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Selection of Curricular Topics Using Extensions of Quality Function Deployment

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Abstract

Decision science can be an effective tool for enhancing organizational participation during strategic and complex decision making. This involvement develops a group consensus for relating organizational goals and the methods to achieve them. This paper describes an application of Quality Function Deployment (QFD) to define curricular topics that meet program objectives. Based on the ability of QFD to establish relationships, the model identifies the most important topics and quantifies their impact on meeting program goals. The model was developed to support restructuring of a Masters of Engineering Management degree program. The model supported decisions in selecting and prioritizing the required curricular content to support program goals. The model provided a practical methodology for developing faculty consensus in the selection of curricular topics with a strategic focus.

I. Introduction and Organizational Context

The Department of Engineering Management at Old Dominion University offers a Masters of Engineering Management (MEM) degree as its core product. In the fall of 1998 the faculty recognized that the MEM curriculum should be examined to ensure relevancy to existing conditions. Industrial base changes in the southeast Virginia region, faculty personnel turnover, administrative pressures to increase enrollment, and other environmental changes highlighted the need to critically examine the MEM curriculum.

The curriculum redesign effort adopted an outcomes based methodology in which the curricular topics were to be directly tied to desired outcomes. Through a series of facilitated meetings the faculty developed MEM program objectives and associated goals. These are summarized in Table 1-Program Objectives and Goals. However, the faculty recognized that the six program goals were not equally important, the identity and character of our program is highly dependent the emphasis placed on specific program goals. The challenge was to develop a set of curricular topics that not only directly contributed to the identified goals but that did so proportionately to the respective importance level of each goal.

Quality Function Deployment (QFD) provides a framework for linking customer requirements to product characteristics. Although typically applied to industrial problems, the QFD methodology was seen as a mechanism for developing curricular topics in a disciplined and well-structured format. The next section describes the QFD modeling structure and its application within an academic context.

Table 1. Program Objectives and Goals

Program Objectives	Program Goals
1. Provide skills, knowledge and attitudes to manage the technology based, project driven enterprise. 2. Develop ability to choose and apply appropriate approaches to project management problems. 3. Foster outstanding technological leadership skills.	1) Develop and Implement projects 2) System based problem solving 3) Leadership – make a difference 4) Quantitative and analytical skills 5) Written and oral communications 6) Teamwork and diversity (people) skills

II. Quality Function Deployment Portfolio Model

Quality Function Deployment (QFD) originated as a tool for quantifying customer needs and reflecting these needs as requirements through the product design and manufacturing process. Historical information and detailed applications of QFD in a product development framework are found in [1] and [2]. In product design, QFD relates the product performance requirements of the customer with technical design characteristics through a matrix generally known as the "house of quality." This mapping of "whats" (product / customer specifications) to "hows" (technological features) develops a quantitative measure of priority for each technical characteristic based on its impact on the product feature or customer specifications. In this process, QFD has demonstrated an ability to promote organizational consensus building and decision making [3].

These strengths indicated QFD would be an attractive alternative for analyzing the problem of selecting curricular topics. Figure 1 describes the parallel concepts of application of QFD to product development and to curricular development. The specific information presented in this paper generally reflects the methods applied but the details have been modified for brevity while demonstrating basic model concepts.

Product Development Application of Quality Function Deployment

Whats: Customer or Product Requirement	**Hows:** Technical characteristics that impact customer product requirements		**<u>Product Development Data</u>**
Characteristics desired by customer:	Mapping of interrelationships of customer product requirements and the impact of major technical features.	⇨	Importance of technical features in meeting customer requirements

Curricular Development Application of Quality Function Deployment

Whats: Program Objectives	**Hows:** Curricular topics that impact the program objectives.		**<u>Program Management Data</u>**
Skills that promote student success.	Mapping of interrelationships of program goals with curricular topics.	⇨	Importance of curricular topics in meeting program objectives.

Figure 1. Comparison of QFD Applications

III. Impact of Curricular Topics on Program Objectives

This section evaluates the impact of the curricular topics (CTs) on the program goals (PGs). The QFD model measures this impact on two levels. The first level evaluates the direct effect of the CTs on the PGs. Since CTs may also reinforce each other, the second impact level measures the interaction (indirect) effect of the CTs on the program goals.

As described in Table 2, eleven topical areas were identified and scored based on their direct impact on the PGs. Table 2 evaluates this impact employing a traditional (9,3,1) QFD scoring method: nine indicates high impact of a topic on an objective, three indicates medium, one indicates small, and zero indicates no impact. Additional information on scoring methods can be found in [4] and [5]. Evaluation of the interaction of curricular topics is an important feature in understanding the total impact on program goals. The general QFD approach to this problem employs the concept of correlation between the curricular topics to describe interaction [6]. The interaction between a given pair of CTs is a fractional value between ± 1. Using the (9,3,1) rating scale as a basis, a parallel set of interaction scores can be defined:

- High, positive interaction between two CTs is assigned a score of 9 / (9+3+1) = 9/13 = 0.692;
- Medium interaction is scored as (3 / 13) = 0.231;
- Low interaction is valued at (1 / 13) = 0.077
- No interaction results in a zero score.

Table 2. Impact of Curricular Topics on Program Objectives

	Weight	Simulation	Engineering Economy	Quality Control	Project Management	Technology Management	Stochastic Processes	Decision Science	Operations Research	Organizational Behavior	Information Systems	Logistics
Develop / Implement Projects	0.2	3	9	3	9	1	3	3	3	3	3	3
System Based Solutions	0.1	3	3	3	3	9	1	3	1	1	9	3
Leadership - Make a Difference	0.2	1	3	3	3	9	1	1	3	9	1	1
Quantitative Skills	0.25	9	1	9	3	1	9	9	9	0	3	3
Written and Oral Communication	0.1	1	9	0	3	3	1	1	1	3	1	1
Teamwork and Diversity	0.15	0	1	0	3	1	0	0	0	9	0	0

Table 3 uses this approach to develop an interaction matrix that is symmetrical about the main diagonal. Consistent with the concept of correlation, the matrix assumes that the interaction of CTs is mutually equivalent. For example, studies in Stochastic processes will produce a strong positive impact on studies in Simulation and this is demonstrated by the 0.69 score at the intersection of these columns and rows.

Table 3. Interaction Matrix for Curricular Topics

Note: High interaction = 9/13=0.692; Medium interaction = 3/13= 0.231; Low interaction = 1/13=0.077

	Simulation	Engineering Economy	Quality Control	Project Management	Technology Management	Stochastic Processes	Decision Science	Operations Research	Organizational Behavior	Information Systems	Logistics
Simulation	1.000	0.077	0.000	0.077	0.231	0.692	0.231	0.231	0.000	0.000	0.231
Engineering Economy	0.077	1.000	0.231	0.692	0.231	0.000	0.231	0.077	0.000	0.000	0.231
Quality Control	0.000	0.231	1.000	0.077	0.231	0.077	0.231	0.231	0.000	0.000	0.231
Project Management	0.077	0.692	0.077	1.000	0.077	0.231	0.077	0.231	0.231	0.077	0.000
Technology Management	0.231	0.231	0.231	0.077	1.000	0.000	0.000	0.077	0.231	0.231	0.231
Stochastic Processes	0.692	0.000	0.077	0.231	0.000	1.000	0.231	0.231	0.000	0.000	0.231
Decision Science	0.231	0.231	0.231	0.077	0.000	0.231	1.000	0.692	0.000	0.000	0.231
Operations Research	0.231	0.077	0.231	0.231	0.077	0.231	0.692	1.000	0.000	0.000	0.231
Organizational Behavior	0.000	0.000	0.000	0.231	0.231	0.000	0.000	0.000	1.000	0.000	0.000
Information Systems	0.000	0.000	0.000	0.077	0.231	0.000	0.000	0.000	0.000	1.000	0.077
Logistics	0.231	0.231	0.231	0.000	0.231	0.231	0.231	0.231	0.000	0.077	1.000

IV. Curricular Impact Information

Using the data in Tables 2 and 3, the QFD model can develop a range of useful curricular management information. The following questions will provide an analytical framework to illustrate this capability:

1. Curricular topic impact: How can the interactions of the curricular topics in Table 3 be incorporated with the direct impact information in Table 2 to evaluate the total impact of the Curricular topics (CTs) on the program goals (PGs)?
2. Proportional curricular impact: Is it possible to determine if the CTs have been structured to impact the PGs in a manner proportional to the importance (weights) of the PGs?
3. Importance of the curricular topics to the PGs and program: Which work packages are most important to achieve the success of specific PGs and the overall program?

Evaluation of Impact of Curricular Topics on Program Goals

Evaluation of the CT impact on PGs requires integration of the data in Exhibits 2 and 3 to develop a combined measure of the direct and interaction impact. The QFD methodology develops this information using matrix multiplication. In the general case, the direct impact data of Table 2 is a matrix **A** (bold, capital letter denotes a matrix) of m rows representing PGs and n columns representing CTs. The elements of this matrix may be described as a_{ij} (i = 1, 2,…, m and j = 1, 2,…,n). Similarly, the interaction data in Exhibit 5 is an n x n matrix **B** with elements b_{ij} (i, j = 1,2,…, n). The combined impact (including interactions) of CTs on PGs may be defined by the m x n matrix **C** that is the result of the matrix product (**A x B** = **C**). The elements of **C** (c_{ij}) describe the complete impact of CT_j on PG_I.

$$c_{ik} = \sum_{j=1}^{n} a_{ij} b_{jk} \quad (1)$$

The upper half of Table 4 contains matrix **C** and provides the quantitative measure of both direct and interaction impact of the curricular topics on the program goals. In the case of the impact of Simulation on Developing and Implementing Projects:

$$c_{11} = 3*1 + 9*0.077 + 3*0 + ... + 3*0.231 = 8.8 \quad (2)$$

In addition to **C**, the upper portion of Table 4 contains two additional columns: the row total and the normalized row total. The row total elements are defined by the sum of the row impact values. For instance the row total for Developing and Implementing Projects is:

$$\sum_{j=1}^{n} c_{ij} = 8.8 + 18 + ... + 9.0 = 110 \quad (3)$$

Dividing the row total by the grand sum of all the C matrix elements and expressing this value as a decimal or percentage value develops the normalized row total:

$$\frac{\sum_{j=1}^{n} c_{ij}}{\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}} = \frac{110}{519} = 0.21 (21\%) \quad (4)$$

Assessment of Proportional Curricular Impact

The second question examines whether the impact of the CTs on the PGs is consistent with the stated importance (weight) of the PGs. The total impact values of Table 4 provide the basis to analyze this question. Comparison of the importance of a program goal with the total impact of the CTs on the PG is a relative measure to determine if the impact of the CTs is proportional to (consistent with) the stated importance of the PGs. The weight (objective importance) column and the normalized row total in Table 4 provide this comparison. For example, the system based solution objective is 10% of the total program importance, yet receives 18% of the curricular topic impact. This may indicate a disproportionate allocation of curricular topics and the faculty may consider redefining curricular content or developing new topics.

Assessment of Curricular Topic Importance

The final question addresses the importance of a curricular topic both to an individual objective and to the overall program. To examine these issues, the upper portion (**C** matrix) of Table 4 is restated in the lower portion in terms of normalized impact values ($\mathbf{C}^{\mathbf{N}}$ matrix). The elements of the $\mathbf{C}^{\mathbf{N}}$ matrix (c_{ij}^{N}) are:

$$c_{ij}^{N} = \frac{c_{ij}}{\sum_{j=1}^{m} c_{ij}} \tag{5}$$

The elements of $\mathbf{C}^{\mathbf{N}}$ provide direct insight into the importance of a CT for a specific PG. For instance, the normalized impact of Simulation on Developing System Based Solutions is:

$$c_{11}^{N} = \frac{7.8}{91} = 0.09 \tag{6}$$

This value indicates that the Simulation CT produces 9% of the impact for achieving the objective of developing system - based solutions. The most important topic for this objective is Technology Management at an impact of 0.16 (16%).

The last part of the third question addresses the relative importance of the WPs to the overall program and $\mathbf{C}^{\mathbf{N}}$ provides the basis for developing this information. Consider the Logistics topic and its importance to the program objectives. This impact can be quantified by multiplying the importance of each PG by the impact of Logistics on that objective and summing these values. Expressing this in matrix notation, the PG importance can be considered a 6x1 column vector **W** (weight). If **W** is transposed and used with the normalized impact matrix $\mathbf{C}^{\mathbf{N}}$ to develop the product ($\mathbf{W}^{\mathbf{T}}\ \mathbf{C}^{\mathbf{N}}$), the result is a 1 x 5 row vector, **T**, that expresses the importance of each CT to the overall program. For example, the element of **T** that expresses the importance of Logistics to the program objectives (0.07) is:

$$t_{11} = 0.08*0.2 + 0.1*0.1 + ... + 0.02*0.05 = 0.07 \tag{7}$$

Similar calculations produce the remaining entries in the row "Curricular Topic Importance to Program" in Table 4. The values in this row identify Logistics and Information Systems as the least important topics to the program goals and Project Management as the most important for the program as measured by impact on the program objectives.

V. Conclusions

This paper described an application of Quality Function Deployment (QFD) for selection of curricular topics to meet objectives for a graduate program. QFD has been utilized successfully in many industrial applications such as ship - building and in automobile manufacturing. It is a valuable tool that can translate customer desires into specific actions enabling focus on the most influential areas of product/process design in terms of performance and cost. QFD can also point out the problem areas/conflicts that require further attention.

Even though this application is still a work in process, the authors found the application of QFD to curricular development beneficial. QFD structures the difficult process of curriculum development and promotes a decision approach that maintains a focus on program objectives.

Table 4. Comparison of Topics Impact and Objective Weight

Program Objectives	Weight	Simulation	Engineering Economy	Quality Control	Project Management	Technology Management	Stochastic Processes	Decision Science	Operations Research	Organizational Behavior	Information Systems	Logistics	Row Total	Normalized Row Total
Develop / Implement Projects	0.2	8.8	18.0	8.3	18.3	7.5	9.5	10.6	10.7	5.3	4.2	9.0	110	0.21
System Based Solutions	0.1	7.8	9.5	7.7	7.8	14.4	5.6	6.9	7.0	3.8	11.5	9.0	91	0.18
Leadership - Make a Difference	0.2	5.4	8.6	7.2	9.2	13.6	3.8	5.4	6.7	11.8	3.4	5.9	81	0.16
Quantitative Skills	0.25	20.6	9.5	15.2	10.2	7.7	21.5	22.6	23.0	0.9	3.7	14.1	149	0.29
Written and Oral Communication	0.1	4.0	12.4	3.8	10.8	6.8	3.1	4.7	4.0	4.4	2.0	4.8	61	0.12
Teamwork and Diversity	0.15	0.5	3.3	0.7	5.8	3.5	0.7	0.5	0.8	9.9	0.5	0.5	27	0.05
											Total Impact =		519	

Normalized Impact Values

	Weight	Simulation	Engineering Economy	Quality Control	Project Management	Technology Management	Stochastic Processes	Decision Science	Operations Research	Organizational Behavior	Information Systems	Logistics
Projects	0.2	0.08	0.16	0.08	0.17	0.07	0.09	0.10	0.10	0.05	0.04	0.08
System Based Solutions	0.1	0.09	0.10	0.08	0.09	0.16	0.06	0.08	0.08	0.04	0.13	0.10
Leadership	0.2	0.07	0.11	0.09	0.11	0.17	0.05	0.07	0.08	0.15	0.04	0.07
Quantitative Skills	0.25	0.14	0.06	0.10	0.07	0.05	0.14	0.15	0.15	0.01	0.02	0.09
Communication	0.1	0.07	0.20	0.06	0.18	0.11	0.05	0.08	0.07	0.07	0.03	0.08
Teamwork	0.15	0.02	0.12	0.03	0.22	0.13	0.03	0.02	0.03	0.37	0.02	0.02
Curricular topic Importance to Program		**0.08**	**0.12**	**0.08**	**0.13**	**0.11**	**0.08**	**0.09**	**0.09**	**0.11**	**0.04**	**0.07**

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