BARRIERS AND ENABLERS TO TOTAL QUALITY MANAGEMENT IN CONSTRUCTION PROJECTS: A CASE OF CONSTRUCTION PROJECTS IN KUNMING, THE PEOPLE'S REPUBLIC OF CHINA

By
Mr. Liu YIMING

A Thesis Submitted in Partial Fulfillment of the Requirements
for Master of Engineering ENGINEERING MANAGEMENT
Department of INDUSTRIAL ENGINEERING AND MANAGEMENT
Silpakorn University
Academic Year 2023

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โดย
Mr.Liu Yiming

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By	Mr. Liu YIMING
Field of Study	ENGINEERING MANAGEMENT
Advisor	Associate Professor Choosak Pornsing, Ph.D.

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Mr. Liu YIMING : BARRIERS AND ENABLERS TO TOTAL QUALITY MANAGEMENT IN CONSTRUCTION PROJECTS: A CASE OF CONSTRUCTION PROJECTS IN KUNMING, THE PEOPLE’S REPUBLIC OF CHINA Thesis advisor : Associate Professor Choosak Pornsing, Ph.D.

This research investigates the barriers and enablers for total quality management in Kunming's construction industry. The self-assessment scheme of the European Foundation for Quality Management Excellence (EFQM.E.) Model was excerpted into twenty barriers and enablers. A questionnaire was designed and randomly distributed to workers in the construction industry for 400. There were 356 respondents sent back, which accounted for an 89.0% return rate. The demography data analysis showed that most respondents are engineers in construction projects. However, staff from procurement and economic responsibility are also significant numbers. They have experience in the construction industry between 1 and 5 years. The bachelor degree workers are the most.

The respondents' opinions about barriers and enablers were analyzed by using the coefficient of variation (CV), relative important value (RIV), standard deviation value (SDV), and the standardization value of RIV and SDV. The k-means clustering was used to cluster the barriers and enablers with the k value from the elbow method.

The result showed that the most significant barriers were B3 (Deviod understanding of customers' needs), B7 (Inadequate sales communication), and B8 (Mishandling of resources and assets). On the other hand, the most significant enablers were E4 (Understanding current and future marketplace) and E9 (Risk management and performance improvement). Furthermore, one more cluster supports the total quality management of the companies. It is a cluster of E3 (Government and local administration regulations), E7 (Sustainable customer relationship), and E10 (Performance measurement tools: financial and non-financial indicators). The findings are helpful for management in launching a strategic plan to improve total quality management in the construction industry. Furthermore, management can invest resources wisely by focusing on significant barriers and enablers.

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Liu YIMING

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CHAPTER 1
INTRODUCTION

1.1 Motivation

The construction industry is a significant sector in the development of nations. It is not only driving infrastructure development but also the economy of developing countries (Altayeb et al., 2014; Thomas & Jayakumar, 2017). Nevertheless, it is a complex, competitive, and high-risk business due to lacking quality management systems like the manufacturing industry (Hoonakker et al., 2010).

In the past decades, construction projects have been criticized for their poor performance, productivity, and late delivery compared with other industries, e.g., the manufacturing industry (Holt et al., 2000; Loushine et al., 2006). Several management techniques employed to support construction organizations are under scrutiny. The client of the sector is progressing. Customers want better customer service, quicker construction, and technological advancements. It is no accident that the manufacturing business has become a point of reference and a source of innovation for the construction industry. Construction embraces and integrates successful manufacturing-derived ideas, including Total Quality Management (TQM), Lean Production System, and Reengineering. Implicitly, a culture of teamwork and cooperation at intra- and inter-organizational levels is critical for effectively applying these notions (Neyestani & Juanzon, 2016a).

Construction organizations increasingly implement quality management to address quality issues and satisfy the client's needs (Neyestani & Juanzon, 2016b). If there was ever an industry that needed to adopt the notion of TQM, it was the construction sector. According to Ardity & Gunaydin (1997), the size of the construction business very likely makes it more profitable to enhance performance than any other service sector. However, applying TQM principles in the construction industry is highly challenging due to a lack of standardization and the numerous stakeholders involved.

Several factors in construction projects affect TQM implementation in construction projects. Accordingly, the researcher is interested in investigating the threats and the enablers of TQM in construction projects in Kunming, the People's Republic of China.

1.2 Research Objectives

1. To investigate the barriers and the enablers to construction projects in Kunming, People's Republic of China.

2. To clustering the barriers and the enablers and ordering their important.

1.3 Research Contributions

1. The knowledge and findings of benefits of TQM implementation in construction projects in Kunming are brought out and published.

2. The construction projects in Kunming are recommended the important of barriers and enablers of TQM implementation.

3. The ultimate comtribution of this study is to raise the levels of quality, delivery, and efficiency of the construction projects; additionaly, to reduce cost, environmental, social, and economic impacts.

1.4 Scope and Limitations

1. The area of study is Kunming, a capital city of Yunnan province, People's Republic of China.

2. The duration of data collecting is between the last week of October 2023 and the last week of December 2023.

3. This is the survey research and using statistical tools for data analysis. There is no guarantee for other study areas.

1.5 Abbreviations

BEM	Business Excellence Model
CSF	Critical Successful Factor
CW-QC	Company-wide Quality Control
EFQM.E.M	European Foundation for Quality Management Excellence Model
ISO	International Standard Organization
JQP	Jobsite Quality Planning
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
QFD	Quality Function Deployment
QMS	Qaulity Management System
SQC	Statistical Quality Control
TQC	Total Quality Control
TQM	Total Quality Management

1.6 Glossary

Customer-centricity is the capacity of individuals within a company to comprehend consumers' circumstances, perspectives, and anticipations.

The relative-importance value is a notion akin to the importance value, but it relies on original, somewhat relative, density-frequency-dominance numbers.

Hierarchical cluster analysis is a data mining tool that use statistics in analysis procedure. It clusters objects to build a hierarchy of clusters. It usually presented the clusters in a dendrogram.

CHAPTER 2

LITERATURE REVIEW

This chapter discusses prior research on quality management theory and the use of overall quality management. Section 2.1 examines the general notion of 'quality' in various businesses. This section provides an explanation of the history, evolution, and definition of total quality management. Section 2.2 outlines seven key quality criteria that contribute to the success of quality management. These criteria pertain to several sectors in general.

Nonetheless, section 2.3 changes the direction of quality applications in the construction industry. It elucidates the definition of 'quality' within the building sector. The distinctive features that may vary from those of the industrial business are revealed. Section 2.4 details how total quality management is put into practice in the construction sector. This section also discusses the paradigm shift and cultural change in construction projects. The chapter's conclusion is presented in section 2.5.

2.1 Quality in Industries

This section attempts to define the meaning of quality. It is cumbersome to make the definitive meaning; however, most of previous definitions are mutual. Quality control and quality assurance are described on both resemblers and dissimilarities. Finally, the definition, history, and development of TQM are explained.

2.1.1 Definition of quality

The term 'quality' is commonly utilized and expressed in several contexts. Advertisements using phrases such as 'premium quality,' 'purveyors of quality,' 'where quality comes first,' 'only the best quality materials,' 'the place where quality counts,' and similar terms are widespread in modern commercial society (Howarth & Greenwood, 2018).

Competing with an organization that associates the term 'quality' with anything other than positive meanings is challenging. Quality is typically described as meeting the legal, aesthetic, and functional needs of a project. Quality can be defined as meeting the customer's specifications (Al-Musleh, 2011). Despite intense competition in the business world, many companies have prioritized quality and reduced expenses in order to achieve consumer pleasure from all angles. Strewhart (1931) defines quality as the sum of qualities and characteristics of a product or service that affect its capacity to meet specified or implied needs. Romero et al. (2019) asserted that quality is defined by the client, the marketplace, and encompasses all qualities of the product.

Chung (2002) stated that the definition of 'quality' depends on the individuals involved. Some viewed it as representing client happiness, while others saw it as adherence to norms. As per the International Organization Standard (1994), quality refers to all the features of something that affect its capacity to meet specified or implied requirements. This term closely resembles Strewhart's definition from 1931. In quality management, quality does not refer to excellence in a comparative sense. It is an acronym for 'desired quality' that should be clearly defined (Chung, 2002).

McGeorge & Zou (2012) defined quality within the context of manufacturing. Quality is the capacity to meet client demands and adhere to product specifications. The quality is assessed only based on the product or service's ability to meet a predetermined specification and standard. If a certain percentage of construction projects are finished according to schedule, then these projects are said to have quality.

2.1.2 Quality control and quality assurance

Quality control involves the methods implemented on the assembly line to prevent or eliminate the underlying reasons for subpar performance (McGeorge & Zou, 2012). Prior to manufacturing, the minimal quality needed to fulfill the requirements and the methods to consistently achieve that quality are established. A specific goal allows for the assessment of strength by utilizing the given characteristic strength and the estimated variability. Concrete strength is consistently monitored during production through regular testing and statistical analysis to promptly detect any notable changes in either the average strength or the strength variability. The control system corrects the error to prevent a real issue from arising.

Stringent production control regulations can be paired with forgiving acceptance standards and minor penalties for violation. Alternately, the producer may be granted more creative latitude, but strict acceptability standards are established, and harsh consequences are applied for violation. There will be an optimal setting that is the most cost-effective to run within the range of reasonable production control and acceptance control arrangements.

Developing technical and management skills to achieve specified goals is essential for quality assurance in construction projects. Quality assurance in construction also involves managing people, which includes defining the roles, responsibilities, and obligations of each member of the company. Management is primarily responsible for quality assurance, and it is essential that its structure and implementation be aligned with the organization's overarching framework for construction. Additionally, it should be linked to the company's human resource strategy (Howarth & Greenwood, 2018).

The American Society for Quality (n.d.) stated that quality control is a component of quality management that emphasizes meeting quality standards. Quality assurance is concerned with addressing managerial viewpoints, specifically with how to ensure that a product or service meets quality standards. Quality assurance encompasses the complete quality system, whereas quality control is a component of quality assurance operations. Figure 2.1 displays the subset system of quality.

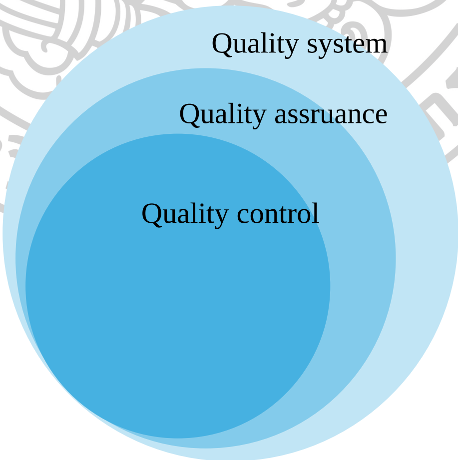

Figure 2.1 The relationship of quality
Source: The American Society for Quality (n.d.)

Brookes (2022) delineated the distinctions between quality assurance and quality control.

1) The main aim of quality assurance is to prevent flaws and errors, whereas the major objective of quality control is to rectify faults once they are identified.

2) Quality assurance focuses on preventing issues and taking proactive steps, whereas quality control focuses on correcting problems and taking reactive steps.

3) Quality assurance is focused on systematic and planned activities in the production of a product or service, while quality control is centered on inspecting and ensuring that quality requirements are met.

4) Quality assurance encompasses defining processes, strategies, and policies, creating checklists, and setting standards for the project. Quality control involves adhering to these guidelines during the project to ensure quality, identify defects, and address them.

5) Quality assurance oversees all parties involved in developing the product or service. Quality control manages a specific staff responsible for testing products or services to identify and correct any defects.

2.1.3 Total quality management

There is no single accepted definition of Total Quality Management (QM). Rampsey & Roberts (1992) defined that,

"TQM is a total system approach (not a separate area or program), and an integral part of high-level strategy. It works horizontally across function and department, involving all employees, top to bottom, and extends backwards and forwards to include the supply chain and the customer chain."

Vincent & Joel (1995) described that

"TQM is the integration of all functions and processes within an organisation in order to achieve continuous improvement of the quality of goods and services. The goal is customer satisfaction."

Harris (2021) gave a short message that

"Total Quality Management (TQM) is an approach that focuses an organisation's efforts towards continually improving its ability to deliver high quality products and services to its customers."

These definitions are similar because they encompass the basic notions of TQM. TQM should first be a holistic approach to quality. Total Quality Management focuses on viewing the entire system as a unified entity. Previously, quality was focused solely on specific parts of the business, such the end product or customer interactions. Furthermore, TQM is continuous. TQM is an ongoing process, unlike the traditional perception of quality as a method that could be applied to enhance particular areas of the product or business. It is now understood that systems can always be enhanced, regardless of their current level of quality.

TQM focuses on customer pleasure, whereas quality control techniques in the past emphasized product improvement over client contentment. Improving a product may not always align with the consumer's preferences, as there can be a discrepancy between what is enhanced and what the client desires. Figure 2.2 illustrates three forces of Total Quality Management (TQM). It encompasses integration, client orientation, and ongoing enhancement efforts.

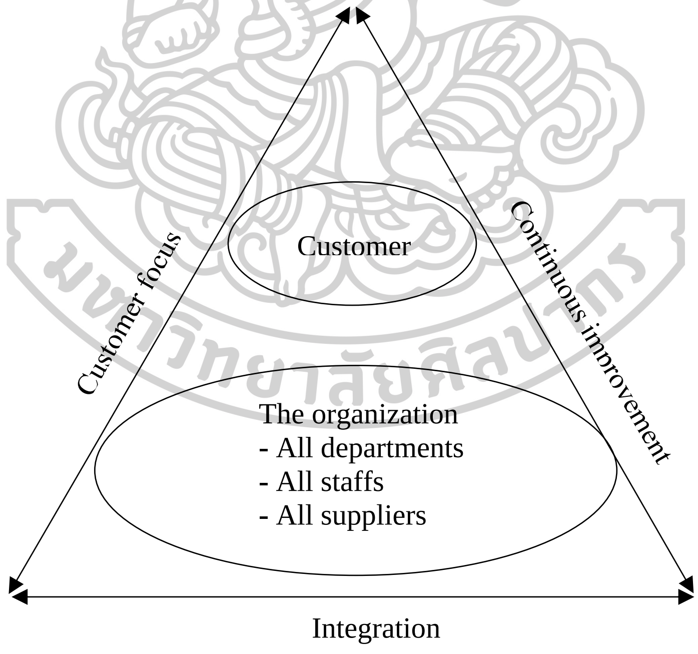

Figure 2.2 Three forces of TQM

Soruce: adapt from McGeorge & Zou (2012)

The idea of quality was initiated in manufacturing industries, initially developed in inspection-based systems. It may say that the first quality system is 'quality control.' Any defective goods that did not meet the standard were weeded out, trashed, fixed, and sold in seconds. The products under inspection were compared to a standard. It was discovered that these inspection-based quality systems had the following drawbacks (McGeorge & Zou, 2012):

● The non-conforming products could not be identified: thus, the defective products were passed on to the end customers.

● It is a high cost for corrective actions to remedy faulty items in inspection-based systems.

● Inspection-based systems do not control other processes except inspection operations. Thus, other workers in the processes would prefer to avoid attending to the quality.

● There is no 'why' question in the inspection-based systems. They focus on what, when, and where. Accordingly, the root causes are not removed.

2.2 Quality in Construction Industry

Quality was initially implemented in the construction industry for safety and reliability, particularly in nuclear sites and offshore projects (Chung, 2002). Quality adoption in building projects is slowly gaining acceptance. The construction product is unique and not mass-produced. They do not exhibit repetitiveness (Baird et al., 2011). Construction procedures involve a diverse range of individuals and suppliers with varying skills and education levels.

Corporate procedures, including tendering, procurement, document control, and record keeping, are used to all projects to varied extents within a construction firm notwithstanding the range of work undertaken. Establishing a quality system can standardize corporate procedures by creating a quality plan tailored to the unique characteristics and standard needs of a certain construction project.

Unarguably, the cost of implementing and maintaining a quality system in construction projects is significantly high. The corporates must invest money, staff, and time to operate the quality assurance. However, the firms should keep sight of the savings that accrue later, significantly reducing rework or reject incidents.

Figure 2.3 illustrates the comparison between projects that have implemented a quality system and those that have not. Roberts (1991) documented seven building projects in Australia that utilized a quality system. The proactive quality system costs around 1% of the project value, leading to a decrease in repair and rework expenses from 10% to 2%, resulting in a net benefit gain of 7%. It demonstrates that quality brings economic advantages through preventive measures.

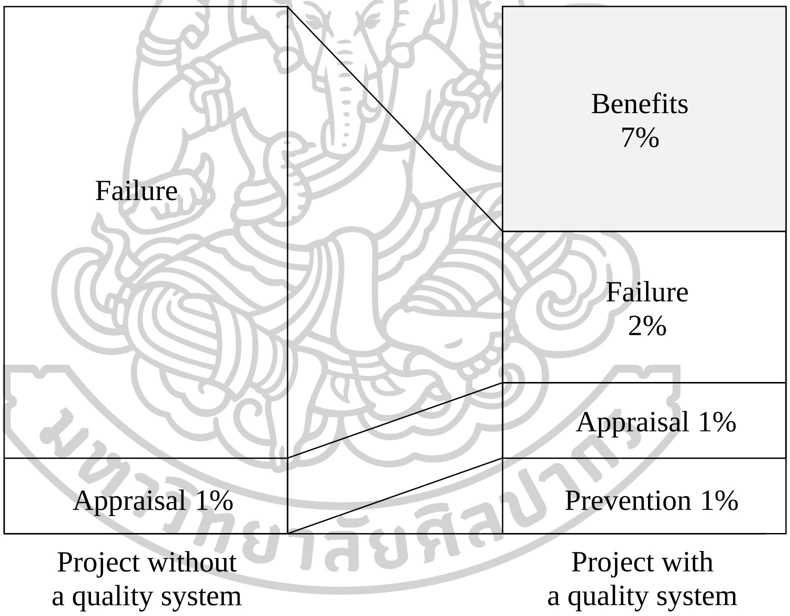

Figure 2.3 Qulity implementation in costruction projects
Soruce: Roberts (1991)

2.2.1 Definition of quality in construction industry

Loushine et al. (2006) analyzed the literature on quality and safety management in the construction sector, focusing on the authors' concept of quality. Researchers in construction quality consider meeting customer expectations, minimizing rework or errors, securing repeat business, adhering to ISO 9000 standards, and finishing projects on time and under budget as indicators of quality performance. Defining quality in the construction business precisely is challenging. Moreover, there is a scarcity of empirical studies about construction quality, regardless of the criteria used. We interviewed contractors and performed two questionnaire surveys to understand their perspectives on defining, measuring, and improving quality in the construction industry, as well as identifying the challenges they face.

2.2.2 Characteristics of quality in construction industry

Quality in the construction sector is described as meeting the specifications set by the designer, constructor, regulatory bodies, and owner. Quality in building projects can be defined as follows.

1) Satisfying the owner's requirements for functional adequacy, completing the project on schedule and within the allotted budget, minimizing lifecycle costs, and ensuring that it is operational and maintained.

2) Providing a well-defined scope of work, a budget to assemble and use a qualified, trained, and experienced staff, a budget to obtain adequate field information prior to design, provisions for timely decisions by the owner and design professional, and a contract to perform necessary work at a fair fee with adequate time allowance. These are the specific requirements that must be met in order to satisfy the requirements of the design professional.

3) Meeting the requirements of the constructor as to the provision of contract plans, specifications, and other documents prepared in sufficient detail to permit the constructor to prepare priced proposal or competitive bid; timely decisions by the owner and design professional on authorization and processing of change orders; fair and timely interpretation of contract requirements from field design and inspection staff; and contract for the performance of work on a reasonable schedule which permits a reasonable profit.

4) Complying with the applicable laws, rules, codes, and policies; protecting public property, including utilities; satisfying the requirements of regulatory bodies (the public) in terms of public health and safety; environmental concerns; and protecting public property.

One must distinguish between 'objective quality' and 'subjective quality.' Providers who deliver services or items that fulfill particular requirements attain quality. Quality in perception is achieved when a service or product satisfies the customer's expectations. A product can have great quality but still not suit customers' needs, and vice versa. An instance of failing to fulfill client requirements is the construction of prefabricated high-rise apartment complexes in the 1970s, which utilized advanced technology for cost-effective building methods. The buildings were demolished in the late 1980s due to a lack of demand for the apartments, despite their affordable rentals. The structures had to satisfy the tenants' requirements for comfort, beauty, and functionality.

It is important to distinguish between 'product quality,' which refers to the quality of elements directly associated to the physical product, and 'process quality,' which refers to the quality of the process that determines whether the product is acceptable or not. In the construction industry, 'product quality' pertains to achieving excellence in materials, equipment, and technology used in building a structure. On the other hand, 'process quality' refers to achieving excellence in how the project is structured and managed during planning and design, construction, and operation and maintenance phases.

2.3 Quality Factors in Construction Projects

Arditi & Gunaydin (1997) discussed the concept of quality in construction projects. A construction project owner must balance seven aspects over three key periods of the construction process: 1) planning and design phase, 2) building phase, and 3) maintenance and operation phase. Below are explanations of the seven factors, and Figure 2.4 illustrates the seven factors of construction quality.

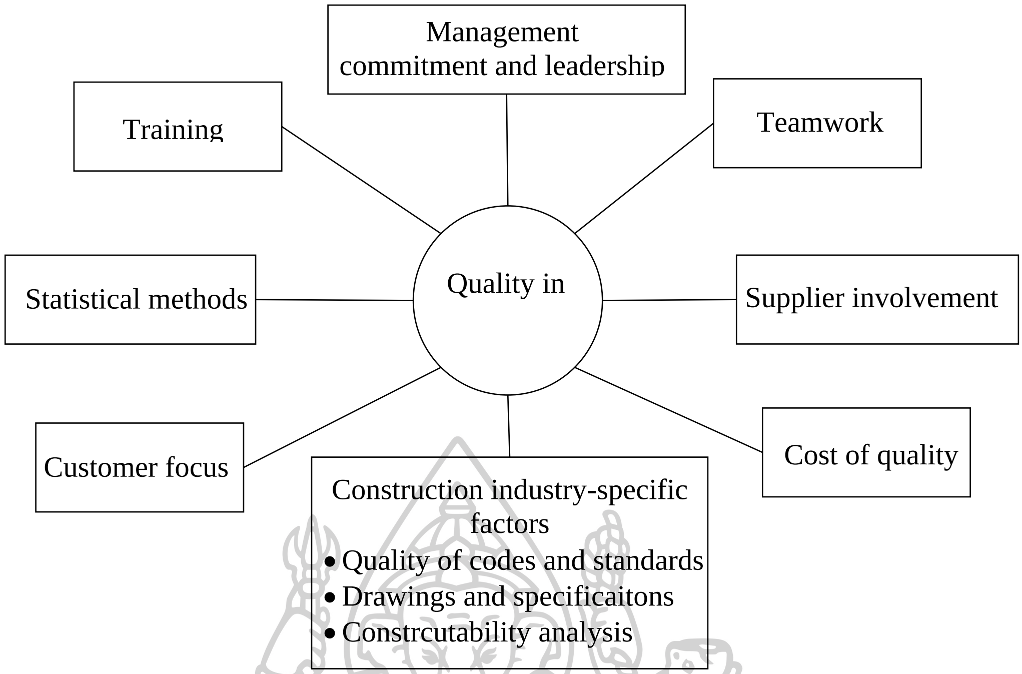

Figure 2.4 Quality factors

Source: Arditi & Gunaydin (1997)

2.3.1 Management commitment and leadership

Poor management practices were the main factors directly or indirectly contributing to the fall in construction productivity. Since productivity is a quality component, management's first move is to acknowledge a problem.

Management techniques are the primary factor that determines a TQM program's success. TQM is a management concept and culture that has to permeate a whole organization. Only senior management that prioritizes TQM will allow it to flourish. Deep knowledge of TQM must accompany this dedication. Senior management can only guide the organization toward attaining of improved quality in its endeavors if this dedication and understanding back it.

Management by control, as opposed to management by participation, is a management strategy that is widely utilized in the United States of America today, particularly in the construction industry. As a result of the challenges brought on by global competition and the growing demands of consumers for high-quality goods and services, industries are reevaluating the effectiveness of management by control. This management strategy places a strong emphasis on the organizational chart as well as the major control points that are located inside the structure. A list of goals for the future year has been delegated to each and every position in management, beginning with the highest one. After that, they delegate objectives to each of their subordinates and impose constraints on those objectives. Every single project in the construction sector has a unique set of objectives regarding time, money, and potentially even quality. It is the achievement of these goals that serves as the foundation for rewarding project managers. This strategy has been adopted with a certain degree of success. Simply put, it is comprehensible and makes perfect sense. On the other hand, problems develop when the controls themselves take the place of the operation. Within an organization, management by control can lead to internal conflict, antagonistic relationships, decreased communication, accusations when goals are not accomplished, and even faked claims of conformity. This is because management by control pushes a company to look within rather than outward to the consumer and the demands of the customer.

When management acknowledges that there is a problem, the next stage is to get a comprehensive understanding of the TQM's guiding principles and the components that make up the TQM. After then, the management demonstrates its commitment to excellence through the actions that it does. With this information, it is quite likely that management will take steps that are opposed to Total Quality Management (TQM), which will reinforce the fears of the workforce and make it impossible for the program to be successful. It was determined that one of the most important aspects that contributed to the overall quality of the constructed facility was the degree to which management was committed to the ongoing improvement of quality.

2.3.2 Training

Every quality expert acknowledges its importance. Quality is the responsibility of all individuals in Total Quality Management (TQM), therefore it is essential that all personnel undergo specialized training. All employees, including management, engineers, technicians, office workers, support personnel, and laborers, should undergo specific training programs.

The construction labor, known for its fluctuations, contrasts sharply with the more consistent manufacturing workforce. Training workers, particularly craft labor, for the construction industry may pose challenges due to their temporary employment status. TQM concepts and safety consciousness in construction companies have many commonalities, such as training and awareness. The Occupational Safety and Health Administration mandated safety regulations for numerous US construction enterprises. Now that their safety solutions are affordable, they utilize their safety records for commercial purposes. Modifying certain techniques to enhance safety awareness among craft workers could foster a similar sense of quality consciousness. It is easy to envision using a strong track record as a marketing strategy.

If TQM principles become widely adopted in the construction sector, workers switching between companies may require less TQM training due to the assumption that they have already received basic quality awareness training in their previous jobs. The training program may cover the fundamentals of Total Quality Management (TQM), cause-and-effect analysis, collaborative problem solving, interpersonal communication, basic statistical tools, and cost of quality evaluation. An investigation of Total Quality Management (TQM) in over 200 companies revealed that interpersonal skills, leadership qualities, and initiative are crucial for improving quality in any project. As technology systems get more intricate and advanced, the demands for interpersonal skills also increase. The training is carried out according to a pre-established approach, and its implementation and effectiveness are closely supervised. It begins with a limited number of pilot teams. The accomplishments of the pilot teams drive the progress of the remaining training tasks. Follow-up training is a requirement in each individual's job description and the comprehensive training program.

In US construction projects applying TQM, staff training was deemed unimportant in the design phase, somewhat relevant in the constructing phase, and crucial in the operation phase. Training should prioritize operation and maintenance teams in established facilities. The results align with ISO 9001, which underscores the importance of training and stresses the necessity of identifying activities that demand acquired skills and providing suitable training.

2.3.3 Teamwork

Quality teams provide companies with the necessary organized framework to effectively implement and consistently utilize the TQM process. High-quality training is provided through a well-planned team structure, and the practice of continuous improvement is implemented. The primary goal of the team method is to involve all stakeholders in the Total Quality Management (TQM) process, including as owners, contractors, designers, vendors, and subcontractors.

Enhanced customer satisfaction is attained in the industry when the Total Quality Management (TQM) approach is expanded to involve collaborative teams, as previously stated. These teams need to set common objectives, strategies, and monitoring systems. The teams provide a means to listen to and communicate with the owner, as well as assess consumer satisfaction. Legal autonomy and distinct operational methodologies of organizations pose obstacles to forming integrated teams. If the owner is dedicated, these issues in the building business can be resolved. There are several case studies demonstrating successful partnerships. TQM was implemented on a large refinery project through a project team approach, with members from the project owner and two major contractors on the project quality steering committee. Despite being a novel concept, it has shown encouraging early outcomes. Department representatives must form teams at the corporate level to implement Total Quality Management (TQM) throughout the organization. The similar team approach can be used at the project level.

2.3.4 Statistical methods

Due to the utilization of statistical methods, the Total Quality Management process has access to several instruments for problem-solving. Ascertaining the past, present, and, to a lesser extent, the future status of a work process, communicating in a clear and easily understood manner, confirming, replicating, and reproducing measurements based on data, confirming, replicating, and reproducing measurements based on data, and basing decisions on facts rather than the opinions and preferences of individuals or groups are all things that they provide team members with the resources they require. In the Total Quality Management (TQM) process, some of the statistical tools that are utilized the most commonly include histograms, cause and effect diagrams, checklists, Pareto diagrams, graphs, control charts, and scatter.

Statistical methods are absolutely necessary for manufacturing organizations to implement in order to improve quality output. Statistical techniques are utilized with the intention of providing the TQM process with essential tools for problem-solving capabilities. There is also high emphasis placed on the significance of statistical methodologies within the ISO 9001 standard. The statistical approaches, on the other hand, were seen as the least relevant factor that influenced quality in the construction process by the designers, builders, and construction managers. The design and construction stages were the ones in which they gave it the least amount of emphasis.

2.3.5 Cost of quality

The cost of quality is the fundamental metric that is used to evaluate quality measurement. Its purpose is to evaluate the effectiveness of the Total Quality Management (TQM) process, choose initiatives that will lead to an increase in quality, and persuade doubters that the expenses are justified. Putting together these low-cost assemble expenses of review, inspection, testing, scrap, and rework is one way to convince management and other individuals of the importance of quality improvement. Over the past few years, there has been an increased spotlight placed on the cost of quality. It is successful in achieving its stated goals, which include raising awareness about quality and alerting management about the financial benefits of the total quality management.

Quality expenses include the cost of deviation, the cost of prevention, and the cost of appraisal. All of these costs are included in the category of quality costs. These expenses are referred to as preventive costs, because they are related with activities that prevent deviations or errors at all. Evaluation costs, on the other hand, are the expenditures that are associated with actions that are used to determine whether or not a product, method, or service conforms with the standards that have been established. One type of expenditure that is included in an appraisal is inspection. On the other hand, assessments of constructability or design, as well as modifications to work methods implemented in order to conform to quality standards, can be termed preventative costs. Without a shadow of a doubt, the most significant obstacles to putting ISO 9000 standards into reality are the higher costs associated with modifying work practices and the additional costs associated with modifying standards. Failure to comply with regulations is the source of the costs that are connected with deviations. Certain expenses related to deviations are incurred on the project site as a result of scrap, rework, failure analysis, reinspection, supplier fault, or price decreases as a result of nonconformity. Once the owner has taken control of the completed facility, additional charges for deviations will become due. Complaints, repairs, processing rejected goods so that they can be replaced, rectifying errors in craftsmanship or equipment, and legal fees are all included in these charges.

In the construction industry, owners select their contractors through a process that involves selection through competition. Even while the bid is frequently believed to be the most important aspect in the selection process, private owners, in particular, take into consideration the safety record of the contractors, as well as their technical assistance, equipment capabilities, and most importantly, their reputation with regard to the quality of the work that was completed. In the current market, which is highly competitive, it is highly likely that contractors who have a reputation for producing mediocre work will be offered only a few assignments. It is beneficial for independent contractors to make investments in tactics that result in high work quality in order to increase their chances of securing contracts.

2.3.6 Supplier involvement

An important factor in the production of a product of superior quality is the relationship that exists between the various parties engaged in the process, including the client, the processor, and the supplier. The success of each stage of a process is contingent on the efficacy of the stages that came before it. The quality of the project that the constructor constructs is directly related to the quality of the plans and specifications that were prepared by the designer, the quantity and quality of the equipment and materials that were given by the vendors, and the amount of work that was performed by the subcontractors. It is vital for the constructor to establish close and long-lasting partnerships with these suppliers in order to achieve the best possible level of both economy and quality.

Contractors, subcontractors, and vendors are typically pitted against one another to compete for low-bid contracts in the construction sector. However, the fourth of Deming's suggestions (Deming, 2018) for achieving high quality emphasizes that businesses must stop granting contracts based on pricing. Quality, life-cycle costs (rather than starting prices), and supplier responsiveness are likely to be the determining factors for successful projects, and these factors can only be met through partnerships with fewer suppliers built on trust. It has already been proven to be true in several segments of the industrial construction sector. Several owners and contractors have established long-term cooperation agreements. Some owners are mandating that their suppliers have formal TQM programs if they want to be considered for future business, and both owners and contractors are mandating that vendors implement TQM.

2.3.7 Customer focus

Customer focus is crucial because it allows managers to deliver goods and services that satisfy customer demand. The challenge with building is that identifying the client is frequently challenging. There are two sorts of customers from the perspective of TQM: end users and internal customers. However, because there are frequently multiple end users, each with different needs, it may not be easy to define even the end user in the construction industry. However, the goal of the value management technique is to maximize the needs of all project end users. Although this is a novel concept, value management should be included in a TQM program since this technique is the most capable of handling the complicated process of resolving the competing interests in the construction project.

There has been prior discussion regarding the concept of the internal customer, particularly in the chapter that deals with benchmarking. Organizational processes and internal customers are notions that are intimately tied to one another. Just like benchmarking and reengineering, Total Quality Management is focused on processes. As a consequence of this, the customer of the process is the internal customer, also known as the person who is further along in the production chain. A discussion on how to improve the quality of service that is offered to the internal customer is presented in the following section on integration.

2.4 TQM in Construction Industry

This section is not about something other than how to implement TQM in the construction industry. It attempts to explain the mian exciting topics in the literature that other textbooks still need to mention. Section 2.4.1 aims to address the significant problem of the TQM implementation. A firm must change its business strategy. It is a business goal, and the whole process from upstream to downstream is based on customer value. The corporate culture is a significant barrier to TQM implementation. It is portrayed in section 4.2.2. Various attempts are merging the TQM into construction projects. The EFQM.E.M is explicated in section 4.2.3. It is a framework initiated by the European Foundation for Quality Management to promote the implementation of TQM in businesses. Finally, section 2.4.4 briefly describes some literature on reported about how the construction industry implements the TQM.

2.4.1 Paradigm shift of TQM

Quality is implemented in construction projects subject to the limitations of the construction sector. These restrictions are beneficial since they demonstrate the established viewpoint of the field and the rules it adheres to. However, there are times in history when these limitations become overly confining, prompting the need to adjust the constraints to reflect developments or support progress.

A company operating under the old paradigm would act as a follower, creating things it is confident will be successful. The primary goal is to generate profit for shareholders and management, with success measured by outperforming other companies. The efficiency measurement compares set figures without examining the underlying causes. The new paradigm focuses on creating products tailored to customer demands that align with consumer value. The objective is not focused on short-term earnings, but rather on acquiring customer loyalty and increasing market share. Table 2.1 displays various elements of the paradigm shift that occurs when quality is incorporated into construction projects.

Table 2.1 The conventional and new paradigmes

Topics	Convential paradigm	New paradigm
Quality	Meeting specification	Customer value
Measurement	Internal measures of efficiency	Linked to customer value
Positioning	Competition	Customer segments
Key stakeholder	Stockholder	Customer
Product design	Internal sell what we build	External build what the customer wants

Source: McGeorge & Zou (2012)

2.4.2 Cultural change in construction industry

Without a shadow of a doubt, the paradigm of a company is inextricably linked to the methods of thinking and doing, as well as the characteristics of a body of established knowledge. To be more specific, the term "culture" refers to the social structures that serve as the foundation for the attitudes and activities of the community. To successfully adopt Total Quality Management (TQM), a mindset shift is required. In the same vein, businesses in the construction industry require a transition in their culture accordingly. Table 2.2 provides an overview of the cultural shift that has occurred in the fields of construction projects.

Table 2.2 The cultural shift for TQM

Conventional	Modern
Meeting specification	Continuous improvement
Complete on time	Satify customer
Focus on final product	Focus on process
Short-term view	Long-term view
Inspection-based quality	Prevention-based
People as cost burdens	People as assets
Minimum cost suppliers	Quality suppliers
Compartmentalized organization	Integration
Top-dow management	Employeed participation

Source: McGeorge & Zou (2012)

2.4.3 The EFQM.E.M

This section examines the European Foundation for Quality Excellence Model (EFQM.E.M) and the connection between Total Quality Management (TQM) and EFQM.E.M. The paradigm simplifies the execution of Total Quality Management (TQM). The EFQM Excellence Model is associated with self-assessment and ongoing improvement (Howarth & Greenwood, 2018).

Total Quality Management (TQM) facilitates the efficient utilization of a company's resources by promoting a culture of ongoing enhancement. It enables managers to optimize their value-adding tasks while reducing time, effort, and energy spent on non-value-adding tasks. Various literature, such as Saeed & Hasan (2012), Likita et al. (2018), Egwunatum et al. (2022), and Riaz et al. (2023), have supported the adoption of TQM. Implementing Total Quality Management (TQM) might be particularly challenging for several construction projects. Furthermore, the cultural contrasts between the Western and the Eastern make TQM deployment hard. Hence, a practical implementation of Total Quality Management (TQM) is necessary, even within a particular domain.

The EFQM Excellence Model is a Total Quality Management deployment model that is developed based on practical use and feedback from practitioners. The Business Excellence Model (BEM) was created from the input of Total Quality Management (TQM) implementations between 1989 and 1991. Several Western firms encountered challenges when implementing Total Quality Management (TQM) and achieving the advantages of applying TQM in real-world scenarios.

1) The customer needs are systematically considered to produce a higher quality product or service.

2) The reduction in processes, time, and costs by minimizing potential causes of errors and corrective actions.

3) The staff development is based on customer-centricity, increased efficiency, and effectiveness.

4) Information flow is improved through team building and proactive management strategies.

The Excellence Model was designed to be (European Foundation for Quality Management, 2000):

"Simple [easy to understand and use]; holistic [in covering all aspects of an organization's activities and results, yet not being unduly prescriptive]; dynamic [in providing a live management tool which supports improvement and looks to the future]; flexible [being readily applicable to different types of organizations and to units within those organization]; innovative."

The EFQM Excellence Model has been widely and effectively implemented in several sectors such as manufacturing, construction, banking and finance, education, management, and consultancy, as shown by Howarth & Greenwood (2018), Fonseca (2022), and Yousaf (2022). Businesses utilize the EFQM Excellence Model to achieve business excellence through Total Quality Management, which is crucial for success in the current global market. EFQM, in conjunction with EFQM.E.M, also sought the European Quality Award in 1991 to promote the adoption of Total Quality Management.

The EFQM Excellence Model offers a structure for self-evaluation. A construction company—or any organization—can determine using this tool whether it is acting appropriately and achieving the desired goals. Results and the caliber of the systems and processes used to attain them assess an organization's performance.

The concept establishes harmony and a relationship between approach (enablers, or how results are obtained) and results (what is accomplished regarding clients, employees, society, and the company). It offers a fair assessment of causation and effect. *Enablers* are the criteria that address causes. *Results* are those that deal with impacts. *Enablers* and *results* are weighted equally from the organization's score, 50/50.

The EFQM.E.M is viewed in four perspectives:

1) It is viewed as a framework that firms can use to facilitate them to create their quality system tangibly.

2) It is a framework that firms can use to understand and identify their business system in the context of crucial linkages, cause and effect relationships.

3) It is viewed as the basis for the European Quality Award. European recognizes the most successful firms and promotes them as role models of excellence in quality.

4) It is viewed as a diagnostic tool for determining the firm's health, agility, and future.

The EFQM Excellence Model is based on and supported by particular concepts which are referred to as 'The Fundamental Principles of Excellence'; there are:

1) Adding value for customers;

2) Creating a sustainable future;

3) Developing organizational capability;

4) Harnessing creativity and innovation;

5) Leading with vision, inspiration, and integrity;

6) Managing with agility;

7) Succeeding through the talent of people;

8) Sustaining outstanding results.

The EFQM Excellence Model is underpinned by specific concepts known as 'The Fundamental Principles of Excellence,' with

1) Adding value for customers

2) Establishing a sustainable future

3) Enhancing organizational capability

4) Utilizing creativity and innovation

5) Leading with vision, inspiration, and integrity

6) Managing with agility

7) Achieving success through the talent of people

8) Maintaining exceptional results

The concepts mentioned above are involved, both directly and indirectly, in relation to several criteria and sub-criteria inside the EFQM Excellence Model. Eight core principles of excellence underlie the nine criteria that a company uses to evaluate its performance, as depicted in Fig. 2.5.

1) Leadership (10%)

2) People (10%)

3) Strategy (10%)

4) Partnerships and resources (10%)

5) Processes, products, and services (10%)

6) Processes, products, and services (10%)

7) People results (10%)

8) Customer results (10%)

9) Society results (10%)

10) Business results (15%)

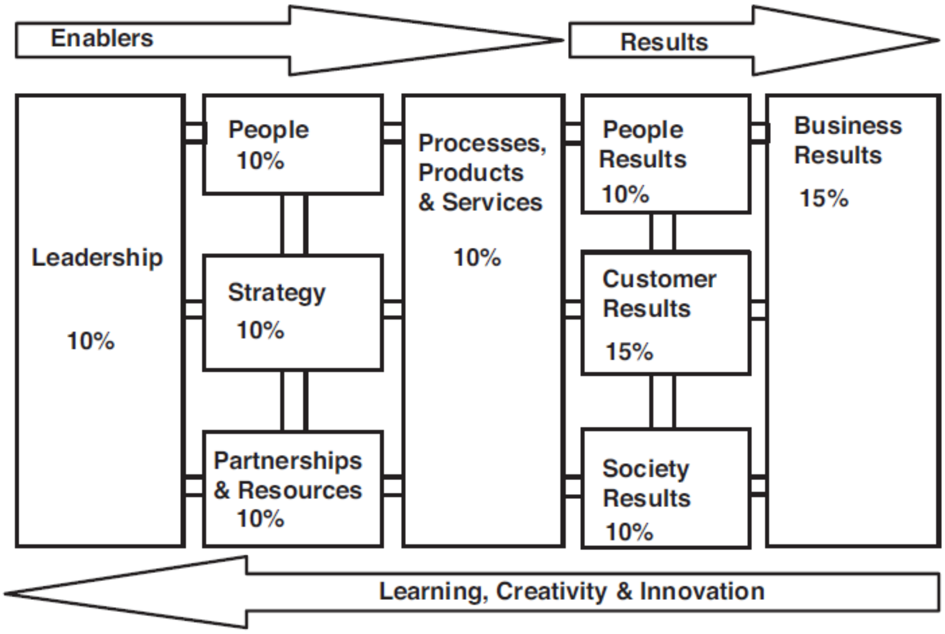

Figure 2.5 The EFQM Excellence Model
Source: Howarth & Greenwood (2018)

Figure 2.5 illustrates a model consisting of two primary sections: *Enablers*, composed of five criteria, and *Results*, consisting of four criteria. The *Enablers* pertain to the actions of a firm, whereas the *Results* refer to the accomplishments of a firm.

2.4.4 TQM implementation in construction projects

Industrial engineering and manufacturing have significantly benefited from the extensive adoption of the Total Quality Management (TQM) approach for process control and defect prevention, which has resulted in millions of dollars in cost savings (Hoonakker et al., 2010). The construction sector requires the same kinds of instruments for the same purposes, but due to the differences between the sectors, it cannot use them in their current forms (Nouban & Abazid, 2017).

Formoso and Revelo (1999) sought to improve the small-scale building enterprises' materials supply system by applying the concepts of Total Quality Management (TQM). Three Brazilian construction companies participated in the study, cooperating at various levels of the TQM implementation. The suggested approach was based on straightforward, well-established methods for identifying, analyzing, and addressing problems, including flowcharts, brainstorming, checklists, and Pareto diagrams. The findings indicated that using such methods and ideas in smaller construction companies is challenging. The findings of a study conducted in Hong Kong (Tam et al., 2000) support the same conclusion.

Several studies have tried to connect a Total Quality Management (TQM) approach with established management systems like project management, partnerships, ISO 9000 and 14000 standards, Quality Assurance Plan (QAP), Quality Function Deployment (QFD), and Jobsite Quality Planning (JQP), with differing levels of success (Koh & Low, 2010).

Implementing Total Quality Management (TQM) in the building and construction industry is challenging. Several factors contributing to the challenges in building and construction include the impermanent nature of the industry, lack of standards, and the involvement of numerous parties. Another reason is the traditional nature of the building sector.

Hoonakker et al. (2010) detailed the similar approach while investigating the measures implemented by construction companies in the Netherlands to improve the quality of work life. Out of the 20 building and construction enterprises surveyed, only one had implemented the teamwork and Total Quality Management (TQM) principles. The other businesses were cognizant of the innovation initiative but chose to be cautious and monitor the results, asserting, "This will never succeed in the construction sector."

These instances highlight the difficulty of implementing change in the building and construction sector and the value of best practices. Building and construction businesses are more likely to implement an idea if they verify that it genuinely works, especially if doing so will lower costs. Additionally, giving businesses a plan for implementing TQM will boost their drive and confidence to make changes.

2.5 Conclusion

This chapter reveals the quality standards throughout several businesses. The definition of quality varies depending on the industry. The distinctions between quality assurance and quality control are delineated. Quality control is a component of quality assurance, which in turn is a component of the quality system. TQM was discussed in several situations. The common interpretation of several definitions is focused on customer-centricity. A study indicates that construction projects have the potential to save expenses by minimizing failures, such as rework, repair, and rebuild expenditures. Constructing a project is really intricate. There are numerous parties associated with the project. The project owner must take into account crucial quality variables in construction projects. This chapter extensively examined Total Quality Management (TQM) in the construction industry. The text discussed the significance, cultural change, and EFQM.EM framework for implementation. This section will be utilized for formulating the research methodology in the upcoming chapter.

CHAPTER 3
RESEARCH METHODOLOGY

In this chapter, the research design and its methods are introduced. The research design can be developed based on the research objectives. The literature and the study of the EFQM Excellence Model are used as the barriers and enablers of finding. The questionnaire design is explained. The population and sample of this study are identified. Four phases of the research process are illustrated.

3.1 Research Design

The study approach is segmented into 4 phases as outlined below. Phase 1 involves reviewing the literature and gaining an understanding of the EFQM Excellence Model. It is crucial to comprehend the obstacles and facilitators to Total Quality Management (TQM) adoption in the existing literature. The lists of barriers and enablers are constructed in this phase. The EFQM Excellence Model guides of the survey research by carefully using its self-assessment procedure. Phase 2 drafts the questionnaire using a five-point Likert scale to weigh the barriers and enablers. The significant level is measured on a five-point scale: 1 = neglectable, 2 = not important, 3 = common, 4 = important, and 5 = extremely important. It is an effective method for observing respondents' views on barriers and enablers.

The Item Objective Congruence (IOC) index will validate the questionnaire. It provides the content validity (CV) of the congruence between the cognitive processing of reading and the test items. This phase needs three experts in research methodology for verification. Then, the questionnaire is tested for its reliability using Cronbach's alpha. Reliability is evaluated by comparing the shared variance or covariance among the items in a tool to the total variance.

Data gathering is carried out in the Kunming area during Phase 3. The information is derived from an online poll conducted over email. A telephone call may be necessary if the respondents fail to return the questionnaire promptly. Phase 4 examines the data through descriptive statistics, including respondent demographics, mean, standard deviation, and variance. Cluster analysis is also performed. This study opts for Hierarchical Cluster Analysis (HCA) due of its ability to group a set of items that share similar characteristics. The procedure initiates by placing each object in an individual cluster and then merges clusters iteratively until only one cluster is left. The Proximity method calculates distance or similarity metrics. Furthermore, statistics are displayed at each level to help an analyst choose the optimal approach. The findings are deliberated and summarized to address the research goals.

3.2 Population and Samples

This study targets to survey 400 respondents in Kunming's construction projects to eliminate population counting. By this number, we can receive a 5% error by calculating Yamane's formula.

3.3 Research Tools

The questionnaire is the research instrument used in this study. The questionnaire is detailed and designed to gather information on respondents' knowledge and opinions regarding obstacles and facilitators to Total Quality Management (TQM) implementation in construction projects. The questionnaire consists of two essential elements.

Part 1 questions the respondents and the analyzed projects, e.g., the position, experience, education, type of project, and project value.

Part 2 asks the respondents to score the barriers and enablers using a five-point Likert scale.

3.4 Data Analysis

As mentioned above, the questionnaire's first part is analyzed using descriptive statistics. The statistics used in this study are frequency, average, standard deviation, boxplot, and histogram.

The hierarchy cluster analysis is used to examine the respondents' opinions. In this analysis, each barrier b_i $\forall i \in (1,2,3,\dots)$ and enabler e_i $\forall(1,2,3,\dots)$ is designated by two variables: relative importance value (RIV_i) and standard deviation value (SDV_i). The calculation of them is determined by using the following formulas.

$$RIV_i = \frac{\sum_{j=1}^{N} x_j}{N} \tag{3.1}$$

where RIV_i is relative importance value, x_j is the score given to the barrier b_i or enabler e_i by respondent j, $\forall j \in (1,2,3,\ldots,N)$, N is the number of respondents.

$$SDV_i = \sqrt{\frac{\sum_{j=1}^{N}\left(x_j - RIV_i\right)^2}{N}} \tag{3.2}$$

where SDV_i is standard deviation value.

Theoretically, the relative importance and standard deviation values equal the weight values. It needs to ensure that these two variables are equally important and that a standardization process is carried out. The two values will be converted to the standardization values $Z(RIV_i)$ and $Z(SDV_i)$ by using the formulas proposed by Kaufman & Rousseeuw (2009).

$$Z(RIV_i) = \frac{RIV_i - \mu_{RIV}}{\frac{1}{M}\sum_{i=1}^{M}|RIV_i - \mu_{RIV}|} \tag{3.3}$$

$$Z(SDV_i) = \frac{SDV_i - \mu_{RIV}}{\frac{1}{M}\sum_{i=1}^{M}|SDV_i - \mu_{SDV}|} \tag{3.4}$$

where M is the total number of barriers or enablers.

$$\mu_{RIV} = \frac{1}{M}\sum_{i=1}^{M} RIV_i \tag{3.5}$$

$$\mu_{SDV} = \frac{1}{M}\sum_{i=1}^{M} SDV_i \tag{3.6}$$

Euclidean distance is used to measure the cluster distance between pairs of barriers or pairs of enablers. The following formula calculates the Euclidean distance between pairs of barriers or between pairs of enablers (e and f).

$$ED(e,f) = \sqrt{\left(Z(RIV_e) - Z(RIV_f)\right)^2 + \left(Z(SDV_e) - Z(SDV_f)\right)^2} \quad (3.7)$$

The shortest Euclidean distance between pairs of barriers or enablers are grouped, and clusters are formed. This study uses the following formula to measure the distance between the pairs of cluster A and B, namely, the average group linkage (Rousseeuw, 1987).

$$CD(A,B) = \frac{1}{|A||B|} \sum_{e \in A, f \in B}^{2} ED(e,f) \quad (3.8)$$

where $|A|$ and $|B|$ are the number of barriers or enablers in clusters A and B, respectively.

The Elbow approach is employed to discover the best number of clusters in the data. This method is a visual technique used to assess the stability of the optimal number of clusters. The objective is to identify the optimal number of clusters by iteratively adding clusters and calculating the sum squared error (SSE) for each cluster (Umargono et al., 2020). This process continues until the maximum number of clusters is reached. By comparing the differences in SSE between clusters, the cluster number that exhibits the most significant change forms the elbow angle, indicating the best cluster number, here is the SSE formula.

$$SSE = \sum_{i=1}^{k} \sum_{x_j \in C_i} \left\| x_j - \mu_j \right\|^2 \quad (3.9)$$

where SSE is the sum square error, x_j is object in cluster c_j and centroid of the cluster.

3.5 Research Process Flowchart

Figure 3.1 shows the steps of this research project.

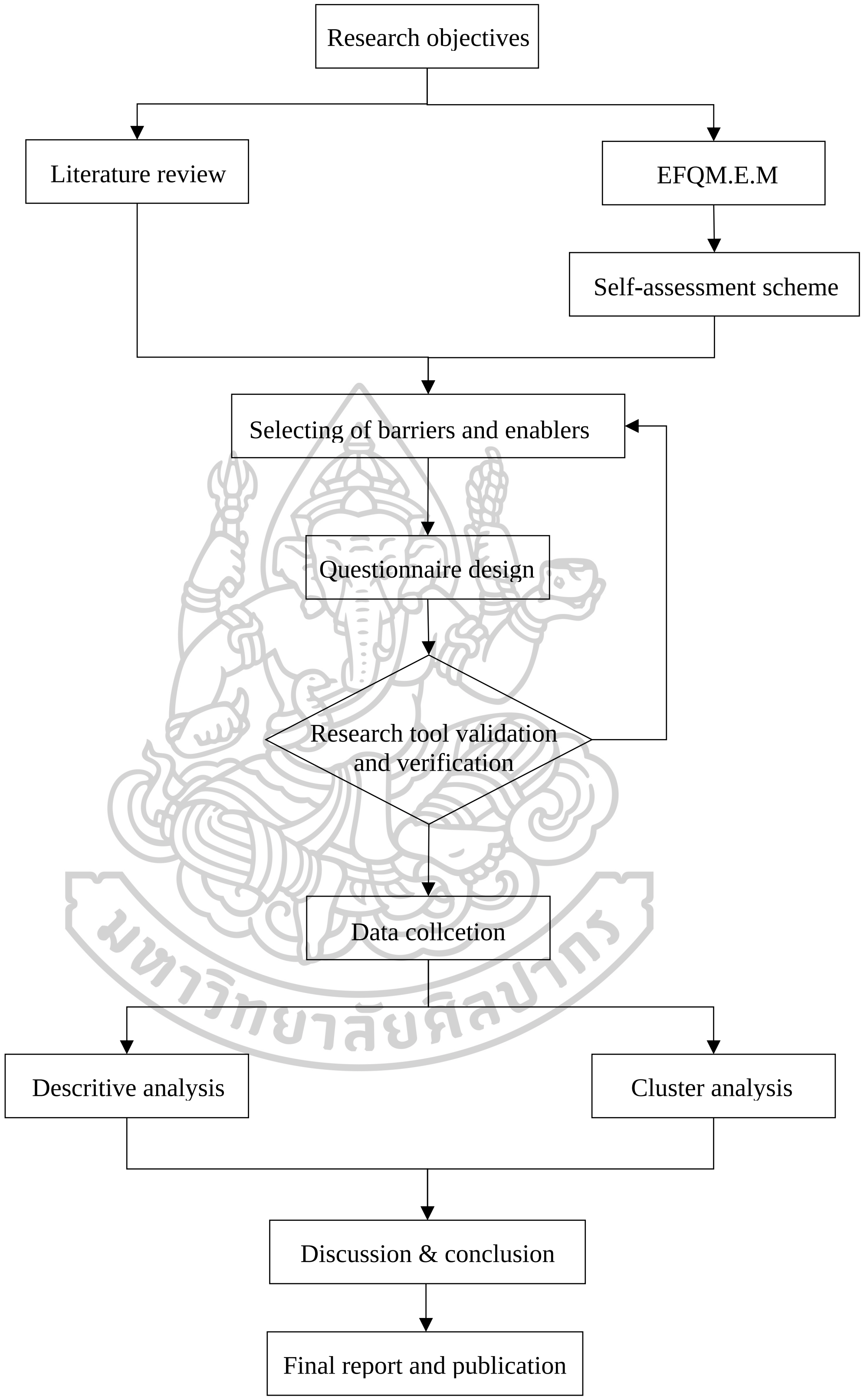

Figure 3.1 Research process flowchart

CHAPTER 4
RESULT AND ANALYSIS

The research instrument is developed here. Section 4.1 examines its validity and reliability. Section 4.2 analyzes the collected data descriptively. Section 4.3 determines the characteristics of the data using the methods mentioned in the last chapter.

4.1 Research Instrument

The questionnaire is designed based on the EFQM Excellence Model (EFQM, 2021). Table 4.1 summarizes seven criteria of the model.

Table 4.1 Seven criteria of EFQM excellence model.

Driver	Criteria	Positioning statement
Direction	1. Purpose, vision, and strategy	An exceptional company is characterized by an inspiring purpose, an ambitious vision, and a strategy that achieves results.
Direction	2. Organizational culture, and leadership	Organizational culture comprises a distinct assemblage of shared values and norms among individuals and groups operating within a given establishment. These values and standards gradually shape the conduct of the members towards one another and with critical stakeholders external to the organization. Organizational leadership pertains to the entirety of the organization, not to a specific individual or group that administers directives from on high. This concept pertains to the organization

Table 4.1 Seven criteria of EFQM excellence model. (Continued)

Driver	Criteria	Positioning statement
		assuming the role of a leader within its ecosystem, being acknowledged by others as an exemplar, as opposed to the conventional view of a top-level management team overseeing the organization.
Execution	3. Engaging stakeholders	Criterion 1 involves aligning an organization's purpose, vision, and strategy with recognizing and comprehending stakeholder demands in the context of its distinct environment. The way an organization implements its strategy to engage stakeholders (Criterion 3) is directly related to how the performance of the organization is perceived by the stakeholder groups it serves (Criterion 6).
Execution	4. Creating sustainable value	An exceptional firm understands that establishing lasting value is crucial for its enduring success and financial stability.
Execution	5. Driving performance and transformation	An organization must simultaneously meet two crucial conditions to achieve and sustain success, both now and in the future.
Results	6. Stakeholder perceptions	This criterion emphasizes outcomes as determined by the perceptions of key stakeholders regarding their individual interactions with the organization.

Table 4.1 Seven criteria of EFQM excellence model. (Continued)

Driver	Criteria	Positioning statement
Results	7. Strategic and operational performance	This criterion focuses on outcomes associated with the organization's success in terms of: • The capacity to achieve its intended goal, execute the plan, and generate lasting value. • Its suitability for future use.

Source: EFQM (2021).

The researcher cafully reviewed and compare to the current situation of construction industry of the case study area. As a result, fifteen items and its descriptions based on EFQM model are shown in Table 4.2.

Table 4.2 Fifteen items of barriers and enablers.

Item	Descriptions	Remark	E/B code
1	Lack of organizational vision, purpose, and strategy	C1	B1
2	Implement circular economy principle for material utilization	C5	B2
3	Devoid understanding of customers' needs	C1	B3
4	Environment, health, and safety performance	C7	B4
5	Disruptive technology and economy	C2	B5
6	Lack of government relationship and support	C3	B6
7	Inadequate sell communication	C4	B7
8	Knowledge management system in construction site	C2	E1
9	Resources and assets mishandling	C5	B8
10	Poor stakeholder perceptions	C6	E2
11	Market research and other forms of feedback	C4	B9

Table 4.2 Fifteen items of barriers and enablers. (Continued)

Item	Descriptions	Remark	E/B code
12	Poor data analysis and performance prediction	C7	B10
13	Government and local administration regulations	C1	E3
14	Understanding current and future marketplace	C1	E4
15	Culture of creativity and innovation	C2	E5
16	Implements advanced analytics, such as predictive models, to get actionable insights and make informed decisions.	C5	E6
17	Sustainable customer relationship	C3	E7
18	Customers' perception about value of product and service	C4	E8
19	Risk management and performance improvement	C5	E9
20	Performance measurement tools: financial and non-financial indicators	C7	E10

Remark: C means criterion, B/E means Barrier or Enabler

The questionnaire is shown in Appendix A. It has two parts. The first part asks about the demographic of the respondents and the second part asks the opinion on item in Table 4.2. The questionnaire was tested with content validity using IOC. The experts were two professor and one construction site manager. The results show that the content is congruent, see Table 4.3.

Table 4.3 Content validity.

Descriptions	-1	0	+1	IOC	Result
Lack of organizational vision, purpose, and strategy	0	1	2	0.67	Ok
Implement circular economy principle for material utilization	0	1	2	0.67	Ok

Table 4.3 Content validity. (Continued)

Descriptions	-1	0	+1	IOC	Result
Devoid understanding of customers' needs	0	0	3	1.00	Ok
Environment, health, and safety performance	0	0	3	1.00	Ok
Disruptive technology and economy	0	1	2	0.67	Ok
Lack of government relationship and support	0	0	3	1.00	Ok
Inadequate sell communication	0	0	3	1.00	Ok
Knowledge management system in construction site	0	1	2	0.67	Ok
Resources and assets mishandling	0	0	3	1.00	Ok
Poor stakeholder perceptions	0	0	3	1.00	Ok
Market research and other forms of feedback	0	0	3	1.00	Ok
Poor data analysis and performance prediction	0	1	2	0.67	Ok
Government and local administration regulations	0	0	3	1.00	Ok
Understanding current and future marketplace	0	0	3	1.00	Ok
Culture of creativity and innovation	0	1	2	0.67	Ok
Implements advanced analytics, such as predictive models, to get actionable insights and make informed decisions.	0	1	2	0.67	Ok

Table 4.3 Content validity. (Continued)

Descriptions	-1	0	+1	IOC	Result
Sustainable customer relationship	0	0	3	1.00	Ok
Customers' perception about value of product and service	0	0	3	1.00	Ok
Risk management and performance improvement	0	0	3	1.00	Ok
Performance measurement tools: financial and non-financial indicators	0	0	3	1.00	Ok

4.2 Demographic Data Analysis

The questionnaire was distributed through an online platform. Telephone calls were needed to expedite the process. However, the respondents must carefully read the questionnaire before answering the questions. Thus, interviews were not allowed in this process. Three hundred eighty-two questionnaires were returned out of 400.

Nevertheless, twenty-six of them were outside of Kunming. Fortunately, 356 respondents were usable in this study. The return rate, thus, was 89.0%, which is satisfactory. Table 4.3 shows the demographics of the respondents and Fig. 1 to 4 corespond the data in pie graph. Please note that not all answers are allowed to be shown in this report because of privacy, confidentiality, and disclosure reasons.

Table 4.4 Demographic data.

No	Question	Answer	Frequency	Percentage
1	What is type of your construction site?	Residential buildings	192	53.93
		Non-residential buildings	95	26.69
		Road construction	3	0.84
		Railway construction	1	0.28
		Bridge, electrical, and plumbing construction	12	3.37
		Utility construction	48	13.48
		Demolition project	2	0.56
		Other	3	0.84
2	What is your job position in the construction project?	Engineer	147	41.29
		Supervisor	26	7.30
		Site manager	18	5.06
		Project manager	29	8.15
		Economic responsible	35	9.83
		Procurement responsible	84	23.60
		CEO	5	1.40
		Other	12	3.37
3	How long you have been working in construction industry?	0-1	49	13.76
		1-3	178	50.00
		3-5	74	20.79
		5-10	32	8.99
		>10	23	6.46
4	What is your education level?	High school	0	0.00
		Vocational	12	3.37
		Higher vocational	35	9.83
		Undergraduate	229	64.33
		Master degree	68	19.10
		Doctoral degree	12	3.37

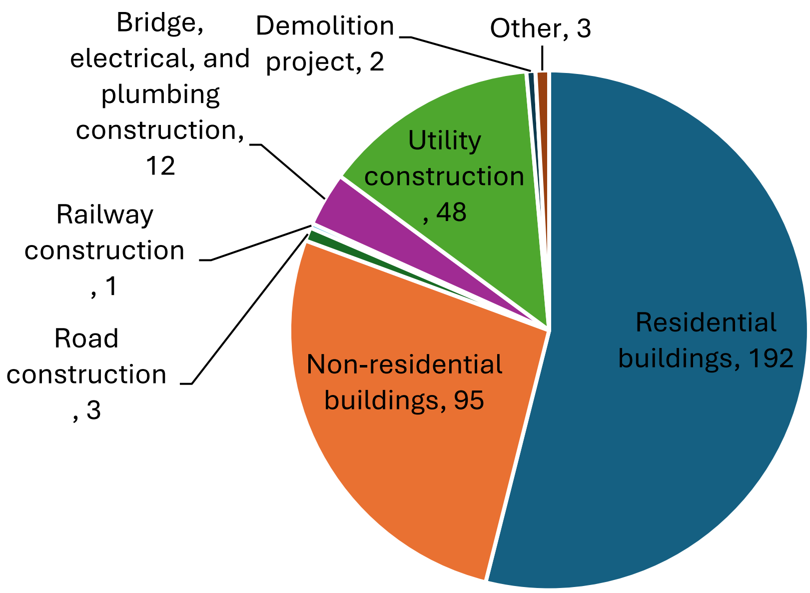

Figure 4.1 Types of construction project.

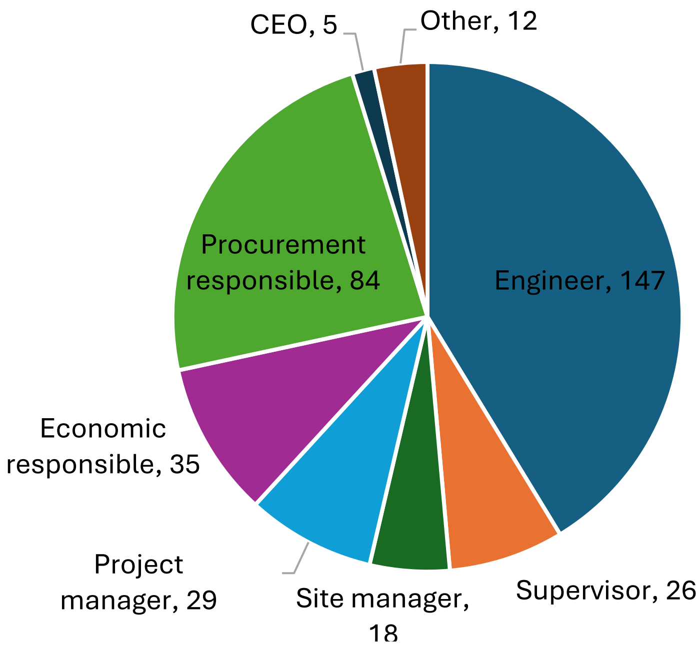

Figure 4.2 Job position of the respondents.

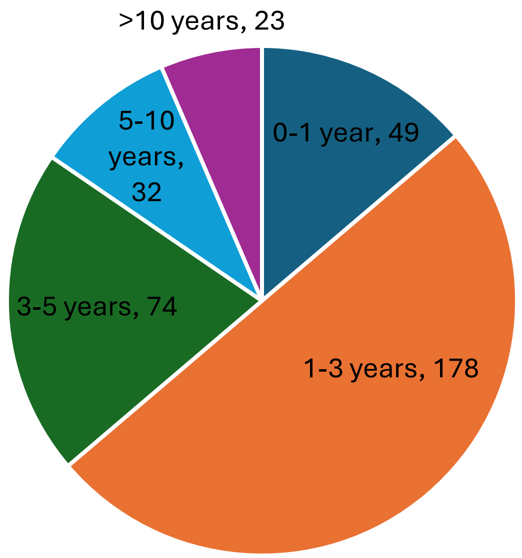

Figure 4.3 Experience of the respondents.

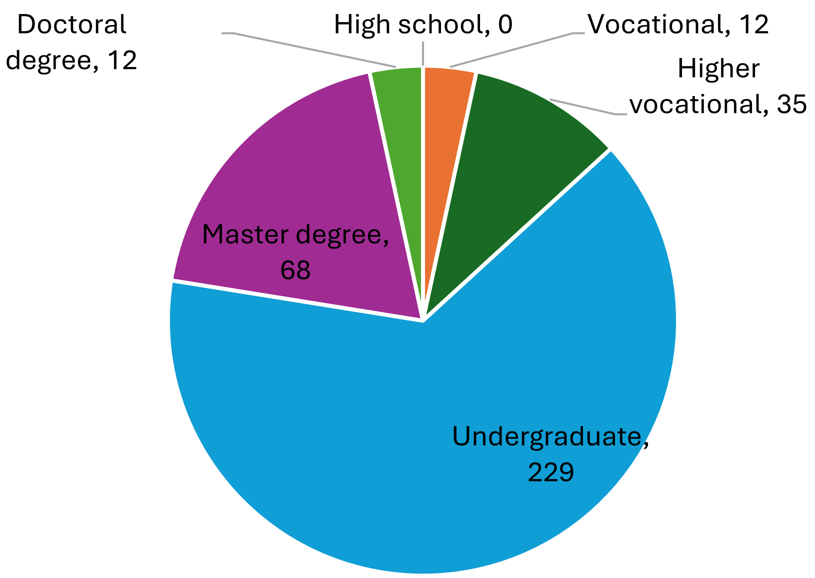

Figure 4.4 Education level of the respondents.

The data show that most respondents work for residential construction projects. Non-residential projects such as commercial buildings, shopping malls, hospitals, or schools are the second rank. Utility construction ranks third in this study. The engineer is the first rank who answers the questionnaire. Procurement and economic responsibility are the second and third ranks, respectively.

Most respondents have 1 to 3 years of experience in the construction industry. The second rank is 3 to 5 years of experience in the construction industry. This data makes us confident in our ability to do further analysis. 64.33% of the respondents graduated with a bachelor's degree. The master's and higher vocational degrees are in the second and third ranks, respectively. Please note that even the experience is important to answer the questionnaire; however, the opinion from new comers are also significance because TQM relates to everyone in the organization.

In conclusion, the demographic data analysis shows that the acquired data is trustworthy and can be further analyzed. Most respondents have experience in the construction industry, graduated from college or university, and have worked as engineers on construction projects.

4.3 Barrier and Enabler Analysis

Twenty statements can be divided into two groups: barrier and enabler groups. Table 4.5 shows the collected data from 356 respondents. They gave the score differently based on their opinion. The coefficient of variation (CV) was used to measure the dispersion of data points around the mean. Technically, it is the ratio of standard deviation to the mean, as is shown in Eq. (4.1)

$$CV = \frac{\sigma}{\mu} \tag{4.1}$$

where μ is the meand of data point which can be calculated as is shown in Eq. (4.2), and σ is the standard deviation which can be calculated as is shown in Eq. (4.3).

$$\mu = \frac{f_1 x_1 + f_2 x_2 + \cdots + f_k x_k}{n} \tag{4.2}$$

$$\sigma = \sqrt{\frac{f_1(x_1 - \bar{x})^2 + f_2(x_2 - \bar{x})^2 + \cdots + f_k(x_k - \bar{x})^2}{n - 1}} \quad (4.3)$$

where f_i is the frequency of data point i, $i \in \{1,2,..,k\}$, x_i is the value of data point i, $i \in \{1,2,..,k\}$,, n is the total number of data points, and $\bar{x}$ is the mean of data points.

Table 4.5 Barriers' responses.

Code	Level of Significance					Total	CV
	1	2	3	4	5		
B1	12	35	178	89	51	356	0.280
B2	0	198	79	43	45	356	0.372
B3	0	24	40	189	112	356	0.201
B4	19	89	214	32	11	356	0.279
B5	0	44	75	112	134	356	0.260
B6	12	145	181	20	7	356	0.273
B7	0	11	32	201	121	356	0.170
B8	7	5	83	194	76	356	0.207
B9	2	23	98	129	113	356	0.238
B10	11	131	202	12	9	356	0.263

From Table 4.5, all barriers have a good CV value. Technically, it must be not oerver 1.00. Table 4.6 shows the collected data from enablers.

Table 4.6 Enablers' responses.

Code	Level of Significance					Total	CV
	1	2	3	4	5		
E1	21	84	213	35	12	356	0.285
E2	57	49	93	67	99	356	0.422
E3	14	21	112	175	43	356	0.252
E4	0	9	39	243	74	356	0.158
E5	17	37	198	24	89	356	0.324

Table 4.6 Enablers' responses. (Continued)

Code	Level of Significance					Total	CV
	1	2	3	4	5		
E6	59	26	83	176	21	356	0.365
E7	16	23	112	195	19	356	0.246
E8	13	78	69	112	93	356	0.332
E9	8	0	32	254	71	356	0.171
E10	3	40	65	173	84	356	0.245

Likewise, the CVs are lower than 1.00, which means the collected data has a good dispersion. The data is good enough to conduct further analysis. Tables 4.7 and 4.8 show the relative importance value (RIV), standard deviation value (SDV), and standardization value of RIV and SDV, respectively. Please note that the calculation used Eq. (3.1) to (3.6).

Table 4.7 Barriers' level of significance.

Code	RIV	SDV	$Z(RIV)$	$Z(SDV)$
B1	3.45	0.965	-0.1098	0.8630
B2	2.89	1.076	-1.0588	1.8513
B3	4.17	0.840	1.1281	-0.2583
B4	2.87	0.802	-1.0973	-0.5955
B5	4.02	1.043	0.8728	1.5552
B6	2.70	0.737	-1.3960	-1.1755
B7	4.29	0.729	1.3353	-1.2423
B8	3.99	0.825	0.8295	-0.3894
B9	4.00	0.951	0.8343	0.7306
B10	2.73	0.718	-1.3382	-1.3390

The primary barirrers to implementing complete quality management in construction projects, as determined by their relative importance value, are the hurdles. The issues identified are as follows: B7—Inadequate sell communication, B3—Devoid understanding of customers' needs, B5— Disruptive technology and economy, and

B9—Market research and other forms of feedback. According to the answers, the most significant factors for ensuring quality delivery are the client and the market. An organization's ability to enhance its quality is contingent upon its understanding of client wants, awareness of market conditions, and effective communication with customers. Currently, the construction projects are not performing well in these areas. The notion of an inner customer and an end consumer might aid projects in enhancing their comprehension of complete quality management.

Table 4.8 Enablers' level of significance.

Code	RIV	SDV	$Z(RIV)$	$Z(SDV)$
E1	2.89	0.823	-2.4411	-0.8410
E2	3.36	1.418	-0.8239	2.1927
E3	3.67	0.925	0.2287	-0.3210
E4	4.15	0.654	1.8555	-1.7014
E5	3.44	1.114	-0.5464	0.6422
E6	3.28	1.198	-1.0919	1.0694
E7	3.58	0.879	-0.0967	-0.5584
E8	3.62	1.203	0.0565	1.0958
E9	4.14	0.708	1.8364	-1.4257
E10	3.90	0.958	1.0230	-0.1524

The two most important factors that facilitate comprehensive quality management in building projects, based on their relative critical value, are enablers E4— Understanding current and future marketplace, and E9—Risk management and performance improvement. Marketing research and forecasting have recently been introduced to the building business in Kunming. The research improves the efficiency of design, construction, and service. The project aims to communicate its objectives directly to its clients. Effective risk management and performance enhancement immediately enhance project quality. Construction projects have several hazards. The dangers hinder site management from many perspectives. Therefore, effective risk management enhances the quality of projects and supports the implementation of comprehensive quality management in construction projects.

Next, the Euclidean distance is computed using Equation (3.7). Tables 4.9 and 4.10 display the distances for barriers and enablers, respectively. The initial stage involves clustering the barriers and enablers in order to develop a comprehensive the total quality management strategy.

Table 4.9 Euclidean distance among the barriers.

From/To	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	0	1.3701	1.6702	1.7613	5.2302	2.4103	2.5535	1.5655	0.9534	2.5214
B2		0	3.0386	2.4471	1.9542	3.0455	3.9117	2.9302	2.1999	3.2025
B3			0	2.2508	1.8313	2.6856	1.0056	0.3262	1.0316	2.6927
B4				0	2.9166	0.6524	2.5171	1.9378	2.3430	0.7816
B5					0	3.5502	2.8354	1.9450	0.8255	3.6421
B6						0	2.7320	2.3602	2.9338	0.1734
B7							0	0.9916	2.0355	2.6752
B8								0	1.1200	2.3665
B9									0	3.0005
B10										0

Table 4.10 Euclidean distance among the enablers.

From/To	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
E1	0	3.4378	2.7200	4.3820	2.4062	2.3388	2.3615	3.1605	4.3173	3.5319
E2		0	2.7252	4.7269	1.5752	1.1548	2.8456	1.4065	4.4911	2.9851
E3			0	2.1336	1.2363	1.9176	0.4028	1.4272	1.9506	0.8119
E4				0	3.3558	4.0453	2.2621	3.3258	0.2764	1.7585
E5					0	0.6929	1.2821	0.7544	3.1550	1.7591
E6						0	1.9080	1.1486	3.8471	2.4424
E7							0	1.6613	2.1187	1.1910
E8								0	3.0864	1.5786
E9									0	1.5109
E10										0

This study deployed the elbow method to find the optimal number of groups. Figure 4.5 shows the elbow curve and the recommendation of k = 4 groups.

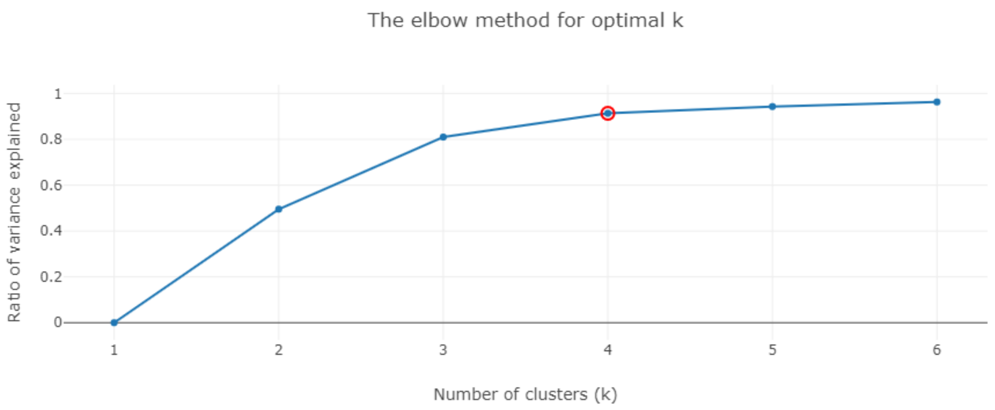

Figure 4.5 Optimal k of barrier clustering using the elbow method.

Then, the barriers are grouped into four groups based on their Euclidean distance. Figure 4.6 illustrates the scatter diagram of the grouping k-means technique. The white circles in the figure are the centroid of each group. Please note that the x-1 axis is the norm Z(RIV), and the x-2 axis is the norm Z(SDV).

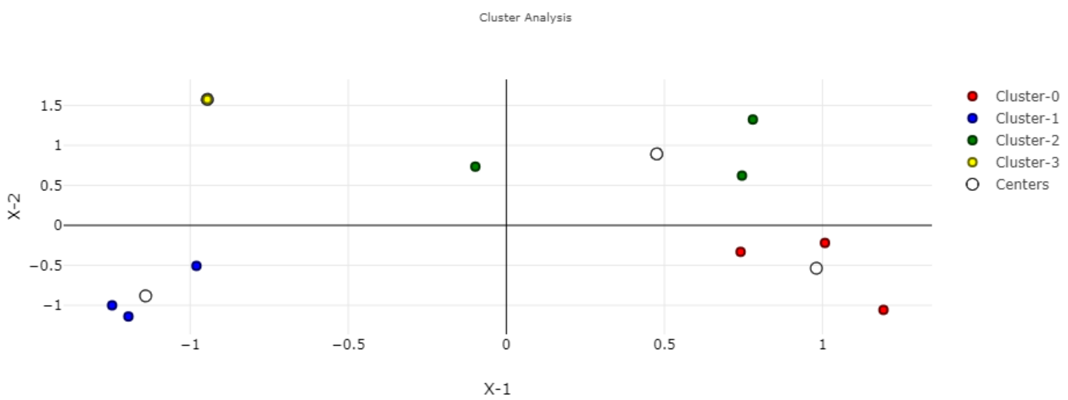

Figure 4.6 Barrier scatter diagram of clustering.

Table 4.11 summarizes the grouping using the k-means technique. The initial cluster is referred to as cluster 0. It consists of three obstacles: B3, B7, and B8. This cluster exhibits a high level of RIV (Relative Importance Value) and low level of SDV

(Standard Deviation Value), indicating a good level of importance assigned by the respondents to the barriers within the cluster. Additionally, there are some differences of opinion among the respondents, although these differences are less pronounced than in other clusters.

Table 4.11 Barrier cluster report.

Code	x_i	y_i	Cluster
B1	-0.1098	0.8630	2
B2	-1.0588	1.8513	3
B3	1.1281	-0.2583	0
B4	-1.0973	-0.5955	1
B5	0.8728	1.5552	2
B6	-1.3960	-1.1755	1
B7	1.3353	-1.2423	0
B8	0.8295	-0.3894	0
B9	0.8343	0.7306	2
B10	-1.3382	-1.3390	1

The second cluster, cluster 1, comprises three barriers: B4, B6, and B10. This cluster has low RIV; meanwhile, it also has low SDV, indicating that it is trustworthy. This group is optional in the barriers of the total quality management. The third cluster, cluster 2, contains three barriers: B1, B2, and B9. This cluster has a high RIV, while its SDV is also eminent. This group is on the waiting list if the company has a low resource. The fourth cluster, cluster 1, comprises one barrier, B2. This barrier is not essential for the total quality management in construction projects. Table 4.12 shows the centroids' cartesian of each group.

Table 4.12 Barrier cluster centroid.

Center	x_i	y_i
0	0.9805	-0.5364
1	-1.1409	-0.8826
2	0.4756	0.8936
3	-0.9458	1.5762

Fig. 4 .7 shows the optimal number of clusters for enablers. The Elbrow method also recommended that k = 4 be a good one. As a result, the 4-means based on Euclidean distance was deployed.

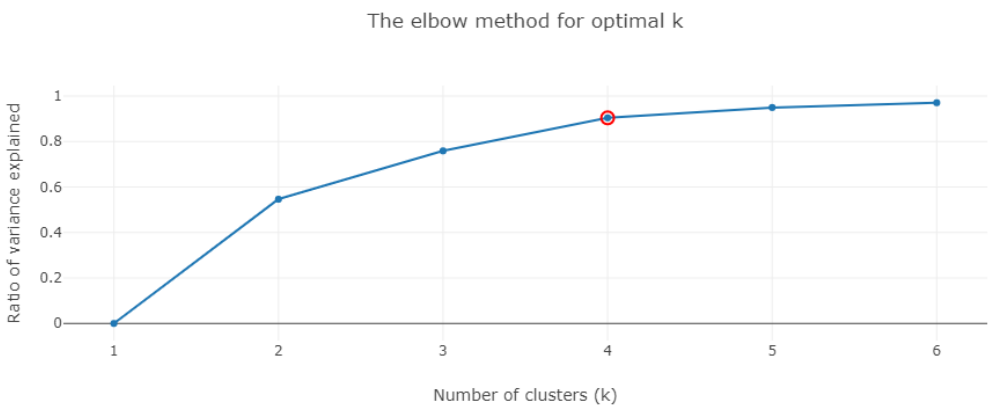

Figure 4.7 Optimal k of enabler clustering using the elbow method.

Figure 4.8 draws the scatter diagram of the clustering result. There are two clusters in quadrant 4, clusters 1 and 3. Cluster 1 comprises two enablers: E4 and E9. Cluster 3 comprises enablers: E3, E7, and E10. Cluster 0 is in quadrant 2. It includes E2, E5, E6, and E8. Finally, cluster 2 is in quadrant 3, which has only one enabler, E1, in there. Table 4.13 details the enabler clustering.

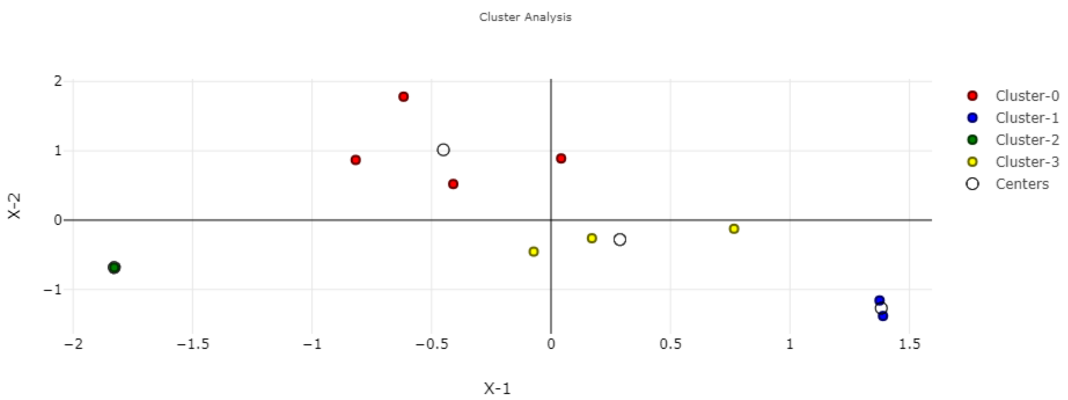

Figure 4.8 Enabler scatter diagram of clustering.

Table 4.13 Enabler cluster report.

Code	x_i	y_i	Cluster
E1	-2.4411	-0.8410	2
E2	-0.8239	2.1927	0
E3	0.2287	-0.3210	3
E4	1.8555	-1.7014	1
E5	-0.5464	0.6422	0
E6	-1.0919	1.0694	0
E7	-0.0967	-0.5584	3
E8	0.0565	1.0958	0
E9	1.8364	-1.4257	1
E10	1.0230	-0.1524	3

As a result, enablers E4 (Understanding the current and future marketplace) and E9 (Risk management and performance improvement) pave the way for the total quality management in construction projects. These two enablers allow the company to respond to customers’ needs while maintaining its performance and risk control.

Enablers E3 (Government and local administration regulations), E7 (Sustainable customer relationship), and E10 (Performance measurement tools: financial and non-financial indicators) support the total quality management. The construction project must comply with regulations well in the design, construction, and maintenance phases. This party is also a stakeholder of the project. Customer relationships mean that even a construction company must communicate with its customers regularly. Finally, many key performance indexes must be initiated to maintain high performance. Table 4.14 shows the centroids of four clustering.

Table 4.14 Enabler cluster centroid.

Center	x_i	y_i
0	-0.4503	1.0155
1	1.3821	-1.2702
2	-1.8277	-0.6832
3	0.2882	-0.2794

Figures 4.9 and 4.10 are the dendrogram of barriers and enablers clusterings, respectively.

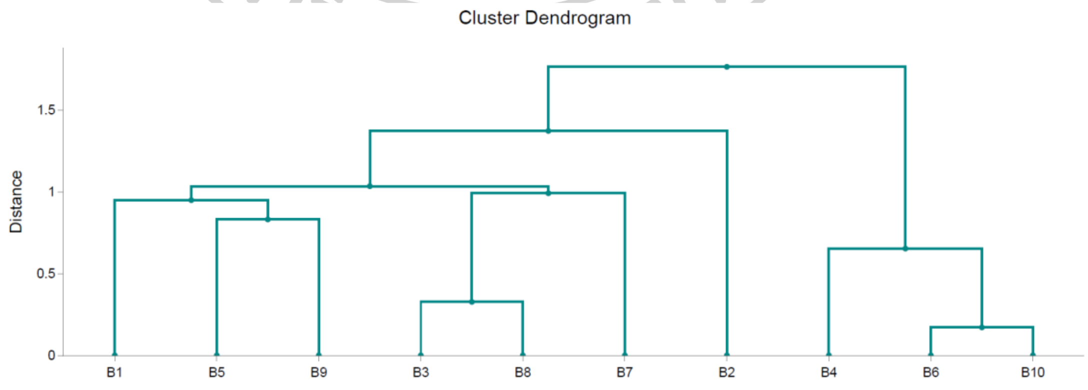

Figure 4.9 Dendrogram of barrier clustering.

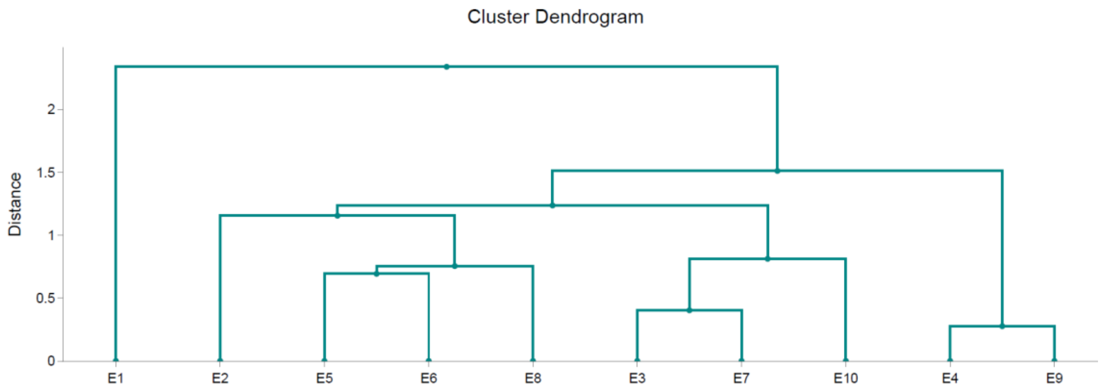

Figure 4.10 Dendrogram of enabler clustering.

CHAPTER 5
CONCLUSION

5.1 Conclusion

The barriers and enablers were drawn from the EFQM Excellence Model. They are a foundation of total quality management in the construction industry. However, it was suspected that the barriers and enablers are significant, especially in the context of Kunming's construction industry. Twenty barriers and enablers were excerpted, and the opinion of three hundred fifty-six workers in the construction industry was surveyed.

The result showed that the most significant barriers were B3 (Deviod understanding of customers' needs), B7 (Inadequate sales communication), and B8 (Mishandling of resources and assets). On the other hand, the most significant enablers were E4 (Understanding current and future marketplace) and E9 (Risk management and performance improvement). Furthermore, one more cluster supports the total quality management of the companies. It is a cluster of E3 (Government and local administration regulations), E7 (Sustainable customer relationship), and E10 (Performance measurement tools: financial and non-financial indicators).

Clustering is useful for management in launching a strategic plan to improve total quality management in the construction industry. Furthermore, management can invest its resources wisely by focusing on significant barriers and enablers.

5.2 Recommendations

The barriers and enablers were excerpted from the EFQM Excellence Model. It may be a different statement if they are excerpted from other quality models. Furthermore, a number of barriers and enablers could not be included in this study because of the survey study.

The study results may vary depending on the contexts of business, economy, and government policy. Accordingly, the results and conclusions in this study are a guide for a reader. The study process and research methodology are utilized.

5.3 Future Research

It is interesting to do more research on the findings of this study. How can a framework be designed for using findings to initiate a strategic plan for total quality management in the context of the construction industry? What are the key performance indexes in the construction industry to maintain high product/service quality and high business performance simultaneously?

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APPENDIX

APPENDIX A

The Quesstionnaire

Questionnaire

This form is the questionnaire for a research project of Mr. Yiming Liu, a student in the Master Degree of Engineering Program in Engineering Management at Silpakorn University. The topic is "Barriers and Enablers to Total Quality Management in Construction Projects: A Case of Construction Projects in Kunming, The People's Republic of China."

There are two parts. The first part asks about the respondent's background in the construction industry. The second part asks the opinion about the factors that influence TQM in the Kunming construction industry. It is a five-point Likert scale:

Score 1 means 'neglectable',

Score 2 means 'not important',

Score 3 means 'common',

Score 4 means 'important', and

A score of 5 means 'extremely important'.

Thank you very much for your cooperation. The data are kept secret and unopened to a third-party organization. The purpose of this study is academic only.

Part I:

No.	Question	Answer
1	Do your construction site is in Kunming?	□ Yes □ No
2	What is type of your construction site?	□ Residential buildings □ Non-residential buildings □ Road construction □ Railway construction □ Bridge, electrical, and plumbing construction □ Utility construction □ Demolition project □ Other……………… (specify)
3	How many employees in your construction site?	……………….employees
4	Is your construction project state-owned?	□ Yes □ No
5	What is your job position in the construction project?	□ Engineer □ Supervisor □ Site Manager □ Project Manager □ Economic responsible □ Procurement responsible □ CEO □ Other……………

No.	Question	Answer
6	How long you have been working in construction industry?	□ 0-1 year □ 1-3 years □ 3-5 years □ 5-10 years □ More than 10 years
7	What is your education level?	□ High school □ Vocational □ Higher vocational □ Undergraduate □ Master degree □ Doctoral degree
8	How old are you?	………………….years

Part II: Please read the questions carefully and then select the score based on your opinion. The statements that affect to the total quality management of your construction project.

No.	Statement	Score				
		1: neglectable	2: not important	3: common	4: important	5: extremely important
1	Lack of organizational vision, purpose, and strategy					
2	Implement circular economy principle for material utilization					
3	Devoid understanding of customers' needs					
4	Environment, health, and safety performance					
5	Disruptive technology and economy					
6	Lack of government relationship and support					
7	Inadequate sell communication					

No.	Statement	Score				
		1: neglectable	2: not important	3: common	4: important	5: extremely important
8	Knowledge management system in construction site					
9	Resources and assets mishandling					
10	Poor stakeholder perceptions					
11	Market research and other forms of feedback					
12	Poor data analysis and performance prediction					
13	Government and local administration regulations					
14	Understanding current and future marketplace					
15	Culture of creativity and innovation					

No.	Statement	Score				
		1: neglectable	2: not important	3: common	4: important	5: extremely important
16	Implements advanced analytics, such as predictive models, to get actionable insights and make informed decisions.					
17	Sustainable customer relationship					
18	Customers' perception about value of product and service					
19	Risk management and performance improvement					
20	Performance measurement tools: financial and non-financial indicators					

VITA

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