

# **USING QUALITY FUNCTION DEPLOYMENT (QFD) IN THE DESIGN PHASE OF AN APARTMENT CONSTRUCTION PROJECT**

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## **ABSTRACT**

Quality Function Deployment-QFD is a powerful development methodology with a wide range of applications. This paper presents a simple case using QFD on the design phase of a Real Estate construction project as a tool of improvement for layout and features of a middle-class apartment unit. The main purpose of QFD in this study was to apply in construction a method of customer-oriented design used in other industries, and to adapt some of the tables and matrices proposed by Akao (1990). Another purpose of this case study was to test the applicability of QFD in real estate projects managed and developed by small companies usually owner-operated.

## **KEY WORDS**

Quality function deployment, lean construction, building design, building construction, the house of quality.

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## INTRODUCTION

Small construction companies that operate in the Brazilian real estate housing market are trying to improve the design development phase in their projects so that they can better satisfy the needs of the buyers and users, especially for new apartment buildings.

Many companies dedicated to multiple-family construction agree that the most important aspect in the real estate market is the Value<sup>2</sup> that they can provide to their clients. These companies understand the value for their customers in different ways. The term “value” means different things to different people. One approach to value calls for the buyers and users’ points of view. Value can be defined as the size of the residential unit in relationship with the price or the technical quality of the materials used in finish work or any other features of kitchen or bathroom. Value can also be understood as something that is appropriate for the money the buyer is investing for the new property. These companies also agree that the primary challenge for the new projects that they are developing is the balance between the perception and requirements of the buyers and users and the financial goals<sup>3</sup> for these projects. These financial goals are typically translated into RoI (Return on Investment), Pay-back, IRR (Internal Rate of Return), speed of sales and cash-flow support.

## IMPORTANCE OF THE DESIGN PHASE

The Design Phase for housing is responsible for achieving client’s requirements and it is in this phase that the company needs to reach the standards of quality through drawings and technical specifications.

The questions for any company are how to obtain the innovative solutions or information for developing new projects, and how to manage decision-making in a way that ensures the best possible results. These issues apply to the strategy for housing design. The search of a balance between external and internal inputs for the design phase was one of the goals of this study. Whatever method is used to design or develop a solution for the project, its success depends on how the company assimilates and manages the client’s requirements.

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<sup>2</sup> According to Webster’s Third New International Dictionary, Value is the amount of a commodity, service, or medium of exchange that is the equivalent of something else: a fair return in goods, services, or money (the method of merchandising is to give the buyer good at the right price – Wall Street Journal).

<sup>3</sup> In this case the company responsible for the project is involved in a development process composed by (1) land acquisition, (2) design and construction of the building, and (3) project sale. How long after development the company sells the residential units of the project depends on the market and the business strategy employed. The project has been an economic success if its market value exceeds the sum total of the land and additional development costs to complete it. It is in this sense that developers are said to “create value”.

## **WHY QFD?**

The study focused in a system capable of translating buyers and users needs into design requirements, and changing these requirements into critical characteristics and specific parts requirements. QFD (Quality Function Deployment) is a method for: a) developing a design quality aimed at satisfying the consumer, b) translating the consumers' demand into design targets and major quality assurance points to be used throughout the production stage (Akao 1990). The QFD system involves constructing one or more matrices containing information related to the others. The first matrix is sometimes referred to as the "House of Quality" and contains information about customer's needs and requirements.

The objectives of using QFD in the project are:

- Define design and specifications for the residential units meeting the highest level as possible of customer requirements and satisfaction.
- Ensure consistency between customer requirements and product's measurable characteristics such as dimensions and features of rooms and finish materials used in the construction work.
- Ensure consistency between the design phase and the construction work. QFD can minimize the problems that usually are detected on the interaction between design and construction phases (including "constructability" problems and construction reworks).
- Optimize the integration of customers' perceptions and variables that can affect the RoI (Return on Investment) such as construction cost, speed of sales, schedule and cash flow.
- Reduce the time to perform quality features throughout product development.

QFD can be applied to the construction industry in different ways. Mallon and Mulligan (1993) used QFD on a hypothetical renovation of a personal computer workroom. Armacost et al. (1994) applied QFD to integrate the customers' requirements in an industrialized housing component: a manufactured exterior structural wall panel. Serpell and Wagner (1997) used QFD to determine preferences on the design characteristics of the internal layout of a building apartment. QFD was also applied to construction (Huovila et al. 1997) involving different players working together in three construction projects: a structural design firm and two contractors. This research objective was to test the applicability of QFD to construction involving companies from different backgrounds.

QFD was used as a tool in this case to prioritize important points that could offer a potential of improvement according to the clients' requirements and needs. It was used specially to improve the basic layout and basic specifications of the middle-class apartment units of the project.

However, some difficulties were identified during the use of QFD:

- The focus group didn't express clearly most of their opinions, needs and requirements.
- Substantial increase on the time expended by the project management team in planning and analyzing the data collected.

- Difficulties in working with large-sized matrix.
- It is hard to process the information inputted in the QFD matrix.

## **CASE STUDIES**

These case studies apply QFD in the design improvement of a multiple-family apartment building located on an urban area of a mid-sized city in Brazil. The project includes 48 units of residential apartments in one tall building (thirteen floors) and the construction area was approximately 5,000 m<sup>2</sup> (about 54,000 ft<sup>2</sup>). The estimated budget for this project was around US\$2.0 million. The basic layout of each unit includes 2 bedrooms, 2 bathrooms, 1 living/dining room, kitchen, laundry and balcony. The developer of this project is a small owner-operated real estate development and construction company.

## **OBTAINING INFORMATION FROM BUYERS AND USERS**

For this case two techniques were used for gathering information on customers needs and desires for the layout of the residential unit. The first technique adopted interviews with salespeople (real estate agents) who have a strong relationship with buyers and users. Another technique used was the “Focus Group” approach using mid-sized and small-sized groups, obtaining information through questions and benchmarking between different projects in order to find out likes, dislikes, trends and opinions about similar current and other projects. Different people including real estate agents, architects, engineers, potential buyers and owners of similar apartments composed the focus group.

Some of the questions submitted to the focus group:

- What are your needs and requirements in this building?
- What do you like in the design of this apartment?
- What do you dislike in the design of this apartment?
- Which features do you think are most important in the layout of an apartment?
- Could you tell me which features are most important for you? Why?
- What do you think the most important features in the kitchen of this apartment are? Why? Choose three features.
- How do you like the bathroom?
- What do you think the most important features in the bathrooms are?

Some of the important features chosen by the focus group:

- At least two entrances for the apartment unit: one by the living room and another by the kitchen.
- A large counter top in the kitchen to provide more space during the preparation of food or other tasks.
- Floor easy to clean in the kitchen and bathroom.
- Beautiful wood floor in the living and dining rooms.

### DEVELOPING THE QFD MATRIX

The QFD matrix used in this case was based on the “House of Quality”. It was developed by Clausing and Hauser (1988), and it drives the marketing people, design engineers, architects and site engineers toward satisfying customers’ desires and preferences.

### IMPLEMENTING THE PERCEPTION OF FOCUS GROUP IN THE QFD MATRIX

In order to obtain the list of “WHATS” customers’ requirements (Figure 1) that will be applied to the project design, the focus group was interviewed after receiving information about other projects with units composed of 2, 3, and 4 bedroom apartments. The focus group could evaluate different aspects of the current design and compare it with the projects of the competition or other previous owner’s experience. For this purpose the group would use drawings and basic information from other projects (specifications, dimensions of compartments, finishing materials, electrical and water features, kitchen layout, etc.).

After the benchmarking between the current project and the competition’s projects, it was possible to establish the degree of importance of the design’s solution (Figure 1).

WHATS		Degree of Importance	Comparison competitors			Customers Rating					
Customers' requirements			Proj. A	Proj. B	Proj. C	0	1	2	3	4	5
Entrance	Social entrance - other for Kitchen	4	3	4	3			•			
	One Kitchen entrance	4	4	2	3			•			
Kitchen	Large counter top - durable material	1	1	1	1		•				
	Space for full size appliances	5	5	4	4						
Laundry	Spacious laundry-full size appliances	5	3	5	4						
Dinning +	Extra space for Stereo and TV	4	1	2	4						
Living room	Space for full size dinning table	5	5	4	4				•		
Balcony	One balcony w/ connection w/ Living	5	5	5	5						
Bathroom	Master Bathroom with Bathtub	2	2	1	1						
Master Bedroom	Natural lighting and ventilation	4	3	4	4						
Bedroom	Large counter top - durable material	1	1	1	1						
	Heat water for faucet in the sink	3	3	1	1		•				
Bathroom # 2	Natural lighting and ventilation	4	4	3	2						
	Large counter top - durable material	1	1	1	1						
Flooring	Heat water for faucet in the sink	3	3	1	1						
	Bath/kit/laund/w/ tiles easy to clean	3	3	3	2						
Walls	Dinning/Living w/ wood flooring	3	2	3	1						
	Bedrooms with anti-allergic carpeting	2	2	2	2						
Windows	Baths/kitchen w/ tiles-easy to clean	3	3	3	1						
	Laundry easy to clean - water proof	2	2	2	2		•				
Doors	Bedroom/Din./Living-light color paint	2	2	2	2						
	Frames that don't leak-easy to clean	2	1	2	2						
Special installations	Social entrance w/ wood door decor.	4	4	3	4						
	Kitchen doors easy to clean-smooth	3	4	2	2						
Special installations	Internal doors easy to clean-smooth	2	2	2	2						
	Telephone plugs in all rooms	5	5	1	1						
Special installations	VHF/UHF, cable TV read all rooms	1	1	1	1						
	Emergency lighting - common areas	1	1	1	1						
Special installations	Phone conn. main gate/other units	5	1	5	5						
	Quality Heater-cheap maintenance	1	1	1	1						

Degree: 1 2 3 4 5 - Worst to Best

Figure 1: Customer Needs (WHATS) and Prioritized Needs and Analyzed Competitive Benchmarking



By using QFD the design team could also evaluate some details of the layout and features during the development of the design. By using the “roof” of the QFD Matrix (Figure 2), it was possible to examine the correlation among technical requirements. The roof of the House of Quality helps identify the interactions among the technical requirements and provide early recognition of positively and negatively correlated features with technical solutions defined by the design team.

After the project design team has determined the technical solution directions, and had assigned the relative importance and weight to these solutions, the next step was to determine Target Values (Figure 3) for the technical solutions agreed.

Target Values
Door with 0.90 x 2.10 mt.
Door with 0.90 x 2.10 mt.
Marble style/color ..... - Size at least 1.70 m long
Increase 1.0 square meter
Increase 0.5 square meter
Area around 5.0 square meters ( +/- 0.5 sq. mt.)
Area around 18.0 square meters ( +2.0/-0.5 sq. mt.)
Decrease the number of Balcony - only one connected with the Living
Small bathtub (max. 1.40 mt)
Increase at least 10% in area of standard window
Marble style/color ..... - Size 1.00 m long
Faucet with Heat water (around 70 o Celsius)
Increase at least 10% in area of standard window
Marble style/color ..... - Size 1.00 m long
Faucet with Heat water (around 70 o Celsius)
Size 0.25 x 0.15 m, color #
Wood flooring width 0.15 - Specification .....
Thin Carpeting - anti-allergic - 10 mm -specification ...
Size 0.15 x 0.15 m - model #...
Epoxy Painting - color 3 - according NBR ...
Painting according NBR ... mixing colors #s
Windows frame - model size #
Increase door size to 0.90 meter
Increase door size to 0.90 meter
Increase door size to 0.80 meter
at least 6 telephone plugs
at least 4 TV plugs
Install System Phillips #..... according to NBR ...
Install interphone in the kitchen, model # .....
Gas heater - system # ..... according to NBR...

Figure 3: Target Values

To complement the information for the Target Values definition, a technical analysis was developed as shown in the “Technical Requirements: Relative Weight Chart” (Figure 4).

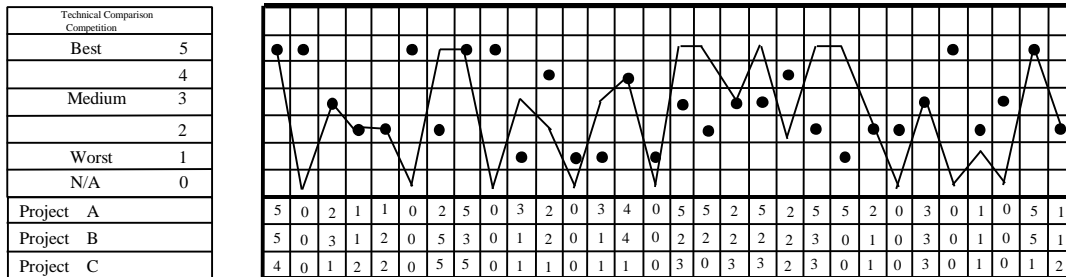


Figure 4: Technical Requirements: Relative Weight

### QFD CORRELATION MATRIX

By using the correlation between the customer needs (Whats) and the technical requirements (Hows), it was possible to determine strength of relationship and impact on the need (Fig. 5).

One important procedure during this phase was the second or third analysis of the blanked cells (no relationship correlation). When no relationship is detected during the evaluation, the design team should check again the HOWs versus WHATs and decide if the relationship will occur (blanked cells).

Finally it was possible to identify and prioritize the most important requirements and needs for the new design of the project. Using the lower part of the House of Quality matrix, the level of importance of the design requirements was determined using the results of the Importance Weight and the Relative Weight of the Technical Requirements (Figure 6).

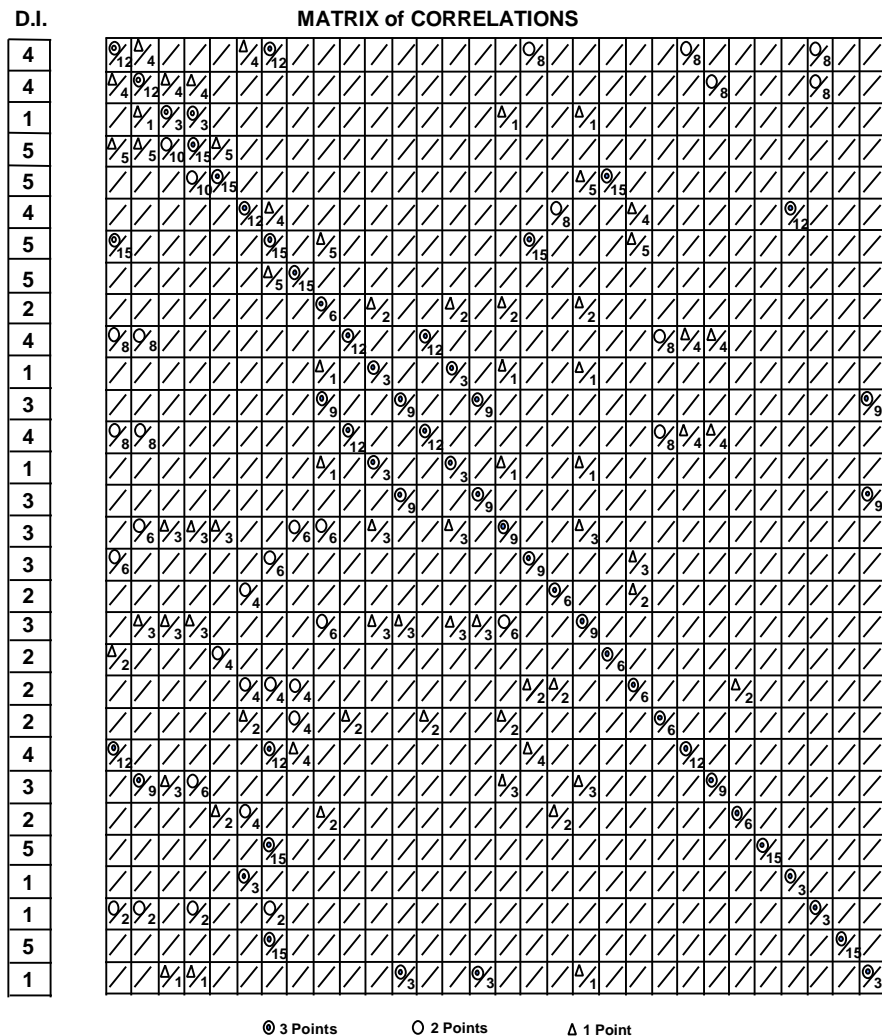


Figure 5: Correlation Matrix - Technical Requirements (HOWs) correlated to Customer Needs (WHATs)



Importance Weight	74	52	27	47	29	33	90	38	31	26	14	24	26	14	24	25	38	18	26	21	20	22	28	25	8	15	15	19	15	21
Relative Weight (%)	9%	6%	3%	5%	3%	4%	10%	4%	4%	3%	2%	3%	3%	2%	3%	3%	4%	2%	3%	2%	2%	3%	3%	3%	1%	2%	2%	2%	2%	2%

Figure 6: Importance Weight and Relative Weight of Requirements (%)

### DESIGN IMPROVEMENTS

After obtaining the final results of the Importance Weight and the Relative Weight of the Technical Requirements, it was possible for the design team to prioritize and implement the new layout solutions and new features in the specification and design of the apartment unit. In the new design, it was necessary to increase or decrease some of the areas or shapes of compartments and to eliminate or add new specific solutions.

Technical Requirements	Level of Importance	Acumulated Weigth (%)	Design Solutions
1- Space for full size Dinning table	10%	10%	Modify Lay-out of Living/Dinning Room and increase area >= 18 sq.mt.
2- one social entrance/other for the kitchen	9%	19%	Create one social entrance separated from kitchen entrance
3- One kitchen entrance separated	6%	25%	Create one kitchen entrance separated from social entrance
4- Space for full sized appliances in the kitcher	5%	30%	More space in the kitchen - increase area in at least 1.0 sq. mt.
5- One balcony w/ connection w/ Living Room	4%	34%	Decrease the number of balcony, eliminate the balcony of master bedroom
6- Dinning/Living Room w/ wood flooring	4%	38%	Specify hard wood flooring in the finish of Living/Dinning Room
7- Extra space for stereo and TV	4%	42%	Add a multi-purpose space for TV and Stereo
8- Bathtub in the Master Bathroom	4%	46%	Introduction of Bathtub in the master bathroom
9- Spacious laundry w/ full sized appliances	3%	49%	Increase the area of the laundry in 0.5 sq. mt. For full sized appliances
10- Social entrance w/ natural wood door	3%	52%	Specify a door made in natural wood material w/ wide size in social ent.
11 to 30- Other technical requirements	48%	100%	

Figure 7: Technical Requirements and Level of Importance

The improvement of performance for the project in terms of design and features was evaluated by the project team measuring the differences of the design index before and after application of QFD.

Table 1: Design Characteristics of the Apartment Unit before and after QFD

Technical Index	Before QFD	After QFD	Improvement
Area of apartment (unit)	88.04 sq. meters	86.28 sq. meters	2.04 %
Compact Shape Index	77.17 %	82.74 %	7.22 %

A general view of the old version of the layout design and the new layout can be observed in Figures 8 and 9.

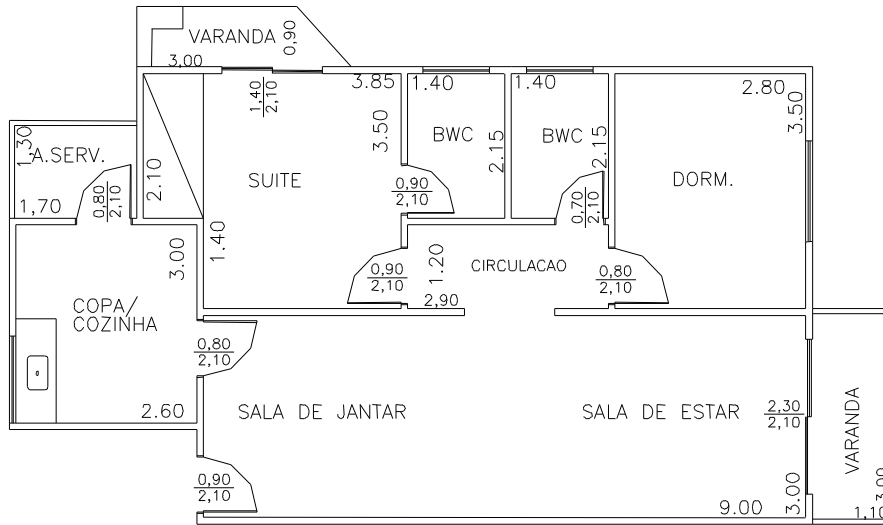


Figure 8: Design Layout of the Apartment Unit Before QFD

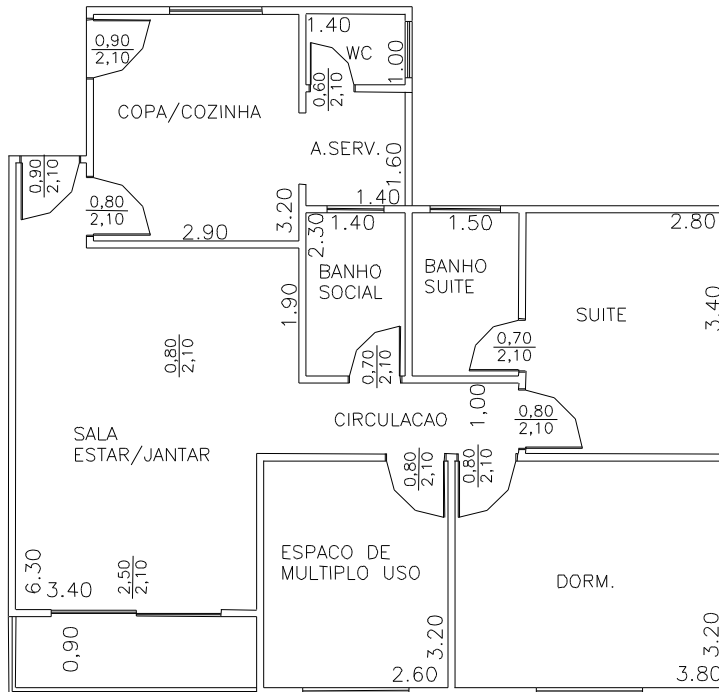


Figure 9: Design Layout of the Apartment Unit after QFD

## CONCLUSIONS

QFD is a valuable and very flexible tool for Design. The sequence of parts and steps during the QFD process can be changed according to the strategy adopted by the design team. The correlation matrix is the heart of the QFD process and stores precious information needed for design improvements.

QFD helps prioritize the improvements and design specifications. QFD also helps translating the buyers and users needs into information that can be managed by the design team. Besides, it facilitates the use of benchmarking information in a systematic way. The most difficult aspect in the use of the QFD as a tool in the design of a real estate project was the previous lack of strong coordination in the beginning of the project especially in features related to detail solutions. Another difficulty was making the project team recognize that QFD is a powerful and flexible tool for construction. One last important issue in the use of QFD is the size of the core matrix. The project team coordinator in this case study decided to limit the size of the matrix to 30x30, which proved to be a good decision.

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