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A QFD Framework for Developing Engineering Laboratories

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In recent years, quality function deployment (QFD) has been used to guide the introduction of organizational change in market-driven industrial companies to achieve a clearer focus on quality. In the years ahead, ever-increasing competitive pressures will force many universities to undertake a critical examination of their mission and attempt to adopt a similar customer-driven orientation. A QFD framework can provide a useful approach to guide this change process. In this paper, we present the building blocks of QFD and provide a case study to illustrate the application of this concept in developing engineering laboratories in academia.

INTRODUCTION

QUALITY function deployment (QFD), a paradigm for product development, was first developed and applied by the Japanese in the early 1970s [1]. QFD helps identify and prioritize customer requirements and relates these needs to corresponding product or service characteristics. The House of Quality (HOQ), a series of matrices, is used to link relationships and provides a graphical summary, making it easier to utilize, analyse and evaluate this information. QFD can thus ensure that customer requirements will be correctly built into the product or service.

QFD has been adopted by several manufacturing firms in the U.S.A. including Ford Motor Company, General Motors, Rockwell International, AT&T, DEC, Hewlett-Packard, and Polaroid [1]. Several companies in the service sector have also adopted QFD. However, academia has shown little interest in adopting this approach to better meet the needs of its customers—students, faculty, staff, and employers in industry. In this paper, we will review the QFD concept and methodology, and examine its potential as a framework for managing change. An illustrative case study will be presented to illustrate the use of the QFD framework for managing the ongoing development of engineering laboratories in universities.

QFD—AN OVERVIEW

The QFD team

One of the most important concepts in QFD is that of the multi-functional team. This concept is also embodied in the concurrent engineering (CE) ideal [2]. Design engineers, for example, have to work not only with marketing people and customers to determine the scope of the product, but also with engineering personnel to set control characteristics for each requirement. Since working together is a critical issue in QFD, team formation is important. Thus individual team members should be competent within a particular area of work, and should also be team players. A team leader or facilitator is often necessary to provide some structure and direction for the team [3]. Several group decision-making techniques can be used, e.g., brainstorming to create ideas, tree diagram to establish hierarchy, fishbone diagram to identify all the possible causes of a problem. A list of these techniques is provided in Table 1.

The QFD process

The tasks associated with the QFD process are as follows.

- Define the customer: the QFD team has to determine whom the company is trying to satisfy, so as to obtain the right information about the product.
- Obtain customer preferences and non-preferences about the product: this information is called the 'voice of the customer'.
- Product quality deployment: this converts the 'voice of the customer' into quantitative technical, counterpart engineering characteristics, or design attributes.
- Deployment of quality function: this is the process of assigning the defined technical characteristics to specific departments.

The major difference between QFD and other typical product development processes is that in QFD 'the voice of the customer' is the driving force for all the activities. Instead of limiting quality considerations to the control of the manufacturing process, this approach has a quality focus in every

Table 1. Techniques for decision-making in QFD teams

Decision-making techniques	Purpose
Brainstorming	To generate ideas
Nominal group technique	To generate ideas and to find final solution
Analytical hierarchy process (AHP)	To establish relative importance of factors
Fishbone diagram	To identify the possible causes of a problem
Histogram	To reveal the frequency of each variation in a process
Scatter diagram	To observe the relationship between 2 variables
Pareto chart	To determine the order of problems to be solved
Affinity diagram/KJ method	To organize large amounts of data
Tree diagram/system flow	To establish a hierarchy
Interrelationship digraph	To determine relationship between several items
Pugh concept selection	To narrow the existing alternatives/ concepts down to the best few ones
Arrow diagram	To plan and control the most appropriate schedule for any task
Matrix diagram	To display and relate two or more lists of items together
Matrix data analysis	To show the strength of the relationship between variables
Process decision program chart (PDPC)	To map out the possible events of a selected solution

step of the product development cycle. This enables a company to gain the following benefits:

- the product is exactly what the customers want;
- all the tasks for every department are accurately defined;
- all resources are effectively utilized;
- the strengths and weaknesses of the product are listed.

The House of Quality (HOQ)

The House of Quality summarizes and organizes all the information into a graphic display. This framework guides the team through the QFD process. In order to build a house of quality, the following tasks have to be done:

- identify the market needs;
- identify the corresponding design characteristics;
- construct the relationship matrix.

The HOQ is built by putting this information together in a specific format (see Fig. 1) and may include other related product information such as the target value for each design attribute and the technical difficulty for each design characteristic. The QFD team might build several other similar relationship matrices for the ensuing steps in the product design and development process.

QFD software

Although it can be inferred from many users of QFD that computers are used in most QFD projects, the literature contains little discussion on QFD software. Some discussion appeared in Daetz's paper about the limits of constructing the QFD matrices due to the lack of appropriate software [4]. However, in AUTOFACT '89, a conference on advanced production systems, personnel from Ford Motor company presented a paper describing Technical Information Engineering Systems (TIES), an in-house developed knowledge-based system based on QFD concepts to help users of QFD [5]. Ford also developed the QFDPlus software to be used within Ford and among its suppliers.

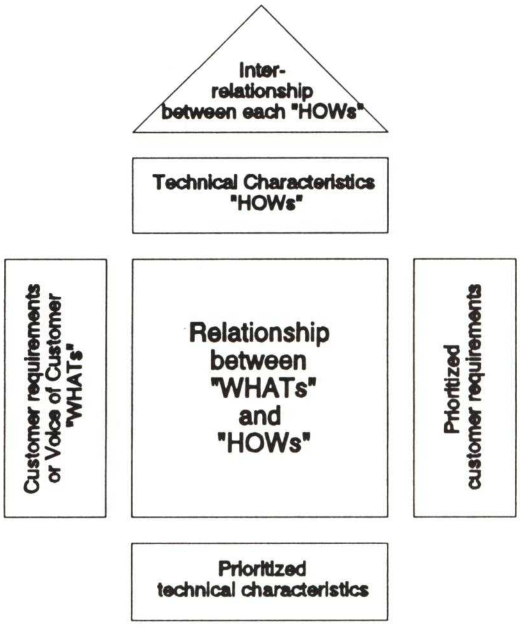


Fig. 1. Format for the House of Quality [11]

In QFDPlus, the four phases of work defined are product planning, design deployment, process planning, and production planning. After creating phase 1 data, or the HOQ, the ensuing phases can be created either based on the data of the previous phase or from totally new data. The software allows the user to change the graphic presentation of the matrices to a format that can be used with other software such as AutoCAD or EasyCAD, and also allows the data in phase 1 to be imported or exported as ASCII files. QFDPlus also provides flexible ways to plot or print each matrix or other outputs. In general, the QFDPlus software is user friendly and provides special functions like the Pugh Chart to provide an objective method for selecting the best design. However, QFDPlus is just a decision-making tool to facilitate data analysis and provides no conclusions or decisions.

APPLICATIONS

Industry

QFD has attracted attention from a wide range of progressive industrial organizations in the U.S.A. and overseas. A summary of the typical applications reported in the literature is provided in Table 2.

QFD has also been proposed for use in the area of software development. Here the QFD matrices may not be the same as of those for the product development. Software quality can be obtained by concentrating on discovering software defects from inspecting, testing, and complaints, then trying to eliminate their causes. QFD can help reduce these trial-and-error activities [1].

QFD has also been applied in service areas. AT&T, for example, defines the 'whats' as the customer needs and the 'hows' as the characteristics of a service that would fulfil the customer needs [6]. Another example is the Spa Resort case reported by Neff and Miller [7].

Academia

In academia, decision-making must invariably be effected in groups operating in committees, task forces, or project teams. The goals of engineering educational institutions are multi-dimensional, difficult to quantify, and often conflicting. In the years ahead, ever-increasing competitive pressures will force many universities to undertake a critical examination of their mission and attempt to adopt a more customer driven orientation. QFD can be used to facilitate effective means of communication, timely information transformation, and efficient resource utilization. In the following section, we describe an application of QFD via a case study of planning engineering laboratories in academia.

CASE STUDY

The UMR Engineering Management CIM Lab

The Computer Integrated Manufacturing Laboratory (CIM Lab) of the Engineering Management Department at the University of Missouri-Rolla was granted an area of 5072 square feet in 1987. This lab was intended to stimulate interest in teaching and research in advanced manufacturing systems and was expected to provide a centre of technical excellence in CIM education for industry in Missouri. A pairwise comparison of the lab's three objectives and five goals was provided by a group of six faculty members who were interested in incorporating the CIM lab into their teaching, research, and extension activities. This was used by the AHP process to determine appropriate priorities to be assigned to each goal and objective [8]. After the priority assignment (Fig. 2), a linear goal programming model was established to determine the optimum space to be allocated to each department in the CIM laboratory.

Table 2. Typical QFD application in manufacturing industry

Users	Type(s) of business	Areas of application
Hughes Aircraft, Delco Electronics, General Electric, AT&T, and Pacific Monolithics	A multi-company project for a defense contract. The project is to assemble a low-cost, high volume manufacturing facility for microwave module hybrids	Communication tool, Process development, part of the TQM system for the manufacturing line built
AT&T	Communication	Product, software, and service improvement and development, enterprise planning, process management, new technology assessment
Rockwell International	Supplier for both commercial and government sectors	Product improvement and development, process planning
Hewlett-Packard	Hardware producers	Hardware and software improvement and development
In Italy	Automobile, household appliance, office and home furniture, etc.	Product and subsystem improvement and development

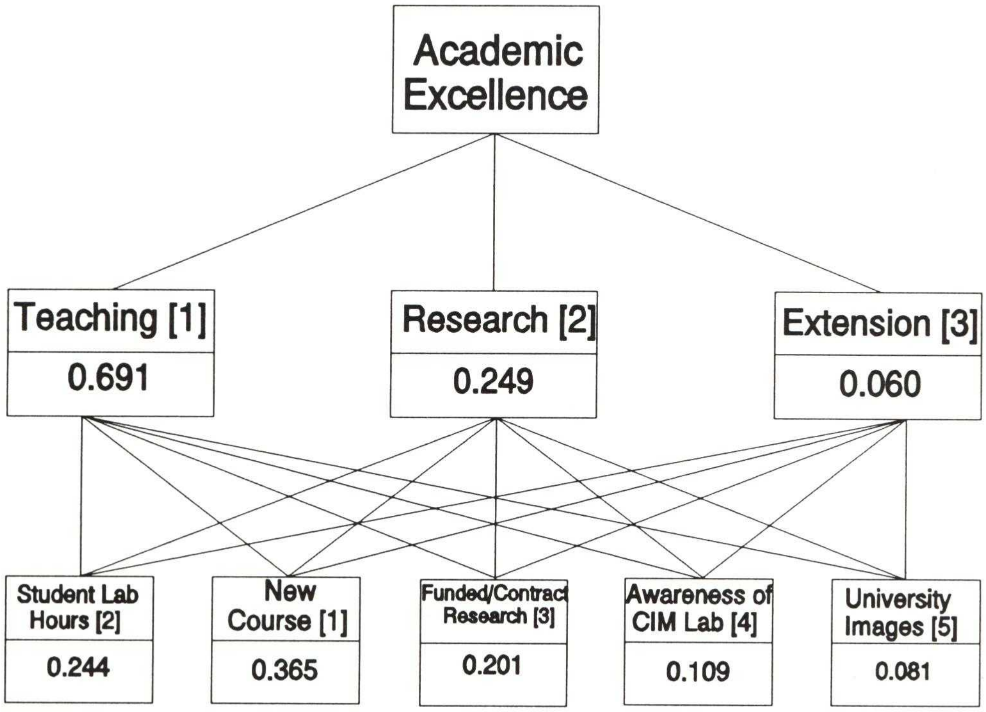


Fig. 2. Hierarchy of the university goals and objectives [8]

Application of QFD

In recent years, the university's mission in higher education has shifted to reflect a renewed emphasis on teaching at the undergraduate level. There has therefore been a need to see how the CIM lab can best serve this new mission of the university, and also to find a framework for implementing necessary improvements. Instead of using AHP as was done in a previous study, QFD was selected as the tool to be used to estimate the priority of the lab's objectives. Students were used instead of faculty members in determining customer needs. Since the objectives of the university have not changed noticeably, the hierarchical

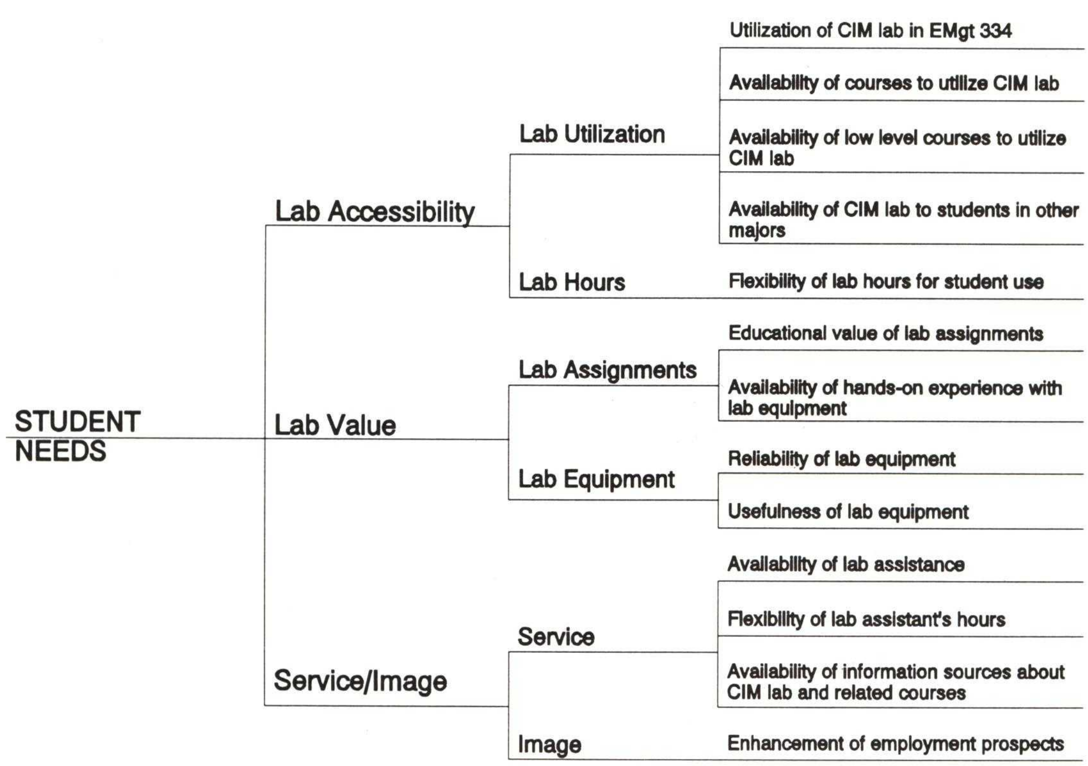


Fig. 3. Tree diagram of student needs

structure of 3 goals and 5 objectives used by Benjamin, Ehie, and Omurtag was adopted.

The QFD process was divided into the following six steps.

Define the problem. The problem was defined as 'How to utilize the CIM lab to enhance the environment for undergraduate engineering education.'

Obtain the students' preferences. Twelve undergraduates enrolled in course EMgt 257, Plant Layout and Material Handling in Fall 1992, were used as a sample group. The students' preferences were obtained by the use of the Nominal Group Technique, a limited and silent version of the brainstorming technique [9].

Organize the students' preferences using a tree diagram. All factors listed by the students were grouped into 3 major areas using a tree diagram (see Fig. 3).

Obtain the relationship between objectives and students' preferences. A subjective assessment was made of the relationship between each objective and the students' preference. This information was summarized in a matrix diagram (see Fig. 4).

ORIENTATION = MIN ↓ MAX ↑ TARGET ○

PLANNING OBJECTIVES

CUSTOMER REQUIREMENTS (NEEDS & EXPECTATIONS)

ITEM NUMBER / CUSTOMER IMPORTANCE RATING (1=LEAST 5.0=MOST)

RELATIONSHIP MATRIX
9 = STRONG RELATIONSHIP
3 = MEDIUM RELATIONSHIP
1 = WEAK RELATIONSHIP

Item	Customer requirement	Importance	01 STUDENT LAB HOURS ↑	02 NEW COURSES ↑	03 FUNDED/CONTRACT RESEARCH ↑	04 CONTINUING EDUCATION SEMINARS AND COURSES ↑	05 PUBLIC TOURS AND DEMONSTRATION ↑
01	LAB ACCESIBILITY						
02	LAB UTILIZATION						
03	AVAILABILITY OF COURSES UTILIZING LAB	4.6		9	3	3	
04	LAB HOURS						
05	FLEXIBILITY OF LAB HOURS FOR STUDENTS	4.4	1	1	1		
06	LAB VALUE						
07	LAB ASSIGNMENTS						
08	EDUCATIONAL VALUE OF LAB ASSIGNMENTS	4.5	9	3			
09	LAB EQUIPMENT						
10	USEFULNESS OF LAB EQUIPMENT	4.4		3	3	3	1
11	SERVICES/IMAGES						
12	SERVICES						
13	AVAILABILITY OF LAB ASSISTANTS	4.5	1	1	3		
14	IMAGES						
15	ENCHANCEMENT OF EMPLOYMENT PROSPECTS	4.2	3	3	3	3	9

From QFDPlus software

Fig. 4. Matrix diagram of student needs and university objectives

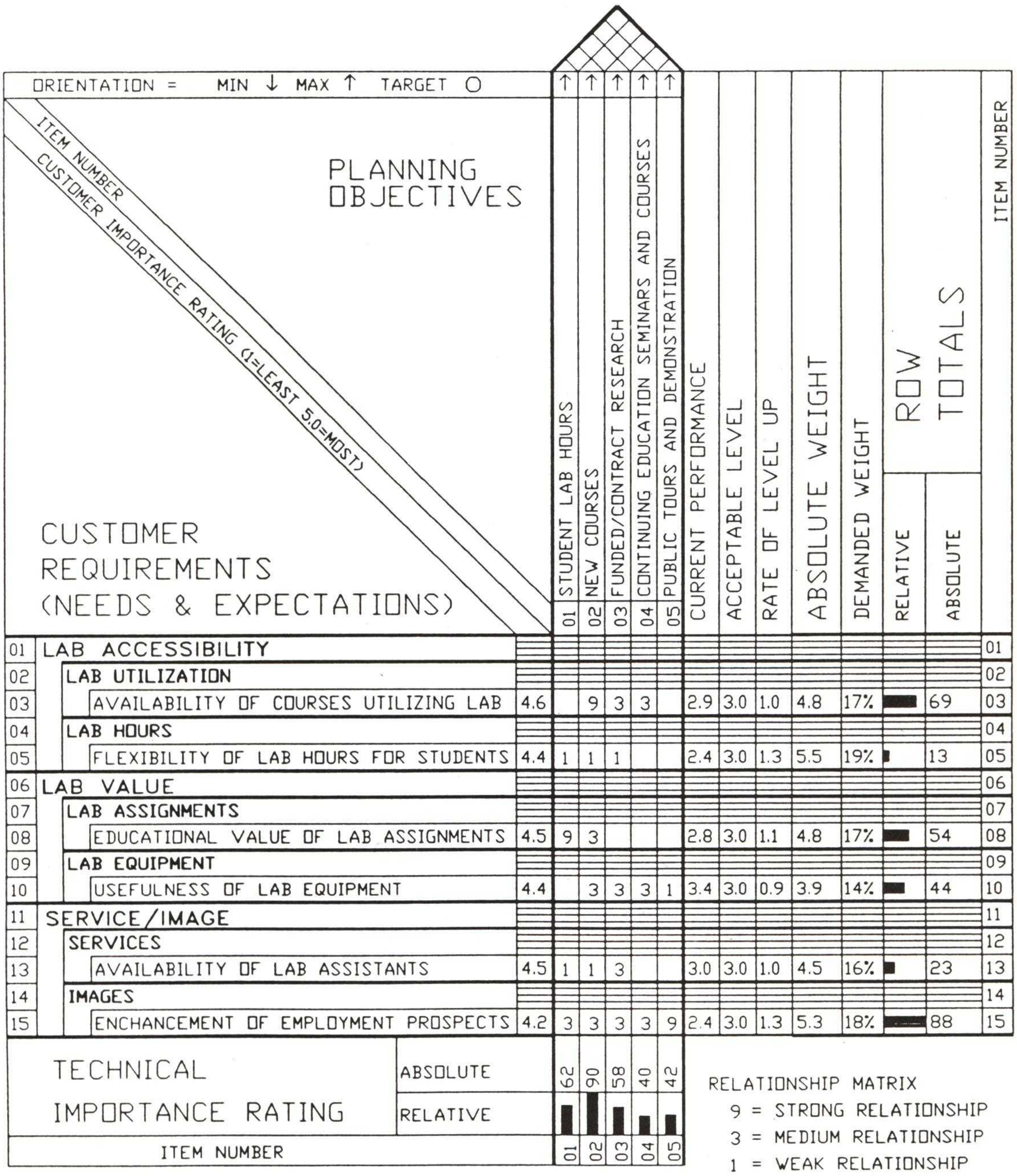
Create the HOQ. All data were entered into the QFDPlus software which was used to create the HOQ. The HOQ developed using the student importance ratings is shown in Fig. 5.

Evaluate the outcome. The results can then be analysed and interpreted and used as a basis for implementing improvements.

Discussion of results

Six factors associated with lab performance were identified. Each student was asked to evaluate the importance of these two factors and to rate the current level of performance. From the student responses, each factor was then assigned an importance rating and a rating for the current level of performance obtained. Students were encouraged to list other factors which were perceived to be important in the use of CIM lab. Fig. 6 provides a profile of student needs and perceptions of current levels of performance. The results of this study are given in Table 3. (For additional information see Pattanapanchai and Benjamin [10].)

From the results, we see that the most important objective is the introduction of *new courses*, followed by the expansion of *student lab hours*. *Funded/contract research* and *public tours and*



From QFDPlus software

Fig. 5. House of Quality using customer importance rating

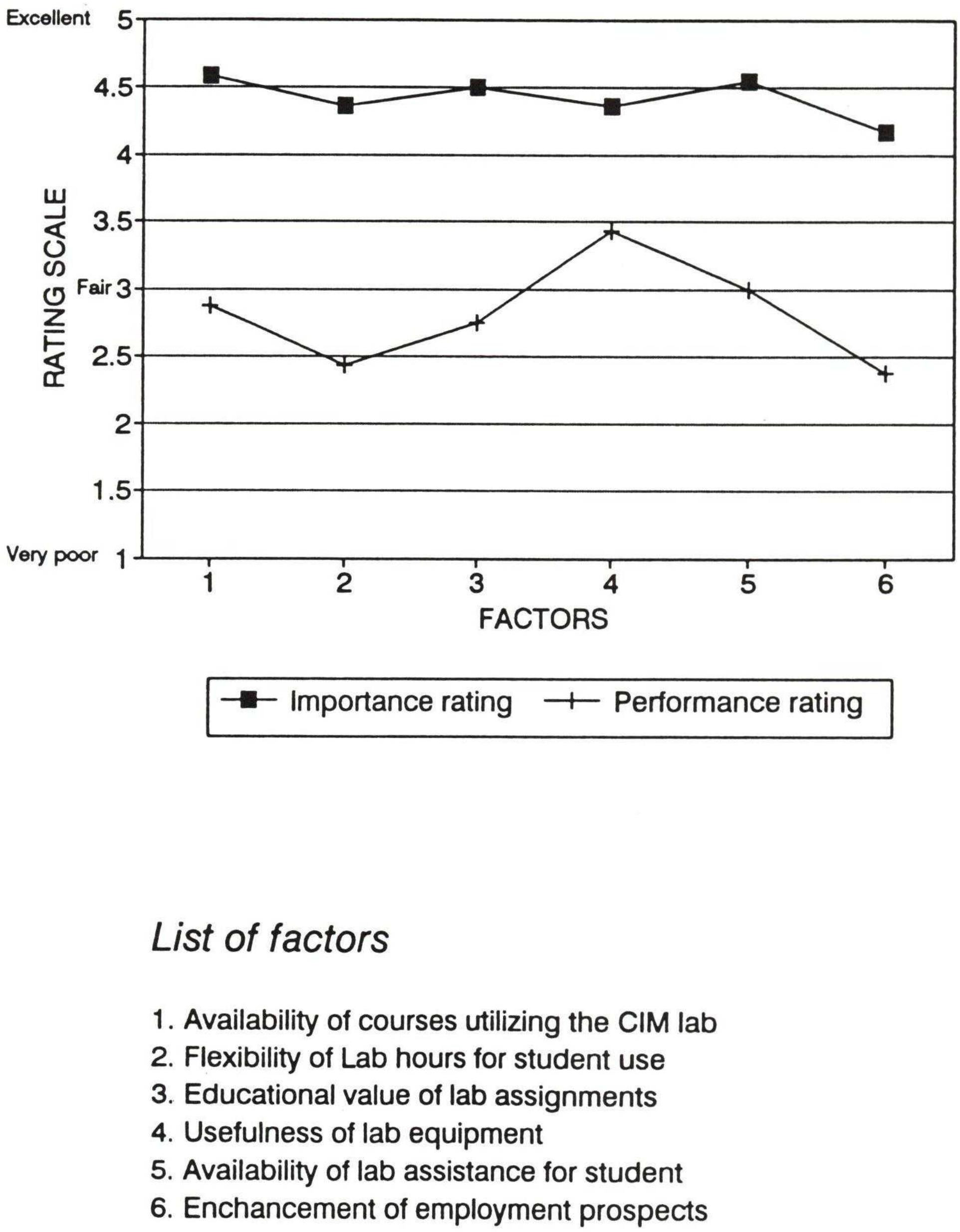


Fig. 6. Profile of student needs and current level of performance

Table 3. Comparative evaluation of educational preferences obtained from QFD and AHP techniques

Objectives	QFD		AHP*	
	Importance rating score**	Rank	Importance rating score	Rank
1. Student lab hours	62 (241)	2	0.244	2
2. New courses	90 (330)	1	0.365	1
3. Funded/contract research	58 (211)	3	0.201	3
4. Continuing education seminars	40 (145)	5	0.109	4
5. Public tours and demonstrations	42 (178)	4	0.081	5

Notes:
* Information is obtained from [8].
** Numbers in parentheses are the consequences of using demanded weight in calculation.

demonstrations are third and fourth respectively. The last one is *continuing education seminars and courses*. The results also show that while students are satisfied with the educational value of the lab assignments, some attention must be given to providing more flexible lab hours and using the lab to provide enhanced employment prospects for students. The HOQ provides information on actions that can be taken to impact these areas.

CONCLUSION

QFD has proven to be an effective tool in managing product/service development in manufacturing industry, in software development, and in service industries. It is a powerful tool for enhancing effective communication, defining clear and accurate tasks, and achieving effective resource utilization. This makes the technique attractive to enhance any group decision-making process. The case study reported in this paper illustrates the application of QFD to the planning of a university engineering laboratory. This represents a preliminary attempt to examine the potential of using QFD to provide a framework for managing change in academia. In this case, the QFD framework yielded results consistent with those obtained from a comparable study conducted using the AHP technique [8]. Additional work is required to solicit input on needs from other customer groups e.g. faculty, staff, and industrial employers and have these integrated in an expanded set of customer needs. The impact on the priority rating assigned to goals and objectives can be examined and a comparative evaluation made of the utility of QFD as a group decision-making framework in academia.

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