Engineering Letters, 14:1, EL_14_1_6 (Advance online publication: 12 February 2007)

Using Quality Function Deployment in Singulation Process Analysis

Hang-wai Law and Meng Hua

MEEM Department, City University of Hong Kong

***Abstract*—This paper presents the application of quality function deployment (QFD) to process analysis. QFD has been applied in various industries since the 1960s, but traditional QFD methodologies still have many limitations. An improved QFD framework is proposed, in which, customer requirements are identified through value engineering and strategic analysis. Process mapping using the IDEF methodology is then employed to formulate the design specification of a system before the "House of Quality" is applied. A case study is conducted to demonstrate the usefulness of the proposed framework in analyzing the effectiveness and performance of two types of sigulation processes in semi-conductor industry.**

***Index Terms*—Quality Function Deployment, Engineering Process**

I. Introduction

From time to time, engineers are obliged to re-design an existing process to improve its productivity and cost effectiveness, which means that a different design must be decided upon. Different techniques, such as decision analysis (DA), analytical hierarchy process (AHP) and techniques for multiple criteria decision making (MCDM) are reported by Kirkwood [1] to be applicable for use in the decision making process. This paper proposes a quality function deployment (QFD) framework and demonstrates its successful application to process analysis.

We begin with an overview of quality function deployment and some of its limitations. An improved QFD framework is then proposed that involves process mapping using Integrated DEFinition (IDEF) to formulate a process for arriving at the design specification of a system before the "House of Quality" is applied. A case study is then conducted to illustrate the use of the proposed framework in the analysis of two types of singulation processes in the semi-conductor industry.

Manuscript received April 7, 2006. This work was supported in part by the City University of Hong Kong under Grant TDG0049.

Hang-wai Law is with the MEEM Department of the City University of Hong Kong, Kowloon Tong, HKSAR, China. (Tel: (852) 27888426; fax: (852) 27888423; e-mail: mehwlaw@mehwlaw.edu.hk).

Meng Hua is with the MEEM Department of the City University of Hong Kong, Kowloon Tong, HKSAR, China. (e-mail: memnghua@cityu.edu.hk).

II. Overview of Quality Function Deployment

QFD is a tool for improving the development cycle and manufacturing products that better match customer needs [2]. QFD accomplishes these goals through the use of a design tool that is known as the "House of Quality" (HOQ) as shown in Figure 1 [3][4]. The "Whats" room represents the voice of the customer and on the right is a customer competitive assessment that is expressed in form of a rating. The "Hows" room records the functional characteristics of a product including how customer needs can be met. The roof is the correlation matrix room which indicates the positive and negative relationships between the technical characteristics of the product. These relationships can help to generate new alternatives by highlighting areas for improvement in current products [2]. After completing the "Whats" and the "Hows" rooms, these relationships can be worked out and expressed in a relationship matrix as indicated in the center of the house. Once the relationship matrix has been completed, the extent to which the product performance will satisfy customers is calculated and is expressed as an absolute score and a score that is relative to the target value.

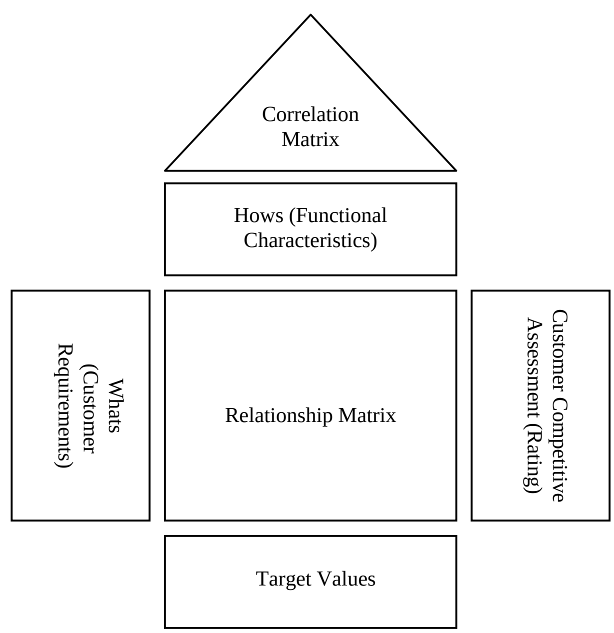

Figure 1 The House of Quality

Traditional QFD methodology has many limitations. For example, the identification of customer requirements is ambiguous and unsystematic and the functional characteristics of a complicated product (in this case an engineering process) cannot be easily determined. In this paper, an improved QFD framework is reported in which customer requirements are identified systemically using the “value engineering” concept and then the IDEF methodology is used to understand the engineering process and systemically formulate its functional characteristics.

III. Proposed Methodology

The proposed methodology is shown in Figure 2. It is suggested that customer requirements are identified systemically using value engineering and strategic analysis. Value engineering is best applied to the areas of product cost, quality and performance whereas strategic analysis is best used to analyze the strength of the product position and identify the factors that may influence this position. The process of strategic analysis can be assisted by a number of tools [5], as listed in Table 1. Integrated DEFinition (IDEF) methodology is then used for process mapping to systemically formulate the functional characteristics of the product.

We next describe the application of the proposed methodology to analyze the effectiveness and performance of two type of singulation processes in the semi-conductor industry.

PEST Analysis - a technique for understanding the environment in which a business operates
Scenario Planning - a technique that builds plausible views of possible futures for a business
Five Forces Analysis - a technique for identifying the forces that affect the level of competition in an industry
Market Segmentation - a technique that seeks to identify the similarities and differences between groups of customers or users
Directional Policy Matrix - a technique that summarizes the competitive strength of the operations of a businesses in a specific markets
Competitor Analysis - a wide range of techniques and analyses that seeks to summarize the overall competitive position of a business
Critical Success Factor Analysis - a technique for identifying the areas in which a business must outperform the competition to succeed
SWOT Analysis - a technique for summarizing the key issues that arise from the assessment of the internal position and external environmental influences on a business

Table 1 Tools that assist the process of strategic analysis [5]

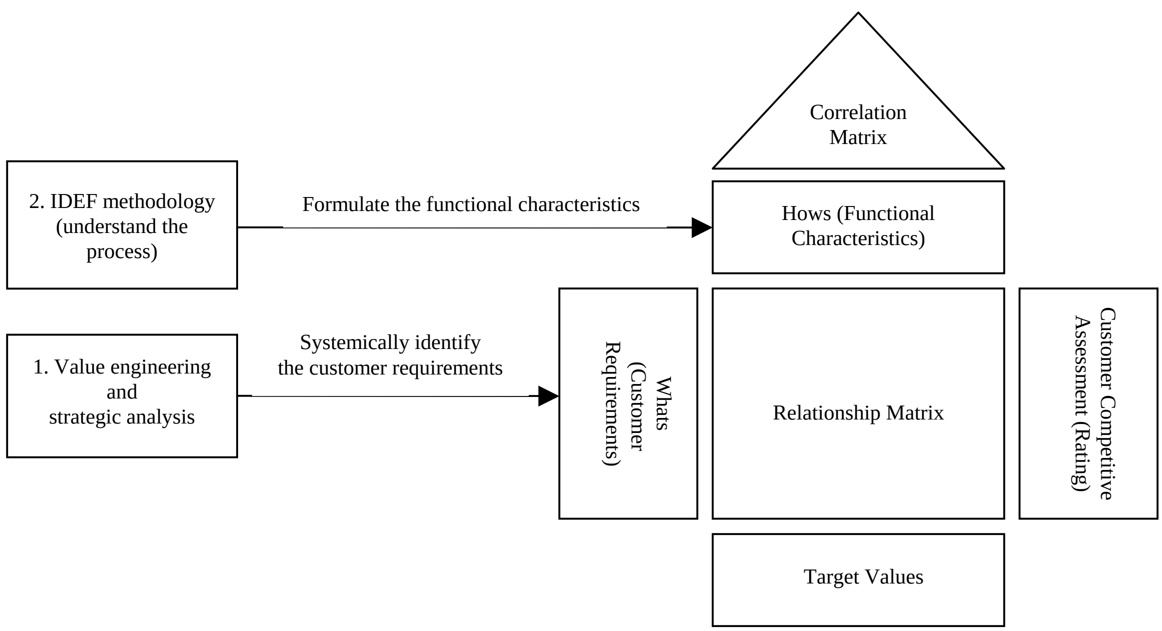

Figure 2 Proposed Methodology

IV.

V. Applications of the Proposed Methodology – Analysis ofa Singulation Process

Singulation is a technique that is used in the semi-conductor industry to divide individual units from biscuit-type packaging. There are two common types of singulation processes: the standalone system and the inline system. This case study demonstrates the successful application of the proposed QFD framework to carry out a process analysis of a standalone system and an inline system that have been developed by a design group.

A. Systemically identification of customer requirements

The customer requirements are identified systemically using value engineering and strategic analysis. Those that are identified using value engineering include: *high productivity, a longer mean time between assists, a longer mean time between loads, a lower equipment cost, a reduce the extra material cost, reduced human error, easy maintenance, multi-function, independence from the functional module, a wide package size handling capacity, a lower the packaging cost* and *a smaller equipment floor space requirement*. The requirements that are identified using strategic analysis include: *safe working conditions, reduced skill level requirements for operators, reduced labor requirements, easy equipment transportation, easy operation, a line balanced system, an adequate level of work in process, good process yield* and *an efficient processing cycle*. After obtaining the requirements, a questionnaire is designed and distributed to the target customers to identify the importance of the requirements.

B. Process Mapping by the Integrated DEFinition

IDEF is a group of modeling methods that can be used to describe business and engineering operations. IDEFØ is one of the IDEF methods which is designed to model the decisions, actions, and activities of a system [6], and is used in this case to carry out process mapping to systematically formulate the functional characteristics of the standalone (Figure 3) and integrated (Figure 4) systems. Based on the process mapping and resulting IDEF diagrams and the customer requirements, the engineering team is asked to identify the functional characteristics that would achieve these requirements.

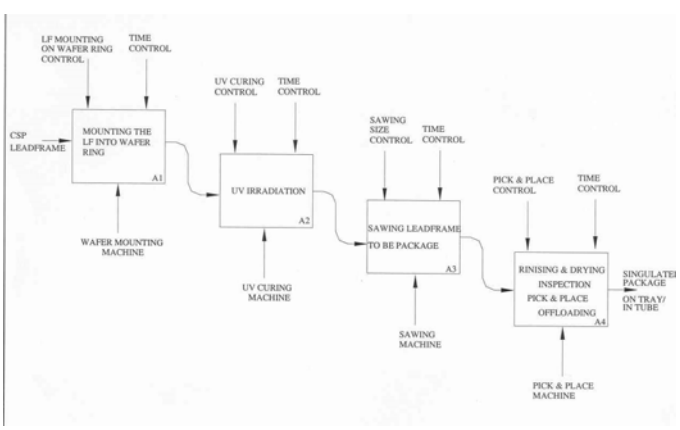

Figure 3 IDEF diagram of the standalone system

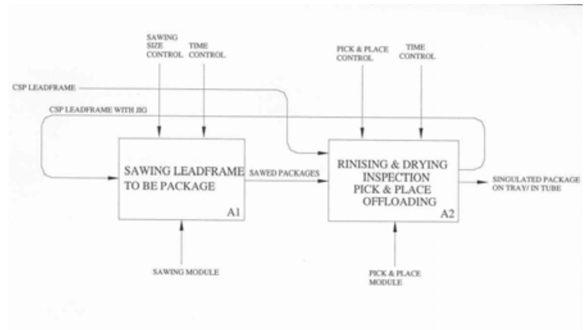

Figure 4 IDEF diagram of the integrated system

Twenty functional characteristics are identified including *speed up the motion, minimize the material transportation distance, minimize the machine size, reduce the number of machine modules, include more sensors for material monitoring, allow a longer time for inspection, increase the size of the loading platform, increase the size of the unloading platform, minimize the number of the loaders, minimize the number of unloaders, provide a safety cover for the machine, simplify the design and layout of the machine, minimize the number of conversion items, design a special collection box, automat the magazine transfer through the modules, use reusable jig and fixtures, simplify the control panel layout, devise a programmable lead frame (LF) track, create an independent modular machine* and *make the design fool proof*.

C. Establishment of the Relationship Matrix and Correlation Matrix

After completing the "Whats" and the "Hows" rooms, the relationship matrix can be established. Each relationship is assigned a degree of strength - strong, medium, or weak - as represented by the symbols "◎", "◯" and "△" respectively. For example, the relationship between "*high productivity*" and "*speed up the motion*" is strong, or "◎", whereas that between "*a longer mean time between assist*" and "*include more sensors for material monitoring*" is medium, or "◯". The relationship between "h*igh productivity" and "minimize the machine size"* is weak, or "△". The final relationship matrix is as shown in Figure 5.

The correlation matrix measures the interaction between the functional characteristics of the system and provides early recognition of the different levels of correlation and solutions as determined by the design team. There are four levels of correlation: Strong +, or "●"; Positive, or "◯"; Negative, or "X"; and Strong –, or "𝕏". The final correlation matrix is shown in Figure 5.

D. Competitive Assessment and Formulation of the Target Values

A technical team is formed to undertake an open-minded analysis to compare the two systems in terms of the extent to which they match the customer requirements using a five-point scale in which five points represents the best match and one point the worse. The ratings are presented in the comparison rating chart.

Then target values room is then calculated, in which there are two sets of scores: the absolute scores and the relative scores. The ratings are calculated by summing each column of customer requirement ratings and the values that have been assigned to the correlation symbols. A value of 9, 3, and 1 is assigned for a strong, medium, and weak relationship, respectively. The relative value is simply the absolute value expressed as a percentage of the total value. By grouping all of the results, the HOQ matrix can be finalized as show in Figure 5.

VI. Process Analysis Based on the QFD

Analysis of the comparison-rating chart of the QFD matrix shows that most the integrated system has more advantages. In particular, the integrated system achieves better ratings for the customer requirements that were identified using the strategic analysis method. The standalone system achieves better ratings only for about one third of the requirements that were identified using value engineering.

VII. Conclusion

An improved QFD framework is proposed in this paper, the usefulness of which is illustrated through a case study that analyzes of two alternative systems in a singulation process. The integrated system is found to better meet customer requirements.

The case study shows that the proposed framework allows the systematic identification of customer requirements and that the identification of the functional characteristics of a complicated product (in this case an engineering process) can be recognized better using IDEF methodology.

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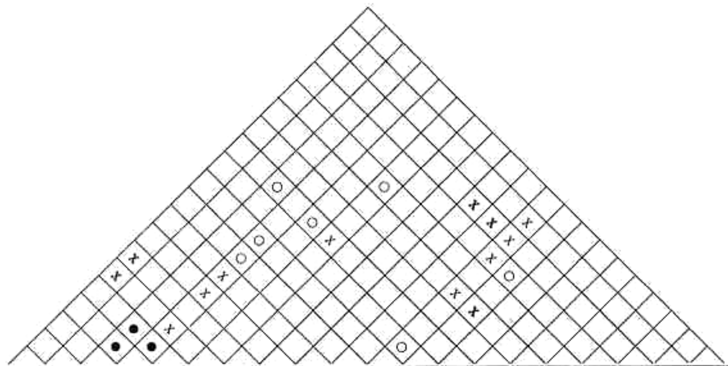

	CUSTOMER REQUIREMENT \ ENGINEERING CHARACTERISTICS	IMPORTANCE	Speed up the motion	Minimize the material transportation distance	Minimize the machine size	Reduce the number of machine modules	Include more sensors for material monitoring	Allow a longer time for inspection	Increase the size of loading platform	Increase the size of unloading platform	Minimize the number of loaders	Minimize the number of unloaders	Provide a safe cover for the machine	Simplify the design and layout of the machine	Minimize the number of conversion items	Design a special collection box	Automat the magazine transfer thr. the modules	Use reusable jig and fixture	Simplify control panel layout	Devise a programmable lead frame (LF) track	Create an independent modular machine	Make the design fool proof
Value Engineering	High productivity	9	◎	◎	△	△																
	A longer mean time between assists	8					○	○														
	A longer mean time between loads	8							◎	◎	○	○										
	A lower equipment cost	7				◎								○								
	A reduce the extra material cost	7																◎				
	Reduced human error	9									○	○					◎					◎
	Easy maintenance	7												◎								◎
	Multi-function	7																		○		
	Independence from the functional module	7																			◎	
	A wide package size handling capacity	8																		◎		
	A lower the packaging cost	8	△															△				
	A smaller equipment floor space reqt.	7		◎							○	○		△								
Strategic Analysis	Safe working conditions	8											◎		△				○			◎
	Reduced skill level reqts. for operators	6				△	○						△	◎	△	○	◎		◎			◎
	Reduced labor requirements	5				△			△	△				△	△	△	◎		◎	◎		○
	Easy equipment transportation	4			◎	◎					○	○										
	Easy operation	5				◎					△	△					◎		◎			
	A line balanced system	5															○					
	An adequate level of work in process	5				◎								◎								
	Good process yield	9		△		◎	◎	◎			○	○					◎					
	An efficient processing cycle	8				◎								◎								
Engg. Characteristics Importance Rating	Absolute		89	153	45	372	123	105	77	77	116	116	77	267	19	23	366	68	168	138	63	285
	Relative		3	6	2	14	4	4	3	3	4	4	3	10	1	1	13	2	6	5	2	10

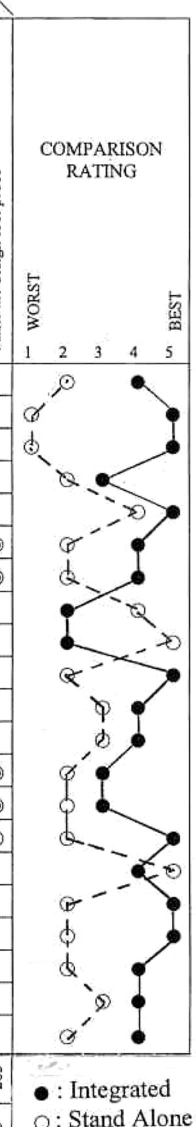

Figure 5 HOQ matrix of the two singulation process