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QUALITY OF DESIGN: AN EVIDENCE FROM INDIAN HOUSING CONSTRUCTION INDUSTRY

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Abstract

This paper aims to develop a methodology to improve the quality of housing construction projects to enhance client satisfaction. A detailed methodology was developed to improve housing construction project quality using Quality Function Deployment (QFD) concept. Benchmarking of the project technical descriptors was done to identify opportunities for project quality improvement. The methodology has been verified with the help of a real-time housing construction industry case study. The prioritized client needs identified were general amenities, property location, material brand, room size, interior fit-out works, commercial premise, and the flat final price (client budget). An analysis of prioritized project descriptors revealed that important descriptors influencing the project quality in descending order were finance, planning and budgeting, project feasibility, material selection, inflation rate, and design changes.

Keywords: House of quality; Housing Projects; Project Feasibility; Project Quality; Project Technical Descriptors; Quality Function Deployment

1. INTRODUCTION

Project quality management is the process of meeting the stakeholder's expectations through programs like the quality of design, quality control, quality assurance, and continuous quality improvement. Quality of design involves identification of quality standards for the project and developing plans to meet them. While quality assurance tries to implement processes to ensure that the project meets established quality standards, quality control focuses on monitoring and measuring quality of the project deliverables and taking corrective actions, if required. An integral part of a quality improvement program is continuous quality improvement. This involves identifying opportunities for improving project quality and implementing these quality initiatives. Effective project quality management is essential for successful project execution to meet the stakeholder's expectations. Project quality of design refers to the design of projects that are functional, efficient, and effective in meeting the intended project purpose. It is essential for ensuring that the project is successful in meeting its objectives. It can be assessed through various methods such as peer review, prototyping, testing, and validation. Effective project quality of design requires a structured approach including planning, monitoring, and controlling the design process. It ensures that the design is consistent, meets the required standards, and is completed on time and is within budget. One of the effective tools for ensuring quality of design is QDF concept which helps organizations translate customer needs into specific engineering characteristics (Lin and Pekkarinen, 2011). The ultimate goal of QFD is to align design efforts to fulfill customer expectations. The process typically involves a cross-functional team that uses a series of matrices to identify customer needs, ways to

meet these needs through specific product /service features and prioritize design efforts considering the relative importance of each feature.

The primary output of QFD is a House of Quality (HOQ) matrix, which is a visual representation of relationships between customer needs, product features, and design requirements (Kazemzadeh et al.,2009). This matrix is used to guide the design process to meet the customer needs. QFD can also be used to reduce development time and cost by eliminating unnecessary features and focusing on resources that are most important to the customer. Involving customers in the design stage helps in building customer loyalty.

Considering the importance of QFD in enhancing customer satisfaction, following objectives are set for the study.

1. To understand and apply the QFD concept in a real-time housing construction project environment.
2. To identify the important client requirements to direct organizational resources to improve client satisfaction.

The rest of the paper is organized as follows. Section 2 provides a detailed discussion on the literature review. In section 3, a stepwise QFD implementation methodology is given. Section 4 discusses a case study on the housing construction project to identify important factors influencing client satisfaction. Section 5 provides results and discussion of the study. In section 6, the conclusion and further areas of research are provided.

2. LITERATURE REVIEW

Quality of design refers to how well a product/service meets the needs of the customer (Juran and Juran, 1992). It focuses on the design process to meet customer requirements. The quality of design is determined by the features, characteristics, and performance of the product/service. The concept can be used to enhance quality of construction projects like new buildings, infrastructure, or facilities. Multiple parties are involved in the construction project execution. Arditi and Gunaydin (1997) defined construction quality as meeting functional, legal, and aesthetic requirements of a project. One of the effective tools to ensure the quality of construction projects is QFD. The concept focuses on designing products to minimize variations in quality characteristics. Based on the review of the papers on QFD and value engineering published between the year 2010 to 2019, Ishak et al.(2020) concluded that organizations can get more options for improving the quality of products/ services by integrating QFD and value engineering to help enhance customer experience. Eldin et al. (2003) used the QFD concept to design large college classrooms. In this study, the voice of customer (VOC) was captured using focus group discussion. Sharma (2020) developed a method to numerically establish relationship between customer expectations and engineering characteristics using QFD. Hadidi (2016) used the QFD methodology to identify critical factors for customer satisfaction for a mega public company in Saudi Arabia.

Li et al. (2019) developed a framework of risk management for hazardous materials transportation by road. They used QFD along with fuzzy failure mode and effect analysis and fuzzy AHP. Vimal et al. (2021) developed a two-phase remanufacturing QFD model considering environmental sustainability issues. Pan and Zhang (2018) used QFD along with criticality analysis and failure mode effects analysis to improve customer satisfaction. Mallon and Muuigan (1993) stated that applications of QFD are confined to the manufacturing industry and there is scope to implement this methodology in the construction industry. They tried to find the relationship between QFD and Total Quality Management (TQM) and stated that commitment to quality by organizations is the prerequisite for successful implementation of QFD methodology in construction projects. Recent studies on construction quality management have revealed that the construction industry is slowly adopting QFD methodology to improve customer satisfaction. Abdul-Rahman et al., (1999) applied the QFD methodology for low-cost housing and using the case study approach demonstrated priorities to enhance customer experience. Yang et al. (2003) applied integrated fuzzy set theory with QFD to minimize vagueness and imprecision in QFD implementation to improve the design and related decisions of construction projects. Dikmen et al. (2005) advocated QFD as a strategic tool for high-rise housing projects in Turkey to facilitate marketing decisions.

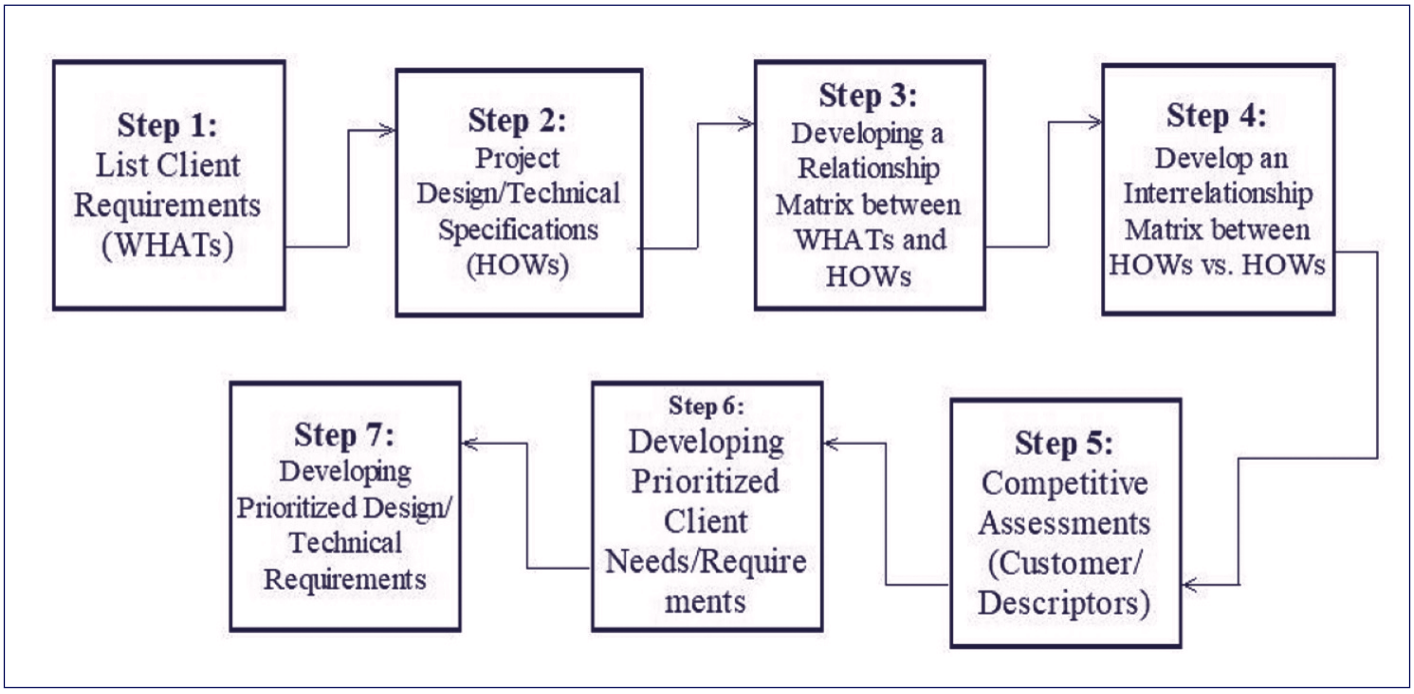
Lee et al. (2006) developed a quality performance index for design–build projects. Jafari, (2013) developed a QFD-based model for pre-qualification of the project contractors. Yafai et al. (2014) developed a model of risk assessment for the construction industry in Oman. Ulubeyli et al. (2015) applied QFD to understand buying behaviour of customers of ultra-luxury villas. Bolar et al. (2017) developed a QFD based framework and Markov model to prioritize the expectations of infrastructure users. Paul and Seth (2017) used benchmarking and QFD for the selection of technology for large-scale construction projects considering sustainability concept. Bazaati and Beheshtizadeh (2017) used QFD methodology for construction organizations in Iran and identified accessibility, earthquake resistance, and heating and insulation specifications as the critical variables impacting customer satisfaction. Mao et al. (2019) developed QFD based framework to improve resilience of critical infrastructure systems. Salah (2020) used QFD methodology for the identification of construction project delays. Based on the literature review, it can be concluded that the construction industry has slowly started implementing QFD methodology for improving customer satisfaction. However, application of the methodology is restricted to specific areas of the industry and it has not been applied to small housing projects. Hence, there exists scope to implement the methodology for such projects. Thus, this study aims to apply the QFD methodology for small housing projects to improve construction quality. Details of the methodology are given in section 3 below.

3. QFD METHODOLOGY FOR HOUSING CONSTRUCTION PROJECTS

QFD methodology is used in project management to ensure that client needs are fully understood and met. The methodology starts with identification of client needs through surveys, interviews etc. Once the client's needs are identified, next task

is to translate these needs into specific design requirements and technical specifications. Based on the client's needs and technical specifications, projects are designed. The designs are continuously improved based on client feedback. The stepwise methodology adopted using QFD is shown in Figure 1 given below.

Figure1: QFD Methodology for Housing Construction Projects



A detailed description of each stage of QFD methodology for housing construction projects is given below.

Step 1-List Client Requirements (WHATs): Listing the client requirements is the first stage in QFD implementation. For housing projects, client is the flat owner or the potential occupant. Potential client needs can be assessed through client survey, focus group discussion, or interviews. Client needs may be gauged using a five-point Likert scale. This can help understand relative importance of different client needs which are shown on the left-hand side of HOQ.

Step 2- Project Design/Technical specifications (HOWs): After client needs identification, QFD team must come up with project technical descriptors/engineering characteristics (HOWs) that may affect one/more client requirements. The ceiling of the HOQ is formed by these technical descriptors. In the case of housing projects, the technical descriptors might include sight selection and permissions, design, and execution, changes in budget, etc.

Step 3– Relationship Matrix: Within the HOQ, a relationship matrix needs to be filled by the QFD team. This matrix shows the degree of influence project technical descriptor exercise on client requirements. Team members coming from diverse areas should have consensus on the degree of relationship. The common symbols used for identification of the relationships between the project technical descriptors and client needs are solid circle, circle, and triangle representing strong, moderate, and weak relationships respectively. Numerical weights of 9, 3, and 1 are assigned to strong, moderate, and weak relationships respectively.

Step 4- Develop an Interrelationship Matrix between HOWs vs. HOWs: The interrelationship matrix forms the roof of HOQ which is used to identify correlations existing among the technical descriptors. If there exists a strong positive relationship between the descriptors, it is shown by a dark circle, a positive correlation is shown as (++), a weak positive correlation is shown as (+) and a negative relationship is shown as (x). The cells without any relation are kept empty.

Step-5-Competitive Assessments: The competitive assessment is an assessment of current organization with respect to client requirements and project technical descriptors. The client competitive assessment represents the columns corresponding to each of the client requirements in the HOQ on the right side of the interrelationship matrix. Using a five-point Likert scale, how the specific client requirements are fulfilled by the organization is gauged. A similar exercise is conducted for the competitors of the project organization. Thus, the QFD team can better understand the standing of the project organization with respect to the competitors. Similarly, project technical competitive assessment represents the rows corresponding to each project technical descriptor, below the interrelationship matrix in the HOQ. Here also, a five-point Likert scale is used to gauge how the project organization is able to fulfil the specific project technical descriptor. A similar exercise is conducted for the competitors of the organization. This can help the QFD team understand the technical competency of the project organization with respect to the competitors.

Step 6-Developing Prioritized Client Needs/ Requirements: Corresponding to each client need makes up a block of columns

on the right-hand side of the client competitive assessment in HOQ, known as prioritized client needs/requirements. This contains columns such as importance to the client, target value of client requirement, scale-up factor, sales point, and absolute weight. All these points are elaborated below.

Importance to customer (ITC): QFD team must rank the client requirements on a scale of 1 to 10 by consensus. Here, 1 represents 'the least client requirement' and 10 represents 'the highest client requirement'. QFD team can prioritize actions based on this ranking.

Target value (TV): The target value is decided for each client requirement on a scale of 1 to 5. The decision on the target value is taken by the QFD team. A higher rating given to the target value indicates an extra effort of QFD team to improve quality.

Scale-up factor (SUF): It is the ratio of 'target value' to the 'client competitive assessment' score for each client requirement. Higher the scaleup factor, more the effort needed by QFD team to improve quality of the project.

Sales point (SP): For all the client requirements, a sales point value ranging between 1 (min.) to 2 (max.) is assigned which is an indication of how customer requirements will sell in the marketplace.

Absolute weight (AW): For each client requirement, the absolute weight is calculated by using eq. (1) given below.

$$AW = (ITC \times SUF \times SP) \quad (1)$$

Direction to the project development is obtained based on the absolute weights.

Step 7: Developing Prioritized Project Design/Technical Requirements: In the HOQ, below the project technical competitive assessment, forms the rows known as prioritized project technical descriptors. These consist of the degree of technical difficulty, target value, and absolute and relative weights.

Degree of Difficulty (DOD): The degree of difficulty forms the first row of the prioritized project technical descriptors. It shows how difficult it is to go ahead with the specific technical descriptor. It is measured on a ten-point scale.

Target value (TV): Below the degree of project technical difficulty row is the target value row for each project technical descriptor in the HOQ. It defines the minimum value that must be ensured to achieve the project technical descriptor. For exceeding client expectations, a higher value of TV must be selected.

Absolute Weight (AW): The next row below the target value is the absolute value row. The absolute weight for the technical descriptor (j) is calculated using eq. (2).

$$a_j = \sum_{i=1}^{n} R_{ij} C_i \quad (2)$$

where,

R_{ij} : Weight assigned to the client requirement (i) and the project technical descriptor (j).

C_i : Importance to the client for the client requirement (i).

m: Number of project technical descriptors.

n: Number of client requirements.

Relative Weight (RW): Relative weight is obtained by multiplying weight assigned to the client requirement (i), project technical descriptor (j) and absolute weight of client requirement (i) as given in eq. (3).

$$b_j = \sum_{i=1}^{n} R_{ij} d_i \quad (3)$$

where,

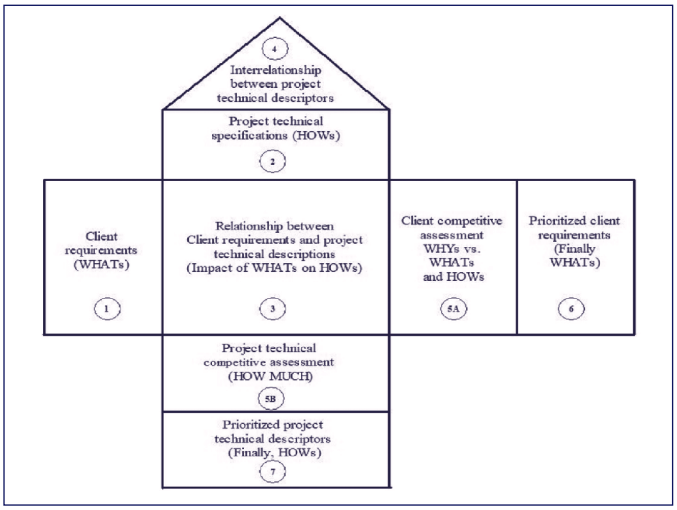
R_{ij}= Relative weight of each project technical descriptor (j).

d_i= Absolute weight for the client requirement (i).

Higher value of relative weight indicates higher importance of the project technical descriptor in satisfying customer needs. Decision on allocation of resources for specific technical descriptors can be taken using relative weights.

A typical HOQ built using QFD methodology is shown in Figure 2 given below.

Figure 2: House of Quality for Housing projects
(Source: Mitra, A., 2016)



4. REAL-LIFE CASE STUDY OF HOUSING CONSTRUCTION PROJECT USING QFD METHODOLOGY

For understanding real-life application of QFD methodology given in section 3, it was implemented in a housing construction project in South India. The details of the case are given below.

Step 1-List Client Requirements (WHATs): QFD deals with VOC known as WHATs i.e. identification of client needs. For housing projects, these requirements were divided into three categories viz. primary, secondary, and tertiary requirements. Primary requirements were indoor facilities and outdoor facilities and finance. These primary requirements were divided into secondary requirements to bring more clarity in understanding client requirements. The secondary client requirements were further divided into tertiary requirements. All these client requirements are shown in Table 1 given below.

Table 1: Client Needs/ Requirements (WHATs)

	Primary	Secondary	Tertiary
Client requirements (WHATs)	Outdoor facilities	Property location	Nearby hospitals, schools, easy approach road.
		General amenities	CCTV surveillance, gym facilities, community hall, gardens, indoor and outdoor sports area, swimming pool.
		Special services	WWT plant, solar power, Internet facility, gas pipelines, solar water heaters
		Commercial premise	Prime business areas, commercial activities inside and outside the community, hospitals, educational institutes etc.
	Indoor facilities	Building height	Number of floors per tower/ individual unit height/duplex house
		Floor preferences	Position of flat on the floor, balconies, open space at floor level common area, and firefighting system.
		Built up area	Built up area and carpet area as per regulations, floor space index, plinth area.
		Room sizes	Min. room sizes need to accommodate all furniture and fixtures.
		Material brands	Use of branded materials with top-ranking quality.
		Interior fit outs	Interiors consisting of wardrobes, ceilings, electrical and sanitary fittings, etc.
		Vastu compliance	Design of the flat as per ancient Indian vastu guidelines.
	Finance	Budget	Investment in the project vis. a vis. the project offered by the competitor and client budget.
		Mode of payment	Bank loan vs. self-finance.

To gauge the client needs (WHATs), a client survey was conducted considering thirteen tertiary client requirements given in Table 1. Data was collected using five-point Likert scale in which '1' represented 'the least importance' and '5' represented 'the highest importance' of the need/requirement of the client. Responses from 222 clients were collected, the average values of which is summarized in Table 2.

Table 2: Client needs/ requirements (WHATs) survey data

No.	Questionnaires	Average rating
1	Does the property location matter to you?	4.67
2	How important are the amenities like a park, community hall, swimming pool, indoor/outdoor sports area, gym etc.in the building for you?	4.46
3	How important are the amenities like CCTV, solar panels, solar water heater, gas pipeline, and wastewater treatment plant in the building for you?	3.93
4	Would you like to prefer a commercial premise against a non-commercial premise?	4.27
5	Do you prefer High-rise buildings?	4.05
6	Does the floor preference matter to you?	4.61
7	How important is built-up area while buying the flat for you?	4.31
8	To what extent does room size in the flat matters to you?	4.67
9	Choice and brand for tiles, paint, sanitary fittings etc.?	4.50
10	Do you want interior fittings to be done by builders?	4.55
11	Would you prefer vastu-compliant construction?	4.17
12	Does the budget matters when purchasing a flat?	4.68
13	Your preference for mode of payment (a mix of single payment and bank loan)	4.19

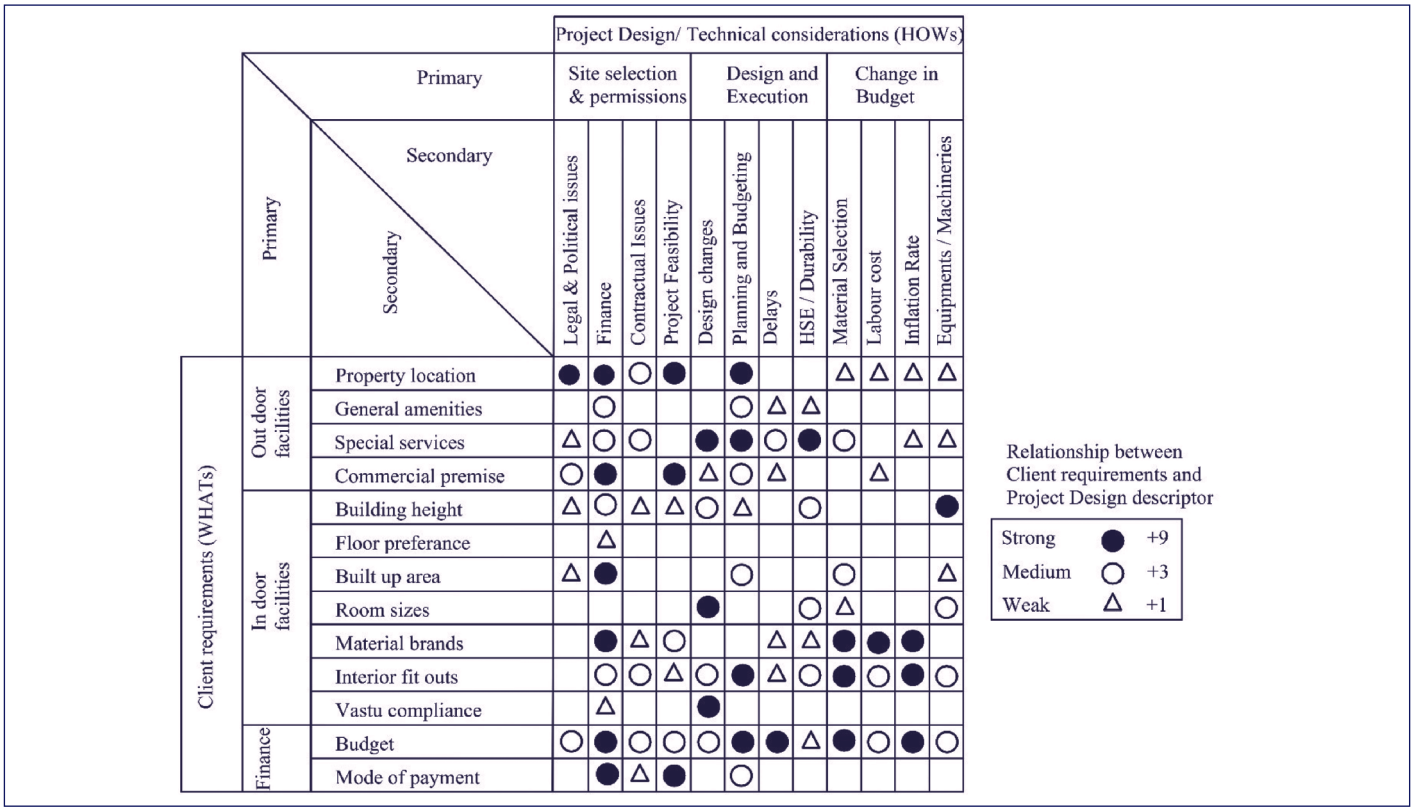
Step 2- Project Design/Technical specifications (HOWs): The second stage of HOQ is the ceiling which is made up of the design/technical parameters (HOWs) that decide the project deliverables. These are decided by the engineering/design team based on their experience. In this work, HOWs were divided into three categories as site selection and permissions, design, and execution, and change in the budget. Each of these primary project technical descriptors were divided into secondary and tertiary technical descriptors as given in Table 3.

Table3: Project Design/ Technical descriptors

	Primary	Secondary	Tertiary
Design/ Technical specifications (HOWs)	Site selection and Permissions	Legal and political issues	Legal changes, municipal laws, work permits, local allegations, political issues, etc.
		Finance	Land cost, loans on the land, and other financial issues.
		Contractual issues	Type of contract for work execution, contractual clauses, tendering and bidding procedures etc.
		Project feasibility	Well-developed facilities, access roads, timely delivery etc.
	Design and Execution	Design changes	Change in the scope of works, architectural and structural drawing changes, soil condition etc.
		Planning and budgeting	Scheduling/planning, scope of work, budget allocation, and project delivery schedules.
		Delays	Project delivery period and external delays
		HSE/ durability	Safety measures, stability of the structure, fit-outs quality, material properties, etc.
	Change in Budget	Materials selection	Construction material selection, properties of materials to sustain in life span of the project.
		Labour cost	Change in labour cost along with project duration.
		Inflation rate	Impact of inflation rate on investment by the client.
		Equipment/machinery	Technology usage, adaptability of machinery, equipment, and tools used for the construction.

Step 3: Developing a Relationship Matrix in between WHATs and HOWs –Relationship Matrix: The third step in the HOQ is to establish the relationship between client needs (WHATs) and project descriptors (HOWs). The matrix so developed by defining this relationship is known relationship matrix. Each client requirement was evaluated against all project descriptors. The Figure 3 shows the relationship matrix.

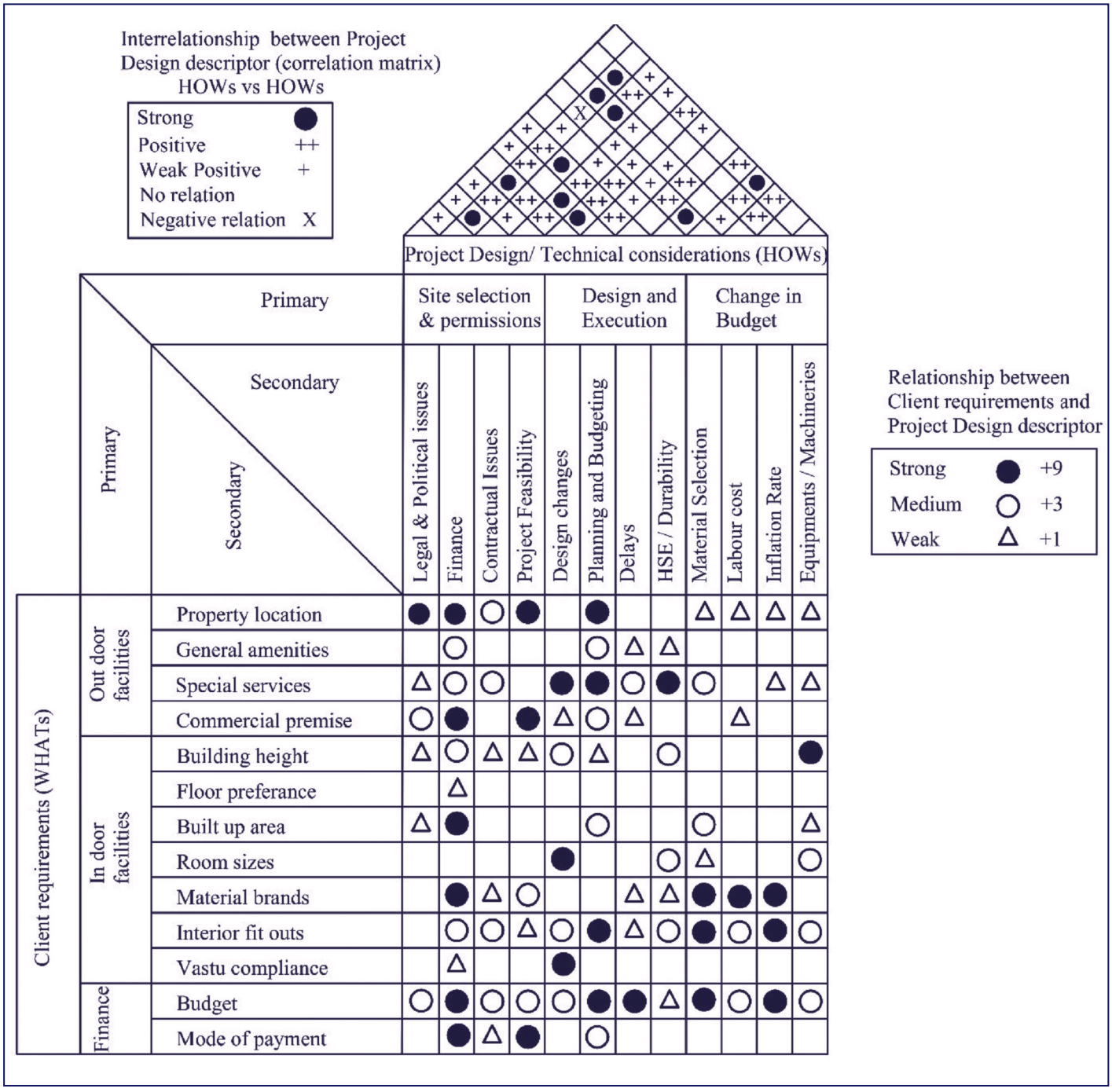
Figure 3: Relationship matrix



It can be noted in the above figure that the degree of association/ relationship between the client requirements and the project technical descriptors is shown by different symbols and quantification of the relationship is also done.

Step 4- Develop an Interrelationship Matrix between HOWs vs HOWs: The correlation matrix forms the roof of the HOQ. This matrix represents the correlation between project technical descriptors. Different symbols as shown in Figure 4 are used to define the degree of relationship.

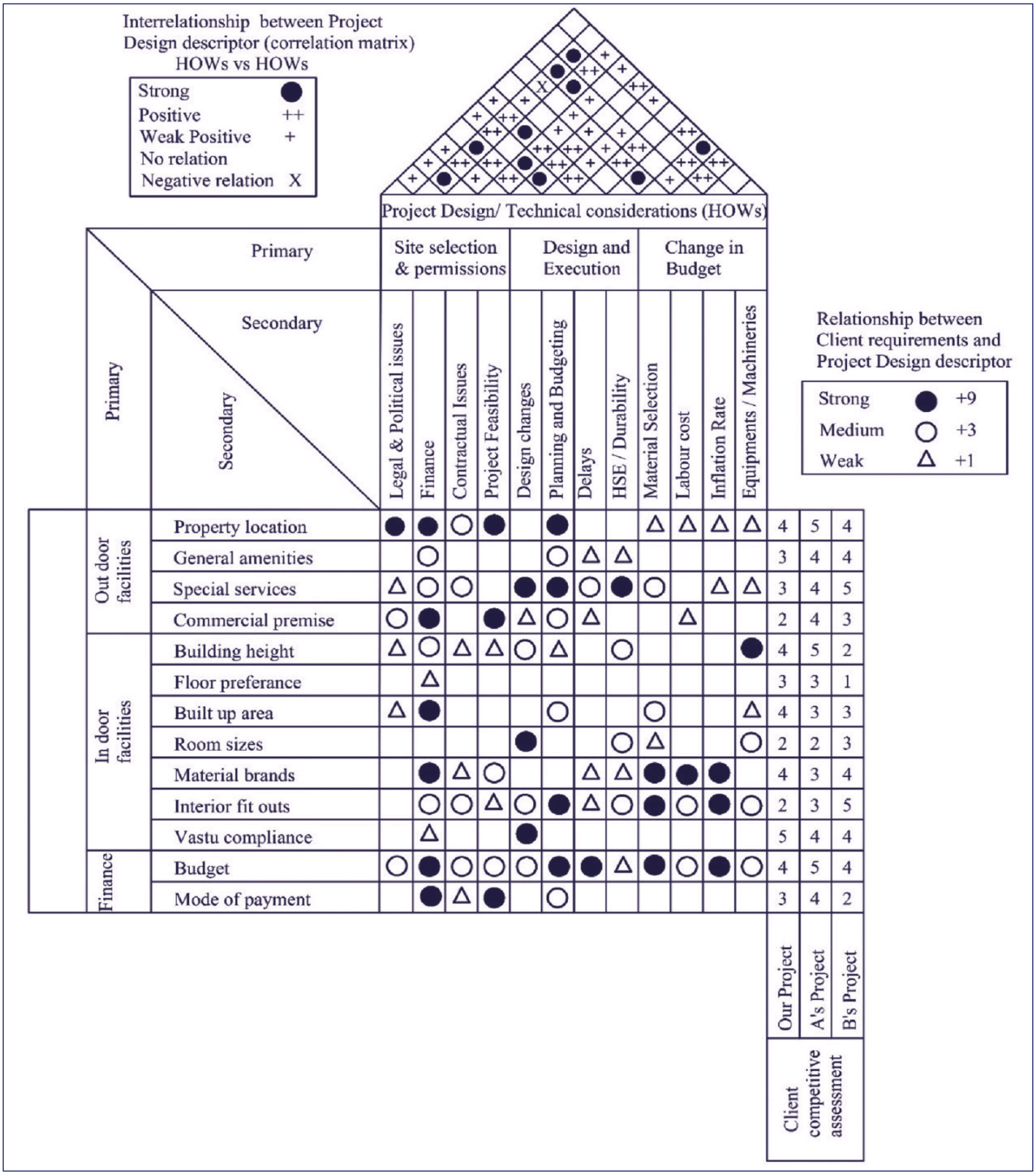
Figure 4: Interrelationship matrix



Step-5-Competitive Assessment: Competitive assessment in the HOQ is divided into client competitive assessment and project descriptor competitive assessment as given below.

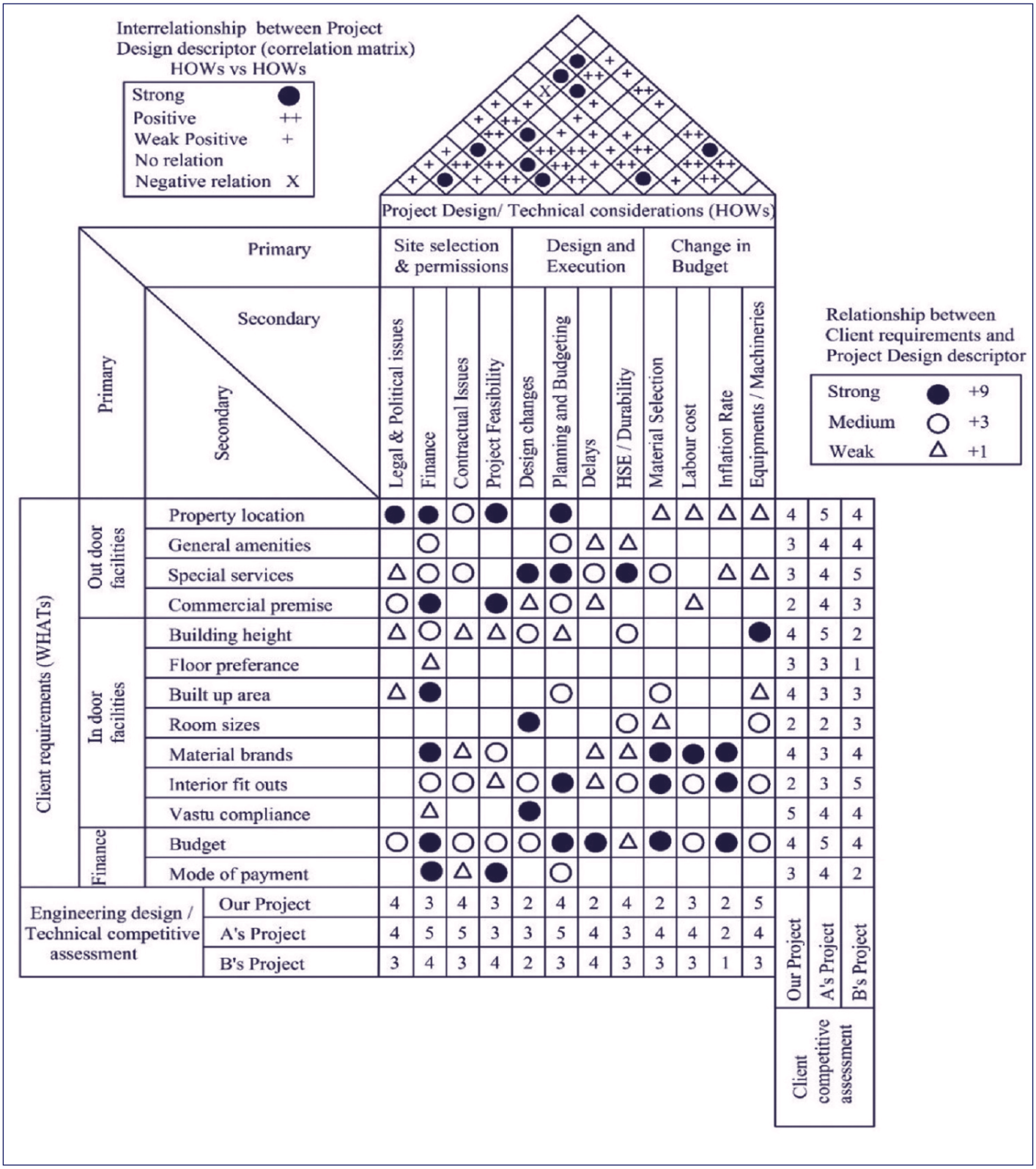
Client competitive assessment: On the right-hand side of the relationship matrix in HOQ represents three columns of which the first column represents the ability of the project organization to satisfy client requirements on a five-point Likert scale (1 being 'the least' and 5 being 'the best'). Next two columns represent ability of competitors to satisfy client requirements. Such an analysis is useful in understanding the areas where project organization needs to focus efforts to enhance client experience. Client competitive assessment is shown in the Figure 5.

Figure 5: Client competitive assessment



Project descriptor competitive assessment: The project competitive assessment represents the rows corresponding to each technical descriptor, below the interrelationship matrix in HOQ. Assessment is done on a scale of 1 to 5 (1 being 'the least' and 5 being 'the best') to understand how the project organization is able to fulfill all technical descriptors. A similar exercise is conducted for competitors of the project organization. This can help the QFD team understand the technical competency of the project organization and the strengths/weaknesses of competitors. Project descriptor competitive assessment in the HOQ is shown in Figure 6 below.

Figure 6: Project technical competitive assessment

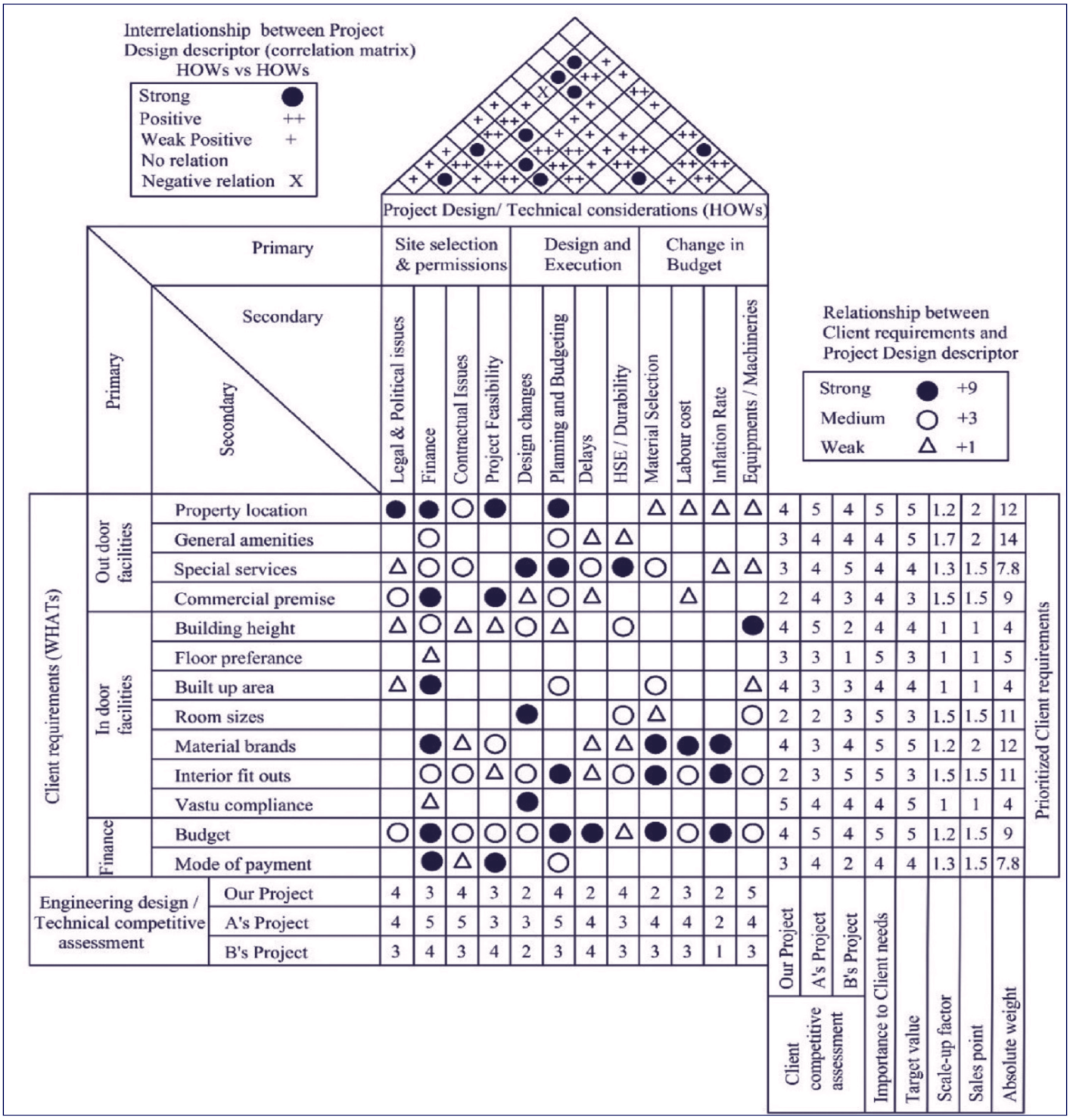


Step 6-Developing Prioritized Client Needs/ Requirements: A block of columns comprising of importance to the client, target value of client requirements, scale-up factor, sales point, and an absolute weight are shown in figure 6, on the right side of customer competitive assessment in the HOQ. The absolute weights were calculated by using eq. (1) given in section 3, e.g. absolute weight for the property location is calculated as

Absolute weight for the property location = $5 \times 1 \cdot 2 \times 2 = 12$ (3)

In a similar manner, absolute weights for all other client needs/ requirements were calculated as shown in Figure 7.

Figure 7: Prioritized client needs/ requirements



Step 7: Developing Prioritized Project Design/Technical Requirements: In the HOQ, below the project technical competitive assessment, the numerical values were filled in the rows of technical difficulty, target value, and absolute and relative weights based on the discussion among QFD team members. For calculation of the absolute and the relative weights, eq. (2) and eq. (3) respectively were used as given in section 3. Sample calculations of these weights for the project technical descriptor 'legal and political issues' are shown below.

Absolute weight =

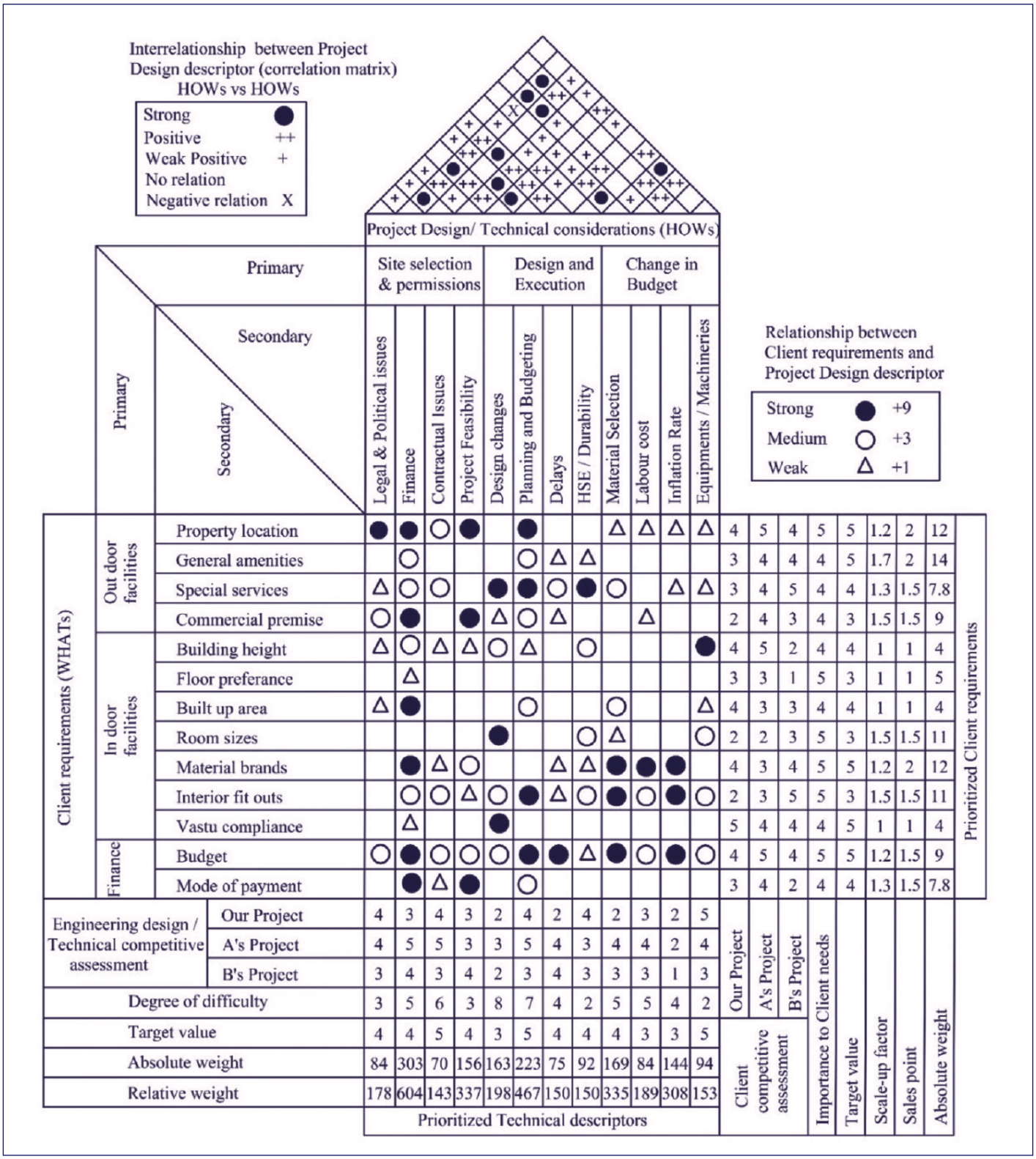
$$[(9\times5)+(1\times4)+(3\times4)+(1\times4)+(1\times4)+(3\times5)]=84 \quad (5)$$

Relative weight =

$$[(9\times12)+(1\times7.8)+(3\times9)+(1\times4)+(1\times4)+(3\times9)]=178 \quad (6)$$

These weights for all the project technical descriptors are shown in Figure 8 below.

Figure 8: Prioritized project technical descriptors



Based on the above case discussion, section 5 provides details on results and discussion.

5. RESULTS AND DISCUSSION

Considering the case analysis using HOQ, the prioritized client needs identified for housing construction project using absolute weights were general amenities, property location, material brand, room size, interior fit-out works, commercial premise, and flat final price (client budget). Based on these prioritized client needs design and planning team must plan the project activities to enhance client experience. Scaleup factor analysis revealed that property location, general amenities, special services, commercial premise, room size, material

brand, interior fit-outs, budget, and mode of payment were the identified client needs that had scope for improvement. While it is difficult to change the location of the property, the project team must try to increase score of the other identified needs which may lead to client satisfaction. An analysis of prioritized project descriptors revealed that importance descriptors influencing project quality in descending order were finance, planning and budgeting, project feasibility, material selection, inflation rate, and design changes. Design and operations teams must leverage the organizational strengths to provide best project quality to the clients based on above project technical descriptors. Engineering design department can decide the project deliverables and scope of the project based on this assessment.

6. CONCLUSION AND FURTHER RESEARCH DIRECTION

A thorough assessment of client needs and project technical descriptors is essential before the execution of the housing construction projects. Such an analysis can help offer the best project quality to the clients. In the absence of such analysis, there are chances of delivering substandard quality projects, leading to client dissatisfaction. In this work, we have made a conscious effort to identify the areas of quality improvement for housing projects. QFD matrices give a better prediction about the client requirements and the organizational ability to satisfy these requirements. Benchmarking client needs and project technical descriptors can help project organization assess its current performance and identify avenues for operational excellence. If the organization works on the identified areas, it can definitely enhance project quality. This ultimately can help project organization improve its competitive position in the market place. The focus of the study was a residential housing project to enhance project quality and the sources of data were client survey and inputs from QFD team. Also, the number of clients surveyed were limited. The methodology needs to be implemented on more housing projects to obtain generalized inputs for project quality improvement. An integrated QFD methodology considering analytic hierarchy process/analytic network process and inputs based on client focus group discussion can be the future research direction.

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