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A comprehensive study on the design of a thermal hotel using the AHP-QFD methodology

Sushil Bhange
Kalinga University Raipur
Email ID: sudhilbhange@yahoo.co.in

Abstract
This research paper explores the utilisation of Analytic Hierarchy Process (AHP) along with Quality Function Deployment (QFD) methodologies in the design of a thermal hotel, aiming to enhance customer satisfaction and operational efficiency. The objective of this project was to identify design parameters that prioritise client pleasure and subsequently enhance the overall design quality of a thermal hotel building.Subsequently, the AHP is applied to establish a hierarchical structure for the design criteria, allowing for the quantification of their relative importance. QFD is then utilized to translate these priorities into actionable design requirements and specifications. The results showcase how this approach facilitates a balanced consideration of diverse factors, including thermal water quality, architectural aesthetics, sustainability, and guest experience. The research findings provide significant contributions to hotel design, particularly for establishments harnessing thermal resources.

Keywords: *AHP; QFD; Thermal Hotel; Customer Satisfaction; Architectural Design*

1. INTRODUCTION

The hospitality sector has seen an increasing interest in incorporating thermal components into hotel architecture as part of its commitment to sustainable and creative architectural solutions. Figure 1 illustrates the total number of research papers that used the AHP approach over a span of 20 years. It is evident that the algorithm was mostly employed in 2014 (Juan et al., 2019; KürümVarolgüneş and Canan, 2018). With the growing awareness of the environmental consequences of human actions, it is crucial for organizations to embrace environmentally friendly and energy-efficient methods. The building design (BD)procedure starts with a concept and a set of specifications (KürümVarolgüneş and Canan, 2018). This process advances by activities like inputs, along with processes, along with outputs. To achieve a thermal hotel's success, a rigorous strategy is necessary to provide a harmonious balance between visitor comfort, environmental sustainability, and operating efficiency (KürümVarolgüneş and Canan, 2018) .

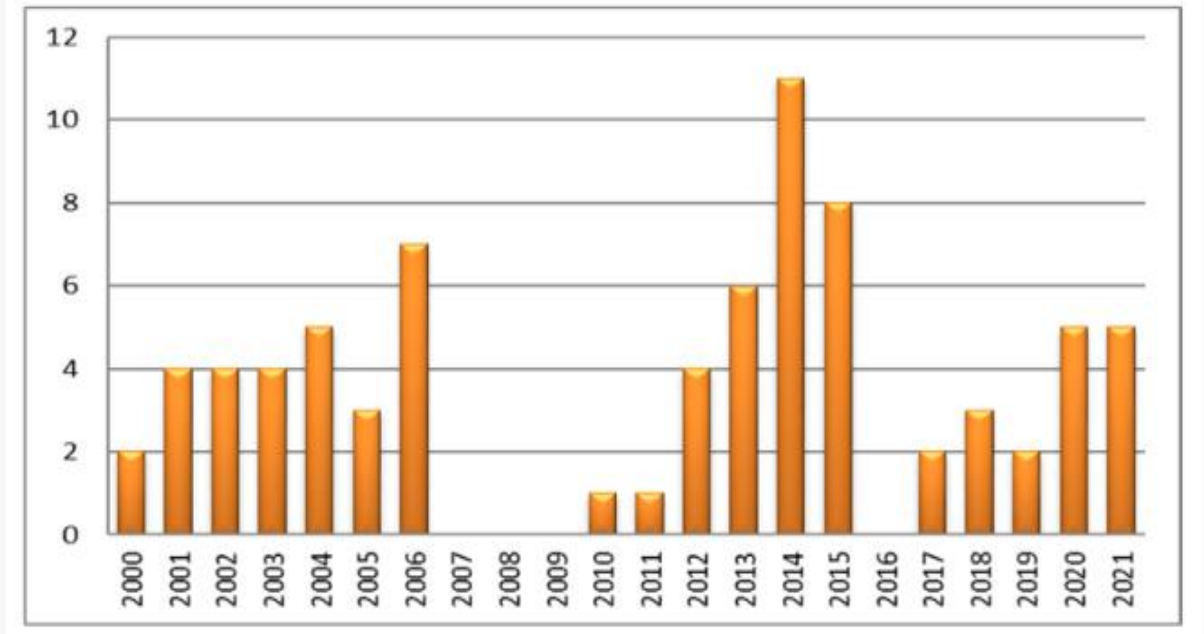

Figure 1: AHP graphical information(Shen et al., 2020)

This study combines AHP with QFD, a technique that aims to convert client needs into precise technical features (Shen et al., 2020).

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This research paper's goals are:

1. To examine the distinct difficulties and advantages related to the creation of thermal hotels, taking into account the many aspects that impact such endeavours.
2. To demonstrate the practicality and efficiency of the AHP-QFD technique in guiding decision-making in the design phase.
3. To provide architects, hospitality workers, and academics with significant insights on sustainable hotel design and the incorporation of thermal features.

The literature research reveals that several studies have used the QFD approach in the construction sector, as discussed in the following section.

2. LITERATURE REVIEW

Author and Year	Research Contribution	Remark
Ho and Ma, (2018)	QFD was considered a method that oversaw the development of a new production.	QFD was used in a BD project.
KürümVarolgüneş and Canan, (2018)	Utilised the Knowledge-Based Decision Support System and QFD	To choose the building envelopes.
Juan et al., (2019),	The QFD technique was used to uncover the expectations along with cognitive disparities between the designers along with residential users, and also to provide answers.	The author suggested that customer expectations vary in the construction of residential properties throughout the building sector.
Zhang et al., (2022),	Building designers were recommended to prioritize QFD in the construction business to ensure they could make optimal judgments.	When designing building envelopes, sustainable and adaptable design objectives were considered.
Eryürük et al., (2021)	Used QFD method	Improved occupant contentment in the design of green hospitals

Previous studies have shown that QFD-AHP techniques were utilized in different sectors of the construction industry. However, research integrating these approaches with BDprocedures has been scarce. In the present research, it was emphasized that using a multi-criteria approach was crucial for identifying the appropriate methods.

3. METHDOLOGY

Qualitative and quantitative methodologies were used in the study and evaluation of the gathered material to maximize objectivity and measurability of the criteria.

A. Quality Function Deployment (QFD)

In construction, quality refers to the ability to produce effective solutions that meet various factors, including cost targets, project duration, along with physical performance standards, functional expectations, along with aesthetic preferences, acquiescence with environmental along with legal regulations, feasibility, along with sustainability, along with energy efficiency. A design's quality may be defined as the incorporation of client expectations into the process of constructing a design. Various interdisciplinary strategies are being experimented with to enhance the quality of architectural design. QFD is a strategy that methodically addresses client (occupant) needs and converts their requirements into numerical values, offering accurate and clear data (Shen et al., 2020) .

QFD is the process of converting customer wants into technical requirements across all stages of product development and manufacturing. The house of quality (HoQ) consists of intricate matrices that form the core framework of the QFD (Eryürük et al., 2021) . The HoQ is a conceptual map that facilitates interfunctional planning

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along with communications (KürümVarolgüneş and Canan, 2018) . The HoQ serves as a framework for organizing and categorizing information pertaining to customer expectations and technical needs.

The process of constructing a home of quality involves seven sequential steps: The process consists of several steps. Step 1 involves gathering and understanding the customer's needs and requirements. In step 2, the priority of these requirements is determined using the AHP method, which involves grouping client expectations using an affinity along with hierarchy diagram. Step 3 involves identifying the technical necessities (Eryürük et al., 2021). In Step 4, the objective is to identify approaches to matrices that establish the connections between client specifications and technical specifications. Step 5 entails determining the level of technical importance and the level of standardised technical importance. Step 6 involves creating correlation matrices. Finally, in step 7, a competitive exploration is conducted and goals are determined as seen in figure 2.

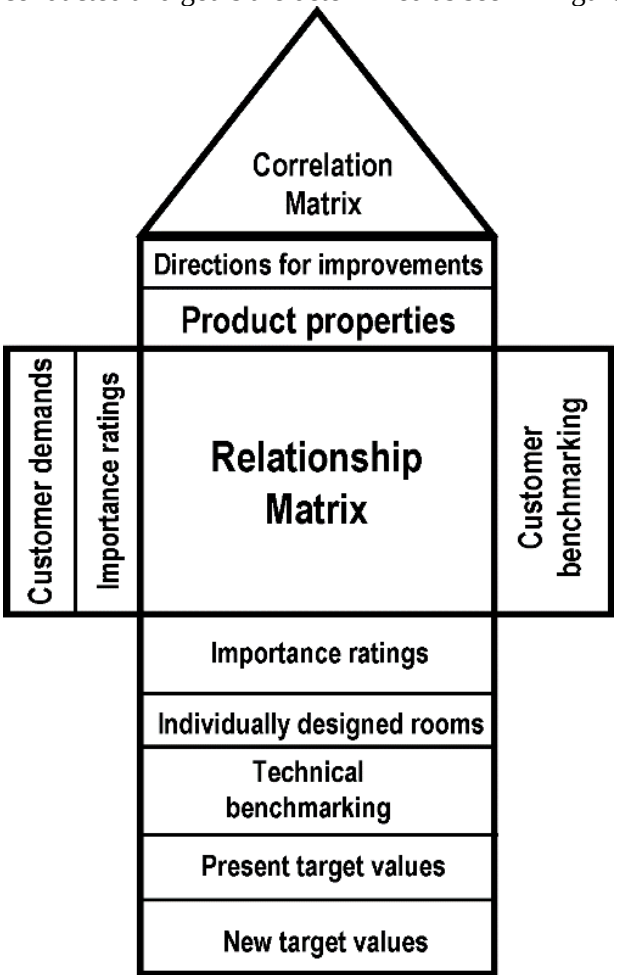

Figure 2: Steps of the HoQ diagram (Eryürük et al., 2021).

B. Steps of HoQ Diagram

- *Focus group interviews are a crucial tool used to get client feedback. This approach involves the project team convening with a customer group representative and engaging in a brainstorming session using open-ended questions or gathering their requirements via surveys.*
- *The QFD technique necessitates the assessment of the significance levels of client needs as the key input for determining the priority aspects that facilitate the production of the product at the desired quality level (**Zhang et al., 2020**).*

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- *The purpose of using AHP is to systematically arrange both tangible and intangible aspects and provide solutions throughout the choice-making procedure of situations. Per this approach, the aim is expressed at the greatest level of the constructed hierarchical structure, with subgoals and options given below:*
- *The consistency ratio is configured as:*

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

$$Consistency\ Ratio\ (CO) = \frac{Consistency\ \ Index\ (CI)}{Rando\ \ Consistency\ \ Index\ (RI)} \quad (2)$$

- After establishing the client expectations portion of QFD matrices, the subsequent task is to evaluate the information in this area and use it as input to formulate the matrices' technical needs section.
- The main purpose of the QFD` approach is not to offer design or even application solutions during the first phases of the project (Juan et al., 2019).
- Once the technical requirements necessary to fulfil consumer wants have been recognized, the correlations across these requirements and clientrequirements are established. The relationship level inside the HoQ is denoted by a distinct grade. The research favoured the American rating method, which assigned a value of 9 to indicate a strong connection, a value of 3 to designate a moderate relationship, and a value of 1 to designate a poor relationship.
- Once the technical requirements necessary to fulfill consumer wants are identified, the connections between these requirements and client requirements are established. Within the framework of the HoQ, the purpose of the relationship matrices is to ascertain the Importance of Technical Requirements (IoTR) in order to fulfillclient requirements.
- The correlation matrices are used to ascertain the positive or negative relationships between the technical criteria.
- The QFD team determines the number of competitors to analyze work or service-related data, and creates corresponding columns in the HoQ. After inputting all the required data into the HoQ, analyses are conducted using Formulas 3 and 4.

$$Improvrmrnt\ Ration(IR1) = \frac{Max\ competitor\ \ Rate}{Company\ \ Rate} \quad (3)$$

$$Importance\ of\ Imrovement\ (\text{IOI}) = IR_1 \times IoCR_1 \quad (4)$$

4. RESULTS AND DISCUSSION

In August 2017, a series of interviews were performed with anarbitrarily chosen focus group including 60 individuals utilising facilities, in order to gather their specific requirements for thermal hotels. Also, the responses provided in the surveys were arranged in order of positivity using the "average of the scores" approach. The first step was organizing a large amount of unstructured data obtained via surveys (Zhang et al., 2020). This was accomplished by using the affinity diagram, which facilitated the grouping of related data. Subsequently, the hierarchy diagram was used to further categorize the data into major and subgroups. The AHP pairwise comparison matrix (PCM) was used in March 2018 to evaluate a focus group consisting of 20 individuals, and subsequent consistency studies were conducted. The AHP PCM analyses are shown in Figure 3.

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	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Health							X											Accessibility
Health									X									Functionality
Health					X													Aesthetic
Health									X									Service
Health							X											Comfort
Health									X									Energy conservation
Accessibility											X							Functionality
Accessibility							X											Aesthetic
Accessibility													X					Service
Accessibility							X											Comfort
Accessibility									X		X							Energy conservation
Functionality							X											Aesthetic
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Aesthetic															X			Energy conservation
Service							X											Comfort
Service									X									Energy conservation
Comfort											X							Energy conservation

The AHP pair-wise comparison scale	
1	Two criteria contribute equally to the objective,
3	Experience and judgment strongly favour one activity over another,
5	An activity is very strongly favoured over another; its dominance demonstrated in practice
7	An activity is strongly favoured, and its dominance demonstrated in practice
9	The evidence from favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Used to represent compromise between the priorities listed above

Main Criteria Results

	Health	Accessibility	Functionality	Aesthetic	Service	Comfort	Energy conservation	λ_{max}	Health	Accessibility	Functionality	Aesthetic	Service	Comfort	Energy conservation	Row Averages
1.Health	1.000	3.000	1.000	5.000	1.000	3.000	1.000	1.450	0.205	0.220	0.283	0.172	0.150	0.164	0.134	0.190
Accessibility	0.333	1.000	0.333	3.000	0.200	3.000	1.000	0.722	0.068	0.073	0.094	0.103	0.030	0.164	0.134	0.095
Functionality	1.000	3.000	1.000	3.000	3.000	5.000	3.000	2.183	0.205	0.220	0.283	0.103	0.449	0.273	0.401	0.276
Aesthetic	0.200	0.333	0.333	1.000	0.143	0.333	0.143	0.266	0.041	0.024	0.094	0.034	0.021	0.018	0.019	0.036
Service	1.000	5.000	0.333	7.000	1.000	3.000	1.000	1.528	0.205	0.366	0.094	0.241	0.150	0.164	0.134	0.193
Comfort	0.333	0.333	0.200	3.000	0.333	1.000	0.333	0.431	0.068	0.024	0.057	0.103	0.050	0.055	0.045	0.057
Energy conservation	1.000	1.000	0.333	7.000	1.000	3.000	1.000	1.147	0.205	0.073	0.094	0.241	0.150	0.164	0.134	0.152
Column Total	4.867	13.667	3.533	29.000	6.676	18.333	7.476	7.728	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

n	7	Consistency
λ_{max}	7.7278	$\lambda_{max \geq n}$ eligible
CI	0.1213	
RI	1.3200	
CR	0.0919	0.1 consistent

Figure 3: The outcome of AHP pairwise comparison matrices (Ho and Ma, 2018)

The client needs' significance was determined using the AHP methodology.In March 2018, the AHP PCMs were used on a focus group consisting of 20 individuals, and subsequent consistency studies were conducted. The PCMs demonstrate the relative significance of the criteria based on a certain rationale. However, in order to ascertain the percentage allocations of these criteria, the sums of the columns that constitute the PCMs are utilised. The vertical axis of the QFD technique, which is aligned with client requirements, comprises the technical necessities portion that encompasses details pertaining to the client. The column containing significance ratings, together with the column next to it containing relative importance ratings, serves as a significant resource for doing in-depth study of consumer demands and expectations (Özdemır et al., 2018).

Once the technical necessities necessary to fulfill customer expectations were identified, matrix resolutions were generated using the HoQ, as seen in figure 4. This approach facilitates the project team's understanding of the correlation between client requirements and technical needs throughout the design stage, and allows for the evaluation of possible risks and possibilities. Once the connections were established, the technical significance rating was computed based on client expectations. The computed technical significance grade is shown at the HoQ's

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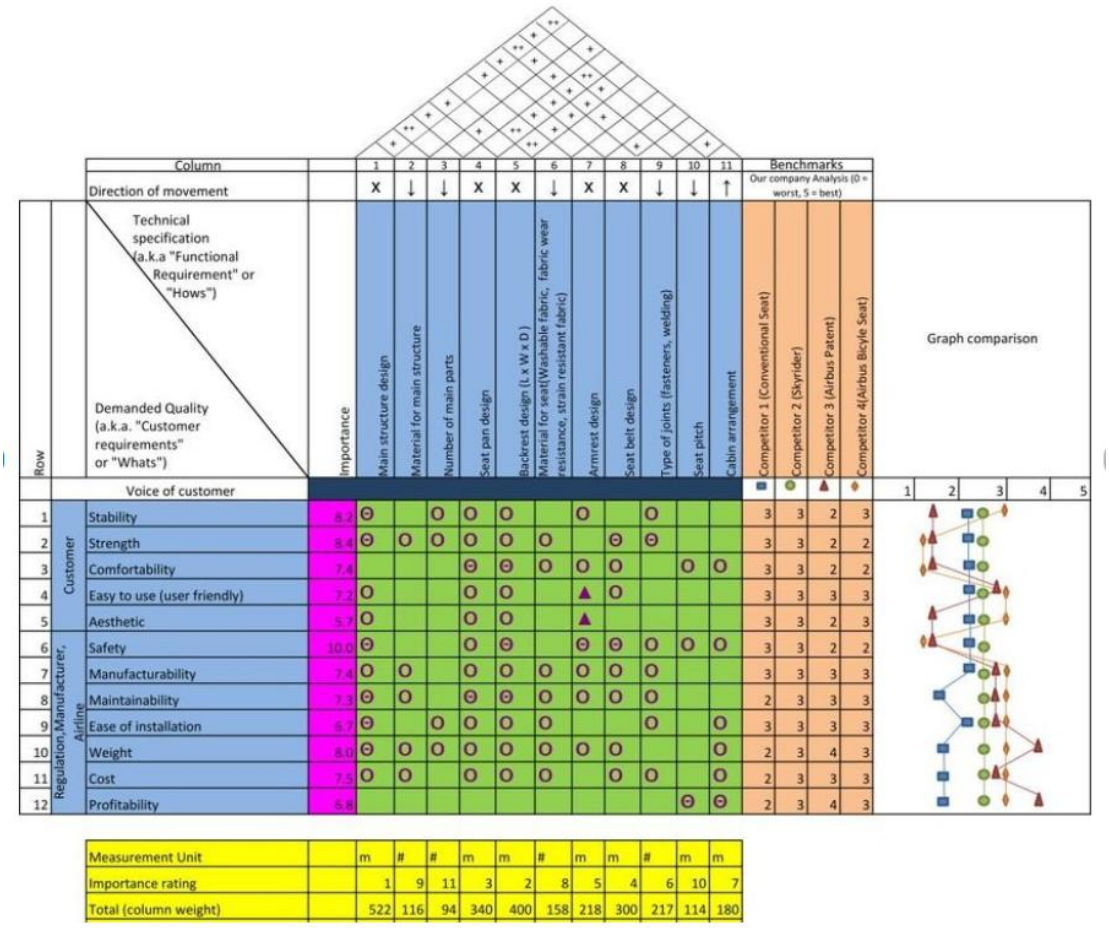

Figure 4: HoQ for thermal hotel design (Özdemır et al., 2018)

The analytical findings indicate that the primary consumer requirements are "health", "service", "comfort", and "functionality". Upon evaluating the client along with technical requirements have been assigned priority ratings. It is evident that the "climate factor and assessment of environmental factors" has the highest important value of "10.20". The research on the influence of human factors on macro- along with microplanning choices in design has received the second greatest relevance rating of 8.85. Additionally, the criterion of "spatial arrangements" has the third greatest level of significance, with a value of "6.65". Additionally, the "geometry and dimensions of the building" received the fourth greatest relevance rating of "6.63". The priority rating for "Transportation and accessibility" is the ninth highest, with a score of 5.15, while the important rating for the "orientation of the building" is the tenth greatest, with a score of 4.94. The technical need for "infrastructure works to safeguard thermal resources and determine capacity" is ranked twelfth in terms of significance, with a value of 4.92. The solutions that are convenient, flexible, and enhanced have been assigned the eleventh greatest significance rating, which is 4.58. Spaces should possess adaptability and the capacity for enhancement. The optimization of interior comfort conditions involves strategically combining various places to enhance energy efficiency.

5. CONCLUSIONS

A model was created utilizing the QFD and AHP techniques, along with its matrix-based solution. The HoQ matrix visually represents the outcomes of several assessments in a concise manner. These models allow for the comparison of the acquired data. The model's capabilities, like the ability to group items based on specified qualities, categorize major and subcriteria inside a hierarchical manner, and evaluate them via PCM, allow for quality evaluation throughout the design process. This research presents a model that highlights the elements for

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evaluating quality and offers a measuring technique that effectively distinguishes various architectural design categories. The QFD method's capacity to conduct comparison analysis enables projects to effectively monitor and evaluate occupant satisfaction for quality control purposes.

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