitoring. The current study aims to bridge this research gap by conducting a large-scale bibliometric analysis of COQ research, to robust understanding of the concept of COQ within the construction industry. To analyse the developments from extant COQ studies, bibliometric analysis is preferred, as it provides a clear picture of how such trends have evolved.

1.1 COST OF QUALITY

The interpretation of COQ might change across various authors. These expenses are referred to by multiple acronyms, such as *'cost of quality*' *'costs of poor quality*,' *'quality cost*,' '*price of non-conformance*,' and '*economies of quality*.' COQ is commonly understood as the combination of conformance and non-conformance costs (Heravi & Jafari, 2014). Conformance costs entail expenses associated with the prevention and detection of poor quality. In contrast, non-conformance costs encompass the financial implications of poor quality resulting from product and service failures, including internal and external failure costs (Garg & Misra, 2021). The COQ system, which was developed has been formalised into four categories of expenses:

I. Prevention costs are the expenses incurred to prevent the occurrence of defects and non-conformities (Schiffauerova & Thomson, 2006). These costs include quality-related expenditures to prevent unsatisfactory products from being produced in the first place (Abdelsalam & Gad, 2009).
II. Appraisal costs are associated with measuring, evaluating, or auditing products, components, and purchased materials to ensure conformance with quality standards and performance requirements (Jafari & Love, 2013).
III. Internal failure costs occur when products, components, and materials fail to meet quality requirements before the transfer of ownership. These are costs that would not exist if there were no defects in the product (Heravi & Jafari, 2014).
IV. External failure costs occur when a product does not perform satisfactorily after the transfer of ownership to the customer. These costs would also not exist if there were no defects in the product (Abdelsalam & Gad, 2009).

Therefore,

Total quality costs = Prevention costs + Appraisal costs + Internal failure costs + External failure costs

Several quantitative approaches have been recently used to measure the COQ and non-quality in construction. Studies such as Love et al. (1999) and Love and Li (2000)

examined the causes and costs associated with rework in Australian construction projects, while Barber et al. (2000) have explored the costs of quality failures in civil engineering projects within the UK. The literature indicates that some construction firms do not measure all three categories of prevention, appraisal, and failure costs, opting instead to focus primarily on failure costs. The terms "defects," "rework," and "quality failure" are synonymous, and the lack of standardised terminology suggests that this research field is still evolving. However, numerous studies have attempted to quantify the costs of rework in civil engineering projects. Despite the development of several construction quality costing systems, these systems are neither widely adopted nor commonly utilised. This limited adoption is largely attributed to a lack of a standardised approach. Many organisations remain unaware of recent advancements in COQ methodologies, leading to inconsistencies in implementation. Furthermore, the inability of these organisations to effectively track and integrate these evolving trends into their existing frameworks exacerbates the problem. As a result, the potential benefits of these COQ systems remain unrealised, hindering overall improvements in QMS.

2. METHODOLOGY

Bibliometrics is a useful tool for analysing literature and identifying breakthroughs in certain fields of study subfields (Udomsap & Hallinger, 2020). This study allows for the assessment of publishing performance, the identification of developing research fields, the evaluation of national/regional cooperation, and the investigation of relevant themes, among other findings. This research used VOSviewer, a text-mining programme, to analyse bibliometric correlations between diverse data in order to better comprehend the COQ concept (Van Eck et al., 2010).

The present study is conducted in six stages, which are outlined in Figure 1.

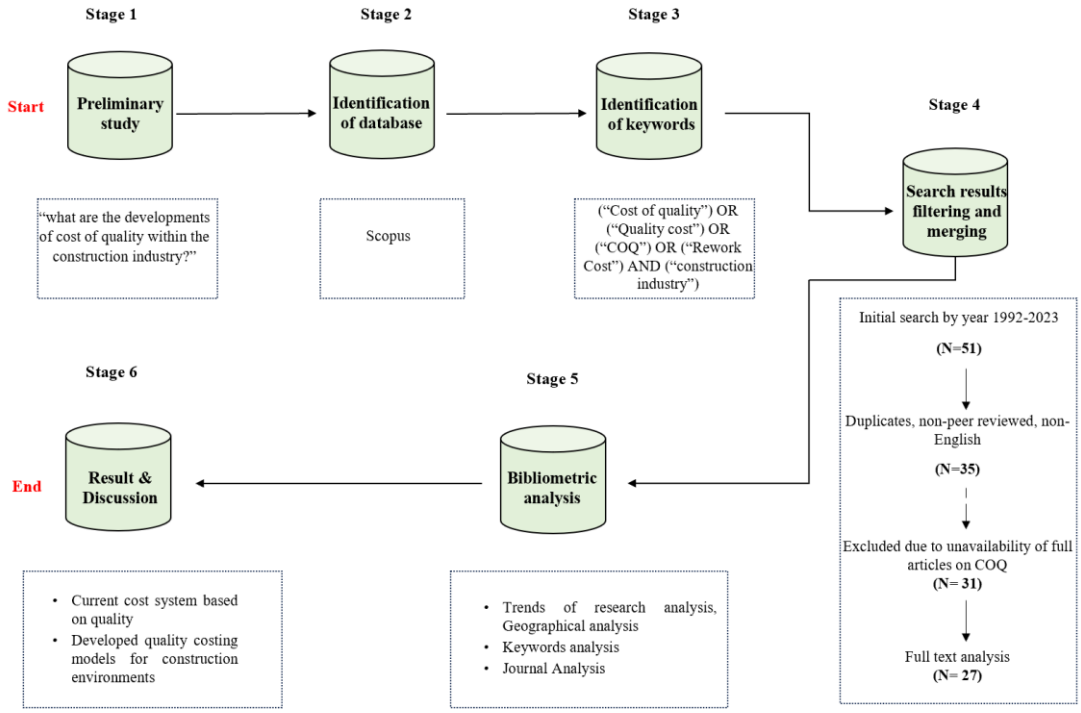

Figure 1: Literature search process

Stage 1: Preliminary study - This stage aims to do a comprehensive literature study to examine the latest and prominent research in COQ through the research objective.

Stage 2: Identification of database - The data collection for this research utilised existing literature retrieved from the Scopus database. Bibliometric studies often rely on a single database to effectively map broad trends (Udomsap & Hallinger, 2020). Scopus was chosen for its extensive coverage of scientific fields and high-quality sources. It is renowned for its efficient indexing process and comprehensive records of abstracts and citations across various disciplines. Additionally, Scopus provides advanced tools for tracking, analysing, and visualising research, enhancing the overall robustness of the study.

Stage 3: Identification of keywords - By utilising the Scopus database, the following search schemes were entered: (TITLE-ABS-KEY) ("Cost of quality") OR ("Quality cost") OR ("COQ") OR ("Rework Cost") AND ("construction industry").

Stage 4: Search results filtering and merging - The search activity included all articles published before December 2023, producing 51 results. After eliminating duplicates, non-English papers, and articles without peer review, 35 articles remained. Next, the titles and abstracts of articles were critically assessed using pre-defined filtering and selection criteria in the database (Jiaa et al., 2018). When it was uncertain whether an article should be retained based on its abstract, the entire article was read. The current research evaluated each article simultaneously, and any issues or discrepancies were resolved by consensus (Roeser & Kern, 2014). After this preliminary screening, 32 papers were selected for further consideration. After exporting the previously filtered articles, a manual full-text analysis was conducted, and 27 papers received consideration for analysis.

Stage 5: Bibliometric analysis of the search results. This strategy effectively reduces the risk of subjective bias from the perspective of the author, since it relies on data retrieved from a database, hence limiting any opportunity for the author's influence to impact the analysis. The present research incorporates bibliometric analysis including the following categories: Trends of research analysis, Geographical analysis, Keyword analysis, and Journal analysis.

Stage 6: Results and Discussion - The conclusion was drawn from the bibliometric analysis that was performed in the previous phases and the following findings.

3. BIBLIOMETRIC ANALYSIS

3.1 TRENDS OF RESEARCH ANALYSIS

The presented data shows an upward trend in the number of articles between 2005 to 2012 with six articles and from 2018 to 2023 with eleven articles published on the COQ subject within the construction industry. The emergence of the fourth industrial revolution began to gain attention after 2011, a factor that may have contributed to the observed rise in the quantity of articles. Furthermore, the research methods used in the articles selected were further studied by bibliometric analysis, as indicated in Figure 2. In accordance with the findings, a total of ten articles used case study methodology, whereas 17 articles utilised different methodologies such as survey (ten), conceptual study (five), and literature review (two). These articles established the foundation for developing the framework regarding the COQ in construction.

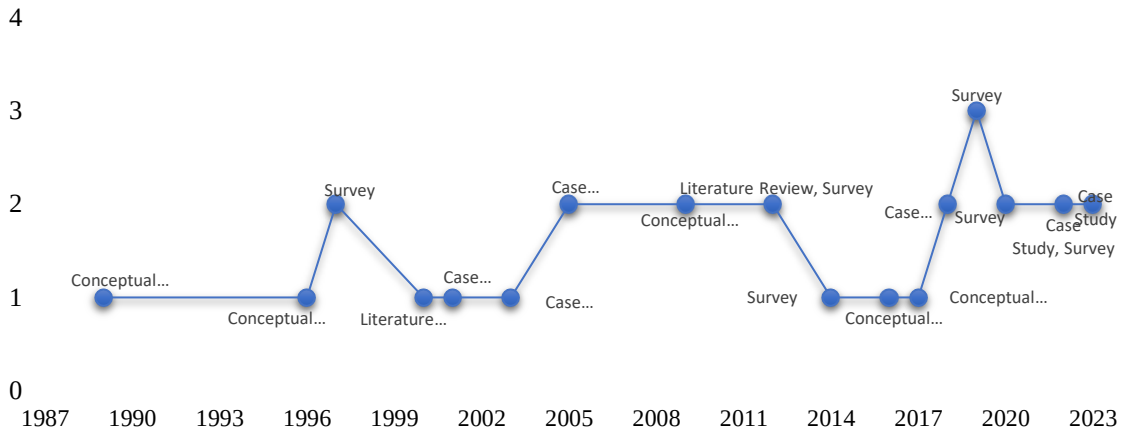

Figure 2: Distribution of articles based on year and type of methodologies

3.2 GEOGRAPHICAL ANALYSIS

The categorisation of research by country is a crucial factor in determining the scope of academic studies worldwide. With respect to the geographical area of the empirical research, a few studies were conducted in Iran, Australia, Turkey, and the UK, while the majority of the articles were carried out in these regions, as shown in Figure 3. The remaining studies were conducted in 16 different countries.

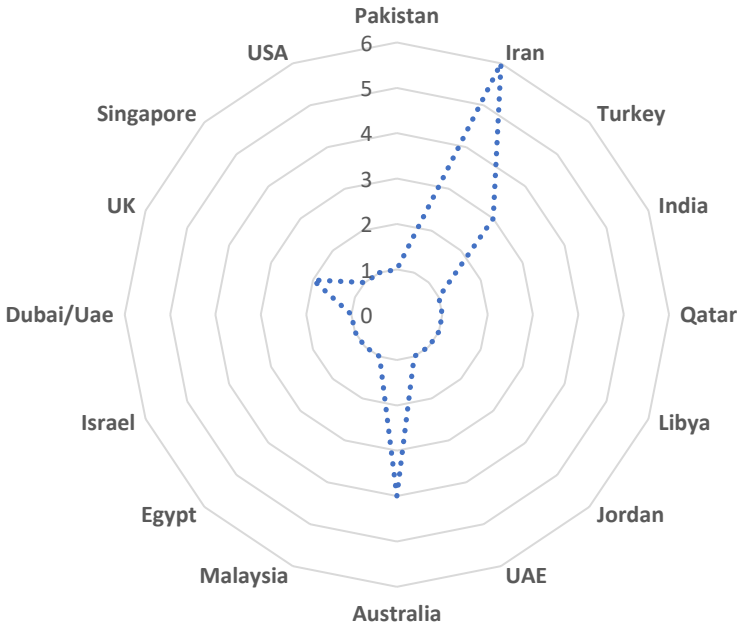

Figure 3: Mapping of articles distributed in different countries

3.3 KEYWORD ANALYSIS

A co-occurrence network of keywords was developed to provide a precise visualisation of the primary research studies and themes explored in the domains of COQ and QMS. In the present research, a set of 50 keywords were chosen and a visual representation of the keyword network is presented in Figure 4. The size of each node in the network corresponds to the frequency of occurrence of the respective keyword. The lines between the nodes indicate the presence of a link between two keywords, while the distance

between two nodes reflects the degree of relatedness between them. Furthermore, the size of the circle is proportional to the frequency of the keywords. The keywords that appeared most frequently were "*construction industry*," "*cost of quality*," "*project management*," and "*quality management*".

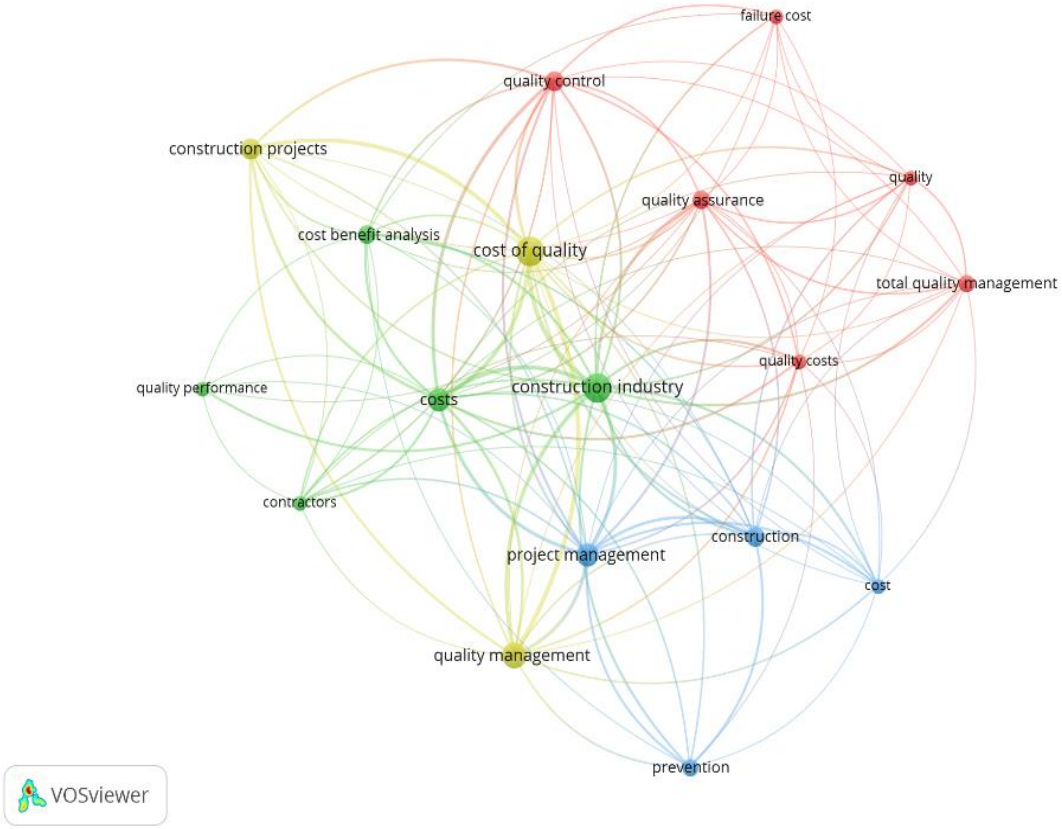

Figure 4: Mapping of keywords

3.4 JOURNAL ANALYSIS

Furthermore, an in-depth review was performed on the cumulative number of publications collected, grouped by journal. This review was carried out to provide researchers with insights into the prominent journals for publishing or accessing COQ-related research, as highlighted in Figure 5. In total, the SLR includes a total of 27 articles that were sourced from a diverse range of 17 academic journals. However, some journals published more COQ articles than others. The study revealed that 37.03% of the sampled articles were published in the three journals identified as follows: *Journal of Construction Engineering and Management* accounted for 14.81% of the articles, followed by the *International Journal of Quality & Reliability Management* and *Construction Management and Economics*, each with 11.11% of the articles.

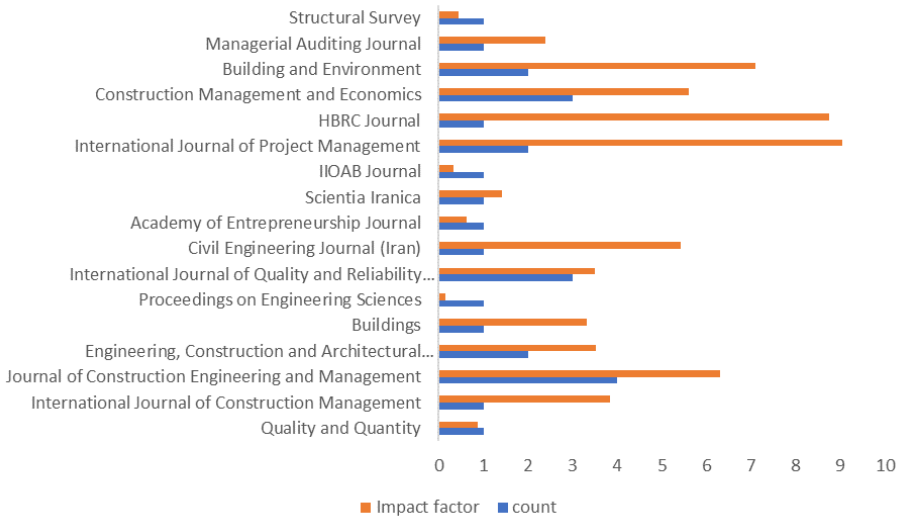

Figure 5: Mapping of publications in particular sources

4. RESULTS AND DISCUSSION

Following the bibliometric analysis, this section summarises the research on the current cost system based on quality and reveals several models adopted for computing COQ.

4.1 CURRENT COST SYSTEM BASED ON QUALITY

Since the early 1980s, a growing focus on the concept of COQ has been observed to improve the QMS within the construction industry (Heravi & Jafari, 2014). The findings of the current study reveal the picture of the COQ technique conducted in multiple countries and on multiple typologies of projects including buildings, industrial, bridges, roadways etc. have been conducted in Iran (Jafari & Love, 2013; Balouchi et al., 2019; Shafiei et al., 2020), Australia (Lopez & Love, 2012; Love et al., 2010; Love & Edwards, 2005; Mills et al., 2009; Love & Li, 2000), the UK (Abdul-Rahman et al., 1996; Barber et al., 2000) India (Garg & Misra, 2021) and Pakistan (Khadim et al., 2023). Despite varied responses and a lack of widespread adoption, the COQ methodology has made significant progress in its implementation across the globe. In addition, several quality issues, such as reworks, failures, and defects, are classified as part of the COQ and reviewed for every construction project, predominantly to minimise the cost and impact on quality. However, few studies have been conducted to identify the type of COQ and examine the limitations and future scope of the studies (e.g., time and cost). For instance, Kazaz and Birgonul (2005) examined a mass housing initiative in Turkey, which included 3100 residential units and required over four years for its completion. Based on the results of the research, it was determined that the average COQ represents approximately 32.36% of the total project cost. The authors of the statement argue that the indicated amount is much higher compared to similar projects, mainly due to a lack of effective management skills and a shortage of contractors with globally recognised accreditation. Similarly, Abdelsalam and Gad (2009) conducted a study on a residential development project in Dubai (UAE), which included the construction of 291 multi-story buildings. The results of this study suggest that the average value of total COQ was 1.3% of the entire project costs, yet the cost incurred due to project failure constituted 0.7% of the overall project cost. The calculation of the external failure cost group was not feasible since the projects

under review had not yet been handed to the client. The limited allocation of resources towards failure costs might be justified by the diligent supervision by the client, through a dedicated project management team and a supervisory consultant. As can be observed, Jafari and Love (2013) conducted a study to evaluate the impact of QMS implemented over 18 months for a monorail project in Iran. The project incorporated a COQ technique, which ultimately led to the estimation of a failure cost equivalent to 5% of the contractual value of the project. The allocation of appraisal costs amounted to approximately 2.32% of the contract value and 2.78% of prevention costs through the utilisation of the QMS. The distribution of appraisal costs represented approximately 2.32% of the contractual value and 2.78% of the prevention costs by using the QMS. The biggest factor contributing to the decrease in COQ within the failure domain was found to be the presence of a trained quality team and the repetitive nature of jobs. The use of active performance management and contractor-led inspection enabled the identification of errors and difficulties related to pre-executed plans. Consequently, this resulted in the improvement of performance in the QMS and the optimisation of mechanisms for reducing costs. In addition, several studies have investigated different kinds of construction defects. However, there is a lack of study explicitly focused on the calculation of the COQ, which suggests that the COQ often ranges from 3% to 5% of the original construction cost. In addition, Forcada et al. (2014), Forcada et al. (2017), Balouchi et al. (2019), Garg and Misra (2021) and Khadim et al. (2023) can be referred to in relation to COQ.

4.2 DEVELOPED COQ MODELS FOR THE CONSTRUCTION INDUSTRY

COQ within the construction industry frequently increases when considering the overall project costs, mostly attributable to the complex nature of quantifying construction processes. Bibliometric analysis reveals that various costing systems for construction quality have been formulated; however, their adoption and implementation are not prevalent.

4.2.1 Prototypes-based Models

Davis et al. (1989) developed the Quality Performance Tracking System (QPTS) which incorporated a comprehensive cost coding system to categorise different items. The QPTS model originated from the Quality Performance Management System (QPMS) and is designed to assure the conformity of collected cost data with the work breakdown structure of an individual project. In recent times, the use of QPTS has facilitated the ability to quantitatively analyse project quality, using a methodical strategy to collect and identify the COQ. According to Davis et al. (1989), quality may be defined as "conformance to requirements," which allows for the quantification of the COQ. Furthermore, Ledbetter and Patterson (1989), used the QPMS to monitor the financial implications of QMS across four different projects. It was assumed that the direct rework expenditures were 12.5% of the overall project cost, whereas an analysis revealed that the quality charges accounted for 25% of the project cost. The relationship between the cost of rework and the QMS cost was then established based on the underlying cause of the errors. Although the aforementioned prototype COQ model exhibited simplicity and adaptability, it failed to account for the impact of failure on time-related costs. Similarly, Willis and Willis (1996) used the QMPS approach to an industrial project through a case study. The authors calculated that 12% of all design and construction labour costs went toward Total Quality Cost (TQC), which includes the costs of prevention and appraisal

at 8.7% as well as the costs of failure and deviation repair at 3.3 %. Furthermore, Willis and Willis (1996) discovered that the frequency of deviation repairs decreases with use of preventive and monitoring techniques by allocation of resources to the prevention category as it reduces spending on internal failures and inspections.

4.2.2 Software-based Models

Earlier studies proposed techniques for predicting project costs, or determining suitable characteristics for the project, based on initial planning and estimation data. In the field of construction, Jrade and Alkass (2007), developed a software application with the purpose of providing life-cycle costs and parametric cost estimates for future projects. The module utilises many factors, including the total floor area, project type, external wall type, and framing system type, to predict the projected cost of the project. In a similar vein, several software-based concepts have been developed around the globe to compute the COQ. These models include the neural network model (Tawfek et al., 2012) and the fuzzy-based COQ model (de Vries & Steins, 2008), which were employed to investigate the different aspects of COQ both directly and indirectly (Feigenbaum, 1956). Tawfek et al (2012) used multiple neural network architectures to estimate project performance, particularly in the context of cost overrun and contractual claims. Such models were developed using a range of rework indicators and associated cost attributes. Similarly, (Fayek & Rodriguez Flores, 2010) used fuzzy logic for the modeling of quality during the conceptual cost estimation phase. This choice was made due to the compatibility of fuzzy logic with the uncertain, qualitative, and subjective characteristics nature of the evaluation. Moreover, the fuzzy logic-based model has found application in multiple domains within the construction industry, including risk assessment, range estimation, prediction and identification of construction performance, evaluation of working conditions, contractor selection, and determination of cost-estimating relationships (Shaheen et al., 2007; Tah & Carr, 2000). Furthermore, ANNs can play a pivotal role in quantifying the multifaceted repercussions of rework. By considering an array of variables such as project delays, cost overruns, and stakeholder dissatisfaction, ANNs can provide a comprehensive perspective on the true impact of rework on project performance. Armed with such comprehensive knowledge, construction practitioners can make informed decisions, devise targeted interventions, and institute measures that bolster quality, efficiency, and cost-effectiveness throughout the project lifecycle.

4.2.3 Framework-based Models

System Dynamics (SD) and rework Cycle of causal Loop Diagrams (CLD) are two examples of attempted framework-based models. System Dynamics (SD) has been widely used in the framing of dynamic characteristics of projects, particularly pertaining to errors and rework and errors (Han et al., 2013; Lyneis & Ford, 2007). Both the quantitative and qualitative aspects of SD have been used in the construction of models aimed at revealing the behaviour and consequences of rework on project performance. However, Shafiei et al. (2020) utilised the concept of SD in their significant works, which have served as a foundation for understanding the systemic characteristics of rework and are fundamental to understanding the application of SD in construction environments. Furthermore, the "Rework Cycle" is an alternative model that describes processes using CLD that include both rework and unplanned rework. The work rate is influenced by the proficiency, efficiency, and accessibility of the staff workers. Additionally, as the project progressed, the remaining workload was reduced. The completion or discovery of work

is dependent upon the quality of the task performed, namely the extent to which it is executed accurately. In the context of unexplored literature, this pertains to inaccuracies that remain unrecognised yet are considered to have been performed. The potential exists for the work performed to fall short of the prescribed standard, hence allowing for the occurrence of error (Forcada et al., 2014). Latent errors, which are not readily detectable, sometimes reveal themselves only after a period of incubation within the system. Over time, these defects are ultimately found or they exhibit their own, leading to the identification of rework, thus augmenting the amount of work for the employees (Love et al., 2021). Similar to the concept of Cognitive Maps (CM), CLDs have consistently depended on interview data as their main source of knowledge. Consequently, the process of retrieving and interpreting information from memory and exercising judgment serves a crucial role in providing a comprehensive understanding of the events that occurred.

4.2.4 COQ-based Models

However, attention is drawn to other methods such as an arrangement of Feigenbaum (1956) known as the Prevention-Appraisal-Failure (PAF) model which would categorise into prevention, appraisal, and failure (internal and external) costs. Prevention costs are associated with actions taken to ensure that a process provides quality products and services, appraisal costs are associated with measuring the level of quality attained by the process, and failure costs are incurred to correct quality in products and services before (internal) or after (external) delivery to the customer. The conventional PAF model is the most commonly used by construction organisations to calculate either prevention or external cost, as discussed by Kazaz et al. (2005), Abdelsalam and Gad (2009), Rosenfeld (2009), Heravi and Jafari (2014), Garg and Misra (2021), and Khadim et al. (2023). However, the PAF categorisation is only a basic concept, and the concrete costing systems still differ considerably from organisation to organisation. However, prior research on the utilisation of COQ within the construction industry has been limited in scope. The construction process has been the primary focus of their attention, while the comprehensive scope of a complete COQ methodology has been ignored.

5. CONTRIBUTION TO THEORY AND PRACTICE

The data obtained from analysing 27 papers spanning from 1992 to 2023 reveals a range of influential discoveries:

i. The fluctuation in articles exploring the COQ, characterised by fewer publications is probably driven by multiple factors within the field of quality management research. Significantly, when considering the timeframe of the sample publications, it is evident that academics have shown an inclination to use cross-sectional data rather than longitudinal data in studying the patterns of COQ. The prominence of such cross-sectional studies may be attributed to their cost-effectiveness and shorter period. Nevertheless, it is important to highlight that longitudinal studies require more resources and time, but they provide a more thorough examination of systems in comparison to cross-sectional research. Emphasising more longitudinal studies in future research could be a valuable methodological approach, enabling a deeper grasp of COQ by uncovering significant relationships between variables that might not be discernible within shorter periods.

ii. The study reveals that case studies are the most used method for undertaking research in the field of COQ, followed by surveys, while there's a dearth of

conceptual and literature review papers in the sampled COQ articles. This trend signifies a preference for empirical research over theoretical exploration in the COQ domain. Emphasising empirical evidence is vital for practitioners as it enables the evaluation of theoretical models in real-world scenarios. However, there exists a gap between empirical and theoretical studies in COQ. To address this, future research should focus on conceptual studies and literature reviews with the objective offering a more comprehensive understanding by integrating theoretical perspectives with empirical findings.

iii. The widespread acceptance of PAF in case studies and surveys may be subjected to its simple structure, which enables a methodical and inclusive evaluation of COQ. The explicit categorisation of aspects allows academics and practitioners to identify, quantify, and assess the several cost components linked to the maintenance or improvement of quality. Furthermore, its transparency enables a broad spectrum of companies, irrespective of their size or sector, to easily use it, therefore enabling comparisons and benchmarking endeavours across different environments. The PAF model's usefulness in providing a systematic framework for comprehending quality expenses has significantly led to its extensive use in case studies and surveys within the field of quality management research.

iv. Most of the research on COQ has mostly focused on Australia and China, with a significant lack of academic articles from other countries, such as the USA and UK. To broaden the range of COQ research, future investigations should investigate extending the settings beyond these conventional domains. Significantly, previous research has mostly focused on developed countries such as Singapore, Spain, and Canada. However, considerable research has been conducted in the context of developing countries, particularly India, with notable contributions from Iran. Future studies should focus on comparing and contrasting COQ practices across organisations in developed and developing countries. This comparison study may provide insights into the differing levels of COQ adoption in different economic environments, hence delivering significant information about the worldwide landscape of COQ practices.

6. CONCLUSIONS

In the realm of the construction industry, COQ is a broad discipline that covers a wide range of academic journals focusing on various cost categories such as rework cost, NCR cost, prevention cost, appraisal cost, and failure cost. The distribution of the 27 articles analysed in this SLR reveals the globalisation of the COQ topic.

The comparative analysis of COQ models in the construction industry reveals distinct differences in accuracy, usability, and adaptability. *Prototype-based models*, such as QPTS, excel in detailed cost tracking but lack consideration for time-related costs. Software-based models offer high accuracy and handle complex variables effectively but require substantial data input and technical expertise. Whereas, *Framework-based models*, like SD and CLD, provide deep insights into dynamic interactions and systemic issues but are challenging to implement due to their complexity. In terms of usability, *Prototype-based models* are simple and accessible, while *Software-based models*, despite their detailed insights, demand significant technical setup. *Framework-based models* are useful for complex projects but pose adoption challenges due to their intricacy. The *PAF model* is widely used for its simplicity in categorising costs but suffers from variability

in effectiveness due to a lack of standardisation. For scope and adaptability, *Prototype-based models* focus on direct costs, whereas *Software-based models* are versatile and adaptable to various project types. *Framework-based models* are highly adaptable for complex project dynamics, and the PAF model is broadly applicable but varies in comprehensiveness. An integrated approach combining elements from all these models could provide a robust solution, enhancing quality management across the construction industry by leveraging simplicity, predictive accuracy, dynamic analysis, and broad applicability. The adaptation of models to conform to the particular requirements of an organisation frequently leads to the expansion of multiple structures for the COQ. Various costs and elements are classified and designated using specific terminologies. Moreover, there exists a variety of elements that are either incorporated or perceived as irrelevant and thus neglected from the calculations.

However, this study is limited by the application of a single database. To overcome this constraint, researchers could broaden the range of their sources, and investigate other databases such as Web of Science, PubMed, or EBSCO to broaden the scope and inclusiveness of the literature search.

7. REFERENCES

Abdelsalam, H. M. E., & Gad, M. M. (2009). Cost of quality in Dubai: An analytical case study of residential construction projects. *International Journal of Project Management*, *27*(5), 501–511. Retrieved from https://doi.org/10.1016/j.ijproman.2008.07.006.

Abdul-Rahman, H., Thompson, P. A., & Whyte, I. L. (1996). Capturing the cost of non-conformance on construction sites: An application of the quality cost matrix. *International Journal of Quality and Reliability Management*, *13*(1), 48–60. Retrieved from https://doi.org/10.1108/02656719610108314

Balouchi, M., Gholhaki, M., & Niousha, A. (2019). Prioritizing the main elements of quality costs in design-build mass-housing projects. *Civil Engineering Journal*, *5*(5), 1136–1146. Retrieved from https://doi.org/10.28991/cej-2019-03091318

Barber, P., Graves, A., Hall, M., Sheath, D., & Tomkins, C. (2000). Quality failure costs in civil engineering projects. *International Journal of Quality and Reliability Management*, *17*(4), 479–492. Retrieved from https://doi.org/10.1108/02656710010298544

Davis, B. K., Ledbetter, W. B., & Burati, J. L. (1989). Measuring design and construction quality costs. *Journal of Construction Engineering and Management*, *115*(3), 385–400. Retrieved from https://doi.org/10.1061/(ASCE)0733-9364(1989)115:3(385)

de Vries, B., & Steins, R. J. (2008). Assessing working conditions using fuzzy logic. *Automation in Construction*, *17*(5), 584–591. Retrieved from https://doi.org/10.1016/j.autcon.2007.10.004

Udomsap, A.D, & Hallinger, P. (2020). A bibliometric review of research on sustainable construction, 1994–2018. *Journal of Cleaner Production*, *254*(8), 120073. Retrieved from https://doi.org/10.1016/j.jclepro.2020.120073

Fayek, A. R., & Rodriguez Flores, J. R. (2010). Application of fuzzy logic to quality assessment of infrastructure projects at conceptual cost estimating stage. *Canadian Journal of Civil Engineering*, *37*(8), 1137–1147. Retrieved from https://doi.org/10.1139/L10-036

Feigenbaum, A. V. (1956). Total quality control. *Harvard Business Review*, *34*(6), 93–101.

Forcada, N., Alvarez, A. P., Love, P. E. D., & Edwards, D. J. (2017). Rework in urban renewal projects in Colombia. *Journal of Infrastructure Systems*, *23*(2), 04016034. Retrieved from https://doi.org/10.1061/(asce)is.1943-555x.0000332

Forcada, N., Rusiñol, G., Macarulla, M., & Love, P. E. D. (2014). Rework in highway projects. *Journal of Civil Engineering and Management*, *20*(4), 445–465. Retrieved from https://doi.org/10.3846/13923730.2014.893917

Jiaa, F., Zuluagab, L., Adrian Baileyb, X. R. (2018). Sustainable supply chain management in developing countries: An analysis of the literature. *Journal of Cleaner Production*, *189*(2018), 263–278. Retrieved from https://doi.org/10.1016/j.jclepro.2018.03.248

Garg, S., & Misra, S. (2021). Understanding the components and magnitude of the cost of quality in building construction. *Engineering, Construction and Architectural Management*, *29*(1), 26–48. Retrieved from https://doi.org/10.1108/ECAM-08-2020-0642

Han, S., Love, P., & Peña-Mora, F. (2013). A system dynamics model for assessing the impacts of design errors in construction projects. *Mathematical and Computer Modelling*, *57*(9), 2044–2053. Retrieved from https://doi.org/https://doi.org/10.1016/j.mcm.2011.06.039

Heravi, G., & Jafari, A. (2014). Cost of quality evaluation in mass-housing projects in developing countries. *Journal of Construction Engineering and Management*, *140*(5), 4014004. Retrieved from https://doi.org/10.1061/(ASCE)CO.1943-7862.0000837

Jafari, A., & Love, P. E. D. (2013). Quality costs in construction: Case of QOM monorail project in Iran. *Journal of Construction Engineering and Management*, *139*(9), 1244–1249. Retrieved from https://doi.org/10.1061/(asce)co.1943-7862.0000704

Jrade, A., & Alkass, S. (2007). Computer-integrated system for estimating the costs of building projects. *Journal of Architectural Engineering*, *13*(4), 205–223. Retrieved from https://doi.org/10.1061/(asce)1076-0431(2007)13:4(205)

Kazaz, A., & Birgonul, M. T. (2005). Determination of quality level in mass housing projects in Turkey. *Journal of Construction Engineering and Management*, *131*(2), 195–202. Retrieved from https://doi.org/10.1061/(asce)0733-9364(2005)131:2(195)

Kazaz, A., Birgonul, M. T., & Ulubeyli, S. (2005). Cost-based analysis of quality in developing countries: A case study of building projects. *Building and Environment*, *40*(10), 1356–1365. Retrieved from https://doi.org/10.1016/j.buildenv.2004.11.010

Khadim, N., Thaheem, M. J., Ullah, F., & Mahmood, M. N. (2023). Quantifying the cost of quality in construction projects: an insight into the base of the iceberg. *Quality and Quantity*, *57*(6), 5403–5429. Retrieved from https://doi.org/10.1007/s11135-022-01574-8

Ledbetter, W. B., & Patterson, L. (1989). The cost of quality: A management tool. Excellence in the Constructed Project, In *Proceedings of Construction Congress I*, (pp. 100–105), ASCE. https://cedb.asce.org/CEDBsearch/record.jsp?dockey=0063875

Lopez, R., & Love, P. E. D. (2012). Design Error Costs in Construction Projects. *Journal of Construction Engineering and Management*, *138*(5), 585–593. Retrieved from https://doi.org/10.1061/(asce)co.1943-7862.0000454

Love, P. E. D. Mandal, P., & Li, H. (1999). Determining the causal structure of rework influences in construction. *Construction Management & Economics*, 17(4), 505-517. https://doi.org/10.1080/014461999371420

Love, P. E.D., & Li, H. (2000). Quantifying the causes and costs of rework in construction. *Construction management & economics*, 18(4), 479-490. Retrieved from Retrieved from https://doi.org/10.1080/01446190050024897

Love, P. E. D., & Edwards, D. J. (2005). Calculating total rework costs in Australian construction projects. *Civil Engineering and Environmental Systems*, *22*(1), 11–27. Retrieved from https://doi.org/10.1080/10286600500049904

Love, P. E. D., Edwards, D. J., Watson, H., & Davis, P. (2010). Rework in civil infrastructure projects: Determination of cost predictors. *Journal of Construction Engineering and Management*, *136*(3), 275–282. Retrieved from https://doi.org/10.1061/(asce)co.1943-7862.0000136

Love, P. E. D., Matthews, J., & Fang, W. (2021). Envisioning rework in practice: emergent insights from a longitudinal study. *Journal of Construction Engineering and Management*, *147*(1), 06020002. Retrieved from https://doi.org/10.1061/(asce)co.1943-7862.0001960

Lyneis, J. M., & Ford, D. N. (2007). System dynamics applied to project management: A survey, assessment, and directions for future research. *System Dynamics Review*, *23*(2), 157–189. Retrieved from https://doi.org/https://doi.org/10.1002/sdr.377

Mills, A., Love, P., & Williams, P. (2009). Defect costs in residential construction. *Journal of Construction Engineering and Management*, *135*(1), 12–16. Retrieved from https://doi.org/10.1061/ASCE0733-93642009135:112

Omar, M. K., & Murgan, S. (2014). An improved model for the cost of quality. *International Journal of Quality and Reliability Management*, *31*(4), 395–418. Retrieved from https://doi.org/10.1108/IJQRM-05-2012-0066

Psomas, E., Dimitrantzou, C., & Vouzas, F. (2022). Practical implications of cost of quality: a systematic literature review. *International Journal of Productivity and Performance Management*, *71*(8), 3581–3605. Retrieved from https://doi.org/10.1108/IJPPM-10-2020-0524

Roeser, T., & Kern, E. (2014). Surveys in business process management: A literature review. *Business Process Management Journal*, *21*(03), 692–718. Retrieved from https://doi.org/10.1108/BPMJ-07-2014-0065

Rosenfeld, Y. (2009). Cost of quality versus cost of non-quality in construction: The crucial balance. *Construction Management and Economics*, *27*(2), 107–117. Retrieved from https://doi.org/10.1080/01446190802651744

Schiffauerova, A., & Thomson, V. (2006). A review of research on cost of quality models and best practices. *International Journal of Quality and Reliability Management*, *23*(6), 647–669. Retrieved from https://doi.org/10.1108/02656710610672470

Shafiei, I., Eshtehardian, E., Nasirzadeh, F., & Arabi, S. (2020). Dynamic modeling to reduce the cost of quality in construction projects. *International Journal of Construction Management*, *23*(1), 24–37. Retrieved from https://doi.org/https://doi.org/10.1080/15623599.2020.1845425

Shaheen, A. A., Fayek, A. R., & AbouRizk, S. M. (2007). Fuzzy numbers in cost range estimating. *Journal of Construction Engineering and Management*, *133*(4), 325–334. Retrieved from https://doi.org/10.1061/(asce)0733-9364(2007)133:4(325)

Tah, J. H. M., & Carr, V. (2000). A proposal for construction project risk assessment using fuzzy logic. *Construction Management and Economics*, *18*(4), 491–500. Retrieved from https://doi.org/10.1080/01446190050024905

Tawfek, H. S., Mohammed, H. E.-D. H., & Abdel Razek, M. E. (2012). Assessment of the expected cost of quality (COQ) in construction projects in Egypt using artificial neural network model. *HBRC Journal*, *8*(2), 132–143. Retrieved from https://doi.org/10.1016/j.hbrcj.2012.09.009

Thekkoote, R. (2022). Enabler toward successful implementation of Quality 4.0 in digital transformation era: a comprehensive review and future research agenda. *International Journal of Quality and Reliability Management*, *39*(6), 1368–1384. Retrieved from https://doi.org/10.1108/IJQRM-07-2021-0206

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 1–12. Retrieved from https://doi.org/10.1061/(ASCE)EI.1943-5541.0000412

Willis, T. H., & Willis, W. D. (1996). A quality performance management system for industrial construction engineering projects. *International Journal of Quality & Reliability Management*, *13*(9), 38–48. Retrieved from https://doi.org/10.1108/02656719610150605