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Developing a new model to control risk and improve quality in the construction industry by integrating risk management and quality function deployment

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ABSTRACT

The construction industry is considered an indicator of a country's development through buildings, residential complexes, investment projects, roads, bridges, and infrastructure projects. Dynamic and complex features characterise this industry, which is directly and significantly affected by external and internal factors, in addition to the influences of its stakeholders. These characteristics and factors are considered one of the main reasons for generating risks in this industry, which can affect the quality and reputation of the construction project if its Risk Management systems are not followed systematically and correctly. Poor quality of construction projects has become a visible and widespread feature worldwide, including in Malaysia. Risk management is still applied on a low level in many projects within the construction industry. Quality Function Deployment is considered an essential modern system that focuses on quality, customer needs, and satisfaction, which can serve the construction industry if linked with risk management tools. The study's primary purpose is to find the relationship between RM and the QFD and develop a modern model for risk control in the construction industry through their integration. The conceptual framework of the proposed model is developed and applied to stakeholders in the construction industry in Malaysia. The results confirmed a solid, complementary, and interconnected relationship between RM and QFD, which can develop a new model for controlling risks and thus improve the construction project's quality. The results of the study recommended adopting this model. Recommendations were made to researchers to develop the model in the future to include broader areas in the construction industry.

Keywords: Construction Industry, Risk Management, Quality Function Deployment, Quality, House of Quality.

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1. Introduction

One sector that enhances countries' economic growth is the construction industry, which contributes significantly to development and improving national income [1]. It is considered one factor that increases the growth of countries' gross domestic product (GDP). It provides many investments and millions of job opportunities and contributes widely to developing the economic and social life of countries [2].
The characteristic of the construction industry is that it is highly dynamic; therefore, more uncertainties are inherent in it than in other industries. No construction project is completely risk-free because risks are considered a vital element or component in any project, regardless of the type or size of the project or its degree of complexity [3]. Leaving the accumulated uncertainties or risks unaddressed in construction projects directly affects the entire performance regarding quality, time, and cost [4].

Risks are defined as uncertain events that affect the project objectives, which include situations or conditions that, if they occur, would negatively affect the individual or overall aspects of the project [5]. In general, many types of risks can be exposed to the project, like (lack of financial allocations, defects affecting the project, accidents, clients, site, force majeure, contractors, employees, subcontractors, workers, crew, environmental, social, and political conditions, etc.) [6].

Risk management is essential in the wide world of project management because all parties contributing to the project monitor risks during implementation, such as (architects, engineers, designers, project managers, quantity surveyors, contractors, subcontractors, and clients). Risk management contributes to addressing uncertainty in the project effectively and decisively to maximise opportunities, reduce pressures, and improve performance [7]. The target of risk management is to control risks, identify their sources, and balance their inputs with their benefits to reach the ideal or convincing value for cost, time and quality, which means it is a type of analysis that compares benefits, losses, and treatment costs [5]. The paper in [8] explained that there are numerous gaps in the Malaysian construction industry relating to the knowledge of risk and quality management, which requires reviewing performance and risk management methods and developing modern concepts, foundations and rules to overcome those risks. Public perceptions of Malaysian construction projects are that they are weak and do not invest enough in training, research, and development, in addition to their poor profitability. The paper in [9] says that companies in the construction sector are the most exposed to risks. The leading players influencing the project, positively or negatively, are the consultants and contractors, and before them come the designers and implementers; this is reflected in quality, reputation, cost, time, and commitment. Different and unique features characterise the construction industry, and project performance can be negatively affected by these features if they are not dealt with properly, and this is evident in Malaysian construction industry projects.

In various production and service projects, customer requirements and needs can be considered drivers that generate risk, directly affecting time, costs, project reputation, and the relationship with project stakeholders [10]. Quality Function Deployment (QFD) was presented as an essential tool that can listen to customers' voices and transform them into technical and design requirements that serve the quality of the project and reduce its risk [11]. To find some solutions to the problems related to the construction industry, and as an objective to achieve high-quality products and services at the lowest cost and minimum time, there arises the need to find an integration that links the risk management processes within the project with a new tool or function, especially concerning risk management. This study suggests introducing another methodology to work alongside risk management. Quality Function Deployment (QFD) is the suggested tool for integration with risk management to control risks in construction projects. Integration with QFD is considered a new method or concept and requires demonstrating the efficiency of the outcomes and determining their effects on the construction project by resorting to more practical applications. The researcher will try to prove this in this study by developing a new model to control risk.

The research gap lies in developing a new paradigm that specifically addresses the unique challenges and complexities of the construction industry. This model should aim to improve risk control and mitigation strategies by incorporating key elements that are often overlooked in existing models. The field of this study has not previously explored the link between RM and QFD, especially in the construction industry. There have been attempts to integrate RM with other components and tools but not with QFD. Therefore, this research is a unique and significant challenge for the researcher. The research problem is poor quality as a result of poor use of RM in the construction industry in general and Malaysia in particular, and the research objectives are: (How can the relationship between RM and QFD be identified, then develop a new model be developed that can enhance quality through risk control in the construction industry). The appropriate methodology for this research (mixing qualitative and quantitative methods) has been chosen by reviewing the previous studies and literature concerning research tools.

2. Literature review

Quality is of utmost importance in the construction industry, as it ensures that buildings and structures are safe, functional, and meet the needs of their intended users [12]. Poor quality in construction projects and buildings can lead to various problems, including safety hazards, structural failures, and reduced lifespan. Stakeholders in the construction industry need to be aware of these quality problems and take steps to address them through proper planning, design, materials selection, quality control, and oversight [13].

The Malaysian industry is one of the sectors in the world that has been affected by poor quality as a result of poor management of risks and following the old classic methods of handling and controlling them [14]. In recent years, the growth of this industry has been widely observed, with government support represented by increased spending on infrastructure projects and private sector investments in residential and commercial development. However, the industry has faced several challenges, including quality problems, safety issues, and delays in project completion [15].

Quality function deployment is one of the most important concepts or methodologies focusing on customer needs. Also, giving importance to the customer's voice and listening to it is considered one of the most important factors that reduce risks and through which problems that occur before and during the project life cycle can be avoided [16].

2.1. Risk management

The modern concept of risk can be divided into three parts: (1) the presence of unexpected effects on the project results as an outcome of certain events; (2) working within unknown outcomes, meaning uncertainty; (3) unexpected benefits, as risks can affect the current experience and its future effects [17].

Risk always generates unexpected opportunities or threats due to various events within the project. It is a state of uncertainty that results in negative or positive effects. The rate of exposure to risks increases with the increase in complexity and diversity of services and products, but risks can be managed and predicted in many cases [18]. In general, many types of risks can be exposed to the project, such as (lack of financial allocations, defects affecting the project, accidents, clients, site, force majeure, contractors, employees, subcontractors, workers, crew, environmental, social, and political conditions, etc.) [6].

Risk management is "The proactive attempts to identify the internal and external events that may affect the success of a project" [19]. Mitigating or reducing potential losses or possible exposure to risks are the main objectives of the risk management (RM) methodology. Risk management contributes to addressing uncertainty in the project effectively and decisively to maximise opportunities, reduce pressures, and improve performance [7]. Several standards have been developed to assist organisations and institutions in implementing risk management effectively [20]. They are intended to provide a shared vision of processes and practices determined by international standards bodies or industrial groups. Many agencies work together to create or design these standards to promote common objectives and ensure that organisations with high quality implement the risk management process [21].

2.1.1. Risk management process

The concept that includes identifying, analysing, evaluating, monitoring and controlling risks is called the (risk management process). The primary objective of this process is to control the risk, reduce its negative effects, and turn it into opportunities. The risk management system can be described as the sequential steps during the project period that enable the identification of steps and options to reduce and control risks [22]. Risk management processes help improve and implement the decision-making process, identify options and mechanisms for mitigating risks, and measure unknown events [23]. Risks can be controlled and understood by developing a detailed risk management plan within risk management systems, which is essential for making the best decisions in the project to reach the specified objectives. (Figure 1) shows the stages of the RM process in general [24].

The paper [25] says the risk management process includes basic steps: (identification, analysis, evaluation, treatment, control, and reviews). To avoid the negative effects that may occur in construction industry projects, risks must be researched and found by applying different and modern methods and techniques within the risk management methodology. Effective risk identification requires the work team to have full knowledge of risk management methods and the ability to apply them correctly and systematically [26]. The risk management process consists of essential components:

Step 1: Risk Identification:

These are the activities that describe, discover, and then classify the potential risks facing the project, which negatively affect the project's work and financial assets, in addition to the significant impact on quality, performance, and reputation [26]. This assessment can be quantitative or qualitative).

Step 2: Risk Analysis

The risk analysis system provides essential inputs to the risk assessment and decision-making process to choose the appropriate strategy for managing and responding to the risk [27]. The process of determining the probability and causes of risks and their effects is called (risk analysis). A systematic risk analysis can be achieved by using two techniques (Qualitative analysis and quantitative analysis). The Risk Analysis Tools and Techniques (Qualitative and quantitative) have different specifications for each one, as shown in (Table 1) [28].

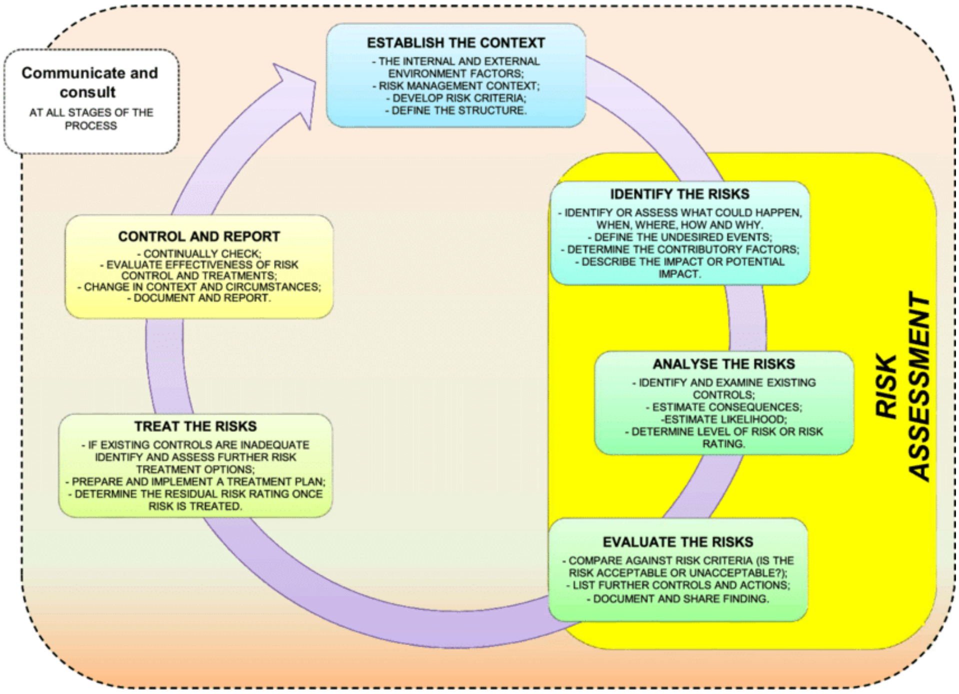

Figure 1. Risk Management Process [24]

Table 1. Specifications of quantitative and qualitative risk analysis

Qualitative	Quantitative
Risk probability and Impact assessment	Data Gathering & Representation Techniques
Probability and Impact Matrix	Quantitative Risk Analysis & Modelling Techniques
Risk Data Quality Assessment	Sensitivity Analysis
Risk Categorisation	Expected Monetary Value (EMV) Analysis
Risk Urgency Assessment	Decision Tree Analysis
Expert Judgment / Direct judgement	Tornado Diagrams - Monte Carlo Analysis
Ranking option	Expert Judgment
Comparing option	Probability analysis
Descriptive analysis	Scenario analysis
	Simulation analysis

Step 3: Risk Evaluation

The risk evaluation process is used to help make appropriate decisions regarding risk treatment, and the identified risks are compared with the expected risks to determine the significance of those risks [5]. Risk evaluation is defined by the Business Dictionary as: "Determination of risk management priorities through establishment of qualitative and/or quantitative relationships between benefits and associated risks" [28]. [5] stated that two additional factors were considered: the duration and cost of treatment, as well as its detection, occurrence, and severity.

Step 4: Risk Treatment

This process involves identifying and implementing the necessary measures and methods to treat risks. The type of treatment varies according to the type of risk and can be (risk-avoiding, risk-transferring, risk-improving, or risk-retaining). [28] explained that the risk modification process is a definition of risk treatment. The risk modification process includes resorting to one or several treatment options to reduce the risk level to low limits acceptable to the company or organisation and can be implemented practically [29].

Step 5: Risk Control

The risk control process includes implementing a risk response plan and monitoring and reviewing the risk response to that plan. The risk control response developed must be fully documented for future project planning and reference [30]. Risk control seeks to reduce risk and does not attempt to remove the source of risk [31]. Risks that remain under control are considered potential threats, but the likelihood of an associated accident is significantly reduced [32].

Step 6: Risk Reviews

The best definition derived from the name risk reviewing is the periodic and regular reviews of project-related risks and planned responses to risks [5]. The effectiveness of the risk response should be documented for further review. Throughout the project period, a risk review process is conducted regularly and periodically to assess the current project environment and indicate whether there is a need to change the risk management plan in the future [33].

2.1.2. Risk Management in the Malaysian Construction Industry

The construction industry is an essential contributor to Malaysia's economy [34]. Despite the development of this industry, there are many problems related to completing the project within the specified time and financial budget. [8] explained that companies in the construction sector are the most exposed to risks. The major players influencing the project, positively or negatively, are the consultants and contractors, and before them come the designers and implementers; this is reflected in quality, reputation, cost, time, and commitments [9].
Many risk-related issues have hampered the work of construction companies in Malaysia and directly affected their operations. These companies are still in the initial stage of implementing risk management systems [8]. The level of implementation of risk management processes is still low in the Malaysian construction industry, and the significant reason for this decline is the lack of complete knowledge of the construction project engineers and technicians about risk management techniques or their poor and unsystematic use [35]. [36] pointed out the use of simple techniques and old tools to identify, analyse, and control risks within Malaysian construction projects, and this relative decline in risk management practices results from a lack of sufficient knowledge of risk management methods. [37] explained that there is a requirement to execute risk management in construction projects in Malaysia because these projects have many risks, and this industry has a dynamic and complex nature.

From what was reviewed in the previous literature, it is clear that the level of RM application in Malaysia is still below the level of expectations and requires a lot of work and effort so that construction projects can be demonstrated in an ideal manner and free of problems related to quality, time and cost.

2.2. Quality function deployment (QFD)

Companies and institutions understand the needs and requirements of customers so that they can develop their products and services, which is reflected in the levels of sales and marketing [11]. Product quality, cost, and high reliability are essential for competition between companies. This requires developing advanced and modern methods for designing and developing products and services and following a systematic strategy to achieve this. The most crucial factor that must be considered when designing a product or service is the Voice of the Customer (VoC) because customers concentrate on the quality and value of products before purchasing them [38].
A methodology or tool called Quality Function Deployment (QFD) is used, which, through its organised processes and plans, can manufacture products and provide services that satisfy customers and fulfil their desires and needs [39]. QFD is a systematic process that helps companies or organisations plan to implement several technical support tools efficiently and effectively to determine customer requirements and needs. [11] defined Quality Function Deployment (QFD) as a tool that achieves maximum customer satisfaction and works to transform customer requirements and needs into technical and engineering characteristics that can be trusted. Because of their high effectiveness in managing quality and determining product expenditures, QFD applications have been widely used and adopted for three decades after Japanese academics and industrialists began formalising QFD techniques in the 1960s and 1970s [38].

[11] pointed out that the QFD tool was developed to link it to modern manufacturing and service provision operations businesses. In recent years, this technology has begun to be used in the construction industry and is being applied in many different manufacturing [40]. The paper [41] reported that QFD is still constantly

evolving due to customer lifestyles, changes in the market, technology advancement, and intense competition between companies. One of the most notable developments in recent years is (ISO 16355), developed by QFD Institute experts. In 2016, (ISO 16355) the first ISO standard for QFD was approved. QFD is also considered an essential tool within Total Quality Management (TQM), and it is used in various industries, the most important of which is manufacturing. Figure 2 shows the history of QFD in Japan and the USA [40].

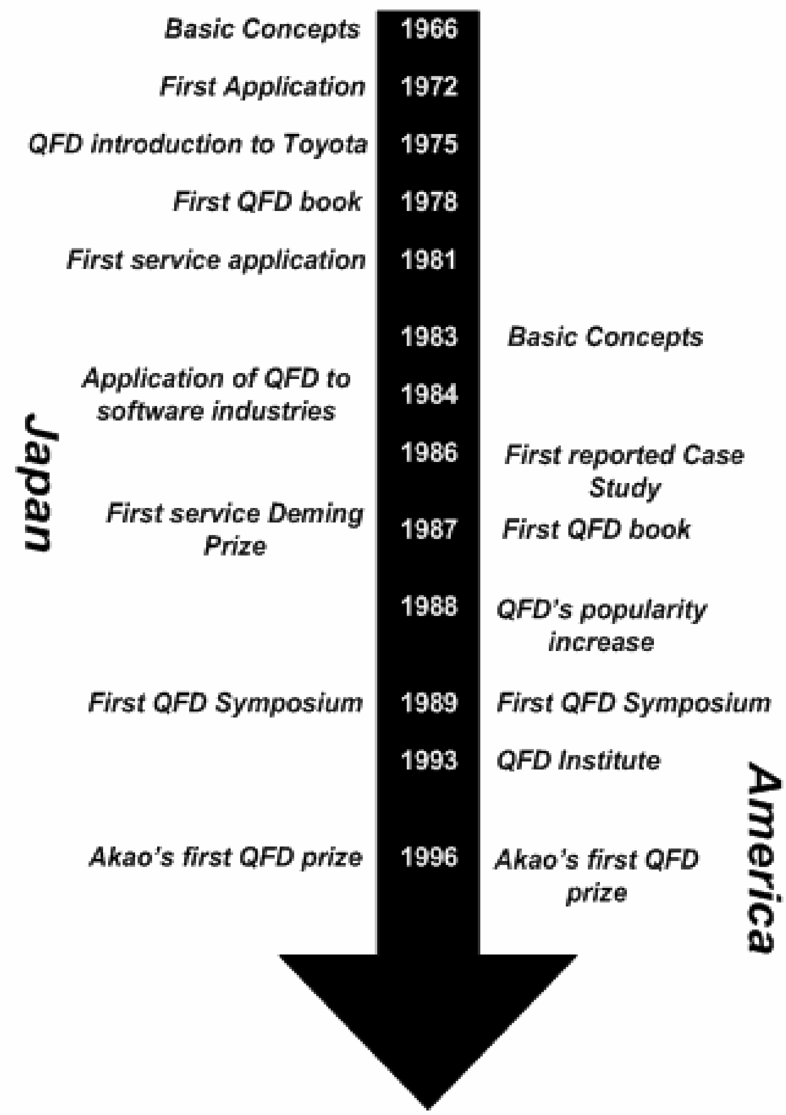

Figure 2. History of QFD [40]

2.2.1. Quality function deployment process

The most significant phase of the QFD process is the product planning matrix, commonly called the House of Quality (HoQ). All product details must be considered in this matrix, through which the mechanism of action is determined in the subsequent stages of QFD [42].

Four main matrices make up the main structure of QFD. The house of quality represents matrix number one, and its task is essential in translating and transforming the needs and requirements of customers into design and technical requirements [43].

The second matrix includes partial specifications, which are part of the technical requirements, which will appear later in the third matrix as process requirements. Quality specifications are specified in the fourth matrix. The most important stage of the QFD process, which stems from the customer's voice, is the House of Quality (HoQ) [44]. Four main stages are involved in QFD processes, which are as follows: (product planning, product development, process planning, and production planning).

1. Product Planning: The matrix of house of quality is used in this phase to translate and transfer customers' requirements and needs into design requirements. This is done by conducting interviews and Focus Group Discussions (FGDs) to collect the Voice of the Customer (VoC). Comments and feedback generated by customer needs are categorised to determine product features and design considerations.

2- Product Design: By identifying the product's assembly components and important parts, the work team can determine the design requirements at this phase. This is done based on the priorities collected during the first phase (product planning).

3- Process Planning: By knowing the list of requirements that were established in the product design phase, appropriate decisions are made in this phase related to the processes (design, manufacturing, assembly) of the product. In this phase, the staff must have the ability to identify the necessary elements, instructions and operational standards.

4- Production Planning: Production, inspection, and process control methods are developed within this final phase. This ensures that product characteristics are subject to continuous evaluation and improvement. Figure 3 explains the four major phases of QFD [45].

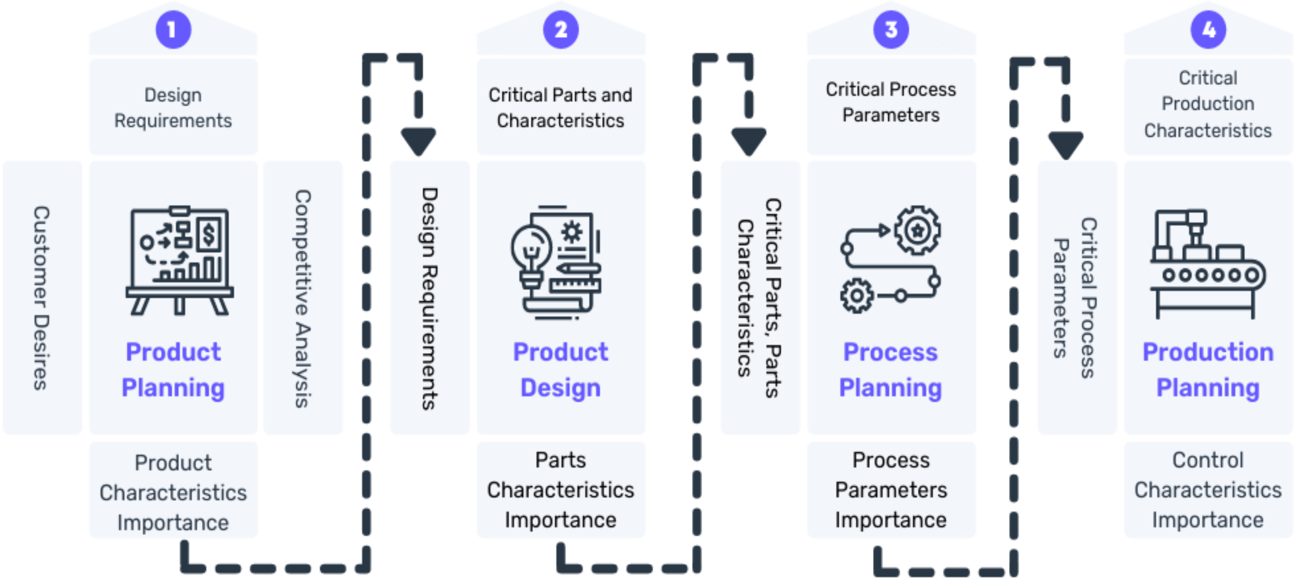

Fig. 3: The 4 Phases of QFD [45]

This method can be used in all industries, services, or administrative processes because it is cost-effective and relatively easy to apply in implementation, analysis, and documentation processes [46]. By using this method, quality costs are better planned, and the planning of products becomes an essential section of the quality planning process in addition to constantly improving product quality. Shortening production cycles, lowering production costs, and identifying the company's ability to compete by identifying its strengths and weaknesses are unique features of QFD [47].

2.2.2. QFD in the construction industry

QFD uses the evaluation of customer expectations to reflect positively on product specifications. It has been applied in many industries globally, and it has been applied in the construction industry in recent times, but it is still at the beginning of its era within this industry [48]. QFD can be implemented and adopted as a tactical instrument in construction projects to facilitate marketing decision-making [48]. The project's financial goals are affected by customer expectations and other elements concerning contractors and the project management team. Considering QFD as a long-term methodology in the construction industry and adopting it by stakeholders helps reduce project delays [49].

[47] explained that the QFD concept has not been broadly used in construction projects to calculate options. This result is considered surprising within the construction industry because of the wide application and use of this methodology in other industries. Many quality concepts can be expanded through the increasing application of QFD in construction management and the transfer of experience from another manufacturing to the construction industry [50]. However, the authors see the possibility of applying QFD in the construction industry to the same extent if it is applied correctly and systematically because it is equally interested in providing high-quality and safe buildings [16].

On construction sites, QFD can be used to control work activities, risky events, and potential consequences within the application of safety measures. This will lead to less ambiguity in qualitative evaluation criteria and greater effectiveness in the decision-making process [51]. Many limitations prevent the expansion of QFD experience in the construction industry, the most important of which is the lack of awareness of this method, the adoption of old classic methods, and the fear of Entering into an adventure by applying modern methodologies in construction management. Like other countries, Malaysia is still initially adopting the QFD methodology, especially in construction projects.

3. Conceptual Framework of the Study

This study's conceptual framework focuses on the relationship between Risk Management (RM) and Quality Function Deployment (QFD) within the construction industry. (Figure 4) shows the details of the conceptual framework (the integration between RM and QFD to enhance quality in the construction industry). The model resulting from the integration is called the Risk Quality Model (RQM).

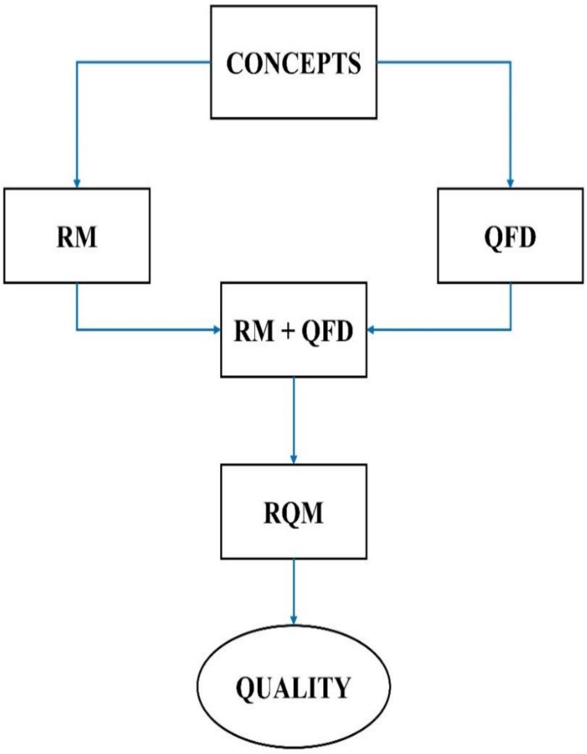

Figure 4. Conceptual framework of the study

Risk Management (RM) and Quality Function Deployment (QFD) are two essential tools that can be integrated to control risk in construction projects. To identify and determine the risks facing the project at an early stage and the possibility of mitigating their effects, systematic measures resulting from the integration of these two tools are used to achieve customer requirements with the least impact from the risk [52]. Companies and organizations can ensure access to the required quality and achieve their values, objectives and customer's desires by applying this integration, in addition to improving the process of developing their products. The proposed model in this study (RQ Model), which results from the integration between RM and QFD, is shown in Figure 5.

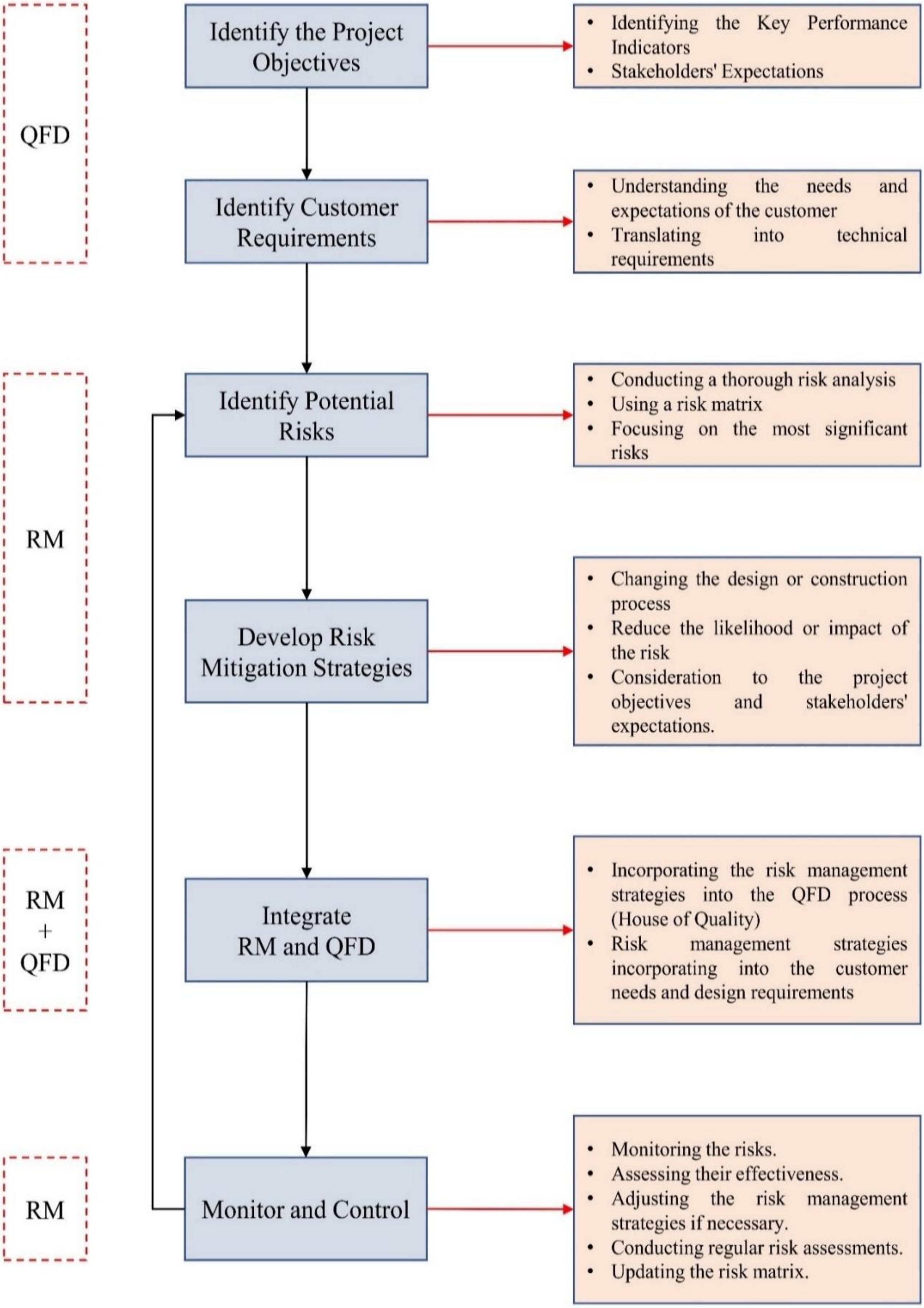

Figure 5. Proposed model of the study (RQM)

The process of integrating and applying study tools (RM & QFD) within construction industry projects is summarized in the following steps:

1. Project Objectives Identifying: To measure the effectiveness and efficiency of the project, one must define Key Performance Indicators (KPIs), which result from the expectations and desires of customers and stakeholders and are reflected in the project objectives. These expectations must be fully consistent with performance indicators.

2. Customer Requirements Identifying: Customers' expectations, needs, and requirements must be understood and transformed into technical requirements in designing the product or service. Determining customer requirements is the main stage in QFD.

3. Potential Risks Identifying**:** The current step, which comes after identifying customer needs, includes identifying risks of importance and high impact through the use of a risk matrix and conducting a comprehensive risk analysis, which enhances the project’s ability to meet those needs.

4. Developing Strategies of Risk Mitigation: In this step, risk mitigation strategies can be developed by determining risk priorities. When implementing any type of strategy, the project objectives and the expectations of customers and stakeholders must be taken into consideration. To reduce or limit the effects of risks and the possibility of their occurrence, a change can be made in the design processes.

5. RM and QFD Integration: Here, risk management strategies can be integrated with QFD processes and linked to design requirements and customer needs, which means that during the product or service design process, risks will be taken into consideration, and a quality management plan will be developed with fewer risks. This ensures obtaining a high-quality product and achieving customer requirements and project objectives at the same time.

6. Risk Monitoring and Control: During the project life cycle and after completing the previously conducted processes, risks must be monitored and controlled. It is necessary to update the risk matrix, assess risks and their effectiveness regularly, and resort to modifying risk management strategies if necessary.

4. Methodology

Risk management is considered one of the most important factors that can be integrated with QFD to improve quality in the construction industry. Previous literature pointed out the weaknesses in the application of risk management systems, which were summarized in:(concepts and implementation, problems and causes, obstructions, and influences). The literature related to QFD has indicated many important factors affecting the application of QFD in the construction industry, which are: (concepts and implementation, customer needs, problems and causes, obstructions, and influences). Finally, the integration process between (RM) and (QFD) can be affected by the following factors (concepts and implementation, obstructions, and advantages). These research tools and the integration process result from the questions and objectives of the study.

Declarative hypotheses were used to achieve the objectives of the study, which consist of the following:

1. H1: RM has a significant and positive influence on integrating (RM and QFD).
2. H2: RM has a significant and positive influence on the QFD.
3. H2.1: Conceptual and implementation have a significant and positive influence on the QFD.
4. H2.2: Problems and causes have a significant and positive influence on the QFD.
5. H2.3: Obstructions have a significant and positive influence on the QFD.
6. H2.4: Influences have an important and positive impact on QFD.
7. H3: QFD has an important and positive impact on integrating (RM and QFD)

The research process related to this study was adapted, modified, and developed, as shown in (Figure 6). The formulation of the research process included three phases related to the research questions, and the mixed method strategy (quantitative and qualitative) was used in this process.

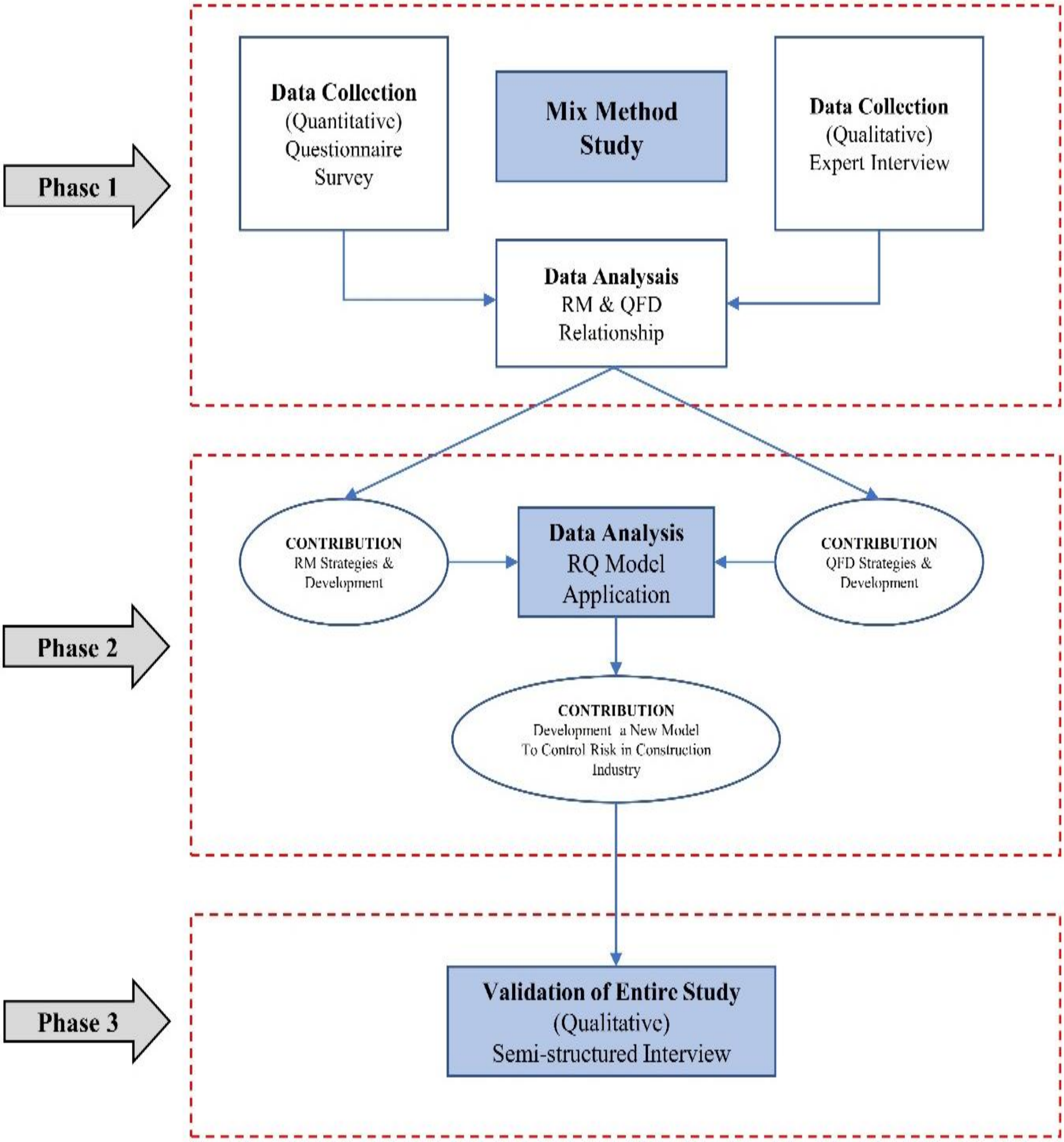

Figure 6. Research process of the study

In the qualitative method, the semi-structured interview questions covered issues such as general perceptions and beliefs about integrating risk management with quality function deployment to enhance quality in the Malaysian construction industry; for validity, the interview questions were also reviewed by experts. The qualitative study relates to regular interviews with (10) experts in the field of RM and QFD (academics and experts), where the interviews included questions for reaching the study's first objective to be compared with the results of the first objective resulting from the quantitative study.

Regarding the quantitative study (quantitative survey), an online questionnaire (Google Form) was conducted that included the opinions of stakeholders in the construction industry, including engineers, technicians, consultants, project managers, company managers, contractors, and academics, to reach the first study objective and compare these results with the pilot study. The final stage included structured and regular interviews with (10) experts in the construction industry and consultants (a qualitative study) to verify the study's second objective and check the validity and reliability of the proposed conceptual framework (the study model).

The study was limited to the construction companies and contractors in Malaysia within grade (G7) in the Construction Industry Development Board (CIDB). Within (CIDB), the highest rating for companies is (G7), Which enables companies within Malaysia to implement large-scale construction projects with unlimited financial value (Mega-projects) [53]. Therefore, they were chosen as samples within this study, as they have the highest chance of winning mega projects and have unlimited tendering capacity. (5,117) construction companies were selected out of (9,332) companies. It is the number of companies of the (G7) in the states of W.P. Kuala Lumpur and Selangor concerned with the study.

In the correlational study, (30%) of the population size was adopted as a highly reliable sample. Population Size = 30% * 5117 = 1535. Based on the statistical equations related to determining the sample size, the required sample size is 308.

Conducting data analysis is a process that includes several stages, such as entering response data, examining data, and choosing the appropriate strategy for analysing the data [54]. In this study, the data examination was conducted to identify errors in the entered data. This examination included (missing data, normality, outliers testing, descriptive data, linearity, multicollinearity, and response bias tests). Version 25 of SPSS software has been used to conduct statistical analysis. In the beginning, the demographic and descriptive properties of the interviewee were analysed, and the reliability and validity of the measurement scale were tested in the second stage. The third version of Partial Least Square (PLS-SEM) within the Structural Equation Modelling (SEM) method was used in the third stage. It was adopted to test the hypothesis relationships, examine the measurement model, and conduct statistical analysis (PLS-SEM) because it is more applicable. To evaluate the proposed model for this study, (Smart-PLS) version 3 was used.

The reflective model was used in this study to assess the assessment model that includes (construct validity, convergent validity, and discriminant validity of reflective constructs). On the other hand, the investigator used the formative model to test the main and sub-hypotheses for risk management (concepts and implementation, problems and causes, obstructions, influences) influence on integration of (RM) and (QFD) and main and sub-hypotheses of quality function deployment (concepts and implementation, customer’s needs, problems & causes, obstructions, influences) influence on Integration of (RM) and (QFD). Also, the study tested the influence of RM on QFD. To further verify the variables, some suggestions were made through the pilot study, confirming that all questionnaire items are considered valid and reliable. A reliability test to verify the reliability of the Likert scale questions was conducted after completing the pilot study consisting of (35) questionnaires that were analysed using (SPSS) version 25.0. After completing the reliability testing of the instrument, the questionnaire was distributed to partners in the construction industry in Malaysia.

5. Results and discussions

A questionnaire (quantitative) was conducted in addition to a pilot study to verify the first objective specified in this study, and quantitative statistical methods were followed for the analysis and presentation of the results. The correlation range includes the probability of three levels of correlation (high, moderate, weak), and its value should be between (- 1.0 ~ + 1.0); it is also associated with a p-value (<0.05) to indicate significance or not.

The highest correlation value that appeared in the results was between the obstructions (QQ) and advantages (IA) (0.794). Followed by problems and causes (QP) and obstructions (RO) (0.844), and the p-value was (0.000). Oppositely, the minimum correlation value between the variables was concepts and implementation (QC) and obstructions (IO) with (0.070) is not significant (p>.05). The correlation values between the variables are less than (0.85); this appeared clearly in the correlation matrix. The results show that among the model constructs used in the study, multicollinearity cannot be considered a problem [55].

The Standard Deviation (SD) and Mean measurement scale were calculated. The Likert scale ranging from five-point (“5” strongly agree to “1” strongly disagree) was used in the study. The main objective of the mean and (SD) is to measure the level of risk management (RM), quality function deployment (QFD) and integration of (RM) and (QFD) among construction stakeholders within the construction industry in Malaysia. Table 2 indicated that the highest value of the mean score was customer needs (QN), with (4.182) out of a maximum of (5) making up (83.6%) and influences (RI) was (4.035) making up (80.7%). In contrast, obstructions (RO) had the lowest mean score at (3.705), making up (74%) of the mean score of these values (the overall mean) was (3.895) out of a maximum of (5) or (77%). Also, the (SD) for all variables set out from (0.271 to 0.936); this means that the data set has a considerable acceptable variability. Table 2 explains the variables' descriptive statistics.

Table 2. Variables descriptive statistics

Main Factor	Sub-Factor	Variable	No. of Items	Mean	%	SD
Risk Management (RM)	Concepts and Implementation	RC	6	3.7905	75.81	.48237
	Problems and Causes	RP	4	3.8152	76.304	.79714
	Obstructions	RO	3	3.7056	74.112	.93627
	Influences	RI	4	4.0357	80.714	.73642
Quality Function Deployment (QFD)	Concepts and Implementation	QC	5	3.9263	78.526	.27118
	Customer Needs	QN	5	4.1822	83.644	.57678
	Problems and Causes	QP	4	3.7600	75.2	.74717
	Obstructions	QO	8	3.9694	79.388	.72229
	Influences	QI	4	3.7632	75.264	.63339
Integration of (RM) & (QFD)	Concepts and Implementation	IC	5	3.8959	77.918	.76255
	Obstructions	IO	4	3.9770	79.54	.72054
	Advantages	IA	5	3.9476	78.952	.73495
	Total		57	3.9402	78.804	.65175

As shown in Table 2, the results indicate that the values of (Cronbach's alpha) lie between (0.754) influences (QI) and (0.940) Obstructions (QQ) while the values of composite reliability (CR) started from (0.844) to (0.949) for the same variables. Therefore, all values for reliability and composite reliability constructs were higher than the recommended value of above (0.60). Constructs have an Average Variance Extracted (AVE) of at least (0.5), and Composite Reliability (CR) measures of internal consistency reliability are above (0.70). To obtain adequate convergent validity, [56] recommended that the AVE of each latent construct should be higher than (0.50) and range from (0.754) QI to (0.931) QC. Thus, convergent validity was confirmed in the study. Related to the measurement values, the minimum estimation required for all constructs has been achieved, which are (0.70) for Cronbach alpha, (0.50) for Average Variance Extracted (AVE), and (0.60) for Composite Reliability (CR). The correlation values between the independent variables were less than (0.85). The discriminant validity was confirmed, as shown in the results of the correlation matrix. The study model appears an excellent suitable for the data as indicated by the value of Squared Multiple Correlations (R^2) for the dependent variable: Integration of (RM) and (QFD) (R^2=0.675), as seen in (Table 3) and (Figure 7). Thus, risk management (concepts and implementation, problems and causes, obstructions, and influences) explained (72.2%) of the variance for the dependent variable, the quality function deployment among construction stakeholders. Meanwhile, risk management and quality function deployment explained (67.5%) of the variance for the dependent variable, the integration of (RM) and (QFD) among construction stakeholders within the construction industry in Malaysia.

Table 3. Coefficient of determination result (R^2)

Independent Variable	Dependent Variable	R^2	Hair et al. (2019)	Cohen (1988)	Chin (1998)
Risk Management (RM)	Quality Function Deployment (QFD)	0.722	Moderate	Substantial	Substantial
Risk Management (RM) and Quality Function Deployment (QFD)	Integration of (RM) & (QFD)	0.675	Moderate	Substantial	Substantial

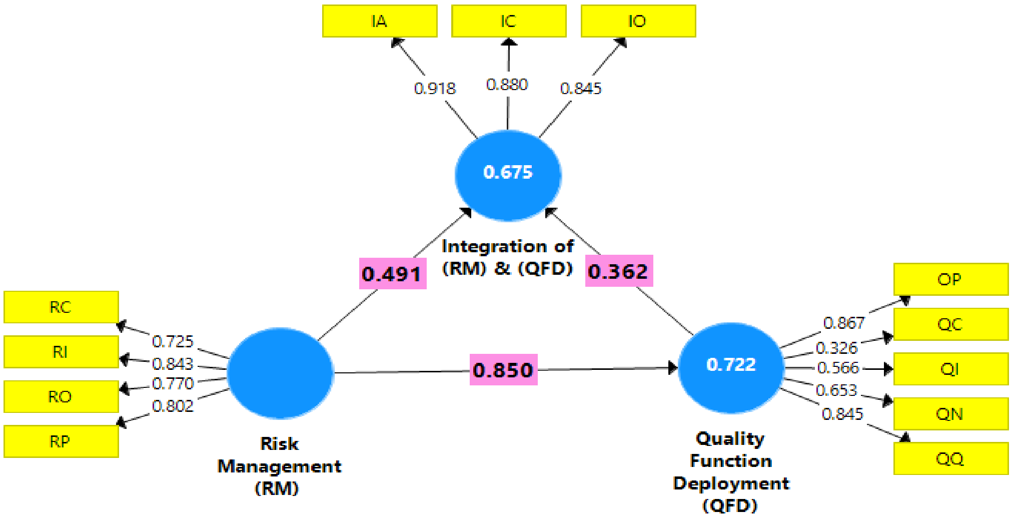

Figure 7. Measurement model with (R^2) for main constructs

The blindfolding method has been used during this study to determine the predictive significance of the research model. This method just uses endogenous latent variables to operationalise the reflective measurement model. To evaluate the predictive significance of the research model, the researcher applied a cross-validate redundancy measure (Q^2) [57]. To check how successfully the model forecasts the omitted case data, the (Q^2) method is used [57]. A research model with (Q^2) statistics greater than zero is considered to have predictive relevance. (Table 4) indicates the cross-validation redundancy measure (Q^2) for two dependent variables, Quality Function Deployment (QFD) and integration of (RM) and (QFD), were above zero at (0.493) and (0.296), consecutively. For this matter, the model has predictive significance [58]. Table 4 and Figure 8 show the construct cross-validated redundancy.

Table 4. Construct cross validated redundancy

Main Variable	SSO The sum of Squares of Observations	SSE The sum of Squares Errors	Q^2 =(1-SSE/SSO)
Integration of (RM) & (QFD)	945.000	479.313	0.493
Quality Function Deployment (QFD)	1,575.000	1,108.523	0.296
Risk Management (RM)	1,260.000	1,260.000	

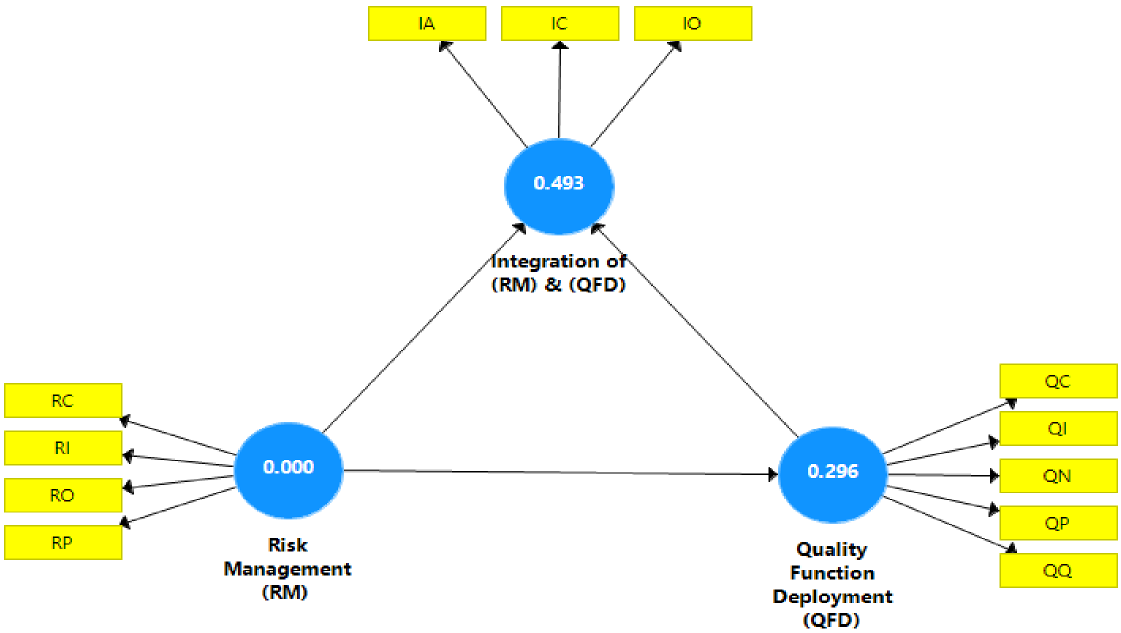

Figure 8. Predictive Relevance (Q^2)

To determine the first objective, the relationship between (RM and QFD) in the construction industry, the Mean and (SD) of the measurement scales were calculated. The outcomes explained that the highest mean score was the (S8) “The obstructions that prevent the implementation or adoption the Integration of (RM) and (QFD) in the construction industry” of meaning standards with (4.70) (more than 3) out of the maximum (5) making up (94%). This is followed by (S2) “Both (RM and QFD) promote a culture of continuous improvement. (QFD) helps in improving product or service quality based on customer feedback, while (RM) ensures that potential risks to quality are proactively managed and minimised” and (S5) “There is a real need to find a new model that links risk management tools with customer needs and QFD” had both 4.60 making up approximately (92%). However, the (S6) “The QFD can be adopted and considered as a tool for RM” had the lowest mean scour with (4.10) (more than 3) out of a maximum of (5), making up approximately (82%). Additionally, the value mean (total mean) was (4.487 or 89.74%). As noted from the interviews of participants, all respondents strongly agreed that there is a relationship between (RM and QFD) in the construction industry in Malaysia. Furthermore, the (SD) for all variables was from (0.483) to (0.738); this means that considerable acceptable variability exists within the set of data. The findings showed that the standard deviation scores for all the interview questions are less than (1.00), and the data have more reliability (around the mean, the data are clustered closely) as indicated by the lower standard deviation [57]. Table 5 presents the mean and SD for interview questions.

Table 5. Descriptive Statistics for the relationship between (RM & QFD) in the construction industry

Code	Questions	Mean	Percent %	Standard Deviations
S1	RM & QFD play complementary roles in ensuring the success of a project or the delivery of a high-quality product or service. In the sense that effective risk management can enhance the quality of products or services developed using the QFD approach.	4.50	90%	.707
S2	By identifying risks early in the QFD process, teams can develop contingency plans or design features that address these risks, ensuring that quality is not compromised.	4.30	86%	.675
S3	Both RM and QFD promote a culture of continuous improvement. QFD helps in improving product or service quality based on customer feedback, while RM ensures that potential risks to quality are proactively managed and minimised.	4.60	92%	.516
S4	RM involves ongoing monitoring and control of identified risks. QFD can benefit from this by incorporating mechanisms to track and control potential risks that could affect product or service quality throughout the development process.	4.50	90%	.707
S5	There is a real need to find a new model that links risk management tools with customer needs and QFD	4.60	92%	.516
S6	The QFD can be adopted and considered as a tool for RM.	4.10	82%	.738
S7	The benefits or outcomes of Integration between (RM) & (QFD) in the construction industry may include the following: □ Increase customer satisfaction □ Meets customer requirements □ Proactive risk mitigation □ continuous improvement □ Improving the quality □ Reducing time and cost □ Avoid tangible losses financially □ Resilience to uncertainty □ Stakeholder confidence □ Save reputation	4.60	92%	.516
S8	The obstructions that prevent the implementation or adoption of the Integration of (RM) & (QFD) in the construction industry may include the following:	4.70	94%	.483

Code	Questions	Mean	Percent %	Standard Deviations
	lack of experience Lack of awareness Fear of adopting a new tool Unexpected results Lack of sufficient data Resistance to change Resource allocation Short-term focus Educational curricula and training courses			
	Overall	4.487	89.74%	.5811

By applying Structural Equation Modelling (SEM), the validity of the statistical model was confirmed, and the proposed framework or model obtained the approval of experts in the construction industry. This process aims to match the study's objectives with the proposed framework and ensure the objectives are successfully achieved. Based on what was stated in the recommendations of [59], the researcher carried out the process of verifying the validity of the research models, and it was sent to ten academic experts and consultants in the sector of construction projects.

As shown in (Table 6), the findings showed that the highest mean score was the (V6) “Recommending the adoption of the model” of meaning standards with (4.60) out of a maximum of (5) making up (92%). This means all respondents recommended the adoption of the study's conceptual framework. This is followed by (V3) “future development potential and flexibility of implementation” (V4) “the positive impact of the model on quality” and (V5) “contribution of the model to the construction industry” had the mean (4.50) out of a maximum (5) making up almost (90%). However, the (V2) “accuracy of the model / connecting tools leads to a positive result” had the lowest mean scour at (4.20), making up approximately (84%). Additionally, the (V1) “accuracy of the model / connecting tools leads to a positive result” had a mean score of (4.40) or (88%). Moreover, the mean of these values (total mean) was (4.45) (more than 3) or (89%). This means it is possible to implement the model of research. Also, the research framework positively influences Quality Function Deployment (QFD). As noted from the results, a low value of (SD) showed that the data are clustered closely around the mean (more reliable and valid) [57]. In summary, it can be observed that most informants agreed with the conceptual framework to enhance the construction quality in the construction industry in Malaysia and verify their validity and reliability.

Table 6. The Mean, percent and standard deviation for developing a conceptual framework and verify their validity and reliability

Code	Interviews Questions	Mean	Percent %	SD
V1	The practicality of the model / It can serve the target	4.40	88%	.699
V2	Accuracy of the model / Connecting tools leads to a positive result	4.20	84%	.632
V3	Future development potential and flexibility of implementation	4.50	90%	.527
V4	The positive impact of the model on quality	4.50	90%	.527
V5	Contribution of the model to the construction industry	4.50	90%	.707
V6	Recommending the adoption of the model	4.60	92%	.516
	Overall	4.45	89%	.208

Table 7 and Figure 9 display all hypotheses tested and a summary of their results.

Table 7. Results summary related to hypotheses tested

Variables	Direct effect with Quality Function Deployment (QFD)		Direct effect with Integration of (RM) and (QFD)	
Variable	Hyp. No.	Result	Hyp. No.	Result
Risk Management	H1	√	H2	√
Quality Function Deployment (QFD)	H3	√	-	-
Concepts and Implementation	H2.1	√	-	-
Problems and Causes	H2.2	√	-	-
Obstructions	H2.3	√	-	-
Influences	H2.4	√	-	-

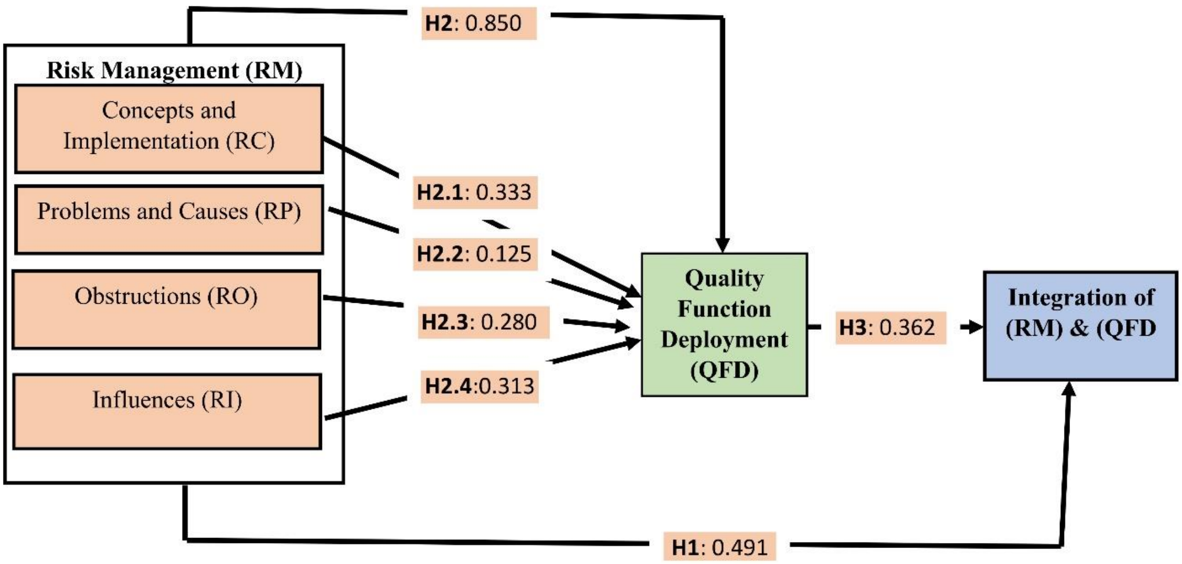

Figure 9. Hypotheses results for path coefficient between the model constructs. Total Hypotheses= 7, Supported= 7, Not supported=0

In general, most experts indicated that the model could serve the objective set for it and that the tools used lead to positive results and are flexible in implementation, with the possibility of future development, as well as having a positive impact on quality, which means its contribution to the construction industry, and finally recommending the adoption of the model. Control risk and quality in the construction industry by integrating risk management and quality function deployment can be improved more and more by cloud, IoT in addition to fog computing if applied while keeping security concerns [57-62].

6. Conclusion and Recommendation

The research results related to risk management showed an evident deficiency in applying (RM) regulations within the Malaysian construction industry, as well as the use of outdated tools and their haphazard application in companies, which negatively affects quality in this industry. It was also noted that no laws and regulations require companies to follow the modern approach to risk management or establish specialised departments for this. Internal factors within the project greatly influenced the implementation of (RM), in addition to not listening to the voice of the customer, which is considered one of the causes of risks in the construction industry. This study showed a decline in the (QFD) within the construction industry or its use in very narrow fields, especially in the Malaysian construction industry, as it is a culture considered new to the construction industry and needs more application and studies. The most significant obstacles that prevented the adoption of this methodology are the fear of change, the lack of reference to it in academic curricula, and the difficulty of reconciling technical requirements with customer requirements. The study reached essential results in the strength of the relationship between (RM and QFD) and customer needs, as the work of these tools can be integrated and give positive results on the construction project. Through this, the need to create or develop a new model linking them became apparent, which the researcher arrived at in this study. This model was created, its components and mechanism of action were determined, and its validity and stability were verified. The results indicated that (RM) can transform risks arising from customer needs into functional elements within the quality function deployment. As another significant result, (QFD) can be considered a standard tool for risk assessment. By integrating (RM) and (QFD), construction companies can enhance their project quality and reduce the effects of cost, delay, or failure.

The most significant obstacles to adopting this model were the fear of change or adopting a new culture in risk management, limited resources (financial allocations, data, specialised individuals), and regulatory regulations. The most important benefits resulting from this model are involving customers in assessing risks, staying ahead of potential risks, meeting customers' needs, building high trust with them, avoiding losses in time and cost resulting from customer's needs, and enhancing the quality of the construction project through early control of risks. This integration is also considered an incentive to find other integrations or models to serve the construction industry. Finally, the importance and effectiveness of this model within the construction industry, whether inside or outside Malaysia, was emphasised, and its adoption and application were recommended.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

Author contribution statement

Al Tekreeti Ahmed Muneer Abdulrahman: Conceptualization, Methodology, Investigation, Writing - Original Draft Preparation. Nuzul Azam Haron: Data Curation, Formal Analysis, Visualization, Writing - Review & Editing. Aidi Hizami Ales: Software, Validation, Resources, Project Administration. Law Teik Hua: Supervision, Funding Acquisition, Writing - Review & Editing.

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