# MEASUREMENT OF SERVICE QUALITY FOR SYSTEMS WITH DEPENDENCY LOOPS AND MIXED COHORTS

by

Graciela de Lujan Perez

B.S., in I.E., Universidad Nacional de Cuyo, 1988

M.I.B., Ecole Nationale des Ponts et Chausses – UNC, 1995

M.S.I.E., University of Pittsburgh, 2000

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SCHOOL OF ENGINEERING

This dissertation was presented

by

Graciela de Lujan Perez

It was defended on

August 8, 2002

and approved by

Mainak Mazumdar Ph.D., Department of Industrial Engineering

Kim LaScola Needy Ph.D., Department of Industrial Engineering

Jayant Rajgopal, Ph.D., Department of Industrial Engineering

Pandu Tadikamalla Ph.D., Katz Graduate Business School

Dissertation Director: Mainak Mazumdar Ph.D., Department of Industrial Engineering

**ABSTRACT**

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Graciela de Lujan Perez, Ph.D.

University of Pittsburgh, 2002

The purpose of this dissertation is to develop an instrument to measure the quality, quality changes and the efficiency of a service system with dependency loops on an ongoing basis in order to provide timely feedback for decision-makers and to set the basis for a continuous improvement cycle. This instrument is developed using an engineering educational system as the prime example.

The first outcome has been a data driven Strengths and Weakness (SW) analysis. It consists of four steps – data collection, data summarization, display of proportions (data aggregated into positive, neutral and negative perceptions), and the construction of a SW table by using a set of heuristic rules that reflects the decision-maker's desired level of sensitivity for the methodology. The core of the method resides in selecting the category with the largest proportion for a finite population where each element is classified into exactly one of $k$ mutually exclusive categories. The heuristic rules used for classification are justified using the concepts of statistical ranking and selection procedures.

Applications of the SW table in cross-sectional and longitudinal analyses are given. Special graphs, e.g. the one-dimensional and two-dimensional arrows that help the analysis have been constructed so as to provide aid to the decision makers in the engineering educational system.

The second outcome provides a scheme for the evaluation of the relative efficiency of processes within this type of service system. Data Envelopment Analysis has been used iteratively to evaluate the efficiency of levels and programs within an engineering educational service system. This is used to chart the changes in students' perceptions as they progress during their career from the freshmen to the senior level.

DESCRIPTORS

Strengths and Weakness Analysis

Selection of Best Multinomial Proportion

Service Quality Management

Finite Populations

Data Envelopment Analysis

Engineering Educational System

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# 1.0 PROBLEM STATEMENT

## 1.1 Introduction

Measuring quality for service systems with dependency loops is a difficult task because there are few instruments and/or methodologies that allow for it to be done timely for decision-making. The term dependency loop has been adopted from graph theory[50] and in this case refers to the set of links that arises from decisions made in one period of time on a given stage of a process, and their impact on the previous, the same and/or following stages in subsequent periods. The complete system can be visualized as a chain of forward and backward decision-making links between stages in a constant and dynamic state.

Without timely feedback of quality, service systems could deteriorate such that recovery is difficult if not impossible. Beyond some cross-sectional studies about how to measure quality in services systems, there have been very few approaches to evaluate the strategic significance of service quality for providers such as establishing baseline measures or how to make service improvements. Even fewer approaches have been devoted to connect service performance to economic and strategic results.

## 1.2 Statement of Purpose

The purpose of this dissertation is to develop an instrument to measure the quality, quality changes and the efficiency of a service system with dependency loops, on an ongoing basis, in order to provide timely feedback for decision-makers and to set the basis for a continuous improvement cycle. This instrument is developed using an engineering educational system as a prime example. Results of this dissertation relate to the following core problem: to determine an efficient and useful method for providing reliable assessment information for qualitative (perceptions) data on students' educational achievement.

The first outcome has been a data driven Strength and Weakness (SW) analysis. It consists of four straightforward steps – data collection, data summarization (data grouped by frequency), display of proportions (data aggregated into positive, neutral and negative perceptions), and the construction of an SW table by the application of rules that reflect the decision-maker's desired level of sensitivity for the methodology. A main difference with other service measurement instruments has been the characteristic of the data collected. Populations are finite and the time horizon for the analysis is a yearly period. Another difference is that no assumption has been made about the continuum of the measurement scale. The core of the method resides in selecting the category with the largest proportion for a finite population, where each element is classified into exactly one of *k* mutually exclusive categories. Then the category with the largest proportion is reclassified into one of several strength/weakness categories following the ideas contained in statistical techniques related to ranking and selection[7].

Requirements for this method were that it should be efficient to administer and analyze, and be able to handle small finite populations and sample sizes. It should also be data driven and easy to use for decision-making purposes. The method should be able to map changes in the student's perceptions and to give a signal if the process enters a state of deterioration. Currently no standard method in the literature satisfies all of those requirements. The challenge resides in analyzing a finite set of surveyed data for decision-making purposes; the drawback to overcome is that most, if not all of the literature is focused on designing the data collection and on working with infinite populations.

A second objective has been to evaluate the relative efficiency of similar processes within the system. The term process refers to the experience of a student as he/she progresses through the educational career. Data Envelopment Analysis (DEA), an operations research technique, has been used to evaluate the efficiency of the programs within the educational setting to create positive perceptions among the students. Dimensions, categories, and coefficients considered in this part are obtained from Step 3 (display of proportions) and Step 4 (SW Table) of the SW analysis. Contributions have been made by applying DEA to longitudinal cohorts, by adding non-linear restrictions on the weights that represent the categories, and then by re-scaling the efficiency indexes iteratively through the application of DEA to cross-sectional cohorts.

### 1.3 General Overview of the Significance of Services and Quality

Developing a comprehensive methodology for measuring service quality requires an understanding of the meaning of quality and services. There are many definitions of quality. Crosby states that quality is conformance to requirements. [31] This definition has been very useful for measuring quality in manufacturing systems, but is very difficult to apply to services. According to Deming, another way of defining quality is to relate it to the point of view of the various stakeholders. It might be proposed that quality for customers is satisfaction; [1] for workers, it is the pride of doing good work; for suppliers, it is profits; and for society, it is an increase of wealth as a whole. The Dictionary of Psychology [22] defines quality as “the relative level of goodness or excellence of anything.” These last two definitions together are more appropriate for our purposes.

Collier[25] defines services as "any primary or complementary activity that does not produce directly a physical product.” He explains that services are the non-goods part of a transaction between a service provider and a customer.

The main characteristics of services are: intangibility, perishability, heterogeneity, and inseparability.[25] In addition, services cannot be stored. Another important characteristic is that products are consumed, but services are experienced. There is also a difference between products and services in the attributes to be measured. In manufacturing a product, the attributes to be measured such as length, weight, brightness or hardness are usually (or most often) quantifiable. These are objective and quantitative measures that are analyzed easily through commonly used statistical methods. In services, attributes are frequently attitudes and perceptions that result in subjective and qualitative measures. For example a physician’s services cannot be quantified, but if the patient feels well he/she is more likely to recommend the physician to other patients. This is the reason why evaluation of services relies heavily on word of mouth. Contrary to a tangible measure, perceptions and attitudes show uncertainty in their continuum and their non-linear nature often renders application of statistical methods frequently used in quality control inappropriate. Finally, another difference is that in a manufacturing system it is possible to use control charts in order to assure a specified level of quality. In services the results of technology, better services, competition and continuous improvement can change service quality standards, meaning that the stability linked to control charts is often difficult to assume.

Figure 1.1 shows a generic conceptual model of a service system. While in a manufacturing system, the customer is the recipient of the final outcome; in a service system the customer is part of the process and moves throughout the system.

White arrows show the movement of students as they progress through the program. At the entrance to the system, there are new customers and/or repeat customers. Repeat customers are those that have experienced the process and return to continue the experience. This experience can be the same, a related one, or a new one. Some customers leave the process without finishing it. Customers that leave the system after finishing the process are called “reputation” customers.

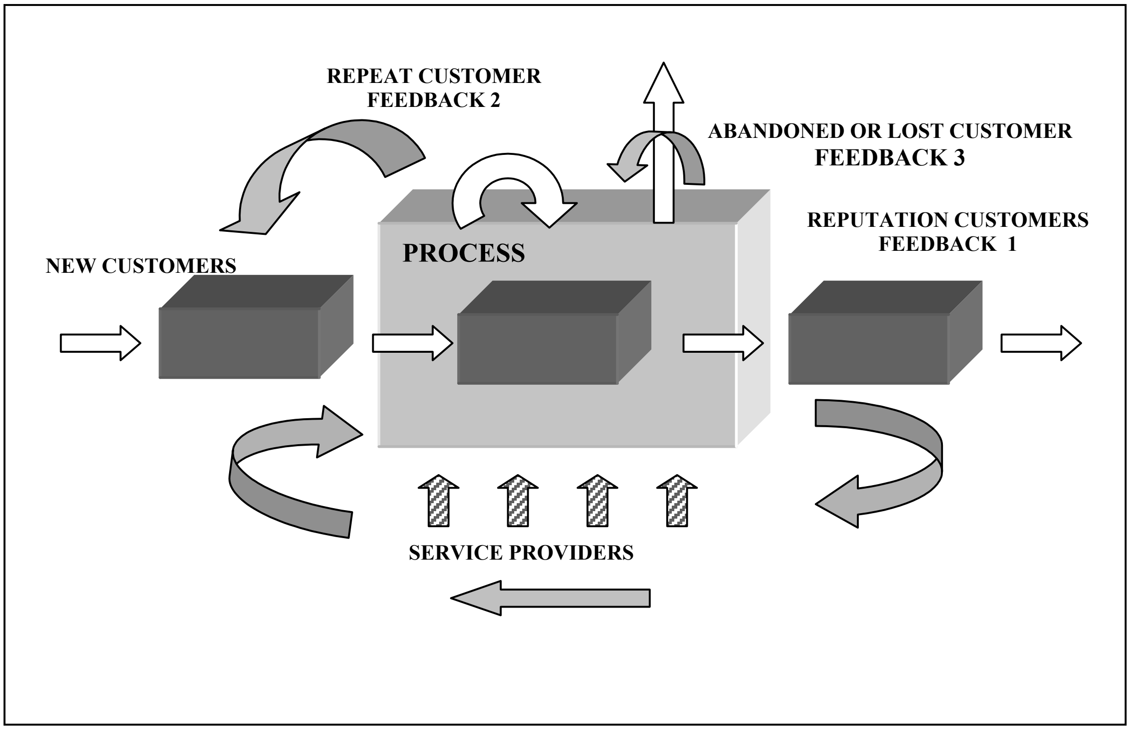



**Figure 1.1 Generic Conceptual Model of a Service System**

Providers or internal clients are responsible for delivering the customer benefit package or CBP[(25)]. This CBP is defined as the set of tangible and/or intangible attributes that a consumer is willing to recognize, use and pay for. In other words it is the value perceived and received by the consumer. Providers are also the recipients of the employee benefit package (EBP), defined as the set of tangible and/or intangible attributes, that an employee is willing to recognize, receive and work for.

Finally, gray arrows in Figure 1.1; show different feedback loops within the system. The generic model shows three different kinds of feedbacks: the feedback of reputation customers, the feedback of repeat customers, and the feedback of customers who abandon the system. The nature of feedback loops demonstrates another difference between services and manufacturing systems. Feedback is obtained after a service is experienced even when attitudes are formed during the process; while in a manufacturing process, the feedback is obtained at pre-specified moments during the process. This fact leads to two conclusions; first, for services it is imperative to do the things right the first time, because there is a little possibility of rework. Second, for service systems there is a delay between input and output measurement. As a result it is necessary to minimize the time to collect and analyze data in order to provide timely feedback.

Let us take a hospital as an example. In a hospital the customer is called a patient. Providers are physicians and nurses. The CBP are the knowledge, skills, attention and politeness of the staff, fast response to patient requirements, etc. The EBP are salaries, technology, social benefits, facilities comfort, holidays, available resources to work, etc. The process can be any treatment, surgery or physical exam. New customers are new patients; repeat customers are those that return for continuing a treatment. Reputation customers are those who have a very good medical or surgical experience and subsequently recommend the hospital and the physician to other patients. Alternatively reputation customers could also be those who have a bad experience and hence will recommend neither the hospital nor the physician. Airlines, hotels, restaurants and travel agencies fall into the same model.

A major example of service system is the educational system. Beneficiaries of educational services are not only the students, but also business and society [(84)]. The consequence of this difference is that students cannot set education specifications autonomously. Other beneficiaries will have the power in setting requirements. However, in order to control the process it is necessary to measure the advancement and satisfaction of students through their career against those specifications, and the satisfaction of students while in the educational process. This service system requires performance to be measured differently.

In the engineering educational system new customers are generally called students. Providers are faculty, staff and administrators. The CBP includes technical knowledge, buildings, reputation of the school, etc. The EBP includes salaries, grants, school reputation, private offices, accessibility to information, resources for research, etc. The process is the building of a professional career. New customers are incoming freshmen or transfers, while repeat customers are sophomores, juniors and seniors. Reputation customers are alumni and industry, business, other schools and the government (even though they do not participate actively in the process). Individuals who have succeeded in their careers are going to recommend the school to new students and perhaps will contribute economically to the school. On the other hand if they cannot compete for a good job, they are not likely to recommend the school or make contributions.

Research in the service quality area can be traced back to 1983, a very recent date compared to that in the manufacturing field. Two waves of research are found in the literature. The first one, in the eighties, defined the necessity of scales and ratings and the differentiation between products and services. The investigators associated with this wave opened the frontiers for research in service quality. These researchers belonged mainly to the marketing field. The second wave was in the nineties. Here, researchers were well trained in qualitative methods, psychology, sociology, anthropology and behavioral sciences. They were focused on establishing relationships within the different components of the service quality defined by the first wave.

While most of the research was performed at the best-known universities in the U.S., research and applications of service quality concepts have not been applied to the higher educational system. Moreover, the few approaches found related to planning and implementing, rather than the task of developing new ways of measuring performance and closing the loop of continuous improvement.

## 1.4 Background of the Dissertation

This dissertation uses the engineering educational system to develop and prove the proposed methodology. This system presents some advantages in comparison with others. First, data is available and it is possible to conduct experiments with different types of customers. Second, progress through the curriculum requires a cycle time sufficiently long to observe changes. Third, the concept of measurement is easy to understand. Finally, since 1996 there has been a strong interest within the engineering educational system for quality improvements.

## 1.5 Overview

The following chapters begin with a detailed discussion of research in the service field. The discussion covers the diversity of concepts and definitions used by researchers and the agreement or lack thereof among them. Different instruments and methodologies developed to measure service quality as well as the criticisms directed against them are presented. Included is a brief discussion of the literature on quality measurement tools developed within the engineering educational system.

The SW methodology developed and tested at the School of Engineering and its application are reviewed. This includes a validation of the methodology, experiments to select the best proportion in a finite population and the construction of charts that provide signals for changes occurring in the system.

This is followed by a chapter on the selection of the main dimensions for measuring efficiency. Here, DEA is applied on longitudinal as well as cross-sectional cohorts to link process and outcomes in order to measure the relative efficiency of the system.

Finally, contributions are presented concerning the instruments, methodologies and results of tests performed. Additional areas of research are suggested.

# 2.0 LITERATURE REVIEW

## 2.1 Introduction

This literature review summarizes in a chronological order the conceptual research and the instruments developed to measure service quality. Shortcomings of these instruments are discussed as well as their inapplicability to systems with dependency loops. This chapter also introduces the Data Envelopment Analysis (DEA) method as the technique selected for developing a model to measure efficiency in creating student satisfaction. It concludes by reviewing the existing and current research in assessing higher quality standards and continuous improvement in engineering education.

## 2.2 Service Quality: Conceptual Research

During the brief history of research in Service Quality, there have been two important waves. The first wave related to service quality can be traced to 1983, when Zeithaml et al.[94] conducted their research in four services sectors: retail banking, credit cards, security brokers, and product repair and maintenance. The researchers determined that the following factors influenced customer's expectations: word-of-mouth communications, personal needs, past experiences, external communications and price. The investigators deduced the five following dimensions a customer uses to judge quality of services; assurance, empathy, tangibles, reliability and responsiveness. Zeithaml et al. developed an instrument for measuring customers' perceptions of service quality called SERVQUAL, where service quality is assessed as the difference between consumer's perception and expectation when he/she is evaluating a given attribute. Experience with this instrument led them to develop their most important contribution, the conceptual model of service quality shown in Figure 2.1.

The model called gap or disconfirmation model, shows five discrepancies that can be manipulated to improve the service quality within an organization. They are:

Gap 1: discrepancy between the customer's expectations and the managers' perceptions of those expectations.

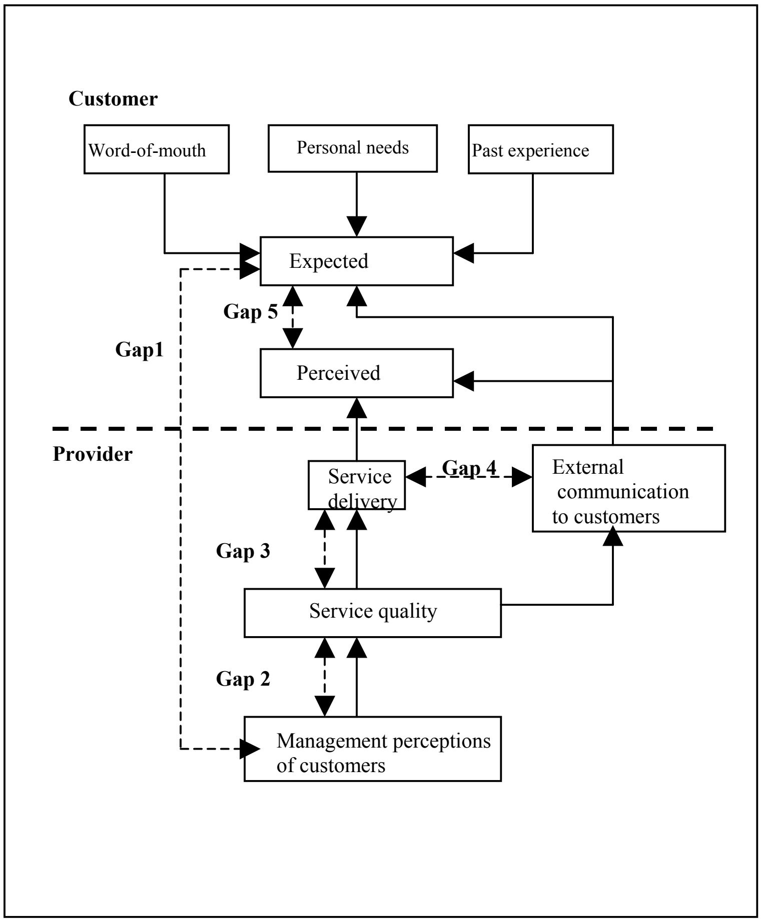



**Figure 2.1 Zeithaml et al. Conceptual Model of Service Quality**

Gap 2: discrepancy between managers' perceptions of customer's expectations and the translation of these expectations into technical specifications of service quality.

Gap 3: discrepancy between technical specifications and the way the service is operationally delivered.

Gap 4: discrepancy between how the service is operationally delivered and how it is marketed.

Gap 5: discrepancy between customer's expected service and customer's perceived service.

The literature(25,18,17,20, 31,3,55,46) suggests that this model has been used widely in marketing and has produced good results. Additionally other researchers like Brown et al.(17) and Candido et al.(20) point out relevant gaps not considered previously. These gaps are sub-sets of the first five. The magnitude and direction of these gaps directly affect the way that customers perceive service quality. Further research by Boulding (14) shows that higher expectations increase perceptions of performance, rather than lower them, as the disconfirmation model would prescribe.

Grönroos (44) identified three components of service quality, technical, functional, and reputational quality. The model is shown in Figure 2.2. Reputational quality is the reflection of the corporate image of a service organization. He concluded that functional quality, or how the service is performed and delivered, is as important as technical quality or what the consumer receives. Second, because a consumer will be able to see the firm and its resources during the buyer-seller interaction, image is of utmost importance for service firms. Third, the overall perception of quality is a function of the consumer's evaluation of the service and the difference between this evaluation and his/her expectations of the service.

In the 1990's the second wave of research by authors like Cronin et al.,(31) suggests that service quality assessment is conceptualized by a weighted perception of a particular provider where the weight is the importance given by the customer to the perception. These researchers developed the SERVPERF model to measure service quality based on the SERVQUAL model.

Teas(88) developed the evaluated performance (EP) model based on the model of Zeithaml et al.(94) Teas' model specified the following model, known as the EP and NQ (normed quality) models of normative quality index. The main issue he addressed is the interpretation of the expectation measure (E).

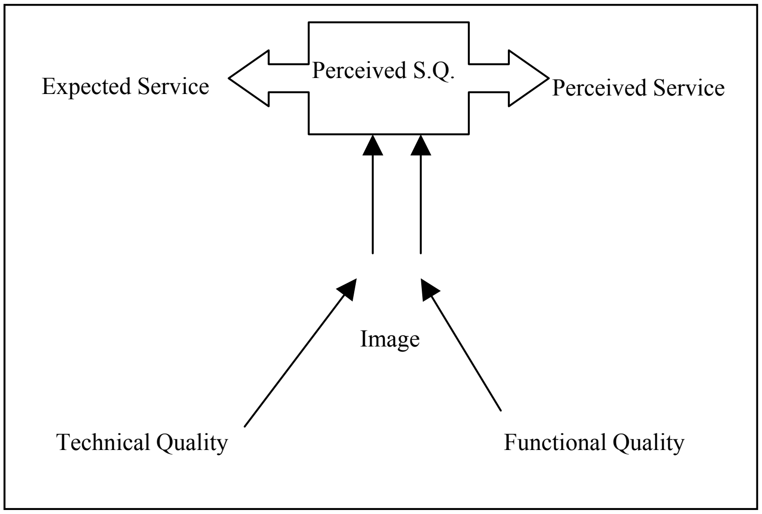


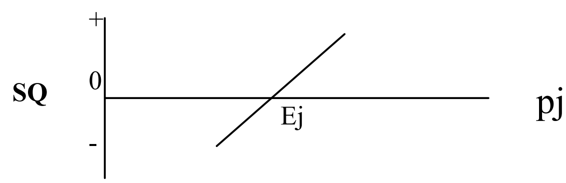

**Figure 2.2 Grönroos' Perceived Service Quality Model**

He concludes that increasing P-E (Perceptions – Expectations) scores may not necessarily reflect continuously increasing levels of perceived quality. This conclusion is based on a service attribute being assessed as a classical ideal point attribute. The classical ideal point attribute is one defined as " a theoretical level of performance under ideal circumstances, that is the best level of performance by the highest quality provider under perfect circumstances." Any performance beyond this point will displease the customer. Teas' model reflects the relationships shown in Figure 2.3

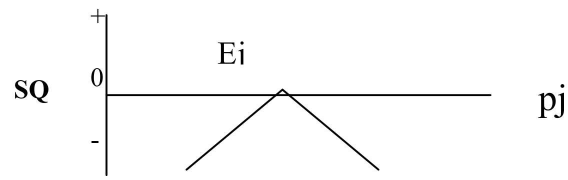
In 1994, Rust and Oliver(80) called for research in the conceptual inter-relationships between quality, value and satisfaction. Since then other conceptual models(29,38,51,87,94,5,35,30) have been researched reflecting the chronological time sequence of development, but no other instrument has been developed.

## 2.3 Service Quality: Instruments

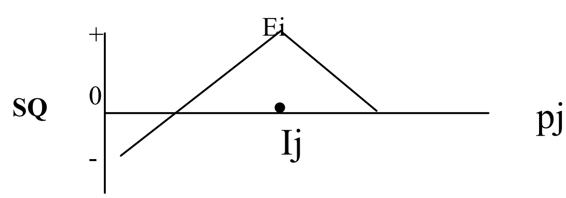
The few existing instruments developed to measure customer satisfaction are based on: 1-customer perception-expectation gap, 2-importance-performance weight, 3-evaluated performance and normed quality, 4-importance-performance maps and 5-conjoint - based model of service quality measurement. These instruments are described next.




Case A: Attribute j is a vector attribute and therefore the general form of the function above holds regardless of how the expectations standard Ej is defined




Case B: Attribute j is a classic ideal-point attribute an Ej is Interpreted as the classic ideal point (Ej=Ij)




Case C: attribute j is a classic ideal-point attribute and Ej Is interpreted as the feasible ideal point.

**Figure 2.3 Teas' Functional Relationships between Perceived Performance (Pj) and Service Quality**

### 2.3.1 SERVQUAL

In 1988 Zeithaml et al.[94] developed an instrument to measure the service quality construct based on the comparison between the expectations a consumer holds and the relative performance of the firm on specific attributes related to quality assessment.

SQ = f(Perception – Expectation) (2.1)

A scale generated in this way is called a disconfirmation scale.

The SERVQUAL instrument contained a set of twenty-two paired expectations/performance items. The first set of twenty-two was rated by the consumer as an ideal of a particular sector (expectations). The second set, was rated as the perceived performance of a specific provider. Both sets were rated using a seven point Likert scale. The following example of both expectations and perception measures has been taken from the SERVQUAL instrument:

*Expectations:*

"Excellent ______ companies will perform the service right the first time."

*Perceptions:*

"XYZ Company performs the service right the first time."

Items were grouped into the five dimensions identified through previous research findings: tangibles, reliability, responsiveness, assurance and empathy. However these dimensions did not capture the relative importance (weights) that the customers of the sector gave to them. The actual SERVQUAL relates SQ in the following way:

SQ = f(Perception – Expectation) x Importance (2.2)

SQ scores are averaged for each of the five dimensions and an overall service-quality score can be obtained through a weighted average of the five dimensions:

$$SQ=\sum_{j=1}^{K} W_j (P_j - E_j) \qquad (2.3)$$

Where:

SQ: SERVQUAL overall perceived quality

K: number of attributes

$W_j$: weighting factor if attributes have different weights

$P_j$: performance perception with respect to attribute *j*

$E_j$: service quality expectation for attribute *j*

This model considers P-E (Perceptions – Expectations) as a vector attribute. A vector attribute uses the concept of the classical ideal point set at infinity. Therefore, the P-E gap concept represents a comparison with a norm, it does not represent a difference between expected and received service. The equation suggests that service quality increases as the difference between perception and expectations increases

### 2.3.2 SERVPERF

SERVPERF developed by Cronin and Taylor,[31] is an instrument that contains the same five dimensions as SERVQUAL and also has the same twenty-two statements, but there is no disconfirmation scale. Consumers were asked to first rate their perception of the twenty-two statements and then the importance of each on a seven point Likert scale. The SERVPERF scale explained more of the variation in consumer perceptions of service quality than the SERVQUAL model as measured by the $R^2$ statistics. This $R^2$ is obtained by analyzing a regression wherein the single item overall service quality measure is the dependent variable, and the deduced five dimensions (same as SERVQUAL) are the independent ones.

### 2.3.3 The Evaluated Performance (EP) and Normed Quality (NQ) Models

In 1993, Teas [88] disagreed with the SERVQUAL psychology features. He proposed a model based on the assumption that the perceived ability of a product (good or service) to deliver satisfaction can be explained as the product's relative agreement with the consumer's ideal product features. The proposed model is,

$$Q_i = -1\left[\sum_{j=i}^{m} W_j \sum_{i=1}^{nk} P_{ijk} \, |A_{jk} - I_j|\right] \quad (2.4)$$

Where

$Q_i$: the individual's perceived quality of object *i*

$W_j$: importance of attribute *j* as a determinant of perceived quality

$P_{ijk}$: perceived probability that object *i* has amount *k* of attribute *j*

$A_{jk}$: Amount *k* of attribute *j*

$I_j$: ideal amount of attribute *j* as conceptualized in classic ideal point attitudinal models

m: number of attributes

n: number of amount categories of attribute *j*

This model posits that "an individual's perceptions of the quality of the performance of object *i* is positively related to the weighted likelihood that the performance of object *i* on *m* performance dimensions is close to the individual's perception of optimal performance on the *m* dimensions." This model works with the concept of classical ideal point where the expectation (E) is set equal to the ideal point (I).

Teas proposed a new model, based on the assumption of *i* the excellence norm that is the focus of SERVQUAL. The quality of an object *i*, $Q_i$ relative to the quality of the excellence norm can be conceptualized as the "normed quality gap" or normed quality as follows:

$$NQ_i = -1 \left[ \sum_{j=i}^{m} W_j \left( |A_{ij} - I_j| - |A_{oj} - I_j| \right) \right] \tag{2.5}$$

Where

$NQ_i$ = Normed quality index for object *i*

$W_j$ = Importance of attribute *j* as determinant of perceived quality

$A_{ij}$ = The individual's perceived amount of attribute *j* possessed by object *i*

$I_j$ = Ideal amount of attribute *j* as conceptualized in classic ideal point models

m = Number of attributes

$A_{oj}$ = The individual's perceived amount of attribute *j* possessed by the excellence norm.

This model works with the concept of "feasible ideal point" where the customer defines expectations and the ideal point.

### 2.3.4 Importance-Performance Maps

Importance-performance analysis(55,46) purports that quality is a function of customer perceptions of performance and importance of the attribute. The importance-performance model has been found to be a valid and powerful technique for identifying areas where scarce resources should be concentrated. Importance is represented by the weight that a consumer gives to each section of a survey. The second dimension is the customer perception of service performance for a specific company. Bopp[13] concluded that importance measures are industry specific and perceptions of service performance are likely to be company specific.

Data is captured from the SERVPERF scale. The X-axis represents the average importance weight of an attribute for the industry and the Y-axis represents the perceived performance of the same attribute for a given company. An example of a map is shown in Figure 2.4. The four quadrants are: Quadrant I-High priority; represents those areas that the consumer considers important, yet perceives the company as only providing adequate service (A); Quadrant II-Low priority, the company performs less adequately on issues that the customer judges as less important (B); Quadrant III-the company performs quite well but the consumer does not perceive it as important (C); Quadrant IV represents those areas where the company is excelling in areas the consumer perceives as very important (D).

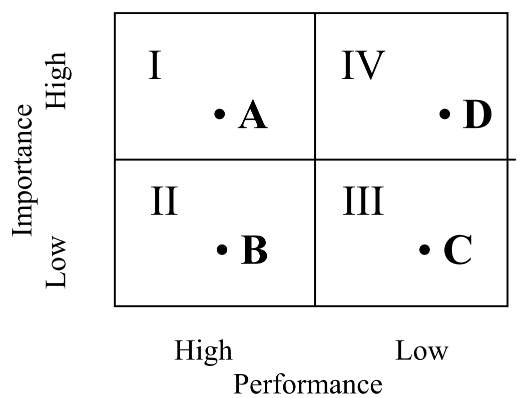



**Figure 2.4 Importance-Performance Map**

### 2.3.5 SERVQUAL Mixed Model

In an attempt to have uniform criteria, Parasuraman et al. [67] proposed a model that assumes some features of each one of the first three models, suggesting that this model would be conceptually more appropriate. Service quality is then measured as

$$SQ = \sum_{j=1}^{m} W_j[(P_j-E_j)D_{1j} - (P_j-E_j)D_{2j} + \{(I_j-E_j)-(P_j-I_j)\}D_{3j}] \quad (2.6)$$

Where

$W_j$ = weighting factor if attributes have differentiated weights.

$D_{1j}$ = 1 if $j$ is a vector attribute, or if it is a classic ideal point attribute and $P_j <= I_j$; 0 otherwise.

$D_{2j}$ = 1 if $j$ is a classic ideal point attribute and $E_j$ is interpreted as the classic ideal point (i.e, $E_j=I_j$) and $P_j>I_j$; 0 otherwise.

$D_{3j}$ = 1 if a classic ideal point attribute and $E_j$ is interpreted as the feasible ideal point (i.e. $E_j<=I_j$) and $P_j> I_j$; 0 otherwise.

Parasuraman et al. also referred to the normed quality model and concluded that if $I_j$ ( ideal point) is in the infinite then the normed quality index ($NQ_i$) is:

$$NQ_i = -\left[\sum_{j=i}^{m} W_j (|A_{ij} - A_{0j}|)\right] \quad (2.7)$$

$W_j$ = Importance of attribute $j$ as determinant of perceived quality

$A_{ij}$ = The individual's perceived amount of attribute $j$ possessed by object $i$

m = Number of attributes.

$A_{0j}$ = The individual's perceived amount of attribute $j$ possessed by the excellence norm

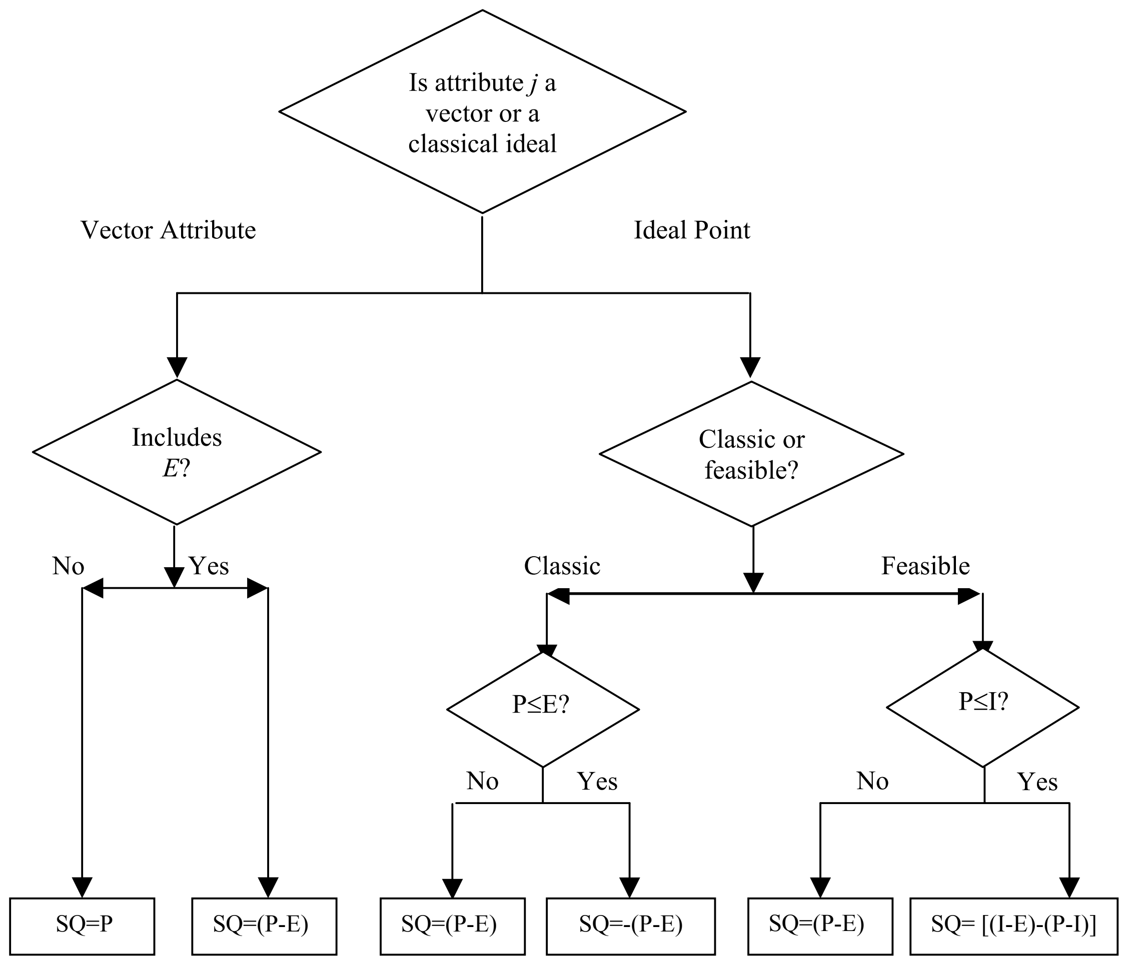
This equation is similar in structure as the original SERVQUAL model.

Figure 2.5 is a summary of the impact of attribute type and expectation standards on the expression for perceived service quality for $W_j$=1. The figure combines Parasuraman's et al., Cronin's et al., and Teas' point of views.

### 2.3.6 Conjoint Based Model of Service Quality Measurement

Green and Rao(43) introduced conjoint analysis in the marketing literature. Consequently DeSarbo(80) and then Gustafsson(45) proposed to find those quality attributes that delight the customer through the use of conjoint analysis in the service area.

Conjoint analysis can be characterized as design of experiments applied to marketing decisions. The attributes to consider are jointly varied according to an experimental plan to form product concepts, which potential consumers are asked to evaluate. The number of attributes is limited by the number of levels within each attribute to six or fewer. As a consequence of this limitation conjoint analysis is best suited for application at a relatively late




E = Expectations; I = Classical Ideal Point

**Figure 2.5 Impact of Attribute Type and Expectation Standard on Expression for Perceived Service Quality**

phase in the development of a product.

Expectations are worded (rated) directly into the collection of perceptions (levels) in the conjoint structure; i.e., “worse than expected,” “same as expected,” and “better than expected” based on Carman[(21)] and Oliver’s[(80)] conceptual disconfirmation work. The structure of the surveys was constructed under the SERVQUAL five dimensions. Importance weights are derived by the conjoint analysis estimation procedure and provide a basis for segmenting consumers, based on the differences in importance that are assigned to the various SERVQUAL dimensions. DeSarbo et al. experimented with two different types of services: a bank and a dental service for students at the University of Michigan. A factorial design was selected for main effects only (they consider 11 factors and three values for the variables). The dummy matrix showed; (0,0) as “same as expected” (1,0) as “worse than expected” and (0,1) as “better than expected”. The students were asked to fill in two questionnaires. For the first set of questionnaires the absolute level of perceived quality is given rated for the eleven outcomes. Students only have to rate service quality based on the information received. In the second set, the student has to rate the eleven outcomes plus the service quality.

The response of a given respondent to the $j^{th}$ profile is given by:

$$Y_j = \sum_{p=1}^{t} \sum_{q=1}^{np} B_{pq} X_{jpq} + U_j \tag{2.8}$$

Where:

$Y_j$=perceived service quality judgment for the $j^{th}$ experimental profile ($j$=1,….30);

$B_{pq}$=part-worth of the $q^{th}$ level of the $p^{th}$ SERVQUAL factor.

$X_{jpq}$=dummy variable{ = 1, if profile $j$ takes on the $q^{th}$ level of the $p^{th}$ SERVQUAL factor, zero otherwise}.

$q_p$=number of levels of the $p^{th}$ SERVQUAL factor ($q_p$=3 for all $p$)

t=number of SERVQUAL factors (t=10)

$U_j$=error term.

To summarize, the absolute values of the coefficients for “worse than expected” were much greater than those for “better than expected” reflecting an asymmetry in the responses. The implication of these results is that the costs of not meeting customer expectations may exceed the benefits of meeting those expectations.

## 2.4 Shortfalls of the SQ Measurement Instruments

The next section describes the shortfalls of the SQ measurement instruments for measuring satisfaction of longitudinal cohorts. It provides motivation for the research carried out in this dissertation.

### 2.4.1 Theoretical

The disconfirmation model has led to some inconsistencies such as predicting that a consumer that expects and perceives poor performance will be satisfied because P-E=0, (perceived – expected).[85] The SERVQUAL model also fails to use standards for expectations, because generally people rate expectations uniformly high.

Owlia et al.,[66] Besterfield-Sacre, [12] and Gatfield et al.[40] demonstrated that in the specific case of engineering education the dimensions evaluated by the students and alumni are: engineering related attitudes, perceived ability to work in teams, confidence in personal abilities, pre-professional experiences (junior and seniors), education and employment information (senior), and university environment and their educational experience (alumni), and confidence in having achieved the EC 2000 outcomes as a common set of measures.

The conjoint–based model is rooted in the statistical design of experiments, however the model is not an instrument for a continuous measurement system. It is only applied during the final step of the service system design.

All the instruments found in the literature review are useful to measure and compare service systems where the population is homogeneous and infinite, the process is repetitive, and the process cycle time is relatively short, e.g., measuring service quality in a library. Their application for measuring satisfaction in a longitudinal cohort when the process has dependency loops is meaningless. One of the reasons is the change of perceptions and expectations that take place over time, and that may result in the same P-E score for two consecutive years when in fact there were changes. Furthermore, services processes are often not repetitive, populations are finite and small, and the cycle time is considerably long.

In the specific case of the engineering educational system goals are set by alumni, industry and society, therefore it is necessary to control the system towards those goals. A way of doing this is to measure students' self-confidence and attitudes towards these goals. This point has been addressed with the SW methodology.

### 2.4.2 Operational (Practical)

All investigators work with pre-determined scales. It has been demonstrated by several authors in the psychology,[2] business,[80] and artificial intelligence[60] fields that scales for the measurement of perceptions are not symmetrical, and the length of each interval within the scale may be not equal. This point represents a drawback such as with the translation of Likert scale into ordinal scale. The relevance of the sample with respect to the population has not been made clear. Moreover, even though they could be correct, the conceptual point of view of the statistics of the categorical variables does not allow the mathematical models to be applied by those instruments during the final analysis of satisfaction. This last statement led to the use of categorical scales to construct the SW Table and supports the fact that the statistical average on a 1-5 or 1-7 point scale may lead to wrong decisions. For example suppose there are ten customers that are rating a service systems on a 1 to 5 scale. Six of them qualify the system with a 2 (fair or disagree), the other four with a 5 (excellent or strongly agree). The average is: (2x6 +5x4)/10 = 3.2. On a five-point scale this result can be interpreted as saying that on the average the position of the perception is neutral. However this result is not the same as having 60% of the population with a feeling of disagreement. The average can mislead the decision-maker, and in this case looking at the frequency distribution and the median response would be better.

Finally, these measures are static, in that they do not consider the history of the service and they fail to capture the dynamics of the changing expectations. Therefore, they cannot signal changes. This is another shortcoming that led to the SW analysis.

### 2.4.3 Functional

From the point of view of a decision-making process these instruments do not show a clear linkage between customer satisfaction and managerial decisions. There is no suggestion on how management can use the former instruments as a strategic lever and better decide what really needs to be changed, how to connect these measures to changes and goals achieved, and how customer expectations are updated, because it is widely known that perceptions vary over time. In fact, managers have to deal with causal loops; i.e., decisions made in one year will have a mediating impact on the following one. Finally, those instruments do not link the continuing process along the time line and do not give an idea of how efficiently the resources are used during the process. This last point supports the idea of linking the SW table with the measurement of efficiency to search for best practices.

### 2.5 The Measurement of Efficiency: Data Envelopment Analysis

There is no instrument described in the literature that is able to evaluate the efficiency in creating self-confidence and satisfaction. After researching different techniques the literature pointed to Data Envelopment Analysis. With roots in linear programming, Data Envelopment Analysis (DEA) is a method used to determine the relative efficiencies of a set of organizational units called decision-making units (DMU's)[(23)]. Most recently, non-linear constraints have been included when modeling with DEA[(23)]. This method is especially useful when the efficiency of a DMU depends on multiple inputs and outputs.

A basic assumption behind DEA is that if process *A* produces $Y_A$ units of outputs with $X_A$ units of inputs, then other processes should also be able to do the same if they operate efficiently. Similarly if a second process *B* is capable of producing $Y_B$ units with $X_B$ inputs, then other producer may obtain similar results. It is possible to combine processes *A, B* and others to form a virtual process with composite outputs and inputs. The core of the analysis consists in finding the best virtual process for each real process. If the virtual process is able to make the same output but with less input than the real process, then the real process is said to be inefficient. The only requirement for measures and units is that they have to be homogeneous. This procedure to find the best virtual process out of a set of *n* (DMU's) can be formulated as a set of n equations.

Until 1999, DEA was applied to cross-sectional cohorts because of the requirement of homogeneity of units and dimensions to be included in the evaluation.[(32)] After 1999, extensions have been carried out so as to allow interdependence between DMUs (some outputs of some DMU's are allowed to be inputs of other DMUs) or to set weight restrictions (non-linear restrictions).

DEA has been applied to measure relative efficiency of a set of hospitals, bank branches, administrative units, schools, program resources, and so forth (references). Nevertheless, DEA has not been applied to longitudinal cohorts yet.

### 2.6 Continuous Improvement of the Engineering Educational System

In the 90's engineering practice changed as a result of the shift from a defense to a commerce based economy as the principal driver for engineering employment.[(74)] The globalization of markets, the power of the Internet, and the growth of a service oriented economy required engineers not only to have a strong technical capability, but also to have skills such as good communication, teamwork ability, and an understanding of the environment.

In 1990, John White[91] former deputy director of the National Science Foundation, stated that it was incumbent on universities to systematically introduce total quality management into the educational process.

In 1991, the third Total Quality Forum to forge strategic links with higher education,[91] was hosted by companies such as Procter & Gamble, American Express, Ford Motor, IBM, Motorola and Xerox. Two hundred Engineering Departments answered the call and a Total Quality Leadership Steering Committee was formed to ensure that the recommendations of the participants were implemented and the dialogue continued. The objective of the committee was (a)- to define a core knowledge generic to total quality for practitioners, scholars and teachers; (b)- to propose curricula and materials for teaching total quality in business and engineering schools; (c)- to develop strategies to facilitate educators' understanding of and commitment to teach and practice total quality; (d)- to create a national research agenda for total quality.

In 1994 as a result of the meetings of those committees, a Joint Task Force on Engineering Education Assessment was formed at a National level.[89] Represented on the task force were the National Council of Examiners for Engineering and Surveying (NCEES), the ABET (the organization that evaluates engineering programs nationwide), the American Society for Engineering Educations (ASEE) and the ASEE Engineering Deans Council. They recognized the necessity of defining a range of tools that could be used in a many-faceted assessment process. A set of criteria known as the EC 2000 was developed with strong industry input[27] and introduced by ABET in 1996. Their focus is on measuring the skills and outcomes of the graduates of an engineering program. Each school must now define measurable learning objectives to achieve the criteria and put in place measurements that can be used to assess the continuous improvement of the educational process. The EC 2000 outcomes are the followings,[89]

- an ability to apply knowledge of mathematics, science, and engineering;
- an ability to design and conduct experiments, as well as to analyze and interpret data;
- an ability to design a system, component, or process to meet desired needs;
- an ability to function on multidisciplinary teams;
- an ability to identify, formulate, and solve engineering problems;
- an understanding of professional and ethical responsibility;

- an ability to communicate effectively;
- the broad education necessary to understand the impact of engineering solutions in a global/societal context;
- a recognition of the need for and an ability to engage in lifelong learning;
- a knowledge of contemporary issues; and
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

At the first Best Assessment Processes in Engineering Education Conference,[75] one problem raised by engineering administrators was related to how to organize, implement and maintain an effective assessment program given the severe constraints of time, manpower, and budget.

Most programs have focused their efforts on identification and selection of assessment methods such as closed-form questionnaires,[11,10,74] open-ended surveys and structured students interviews, focus groups,[11] competency measurement,[56,58,59] student journals,[71,26,4] concept maps,[4,62,54] verbal protocol analysis,[36] intellectual development,[69] authentic assessment,[83] and modeling of the engineering educational system. Although these methodologies measure specific learning outcomes, they lack an integrative overview of the engineering educational system and do not measure service quality.

Different concepts from the Total Quality Management (TQM) literature have been applied to the educational system. Scarbec[84] states that in the TQM theory, the entity that sets specifications for services is the customer. The customer analogy breaks down when the student is compared with a business customer. A TQE (Total Quality Education) model requires a wider consideration of beneficiaries besides the student, such as society and business. Scarbec also states that a customer-driven approach lacks focus on who the primary customers are and who is to set service specifications. Finally, the customer-driven model measures performance based on student satisfaction in meeting educational specifications. He adds that a higher level of student satisfaction does not necessarily measure the quality of the education, though it may be one indicator. He suggests a recipient-driven and recipient-focused model like the one shown in Table 2.1. The table shows the attributes evaluated by the customer in TQM and their counterparts in TQE. This model combines the attributes that influence service quality identified by Garvin[39] with the attributes that influence quality education.

Owlia et al.,[66] Besterfield-Sacre,[12] Gatfield et al.[40] and Madu et al.[52] have developed conceptual models for measuring quality in engineering education. The different models surveyed different levels of students, alumni, academic staff and employees. All of these models used a five-point scale like the one suggested by Saraph et al.[82] that ranges from "Very low" to "Very high" for rating statements, and a Likert scale that ranges from "Strongly Disagree" to "Strongly Agree." After applying factor analysis to diminish the number of questions, the authors used the results to construct different models of the engineering educational system.

**Table 2.1 Attributes of Quality in Product Service Models (TQM) Compared with Quality Education (TQE)**

| TQM | TQE |
|---|---|
| Performance | Student Performance |
| Features | Degree options and courses |
| Reliability | Capabilities and skills developed |
| Conformance | Conformance to national, state and professional standards |
| Durability | Marketability of learned skills/knowledge |
| Serviceability | Ability to meet professional requirements and accreditation |
| Perceived quality | Contribution to improving society |

They have pointed out specific areas of improvement, however they did not go further in looking for a way of developing a complete system to analyze the data, and closing the loop of a continuous improvement cycle.

This is another of the motivations in developing the SW analysis, to analyze, organize, implement, and maintain an effective assessment program given the severe constraints of time, manpower, and budget.

# 3.0 METHODOLOGY – SW ANALYSIS

## 3.1 Introduction

Chapter 2 has enumerated the shortcomings in the instruments developed thus far for application to the measurement of service quality for longitudinal cohorts. A new methodology is presented for measuring service quality for the special case belonging to an engineering educational system. This methodology is called the Pitt-SW analysis and consists of four straightforward steps: data collection, data summarization, display of proportions and construction of the SW table through the application of certain heuristics rules. These rules are derived from the expertise of faculty and administrators and the application of statistical procedures for the selection of the category having the largest proportion in a finite population. By using this table it is possible to obtain the strategic position of departments and schools, as well as to track changes with time.

The statistical background of the Pitt-SW analysis is presented in Chapter 4.

## 3.2 The S.W. Methodology

This dissertation attempts to provide engineering faculty and administrators with decision-making information that closes the loop of the continuous improvement cycle(68) within the school. In Chapter 2 was noted that ABET accredits individual engineering programs rather than engineering schools(74). Each program undergoing review prepares a self-study report that serves as the basis for an onsite visit. The EC 2000 criteria force each individual program to express its educational goals in terms of the characteristics and abilities expected from its graduates and to establish a process for assuring that those goals are being met. Hence, both quantitative and qualitative criteria are needed to fully assess a program(78). Quantitative data is typically obtained by direct observation and testing; e.g. measuring a graduate's ability to "understand and apply mathematics, science and engineering principles in addressing engineering problems." Qualitative criteria may be more appropriate for assessing other outcomes such as "understanding engineering's ethical and professional responsibilities;" "communication skills;" or "the ability to work in multidisciplinary teams."

To a large extent, the measurement of whether or not the program is achieving its desired educational outcome depends on the graduates' collective perceptions about their acquired abilities and skills. These perceptions may be influenced by a number of factors including the culture of the school, the students' prior experiences, out-of-classroom experiences, interactions with students from other schools and opinions of other students and alumni. The more the perceptions reflect reality, the more accurate the judgment of the person will be[76]. However, contrary to a tangible measure, a perception scale shows discontinuity and non-linearity; this makes applying pure statistical methods for analyzing perceptions impractical and potentially biased[2]. The discontinuity arises from the fact that changes in the perception occur in jumps depending on whether or not certain relevant stimuli occur or not. The nonlinearity arises from the classical ideal point attribute explained in Chapter 2. Any performance beyond this point will displease the customer, so the perception undergoes changes of sign. This leads to the core problem considered in this dissertation: the determination of an efficient and useful method for providing a reliable assessment based on qualitative data of the students' perceptions of their educational achievement.

By surveying students at appropriate times, data have been collected that measure and assess students' progress towards achieving EC 2000 outcomes and overall student achievement at graduation relative to specific outcomes. It is possible now, based on this data, to analyze how programs within a college of engineering differ in terms of students' outcomes, how programs of different colleges of engineering differ in terms of students' outcomes and key factors that influence students' expectations about their engineering program.

During the academic years 1999, 2000 and 2001, questionnaires were administered to more than 2500 engineering students at the University of Pittsburgh, ranging from freshmen to seniors and also to alumni. These closed form questionnaires were used as a measurement tool to obtain the individual's perceptions and attitudes (generally confidence) about particular topics. These surveys may be viewed as a means of measuring "customer satisfaction," which, in this case can be interpreted as student satisfaction. Furthermore, these measures are analyzed from the point of view of the provider's expectations; i.e. the faculty and administrators' expectations. These expectations are driven by the objectives established for the program which may be influenced by other stakeholders, industry, alumni, and (in some cases) state government. The methodology applied to analyze these types of data has been called the SW analysis, because it is an adaptation of the competitive strategy principle of SWOT (Strength, Weakness, Opportunities and Threats).[51] It consists of four straightforward steps – data collection, data summarization (data grouped by frequency), display of proportions (data aggregated into positive, neutral and negative perceptions), and the construction of a Strengths and Weakness (SW) table by the application of rules that take into account the desired sensitivity of the methodology and the probability of selection of the best proportion within a finite population. Data driven SWOT analyses are not discussed in the existing literature.

### 3.2.1 Step 1: Data Collection

This step belongs to the already established custom of collecting data at the end of each term at the School of Engineering and is considered here for the purpose of explaining the complete process of data collection and analysis.

Freshmen are surveyed at the beginning of the fall and at the end of the spring term. Sophomore and juniors are surveyed at the end of the spring term. Seniors are surveyed just prior to graduation. Alumni surveys are conducted every three years. The instruments solicit: engineering related attitudes, perceived ability to work in teams, confidence in personal abilities, confidence in having achieved the EC 2000 outcomes, pre-professional experiences (junior and seniors), and education and employment information (seniors). Alumni are also asked about the university environment and their educational experience. Each question uses a five point Likert scale for response, where the number 1 is used to represent either “Strongly Disagree”, “Not at All”, “Poor” or “None”, and the number 5 means “Strongly Agree”, “A Great Deal” or “Very Good” depending on the type of question. The numbers 2, 3, 4 represent the intermediate points with 3 being neutral.

### 3.2.2 Step 2: Data Summarization – Frequencies and Percentages

Data are organized in a spreadsheet format. The frequencies of the categorical data and percentages are then calculated, and the results displayed in a bar-chart format. An example is given in Table 3.1 and Figure 3.1.

**Table 3.1 Sample Question Responses**

| Scale | Order | Frequency | Percentage |
|---|---|---|---|
| 1 | Strongly Disagree | 15 | 25 % |
| 2 | Disagree | 6 | 10 % |
| 3 | Neutral | 9 | 15 % |
| 4 | Agree | 15 | 25 % |
| 5 | Strongly Agree | 15 | 25 % |
| | Total | 60 | 100% |

### 3.2.3 Step 3: Display of Proportion – Data Reduction for Decision-Making

With this graphical approach, the task at hand is to observe common patterns and to draw conclusions about the students' perceptions in a wide range of areas. However, the analysis of each graph is time consuming and too complex to arrive at a useful conclusion.

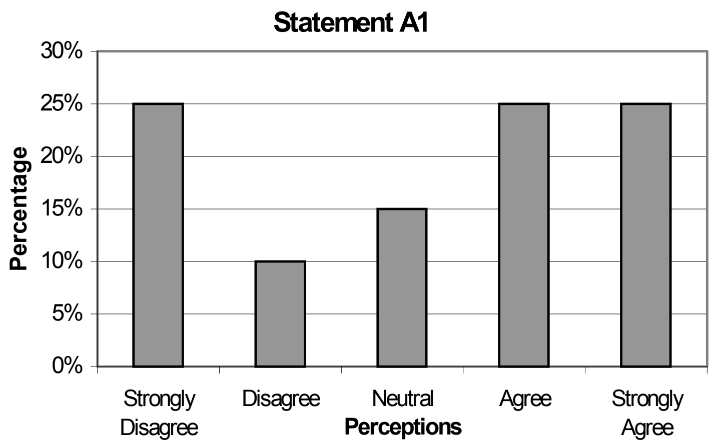



**Figure 3.1 Histogram – Finite Distribution**

For the purpose of this dissertation it may be more informative to determine the favorable/positive and unfavorable/negative attitudes of students with respect to each outcome.

A main reason for using the favorable/unfavorable approach is the small populations sizes that exist in the School of Engineering at the University of Pittsburgh. Populations per level of the School of Engineering at the University of Pittsburgh range form 5 students per course/level to 60 students per course/level. Until 2001, the data collected per term accounted for a response range of 70% to 92% of the student population per level. These samples could be considered to be random because of the uncertainty of the date on which questionnaires were distributed. From year 2002 onwards questionnaires will be given through a web-based survey, and students are asked to fill them voluntarily, it is expected that this will result in a decrease in the response rate. Students who answer the questionnaire are likely to be those who feel more strongly about the statements. For the purpose of the decision-makers this is the group that should be considered in the measuring of satisfaction.

Another reason for pooling data is to increase the probability that the category that represents the best proportion in the sample is the same as the one that represents the best proportion in the population. The nomenclature "best proportion" is taken from Gibbons[41] and refers to the largest proportion of a multinomial distribution. An explanation of the reasons of pooling is found by using the analogy with an infinite population. From Gibbons' Table H.1,[41] in order to have a probability of .9 to select the best proportion for $k$=3 categories, and a ratio 1.2 of the best proportion to the second best, it is necessary to collect 437 data points. For $k$=5 and the same probability and ratio the number of data points should be increased to 964, almost double of the previously required sample size. For $k$=7 the number of data points are 1545 more than 3.5 times than that for $k$=3. Now, if it is not possible to increase the sample size given that the ratio of the best proportion to the second best remains unchanged, the probability of making a correct selection decreases (Gibbons p. 175). This statement with no doubt remains true for finite populations and fixed sample sizes.

Transforming the five-point scale for decision-making purposes into a three-point scale can significantly improve the ability to understand the results. This transformation is done by aggregating percentages of 1's and 2's into a category of negative perception, and into positive perceptions by the addition of percentages of 4's and 5's. Results are displayed in the display of proportions, shown in Table 3.2, where $n$ denotes the sample size and is the number of students that took the questionnaires on the survey date, and $N$ stands for the population and is the total number of students registered for the level/program.

**Table 3.2 Display of Proportions**

| *1. My freshman year prepared me for my sophomore year.* | | | | | | | |
|---|---|---|---|---|---|---|---|
| n= | 18 | 12 | 40 | 32 | 28 | 7 | 25 |
| N | 20 | 15 | 45 | 40 | 35 | 10 | 30 |
| **Department** | **A** | **B** | **C** | **D** | **E** | **F** | **G** |
| **NEGATIVE** | 16.7% | 13.4% | 15.0% | 18.8% | 0.0% | 1.5% | 28.0% |
| **NEUTRAL** | 38.9% | 40.0% | 25.0% | 40.6% | 17.9% | 48.5% | 440% |
| **POSITIVE** | 44.4% | 46.6% | 60.0% | 40.6% | 82.1% | 50.0% | 28.0% |

The largest (best) proportion is selected from the display of proportion for each question, program and level. Define $\hat{p}_{(j)}$ as the sample j[th] ordered proportion in the sample, i.e., $\hat{p}_{(1)} < \hat{p}_{(2)} < \ldots < \hat{p}_{(k)}$. The SW procedure is as follows: define

$$\delta^* = \frac{\hat{p}_{(k)}}{\hat{p}_{(k-1)}}$$ as the ratio between the largest proportion in the sample and the next largest.

With this ratio enter the table in Appendix A that corresponds to population size *N* and sample size *n*; interpolate between columns if necessary. Find the fitted average probability of correct selection *P[cs]* of the largest proportion in the population in the table. Although this observed value of $\delta^*$ is not obviously the same as in the corresponding population value we use this value to approximate the average probability of correct selection of the category with the largest proportion in the population. For example from Table 3.2, the display of proportions shows for Program A, $\delta^*= 1.14$, now from Table A.3 of Appendix A, for $N$=20 and $n$ =18 the *P[cs]* equals 0.69.

**3.2.4 Step 4: Strength-Weakness (SW) Table**

Step 4 is concerned with how to classify this best proportion in the format of the strength-weakness terminology. Two levels of feedback are necessary: one for setting standards for the quality of the schoolwide engineering educational system and a second, for measuring program performances against those standards. The observed best proportion in the sample is classified into one out of five categories through the application of a set of four rules. The five categories are Major Strength, Possible Strength, Neutral, Possible Weakness and Major Weakness. The name and number of the fields have been adapted from Kotler et al.[50]

The first rule mirrors the expertise of the decision-makers of the School, the rest are statistically supported. Together these constitute the heuristics for classifying perceptions. Justifications of these rules are explained in Chapter 4.

First, the average "positive", "neutral" and "negative" perceptions across all departments are calculated. These averages are the standard perceptions or attitudes for the School of Engineering SW Table. Then, the heuristic rules of classification are given as follows (by program or for the entire school):

MAJOR perception:

- If the largest proportion (positive or negative perception) is greater than 50%, then that category is classified as a *Major Strength* if positive or *Major Weakness* if negative.

  Example: from Table 3.2 Program *C*, the best proportion is positive 60% thus it is classified as *Major Strength*

At this stage of the dissertation the 50% threshold is set arbitrarily to account for absolute majority, but later in the dissertation this threshold is raised to 80% for the Major Strength classification. The question for the threshold limit is revisited at the end of Chapter 5.

For the *Possible* classifications set a level of acceptance $P[cs]=Y$ where $Y$ is the preassigned level of acceptance. Then apply the following rules to obtain the classification of the best proportion.

POSSIBLE perception:

Case A: The order in the sample is:

$\hat{p}_{(1)} < \hat{p}_{(2)} < \hat{p}_{(3)}$, where $\hat{p}_{(3)}$, is positive or negative perception and $\hat{p}_{(2)}$, can be any of the other two proportions. Define $\delta^* = \dfrac{\hat{p}_{(3)}}{\hat{p}_{(2)}}$

- If the largest proportion in the sample (positive or negative perception) selected has fitted probability $P[cs]$ equal to or greater than the desired level $Y$ corresponding to the observed value of $\delta^*$, and accounts for less than 50% of the responses, then classify this category as a Possible. If the largest proportion corresponds to positive perception then it is a *Possible Strength* otherwise it is a *Possible Weakness.*

Example; Assume $Y = 0.6$, from Table 3.2, for Program *A* $\delta^* = 1.14$. From Table A.3, $P[cs]=0.69$, the best proportion is positive 44.4% and is less than 50%, therefore classified as *Possible Strength.*

Case B: The order in the sample is

$\hat{p}_{(1)} < \hat{p}_{(2)} < \hat{p}_{(3)}$, where $\hat{p}_{(3)}$ is positive or negative perception and $\hat{p}_{(2)}$ is neutral .

Define $\delta_1^* = \dfrac{\hat{p}_{(3)}}{\hat{p}_{(2)}}$ and $\delta_2^* = \dfrac{\hat{p}_{(3)}}{\hat{p}_{(1)}}$

- If the fitted probability $P[cs]$ by setting $\delta^* = \delta_1^*$ is less than the desired level $Y$ and accounts for less than 50%, but the fitted probability $P[cs]$ by setting $\delta^* = \delta_2^*$ is greater or equal than $Y$ then the category with the largest proportion is classified as *Possible Strength/Weakness.*

Example: Take $Y=0.6$, from Table 3.2, for Program *B* $\delta_1^*=1.17$, From Table A.2 Appendix A, $N=15$, $n=12$, $P[cs]=.57$, which is below the desired acceptance level. From Table A.2, with $\delta_2^*=3.5$, $P[cs] = 1$. The best proportion 46.6% is positive therefore the category is classified as *Possible Strength.*

NEUTRAL perception:

Case C: Same conditions as Case A

- Any other case that it is not covered by the *Major* or *Possible* rules is classified as *Neutral*

This statement can be broke down into

- If both positive and negative perceptions are equal, or
- If the observed $\delta^*$ results in the selection of the best proportion with fitted probability *P[cs]* less than the desired level *Y*, or
- If both extreme (positive and negative) proportions are smaller than its neutral proportion, then the category with the largest proportion is classified as *Neutral.*

  Example: Program *G* of Table 3.2.

To show a comprehensive display of the SW each classification is identified with a symbol *X*. Results are then plotted to show the profile of the Strengths and Weaknesses of the School of Engineering as a whole. If it is desired separate charts can be produced for each program. An example display of the SW table is shown in Table 3.3.

By selecting the best proportion and using the SW classification the problem of linking satisfaction with strategic decisions has been addressed. The SWOT analysis is a traditional tool to make strategic evaluations in any competitive market. The heuristics is providing the decision makers with three feedbacks at the same time:

1) it shows at a first glance those fields where to capitalize upon and those where it is necessary to make improvements.
2) it gives a level of confidence per statement for making a decision driven by customers perceptions, and
3) it prioritizes the decisions.

**Table 3.3 Example Schoolwide SW Table: Confidence in EC 2000 Outcomes – Sophomores**

| *Confidence in Engineering Outcomes* | Major Strength | Possible Strength | Neutral | Possible Weakness | Major Weakness |
|---|---|---|---|---|---|
| Using mathematical concepts to solve engineering problems | X | | | | |
| Using chemistry concepts to solve engineering problems | | | X | | |
| Using physics concepts to solve engineering problems | X | | | | |
| Using engineering concepts to solve engineering problems | X | | | | |
| Designing an experiment to obtain measurements or gain additional knowledge about the process | | | X | | |
| Analyzing a set of data to find underlying meaning(s) | X | | | | |
| Designing a device or process when given a set of specifications | | X | | | |
| Function as an accountable member of an engineering team. | X | | | | |
| Formulating unstructured engineering problems | | | X | | |
| Using appropriate engineering techniques and tools including software and/or lab equipment for problem solving | X | | | | |
| Understanding the professional and ethical responsibilities of an engineer | X | | | | |
| Writing effectively | | X | | | |
| Making professional presentations | | X | | | |
| Effectively communicating engineering related ideas to others | X | | | | |
| Listening to and impartially interpreting different viewpoints | X | | | | |
| Understanding the potential risks and impacts that an engineering solution or design may have | X | | | | |
| Applying knowledge about current issues to engineering related problems | X | | | | |
| Recognizing the limitations of my engineering knowledge and abilities when to seek additional information | X | | | | |

# 4.0 METHODOLOGY JUSTIFICATION

## 4.1 Introduction

Chapter 3 has described the SW method as a data driven approach for classifying categorical variables into new categories for decision-making purposes. The focus lies in reclassifying the category with the largest proportion, where each element in each population is classified into exactly one of three mutually exclusive and exhaustive categories.[41] Specialists in the field of categorical variables like von Eye and Clogg[90] state that researchers are reluctant to work with categories. The reason is that most of the computer programs and methods have been developed for quantitative variables. When working with a finite population, an additional drawback is found; the literature related to the selection of the category having the largest proportion for a finite population is scanty. This gap in the literature has been filled here with simulation. Simulation techniques based on sampling with replacement (bootstrap)[34] have been used to generate different categories and to obtain an estimate of the average probability *P[cs]* that the category with the observed largest sample proportion matches the one having the best proportion in the population. A classification procedure is then suggested. The decision-making procedure in the Pitt-SW method is based on this procedure.

## 4.2 Characteristics of the Data

Populations consist of students per level (class) and program. Population sizes are given by the number of students registered per level and program. Not every one responds to the questionnaire. Sample size consists of the number of students per level and program that completed the questionnaires. For example the sophomore level of Program *A* has 35 students registered (population), but only 30 filled the survey (sample). Populations of students per program and level are small because of restrictions set by the school, e.g.: classroom capacity, restrictions on the maximum number of students per course, interest in taking a course, etc. As discussed in Chapter 3, until 2001 the number of data points per sample accounted for a range of 70-92% of the population per level.

Data to be analyzed here pertain to the questionnaires administered to students at different levels and programs of the School of Engineering at the University of Pittsburgh. These data are primarily a collection of perceptions and attitudes. According to Allport[2], perceptions depend on personal past experience, services delivered, environment, and external information. They are influenced by unknown biases that are likely to increase with time[79]. These unknown biases are not random, but arise due to the potential ambiguity of perceptions[79] and the imprecision resulting from the subjective nature of the scale[79] used to measure the perception. Here, it is necessary to clarify some concepts. The term “ambiguity” is best explained through an example. Let us consider the meaning of the expression “small number”. This has different meanings to different people. The term “imprecision” arises from the personal translation of the perception into a category within a scale, e.g. the range of the scale may be different for different people, intervals of the scale may be of different lengths or the mid-point of the scale may define an asymmetric scale.[80]

The type of data obtained from these questionnaires is by nature meaningful for a short utilization horizon, because the data are highly influenced by contextual changes. Consequently it is not possible to replicate the exact experimental condition from year to year. Moreover, if the objective is to pursue a continuous improvement process, unlike the methods used in standard industrial quality control, populations here cannot be considered infinite.

Perceptions are collected by letting the students select the category that best agrees with their preference. Categories are represented on a 5-point scale that can be Likert five-point in some cases or other qualitative five-point scales. If the Likert scale is used, 5 categories are defined ranging from “Strongly Disagree” to “Strongly Agree”. In the other cases the five points cover categories that range from “Poor” to “Excellent”.

## 4.3 Methodology Justification

### 4.3.1 Statistical Background

Given that the data have already been collected, the emphasis is on the analysis rather than on the determination of the sample size. This last point creates some difficulty because most of the literature on ranking and selection is focused on experimental design where the decision variable is $n$, the size of the sample to be collected. This information is meaningful if the population under question is infinite. In the present case $n$, the sample size and $N$, the population size are fixed by contextual constraints, and the focus is on determining the probability of correct selection $P[cs]$ of the category having the largest proportion.

Step 2 of the Pitt-SW analysis, is concerned with the sets formed by grouping the data into positive, neutral and negative proportions. Because the sample size $n$ is fixed and relatively small, this reduction in the number of categories is carried out in order to have a high probability of selecting the population category with the best proportion[41]. Now the categories are $k$=3 mutually exclusive categories *Ci* with associated unknown probabilities $P_{[i]}$, where $0< P_{[i]}<1$, i= {1,2,3}, and $\Sigma P_{[i]}=1$, and $P_{[1]} < P_{[2]} < P_{[3]}$.

Step 3 of the Pitt-SW analysis deals with the selection of the category in the population that accounts for the largest proportion[41]. In other words the goal is to determine which category dominates the population. Gibbons[41] gives a minimum sample size $n$, given the number of categories $k$, a probability requirement of at least $P^*[cs]$ to select the best proportion correctly, and a critical ratio $\delta^* = \frac{P_{[k]}}{P_{[k-1]}}$, where $P_{[k]}$ is the largest proportion in the population and $P_{[k-1]}$ is the next-to-largest proportion. It is possible to estimate a lower bound for $P[cs]$ when $n$ and $k$ are given by forcing the constants $\delta^*$ and $P^*[cs]$ to be functionally related and obtaining the operating characteristic curve (OC). This process is carried out by working with the least favorable configuration. The least favorable (LF) configuration for a number of categories k is given by:

$$P_{[1]}=P_{[2]}=\ldots=P_{[k-1]} \qquad \text{and} \qquad P_{[k]} = \delta^* P_{[k-1]}$$

The OC determined in this manner is a lower bound for all the pairs ($\delta^*$, $P[cs]$) for a given value of the sample size $n$.[41]

The drawback of using the LF configuration in the case of this dissertation is that given the small populations and sample sizes this $P[cs]$ might be overly conservative when in fact the interest perhaps lies in determining the average $P[cs]$ for $N$ and $n$ fixed, to assess the accuracy of the selection.

The task at hand was to verify if the category observed in the sample (with the largest proportion) meets the preassigned level of probability $P[cs]$ of successfully matching the largest proportion in the population, given a finite population and that the sample size $n$ is fixed.

The study was carried out by performing a simulation based on bootstrap technique,[34] or sampling with replacement to generate the multinomial population with three categories. The starting point was the generation of different combinations of categories. The sophomore level survey was chosen to generate the values of the respective proportions used in the study. This was done because it showed the broadest range of categories per answer. The answers of the 2001 sophomore survey of the School of Engineering at the University of Pittsburgh were pooled in a spreadsheet. The overall sample consisted in 166 students schoolwide. The survey contained 61 questions. This sample was considered as the master population for the experiment. Frequencies and proportions of

1's, 2's, 3's, 4's and 5's were obtained from this master population for each one of the questions. These proportions were applied to generate virtual populations of fixed size *N*. The size of *N* ranged from 10 to 50 by increments of 5, from 60 to 100 by increments of 10, and only one population of size 150. The range of the size of *N* was generated based on the historical population of each program within the school.

A ratio $\delta = \dfrac{P_{[k]}}{P_{[k-1]}}$ was defined for each answer in the population where $P_{[k]}$ is the largest proportion in the population and $P_{[k-1]}$ is the next to largest proportion. By definition $\delta$ should be greater than one. With 61 questions and three proportions for each one, it was possible to obtain a wide range of $\delta$'s. This approach resulted in an important time saving for the experiment. It also permitted to have an accurate idea of the range of $\delta$'s that has an estimate of *P[cs]* less than 1 for a fixed sample size, because for this range *P[cs]* varies for the same value of $\delta$ (*P[cs]* depends on the individual values of the $P_{[i]}$'s and is not uniquely determined by $\delta$.)

Each population was displayed in a spreadsheet where columns represented the answers to the different questions of the surveys. One hundred random samples of size 90%, 80%, 70%, 60%, and 50% from each population for a given question were generated and ordered in five spreadsheets to perform the study. Step 2 of the Pitt-SW analysis was applied. Frequencies of 1's, 2's 3's 4's, and 5's were calculated for each column and thereafter proportions of each one were calculated. These proportions were slightly different from the master population proportions due to round off errors. Proportions were then pooled into the three categories positive, neutral, and negative.

The ratio $\delta$ was calculated for each replication and called $\delta_{[s]}$. Given the number of questions, sixty-one in the case of the sophomore questionnaire, it was possible to obtain in most of the cases many replications for each $\delta$ in the population. The distribution of $\delta_{[s]}$ per answer was seen to be discrete, with an approximated shape of a bell shaped. It is centered around $\delta$ and the standard deviation diminishes as the sample size increases.

The number of categories in the replications that matched the best proportion in the population was counted. Corresponding proportion is the estimated *P[cs]*. The plot in Figure 4.1 shows the fitted *P[cs]* for each $\delta$ whose *P[cs]* is less than or equal to 1 for a population of size 70 as a black dot. The plot shows the fitted *P[cs]* as a function of $\delta$ in the population.

At a first glance it can be seen that $\delta$ values are not continuous but discrete. This is shown in the graph by black dots. The black dots represent the fitted *P[cs]* value corresponding to each $\delta$. A quadratic function was fitted to approximate the relationship between the fitted *P[cs]* and the $\delta$s. The original dots presented a random pattern around the quadratic function. In the figure below the quadratic approximation is represented by a segmented line.

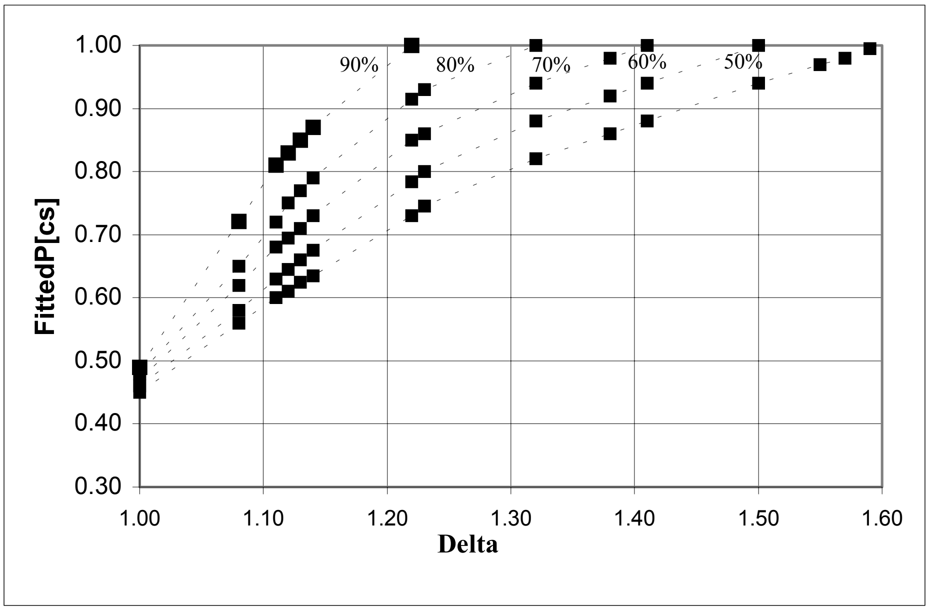



**Figure 4.1 Fitted Probability of Making the Correct Decision. k=3,N=70**

The quadratic lines fitted the dots with a $R^2$ greater than 0.8 in the case of population size 10, with $R^2$ above 0.9 for population size between 10 and 35. For N above size 40, $R^2$ was in almost in every case above 0.99.

The deviations of the estimated *P[cs]* from the fitted quadratic curves were due to two different reasons. They are:

- Deviations due to sampling.
- Deviations due to different proportions $P_{[i]}$ for the same $\delta$

Deviations due to sampling were detected when analyzing plots in which different values of *P[cs]* were obtained for the same value of $\delta$, same proportions $P_{[i]}$ in the population, same sample size and population. Those differences disappeared when the number of replications was increased from 100 to 250.

Deviations in the estimate of *P[cs]* due to different proportions $P_{[i]}$ for the same $\delta$ value, population and sample size were studied in a second experiment. For this experiment the goal was to establish the limits of *P[cs]* for each $\delta$. Population sizes were fixed at *N* equal to 10, 25 and 80. An interesting result was obtained by applying the following set of equations,

$$P_{[1]}+ P_{[2]}+P_{[3]}=1; \tag{4.1}$$

$$P_{[1]} < P_{[2]} < P_{[3];} \tag{4.2}$$

$$P_{[3]} = \delta P_{[2];} \tag{4.3}$$

$$P_{[2]}+ P_{[3]} <1 \tag{4.4}$$

$$P_{[2]}+ \delta P_{[2]}< 1 \tag{4.5}$$

$$P_{[2]} < \frac{1}{1+\delta}; \tag{4.6}$$

$$P_{[3]} < \frac{\text{ä}}{1+\delta}; \tag{4.7}$$

In the least favorable configuration case;

$$P_{[1]}= P_{[2];} \tag{4.8}$$

$$P_{[1]}+ P_{[1]}+ \delta P_{[1]=}1; \tag{4.9}$$

In general,

$$P_{[1]} < \frac{1}{2+\delta} \tag{4.10}$$

For a given $\delta$ , *P[cs]* takes a range of values depending on the values of $P_{[3]}$, $P_{[2]}$, and $P_{[1]}$. When $P_{[1]}$ is close to $\frac{1}{2+\delta}$, the P[cs] is close to the lower bound of its range.

Between 250 and 1000 replications were generated for the same $\delta$ value and for each one of the $\delta$'s in a fixed population to study the effect of different combinations of $P_{[k]}$*'s* and to avoid influences on the variability of *P[cs]* due to sampling.

A first conclusion about the *P[cs]s* was that for small populations sizes (eg. 10 – 15), only a few $\delta$'s allowed more than one combination of the three proportions. For example when the population size is 10, there are only two combinations of $P_{[i]}s$ that allow $\delta$ equal to 1. They are $P_{[k]} = P_{[k\text{-}1]} = 50\%$ and $P_{[k]} = P_{[k\text{-}1]} = 40\%$. See Table 4.1.

The rest of the $\delta$ values for this population size were unique. On the other extreme for population size 80 there were 13 (without considering $P_{[1]}$ equals zero) different combinations of frequencies for the same $\delta$ value equaling 1.

**Table 4.1 P[cs] - (LB;UB) - δ =1**

| Fitted P[cs] | (LB;UB) |
|---|---|
| 50% | (50,50) |
| 45% | (40;50) |

From Figure 4.2 it can be seen that for values close to the critical value $P_{[1]} = .33$ from equation 10, *P[cs]* diminishes abruptly from 50% to 33% for all sample sizes.

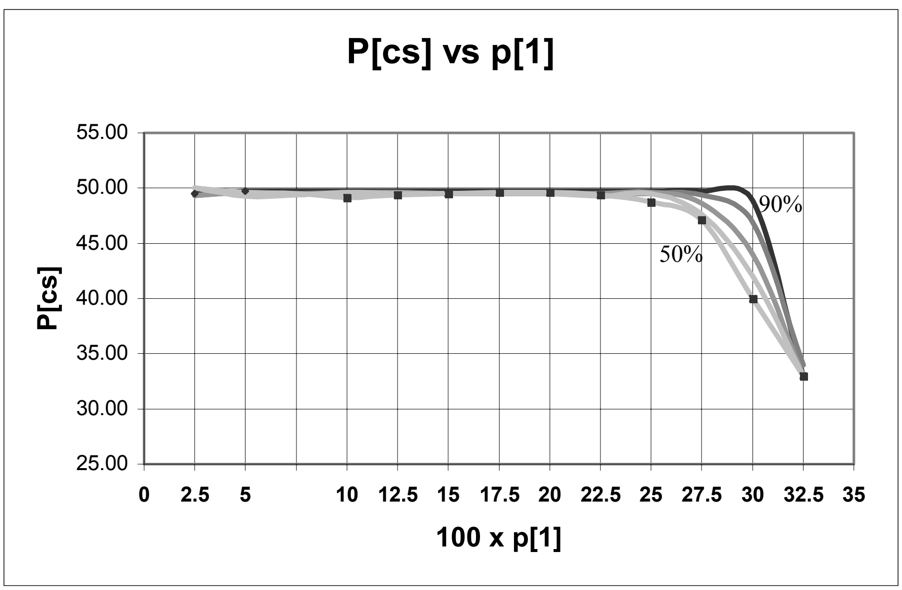



**Figure 4.2 P[cs] vs. 100 x p[1]. δ=1, N=80**

Population size 80 allowed other combinations of $P_{[k]}s$ for different $\delta$'s. For $\delta$ values greater than 1, e.g. $\delta$ = 1.2, and different sample sizes the bounds are shown in Table 4.2.

**Table 4.2 Lower and Upper Bounds for $\delta$ =1.2 N=80.**

| Sample size | Fitted P[cs] | Bounds |
|---|---|---|
| 90% | 1.00 | (.99, 1.00) |
| 80% | .89 | (.84, .89) |
| 70% | .82 | (.76, .83) |
| 60% | .76 | (.67, .77) |
| 50% | .71 | (.58, .73) |

Population size 25 allowed still other combinations of $P_{[k]}$'s for different $\delta$'s. For $\delta$ values greater than 1, e.g. $\delta$ = 1.5, there are only two combinations of frequencies; (15, 10, 0); (12, 8, 5). The estimate of the *P[cs]* values and bounds for different sample sizes are shown in Table 4.3.

**Table 4.3 Lower and Upper Bounds for $\delta$ =1.5 N=25.**

| Sample size | Fitted P[cs] | Bounds |
|---|---|---|
| 90% | 1.00 | (.99, 1.00) |
| 80% | .97 | (.95, .97) |
| 70% | .89 | (.88, .94) |
| 60% | .82 | (.81, .90) |
| 50% | .75 | (.70, .87) |

It can be seen from both tables that the distribution within each interval is discrete and sometimes not symmetric. As a conclusion when $\delta$ increases in value, *P[cs]* also increases and the interval between bounds becomes narrower until *P[cs]* reaches the value 1. After this value is reached the fitted *P[cs]* value is independent of $\delta$. On the other hand, the smaller the sample the greater is the $\delta$ required for *P[cs]* to converge to 1 and the gap between the two bounds becomes wider. The complete set of tables for sample sizes ranging form 90% to 50% are shown in APPENDIX A

### 4.3.2 Procedure for the Selection of the Best Category

The purpose of the former experiments is to select the population's category associated the largest proportion The following procedure is based on the single–stage procedure proposed by Bechhofer et al.,[7] and has been adapted to finite populations in the following way.

Procedure: For the given number of categories *k*, and specified constants *n* and *N*, take a random sample of *n* observations

$X_{ij\,;}$ for ($1< j < n$) and ($1 < i < k$)

$X_{ij} = 1$ if the $j^{th}$ observation belongs to the $i^{th}$ category, 0 otherwise.

$X_{ij}$ (0,1) int, define $y_{[in]} = \sum_{j=1}^{n} X_{ij}$

Terminal decision rule: Calculate the ordered sample sums

$y_{(1)n} \leq \ldots\ldots\ldots \leq y_{(k)n}$, where $y_{(i)n}$ is the number of observations falling in the ordered category *i*. Calculate the δ* ratio by dividing the $y_{(k)n}$ over $y_{(k-1)n}$. With this δ* value enter the table that corresponds to *N* and *n*, find the fitted *P[cs]*. (if this *P[cs]* is acceptable with pre-established criteria *Y* declare the category with $y_{(i)n}$ as the best category. Otherwise consider the best category as neutral. Go to the next step.) Then reclassify the category using the SW framework using the heuristic rules given in Chapter 3.

Remarks: if the sample size *n* falls under the 50% of *N* for values of *N* smaller than 30 declare the best category as not available (*NA*). It is necessary to have further investigations on the situation when *N* size exceeds 30 and the sampling proportion is below 50%.

## 4.4 Data Classification

The Pitt-SW table is concerned with a decision-making process. This dissertation has pointed out that it is necessary to link customer satisfaction with managerial decisions through the construction of a service quality system based on internal standards. These standards depend on the knowledge of the process, the need for consistency in measurement, and flexibility in the decision-making process through the possibility of setting moving threshold limits in order to pursue continuous improvement of the educational system. The literature of TQM first led to the construction of control charts. By definition, the development of control charts is linked with the concept of stability. Control charts need many observations for the "set-up" or in other words, a lot of time to observe the performance of the system to obtain satisfactory feedback. However, one of the characteristics of a pure service system is that it does not afford too many opportunities for the collection of observations. Specifically, this is true in the higher engineering educational service system where newer technology, better or new careers, changes in the national economy, or external policies can rapidly shift the performance standards required to survive. The concept of stability is then lost[25] and with it the applicability of a control chart.

Given that standards are set by the decision-makers of the School, it will be easier for controlling the student's perceptions against those standards by controlling the best proportion of the perceptions in the population. An approach for establishing control in this situation is developed here using the techniques found in the fuzzy logic literature.

### 4.4.1 Development of Heuristic Rules

Rules may be provided by experts or can be extracted from numerical data.[59] The rules that make the Pitt-SW table are a collection of *IF - THEN* statements. The *IF* part is called the antecedent and the *THEN* part is its consequent.

The first rule was issued to determine the classification for a MAJOR perception. Major perception is defined as an absolute negative or positive perception from the point of view of the decision-maker. This Major concept should be sharp enough to be used as a first quick screening of the category having the best proportions. The threshold for a Major perception has been set at 50 % by consensus, the first rule is expressed as:

> If one response proportion (positive or negative) accounts for at least 50% of the cases, then that proportion is classified as a *Major Strength* if positive or *Major Weakness* if negative.

Later in the dissertation this threshold is raised to 80% with statistical and conceptual background for the Major Strength classification.

The second rule is straightforward and answers the following question: what if a perception cannot be classified as a Major one? First the neutral perception which is deemed to occur,

> If both positive and negative perceptions are equal or
>
> If both extreme (positive or negative) proportions are less that the neutral

The justification of these two rules is straightforward. If positive and negative perceptions are equal or less than the neutral perception it is not possible to make a decision, meaning that the antagonistic situation does not allow us to make a conclusion about the statement. These three rules leave room for many other situations without any classification. An intermediate classification termed “Possible” is therefore considered. A possible perception can be defined as one that satisfies the statistical requirement for being selected as positive or negative perception but does not satisfy the rule for the Major perception. The next task is to define a statistical level of “satisfactory”. “Satisfactory” can be set at the $\delta*$ value that satisfies the condition that the fitted *P[cs]* is equal to or greater than *Y* (which is a preassigned probability level.) *Y* is selected by the decision-makers and depends on their level of confidence or risk aversion. If *P[cs]* is greater than *Y* the $\delta$ used in the selection of the best proportion is likely to belong to the same distribution of the $\delta*_Y$ that correspond to *Y* or to one where $\delta*$ corresponds with *P[cs]* greater than *Y*. In section 4.3.1. it was stated that when obtaining the fitted *P[cs]* the $\delta_{[s]}$ where symmetrically distributed around the $\delta$ in the population . The greater the $\delta_{[s]}$, the greater is the chance that it belong to the distribution of $\delta*_Y$.

The rules for classifying a category with the largest proportion as “possible” perception have been stated at the end of Chapter 3 and are repeated here:

Case A: The order in the sample is:

$\hat{p}_{(1)} < \hat{p}_{(2)} < \hat{p}_{(3)}$, where $\hat{p}_{(3)}$, is positive or negative perception and $\hat{p}_{(2)}$, can be any of the other two proportions. Define $\delta* = \dfrac{\hat{p}_{(3)}}{\hat{p}_{(2)}}$

The rule is stated as: if the largest proportion in the sample (positive or negative perception) selected has fitted probability *P[cs]* equal to or greater than the desired level Y corresponding to the observed value of $\delta*$, and accounts for less than 50% of the responses, then classify this category as a Possible Strength. If the largest proportion corresponds to positive perception then it is a *Possible Strength* otherwise it is a *Possible Weakness.*

Case B: The order in the sample is

$\hat{p}_{(1)} < \hat{p}_{(2)} < \hat{p}_{(3)}$, where $\hat{p}_{(3)}$ is positive or negative perception and $\hat{p}_{(2)}$ is neutral .

Define $\delta_1^* = \dfrac{\hat{p}_{(3)}}{\hat{p}_{(2)}}$ and $\delta_2^* = \dfrac{\hat{p}_{(3)}}{\hat{p}_{(1)}}$

The rules is stated as: if the average probability *P[cs]* by setting $\delta^* = \delta_1^*$ is less than the desired level *Y* and accounts for less than 50%, but the fitted probability *P[cs]* by setting $\delta^* = \delta_2^*$ is greater or equal than *Y* then the category with the largest proportion is classified as *Possible Strength/Weakness.*

A third rule for Neutral classification arises as a consequence of not satisfying the preassigned level *Y* of acceptance:

If the observed $\delta^*$ results in the selection of the best proportion with fitted probability *P[cs]* less than the desired level *Y* then the category with the largest proportion is classified as *Neutral*

# 5.0 EXAMPLE APPLICATIONS OF THE METHOD

## 5.1 Introduction

Application of the SW table is the main focus of this chapter. Cross-sectional and longitudinal analyses are shown. Special graphs, e.g. the one-dimensional and two-dimensional arrows that help the analysis are introduced these have been demonstrated to be of practical use within the engineering educational system.[68]

## 5.2 Assessing Students' Progress Towards Achieving Ec 2000 Outcomes: A Cross-Sectional Comparison.

A major concern for any engineering school has been the assessment of students' progress towards achieving EC 2000 outcome objectives. The University of Pittsburgh Strengths and Weaknesses analysis (Pitt-SW) enables individual departments and schools to take a "snapshot" of the academic progress either by level or across all levels. Moreover, additional comparisons of student progress towards satisfying EC 2000 outcomes can be made between the freshman and sophomore levels, sophomore and junior levels or junior and senior levels. These comparisons can be made either for the entire school or for each program.

Table 5.1 illustrates how this information can be displayed. The number of X's in each column of Table 5.1 is counted at the sophomore level. The same count down is made for the junior and senior levels (not shown here). The counts of the numbers of X's serve as a basis for comparison among levels. The progress toward EC 2000 is shown by the increase in the number of X's in the Major and Possible Strengths columns and the decreases in the other categories.

The results given below clearly show the increase in student confidence as they advance through the curriculum. Similar tables can be developed for each program.

**Table 5.1 Students Self-Confidence Towards Achieving EC 2000 Outcomes . AY 2000-Schoolwide**

| | MAJOR STRENGTH | POSSIBLE STRENGTH | NEUTRAL | POSSIBLE WEAKNESS | MAJOR WEAKNESS |
|---|---|---|---|---|---|
| **Sophomore** | 12 | 3 | 2 | 1 | 0 |
| **Junior** | 15 | 2 | 0 | 1 | 0 |
| **Senior** | 17 | 0 | 1 | 0 | 0 |

### 5.3 Assessing Students' Progress towards Achieving EC 2000 Outcomes: A Longitudinal Comparison

Another way of measuring the progress towards meeting the EC 2000 is by tracking a student cohort as it goes from the sophomore to the senior level. Table 5.2 illustrates this comparison. The freshmen level of the School of engineering at the University of Pittsburgh has a common freshman program, the first year comparison can only be done for the whole School. This level is not shown in the table.

**Table 5.2 Students Self-Confidence Towards Achieving EC 2000 Outcomes. AY 1999- AY 2000 Schoolwide**

| | MAJOR STRENGTH | POSSIBLE STRENGTH | NEUTRAL | POSSIBLE WEAKNESS | MAJOR WEAKNESS |
|---|---|---|---|---|---|
| **Junior 99** | **11** | **6** | **0** | **1** | **0** |
| **Senior 00** | **17** | **0** | **1** | **0** | **0** |
| **Change** | **6** | **-6** | **1** | **-1** | **0** |

### 5.4 Comparing Both Assessments

#### 5.4.1 The One-Dimensional Arrow Graphs.

Two different types of graphs were developed to combine cross-sectional and longitudinal results. The first type - one-dimensional - shows movements between academic levels in the same year or between successive years for the same or successive levels. Two levels of the same or consecutive years can be depicted in the same graph. Horizontal arrows display changes from origin on the box that corresponds to the first cohort referred in the title to the tip on the box of the second cohort. If there are no changes, the graph will only show a small square in the same box. The way of making comparisons is shown in Figure 5.1:

The comparisons indicate that there were three improvements for using mathematical concepts to solve engineering problems when the comparison is made between the junior classes of 1999 and 2000 academic years. Two of these improvements are from Neutral to Major Strength (Programs 3 and 5).

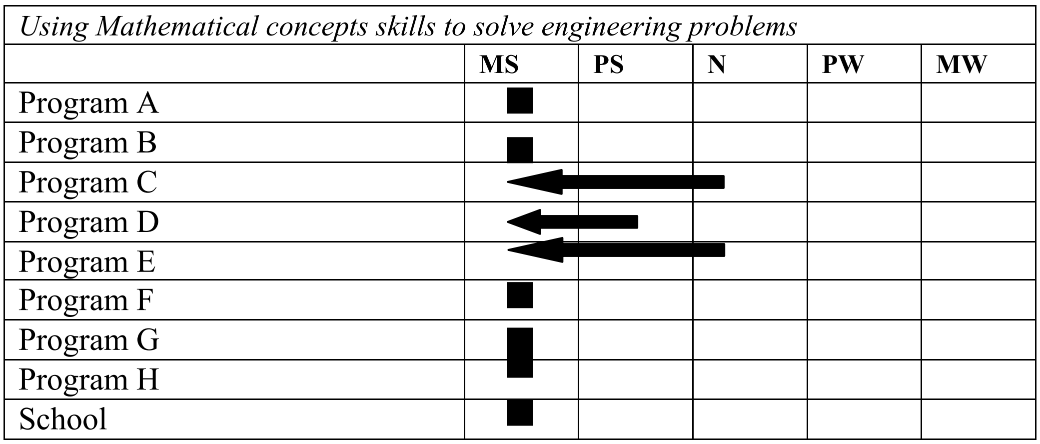



**Figure 5.1 One-Dimensional Arrow Graph**

It can be seen from this figure that five other programs of the junior level of both years rated their math abilities as Major Strength.

This type of table provides a way to assess how student confidence is achieved across the curriculum. These comparisons are useful for evaluating different programs, for sharing and benchmarking experiences across programs, and for detecting structural problems; e.g., when a program's students consistently indicate a particular area of weakness (limited self-confidence). While these graphs can provide valuable information, especially in terms of a specific program or issue, they still display information on a question-by-question basis rather than provide a more comprehensive picture.

### 5.4.2 The Two-Dimensional Arrow Graphs.

In order to obtain a more comprehensive representation, a second type of graph - bi-dimensional - was developed. In this graphs the Y-axis displays the five classifications and the X-axis gives the three academic levels (sophomore, junior and senior). The school graph includes the freshmen level. Hence, one graph can be prepared for each EC 2000 outcome and program. Figure 5.2 provides an example. By varying the size and color of the dots we can distinguish among years and cohorts. For example, lighter colors (and larger sizes) represent earlier years. These characteristics allow us to superpose different years in the same graph without losing clarity. There are no links between dots of the same year; nor are there links if there has been no change for the same cohort from one level to the next. An arrow signals a change for the same cohort between years. An arrow pointing upwards marks an improvement (e.g., light gray or green). An arrow pointing downwards (e.g., red or dark gray) indicates a negative change. Two examples are depicted in Figure 5.2 and Figure 5.3.

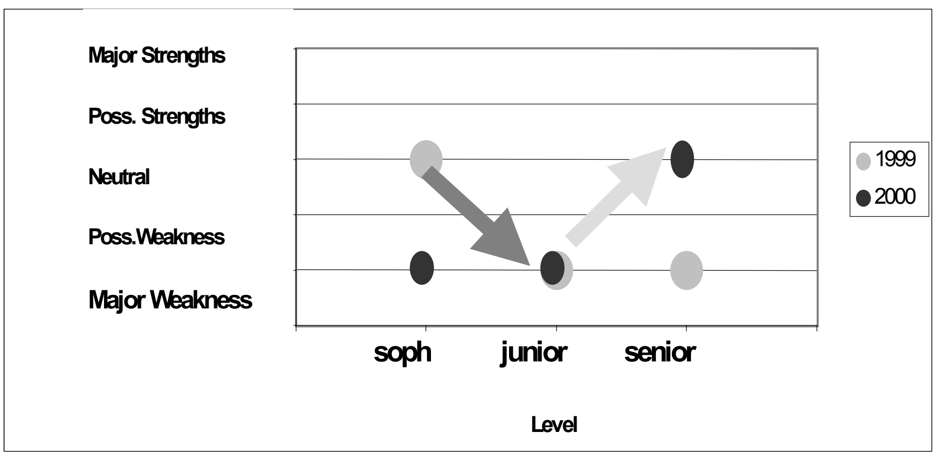



**Figure 5.2 Using Chemistry Concepts to Solve Engineering Problems. Program 1**

The first graph indicates that the confidence of sophomores, juniors and seniors in their skills to apply chemistry concepts is low (although the responses of seniors in 2000 indicated an improvement from their responses as junior in the year 1999). If this pattern is unacceptable, it would be prudent to find its root cause. The second graph shows that the 2000 AY students are more confident in design than they were in the previous year, and, in general, the 2000 AY students are more confident than the 1999 AY students at the same level. These graphs can be presented to the faculty for review and possible action.

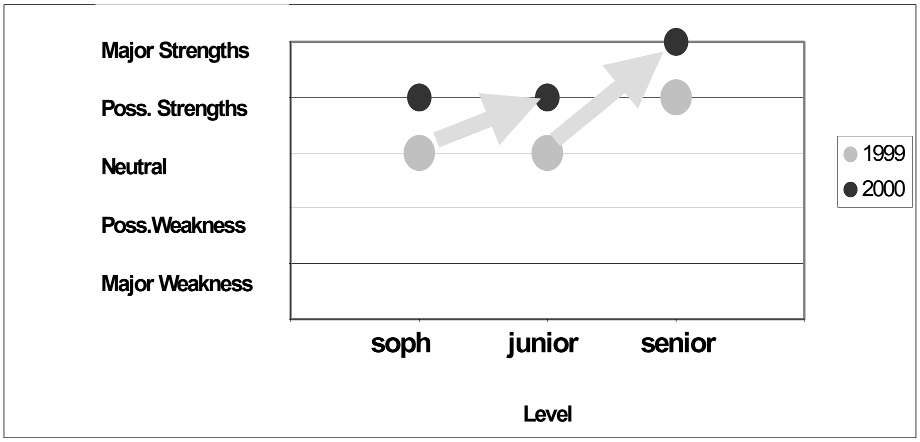



**Figure 5.3 Designing a Device or Process when Given Set of Specifications Program 2**

### 5.5 Re-Sensitizing the Graphs: Changing the Threshold

Another concern in this research is refining the instruments that are being used, especially in determining how good is "good". That is, what should be the threshold for classifying data as Major Strength/Weakness?

While it seems reasonable to classify a category as a Major Weakness when 50% or more of the students negatively perceive their ability to achieve a certain outcome, the opposite may not necessarily be true when classifying Major Strength. Moreover, the Possible Strength/Weakness and the Neutral classifications have been selected based on the fitted probability P[cs] of correct selection. The main concern is determining a more appropriate threshold for a Major Strength classification. All of the positive proportions that accounted for 50% or more and were classified as Major Strength were plotted for the sophomore, junior and senior levels of the same academic year 2000. Results are shown in Figures 5.4, 5.5 and 5.6

There are two reasons for changing the threshold of Major Strengths, first the former threshold of 50% was arbitrary and did not provide an accurate classification in situations like the one shown in Table 5.3.

With the earlier threshold of 50%, Department F is considered to provide a Major Strength in the SW classification. However, the $\delta^*$ ratio here equals 1.03 and the probability of a correct selection of the largest proportion averages 45%, too low to be accepted as Major Strength. Consequently a decision was

Mean: 68 Median: 67 Sd: 13

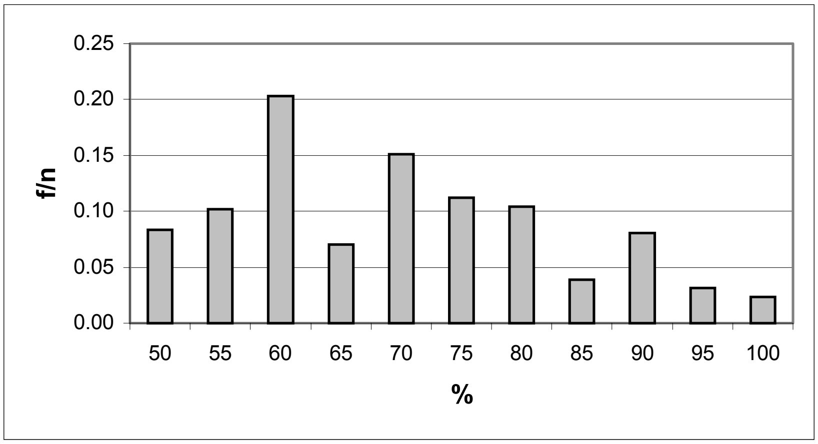



**Figure 5.4 Relative Frequency of Percentages Classified as Major Strengths-Sophomore Level**

Mean: 72 Median: 72 Sd: 14

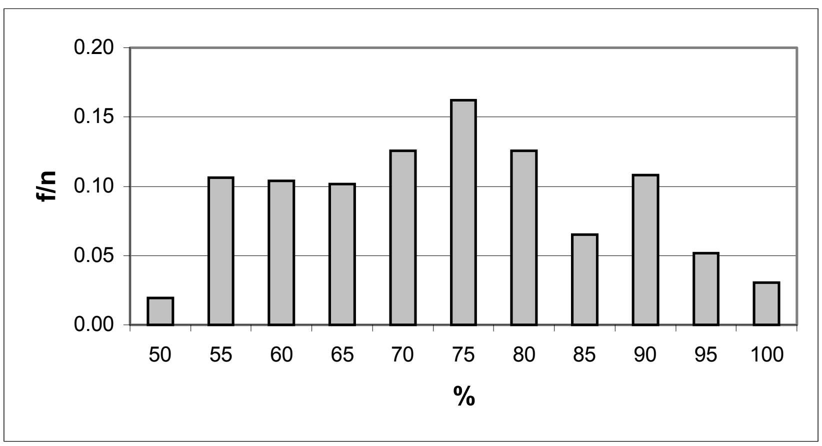



**Figure 5.5 Relative Frequency of Percentages Classified as Major Strengths-Junior Level.**

Mean: 75 Median: 77 Sd: 13

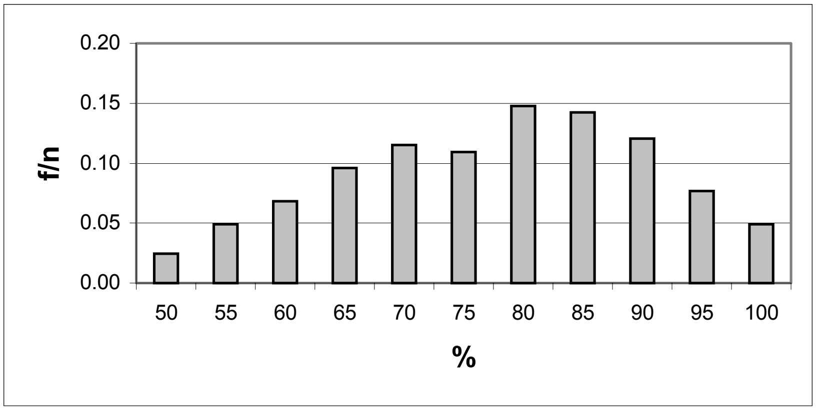



**Figure 5.6 Relative Frequency of Percentages Classified as Major Strengths-Senior Level**

**Table 5.3 Display of Proportions**

**1. My freshman year prepared me for my sophomore year.**

| n= | 18 | 12 | 40 | 32 | 28 | 7 | 25 |
|---|---|---|---|---|---|---|---|
| N | 20 | 15 | 45 | 40 | 35 | 10 | 30 |
| **Department** | A | B | C | D | E | F | G |
| **NEGATIVE** | 16.7% | 13.4% | 15.0% | 18.8% | 0.0% | 1.5% | 28.0% |
| **NEUTRAL** | 38.9% | 40.0% | 25.0% | 40.6% | 17.9% | 48.5% | 440% |
| **POSITIVE** | 44.4% | 46.6% | 60.0% | 40.6% | 82.1% | 50.0% | 28.0% |

reached by consensus that the threshold limit be set at 80%. In this case the minimum $\delta$ * for 80% is 4 and from the Table in Appendix A there is no doubt about the correct selection for any sample size that is greater than or equal to 50% of the population, provided that the population size is larger than 10.

As explained before, the threshold limit of 50% for Major Weakness is enough to draw the attention of any decision maker. A "Weakness" classification means that there exists a good reason to make improvements to situation covered by the statement under question.

As a consequence of adopting the new threshold limit, the profile of the SW has changed with most of the classifications being now Possible Strengths rather than Major Strengths. Further, such outcomes as teamwork, communication skills and professionalism are now categorized as Possible Strength and are considered areas for additional improvement. This result is consistent with the judgment of the faculty. Table 5.4 shows these new results.

Note from Figures 5.4, 5.5, 5.6 that for each consecutive level, the mean and the median of the percentages is increasing, indicating that students' confidence increases as they move from one academic level to the next.

The Mann-Whitney method, a pairwise non-parametric test, was used to confirm the statistical validity of these differences.

That is, the situation tested by the hypothesis is:

$$H_0: \mu_{sophomore} = \mu_{junior}$$

$$H_a: \mu_{sophomore} < \mu_{junior}$$

Where $\mu$ stands for the mean of the proportions' distribution within the Major Strengths field and is obtained from Figures 5.4, 5.5, and 5.6.

The Mann-Whitney test resulted in a p value smaller than 0.001; i.e., there is a significant difference between classifications for juniors compared to sophomores. The test showed similar significant differences for the other comparisons: junior to seniors and sophomores to seniors.

**Table 5.4 Example Schoolwide SW Table: Confidence in EC 2000 Outcomes – Sophomores AY 1999**

| *Confidence in Engineering Outcomes* | Major Strength | Possible Strength | Neutral | Possible Weakness | Major Weakness |
|---|---|---|---|---|---|
| Using mathematical concepts to solve engineering problems | | X | | | |
| Using chemistry concepts to solve engineering problems | | | X | | |
| Using physics concepts to solve engineering problems | | X | | | |
| Using engineering concepts to solve engineering problems | | X | | | |
| Designing an experiment to obtain measurements or gain additional knowledge about the process | | X | | | |
| Analyzing a set of data to find underlying meaning(s) | | | X | | |
| Designing a device or process when given a set of specifications | | X | | | |
| Function as an accountable member of an engineering team. | | X | | | |
| Formulating unstructured engineering problems | | X | | | |
| Using appropriate engineering techniques and tools including software and/or lab equipment for problem solving | | | X | | |
| Understanding the professional and ethical responsibilities of an engineer | | X | | | |
| Writing effectively | | X | | | |
| Making professional presentations | | X | | | |
| Effectively communicating engineering related ideas to others | | X | | | |
| Listening to and impartially interpreting different viewpoints | | X | | | |
| Understanding the potential risks and impacts that an engineering solution or design may have | | X | | | |
| Applying knowledge about current issues to engineering related problems | | X | | | |
| Recognizing the limitations of my engineering knowledge and abilities when to seek additional information | | X | | | |

# 6.0 EFFICIENCY MEASUREMENT: SELECTION OF DIMENSIONS

## 6.1 Introduction

The first part of this dissertation deals with how to integrate the results of surveying students' self-confidence and attitudes into decision-making actions. This step has been accomplished through the Pitt-SW analysis and its applications. The Pitt-SW paradigm expresses its results with respect to each department itself, but it does not measure how efficient a program or department is, thus if the objective is to look for best practices, additional tools are required.

The evaluation of whether or not a program is achieving its desired educational outcomes depends on the graduates' collective perceptions about their acquired abilities and skills. The second part of this dissertation is concerned with the measurement of relative efficiency among different levels and programs within the same institution based on students' self-confidence and attitudes. The objective is to make an intra-institutional benchmarking of best practices to achieve better results. Data Envelopment Analysis (DEA) method is selected in order to accomplish this objective.[23] In contrast with a statistical method where a given process is compared with an "average" process, DEA is a linear programming method that compares each process with only the best one. In the DEA literature, a process is usually referred to as a decision-making unit or DMU.

## 6.2 Relevant Dimensions to Be Included in Dea

A generic efficiency index of a DMU is defined as the ratio of outputs to inputs. An important question to answer before beginning with the DEA analysis is, which inputs and which outputs are relevant to the measurement of efficiency within the engineering educational system.

This chapter focuses on selecting the group of variables within the set of surveys used at the School of Engineering that accounts for the most representative sets of inputs and outputs to be included in the efficiency evaluation. General qualitative dimensions solicited by those questionnaires are engineering related attitudes, perceived ability to work in teams, confidence in personal abilities, pre-professional experiences (junior and seniors), and education and employment information (senior). Confidence in having achieved the EC 2000 objectives, is a common input and output for all the levels. Alumni are also asked about the university environment and their educational experience. Alumni responses are not going to be considered as part of this evaluation. However, for further research, it is suggested that alumni answers should be included as part of the efficiency evaluation.

Some of those questionnaires are still in an exploratory form. The complete survey system of the School of Engineering has not been homologated yet to show continuity from one level to the next one. The focus of this chapter is to look for common features among those questionnaires and at the same time to reduce the amount of data to be used. There are three main requirements with regard to the set of inputs and outputs:

- They should cover the full range of perceptions related to the objective of the study.
- They should capture all levels and performance measures.
- They should include factors common to all units.

As the DEA allows flexibility in the final value of the weights for inputs and outputs, the greater the number of factors and variables to be included, the lower is the level of discrimination of their relative importance. A reduction in the number of variables and factors is desirable to increase the level of discrimination of the DEA model.

Factor analysis (FA) was the technique used here to (a) observe if the dimensions of the questionnaires matched the relevant dimensions observed from the data collected and (b) select the set of variables to be deleted from each dimension and avoid any loss of relevant information related to the efficiency measurement. FA is a technique used to analyze the structure of the relationships among dependent variables, and it provides groupings of highly correlated ones.

Generally, FA does not apply to categorical variables; an exception arises when the variables are measured using the same scale.[(61)]

The output answers to student questionnaires was factor analyzed to see the type of meaningful groups or factors that could arise in order to confirm or to re-label each group, but no data reduction was performed because the outcomes are related to the EC 2000. The full set of answers related to inputs that have direct impact on the outputs within the engineering educational process was factor analyzed in order to select the reduced set of most meaningful dimensions to be included in the evaluation of efficiency. However the reduction was only performed for those statements not related to EC 2000. This selection was performed in two stages. First a visual inspection of the questionnaires covering the freshmen to senior levels was carried out to detect and eliminate yes/no questions.

Then factor analysis was applied. The objective of this step is to reduce the number of variables and to detect a smaller number of underlying constructs called factors

Exploratory principal components with varimax rotation were selected as the preferred methodology of factor analysis. The objective for rotating the factors is as follows,

1) The variance of each variable should be fairly evenly distributed across the factors
2) Each variable should load predominantly on only one factor
3) The factors loading should be close to 1.0 or 0.0
4) The factors loadings should be uni-polar (same sign)

These are the ultimate objectives. The FA procedure was carried out separately on the answers of the four main questionnaires, freshmen post, sophomore, junior and senior. The sample sizes for freshmen (years 97-98), sophomores (98-99), for juniors (years 99-00), and seniors (years 00-01) were 250, 190, 222 and 280 subjects respectively. The variability in the number of subjects among the levels was due to different causes such as the number of transferred students, attrition, co-op within a term, etc. An issue to consider was the homogeneity of the cohort under study. Whether or not the same group of students constituted the different levels, it could be assumed that the influence of external factors (economical, environmental, etc,) and the daily interchange with other students made the cohort homogeneous for the purposes of this study. During the analysis missing values were replaced by the mean score of the column to avoid the loss of information for other variables.

The factor analyses served as a way of selecting which variables to keep as meaningful inputs, and which ones to discard. The purpose was to get rid of any kind of redundancy by looking at the factors. Many questions that seemed to have the same meaning before applying factor analysis resulted in loading on the same factor. The supposition that there were more than one question trying to measure the same attitude was confirmed.

Factor analysis was also used to verify the accuracy in the selection of the variables for the purpose of measurement of efficiency.

For the freshman level four factors were detected as inputs. They accounted for 58% of the total variance, a little lower than the generally accepted lower bound of 60%.[61]

**Factor 1: Engineering expectations**

- I expect that engineering will be a rewarding career
- Engineering is an occupation respected by other people
- Engineers have contributed greatly to fixing problems in the world
- I enjoy subjects of sciences and mathematics the most
- Engineers are innovative
- Engineers are creative

**Factor 2: Confidence in personals study habits**

- I am confident about my current study habits or routine
- I am good at designing things
- I consider myself technically inclined
- I have strong problem solving skills
- I feel I know what an engineer does

**Factor 3: Team working habits**

- Studying in a group is better that studying by myself

**Factor 4: External Influences**

- My parents want me to be an engineer.

**Figure 6.1 Freshmen Final Dimensions**

Each factor defined one dimension. Furthermore, after performing the varimax rotation each variable loaded heavily on one factor with no exceptions. The number of variables was reduced from 52 to 13. Variables and factors are described below in Figure 6.1.

For the sophomore level, the inputs were grouped into the six factors that account for the 62.5% of the total variance. The number of variables was reduced from 42 to 21.With the exception of two variables, the rest of them loaded heavily on only one factor. The two variables were, *ability to apply math concepts* and *ability to set goals on time* that were both related to the factor "engineering knowledge." Figure 6.2 shows variables and groups for the sophomores.

Factors 3, 4, 5 and 6 of the sophomore level constitute the output for the freshmen level. Three additional variables were added to the sophomore input from the freshmen output. Those variables are related to impact of engineering applications on the society, application of external knowledge (economics, environment, etc.) to solve engineering problems, and ethics in engineering.

For the junior level, seven factors were identified. They accounted for 60.2% of the total variation. The number of variables was reduced from 51 to 24. Factor 6 was deleted because the statement "I enjoy sciences and math the most" loaded evenly on two factors. In order to keep the uniformity of the variables among the levels and given that the same statement also loaded on two factors for the sophomore level, it was also deleted from this one. Factor 7 "Ability to apply chemistry concepts to solve engineering problems" was amalgamated with factor 2. This factor consists of the basic sciences variables.

For the efficiency measurement it is necessary to add to the list for the junior level the statements related to the impact of engineering applications on the society, application of external knowledge (economics, environment, etc.) to solve engineering problems and ethics in engineering. These variables are taken from the sophomore output.

Figure 6.3 shows the input groups and variables for the junior level.

**Factor 1: Engineering Expectations**

- I expect that engineering will be a rewarding career
- I am confident that I have chosen the right major
- I feel confident in my ability to succeed in engineering

**Factor 2: Confidence On Major Election**

- My freshman year prepared me for my sophomore year
- My academic advisor has been helpful

**Factor 3: Engineering Knowledge**

- Ability to analyze engineering data
- Ability to solve unstructured engineering problems
- Ability to design a device or process
- Ability to use commercial software packages to solve engineering problems

**Factor 4: Communication Skills And Teamwork**

- Oral communication skills
- Technical writing
- Ability to be an effective team member

**Factor 5: Sciences And Management Skills**

- Ability to apply math concepts to solve engineering problems
- Ability to apply chemistry concepts to solve engineering problems
- Ability to apply physics concepts to solve engineering problems
- Ability to set goals and achieve them on time
- Ability to learn new things by my own

**Factor 6: Technical Support**

- Ability to use proper laboratory procedures
- Computer program skills

**Figure 6.2 Sophomore Final Dimensions**

**Factor 1: Engineering Expectations And Attitudinal Support**

- I expect that engineering will be a rewarding career
- I feel confident in my ability to succeed in engineering
- I am confident that I have chosen the right major
- My academic advisor has been helpful

**Factor 2: Academic Support For c Sciences And Engineering Knowledge**

My sophomore year prepared me for my junior year
Ability to apply math concepts to solve engineering problems
Ability to apply physics concepts to solve engineering problems
Ability to analyze engineering data
Ability to solve unstructured engineering problems
Ability to apply chemistry concepts to solve engineering problems

**Factor 3: Pre-Professional Experience**

- Provided me with the opportunity to pursue learning on my own
- Increase my ability to succeed in engineering classes
- Allowed me to work on "real world" problems
- Helped me to develop my communication skills.

**Factor 4: Management Skills**

- Technical writing ability
- Oral communication skills
- Ability to function in different team roles
- Ability to set goals and achieve them on time
- Ability to learn new things on my own

**Factor 5: Problem Solving And Computer Skills**

- Ability to use proper lab procedures
- Ability to design a device or process
- Computer programming skills
- Ability to use commercial software packages to solve engineering problems

**Figure 6.3 Junior Final Dimensions**

For the senior level five factors were obtained. They accounted for 65% of the total variance, again above the suggested lower bound. This time the variable related to teamwork loaded on two factors: the *engineering technical* and the *engineering professional* factors. Other variables loaded heavily on only one factor, confirming the correct selection of the variables for the DEA analysis. The reduction was from 39 variables to 23. Figure 6.4 shows the groups and variables for the senior level. Factors 2, 3, 4, and 5 constitute the outputs for the junior level.
Two attitudes to highlight are changes in teamwork and self-management skills. They belong to different constructs as students progress through the program. One explanation can be that during the earlier years the teaching emphasis is placed on the basic sciences and as time goes by the emphasis moves to specific engineering skills. Pre-professional experience plays a principal role in the development of communications skills and on hands knowledge of the profession. The professional behavior is also strongly related to engineering ethics and knowledge of current issues and communications skills.

Finally, the number of variables that constitute the outcomes for the senior level were not reduced because they consisted of the EC 2000 criteria. These outcomes were grouped into four factors that accounted for 58% of the total variation, which was less than the recommended bound. In this case the factors were well defined. Figure 6.5 shows this last group.

Results of FA for data reduction are shown in APPENDIX B

**Factor 1: Pre-Professional Experience And Coursework Knowledge**

- Improve communications skills
- Improve time management skills
- Understand the engineering profession

**Factor 2: Engineering Knowledge And Designing Skills**

- My ability to design and conduct and experiment to obtain measurements or gain additional knowledge
- My ability to formulate unstructured engineering problems
- My ability to design a device or process to satisfy a given set of specifications
- My ability to use my knowledge of engineering to solve engineering problems
- My ability to design and interpret a set of data to find underlying meanings
- My ability to use appropriate engineering techniques including software or
- lab equipment for problem solving.
- My ability to function effectively in different team roles

**Factor 3: Engineering Professional And Ethical Behavior**

- My ability to listen and impartially interpret different point of view
- My understanding of potential risks and impact to the public of a proposed engineering solution
- My understanding of the professional and ethical responsibilities of an engineer
- My ability to apply knowledge about current issues to engineering related problems
- My commitment to life long learning
- Effectively expressing engineering related ideas to others
- My ability to write effectively

**Factor 4: Communications Skills**

- My undergraduate education provided a solid background for my career
- My ability to make effective presentations

**Factor 5: Sciences Knowledge**

- My ability to use my math knowledge to solve relevant engineering problems
- My ability to use my knowledge of chemistry to solve relevant engineering problems
- My ability to use my knowledge of physics to solve relevant engineering problems

**Figure 6.4 Senior Final Dimensions (Inputs)**

**Factor 1: Engineering Professional And Ethical Behavior**

- Understanding the potential risks and impacts that an engineering solution or design may have.
- Applying knowledge about current issues to solve engineering problems
- Understanding the ethical and professional responsibilities of an engineer
- Listening to an impartially interpreting different viewpoints
- Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information
- Effectively expressing engineering ideas to others

**Factor 2: Engineering Knowledge And Skills**

- Designing a device or process to satisfy a given set of specifications
- Using appropriate engineering techniques including software or lab equipment for problem solving
- Designing and conducting an experiment to obtain measurements or gain additional knowledge about a process
- Formulating unstructured engineering problems
- Analyzing and interpreting data to find underlying meanings
- Using my knowledge of engineering to solve relevant engineering problems
- Using my knowledge of mathematics to solve relevant engineering problems

**Factor 3: C communication Skills**

- Making professional presentations
- Writing effectively
- Functioning in different team roles

**Factor 4: Science Knowledge**

- Using my knowledge of chemistry to solve relevant engineering problems
- Using my knowledge of physics to solve relevant engineering problems

**Figure 6.5 Senior Final Dimensions (Outputs)**

### 6.3 Disposition of Outputs and Inputs for the Evaluation of Efficiency

The process to follow is backward in time. At every stage time is explained first and then the relationships between inputs and outputs.

The first observation is taken at time of the senior exit, measuring the EC 2000 outcomes as outputs and the perception of the graduate students at the exit about the senior inputs.

Outputs for the senior level are the students' self-confidence perceptions related to the EC 2000. Inputs are students' perceptions of the EC 2000 knowledge and skills acquired from the previous year plus pre-professional experience, coursework knowledge and personal opinion of the complete undergraduate experience.

The second observation is taken at the end of the junior academic year. Outputs for the junior year are the same inputs of the senior year related to students' self-confidence perceptions of the EC 2000 knowledge and skills. Outputs taken at the end of the junior academic year are discarded for the purposes of this study to avoid duplication of measurement. Inputs for the junior level are the EC 2000 perceptions plus attitudinal support, academic support and pre-professional experience plus the sophomore output related to engineering professional and ethical behavior and engineering expectations obtained at the end of the sophomore year.

The third observation is taken at the end of the sophomore academic year. For the sophomore level outputs are the EC 2000 perceptions measured as inputs for the junior level. Outputs taken at the end of the sophomore academic year are discarded for the purposes of this study to avoid duplication of measurement. Inputs are the EC 2000 perceptions plus engineering expectations and confidence in major selection plus the freshmen output related to engineering professional and ethical behavior plus engineering expectations, taken at the end of the freshmen year.

Finally, the observations for the freshmen year are taken at the end of the academic year. Outputs for the freshmen level are the EC 2000 perceptions measured as inputs for the sophomore level and the inputs are engineering expectations, confidence in personals study habits, team working habits, and external influences. Outputs of the same year are discarded to avoid duplication of measurements.

Figure 6.6 shows a flowchart of the links along a program. Links represent the connections between levels in the order that they are to be modeled in the next chapter. Those links show the students' changing perceptions about EC 2000.

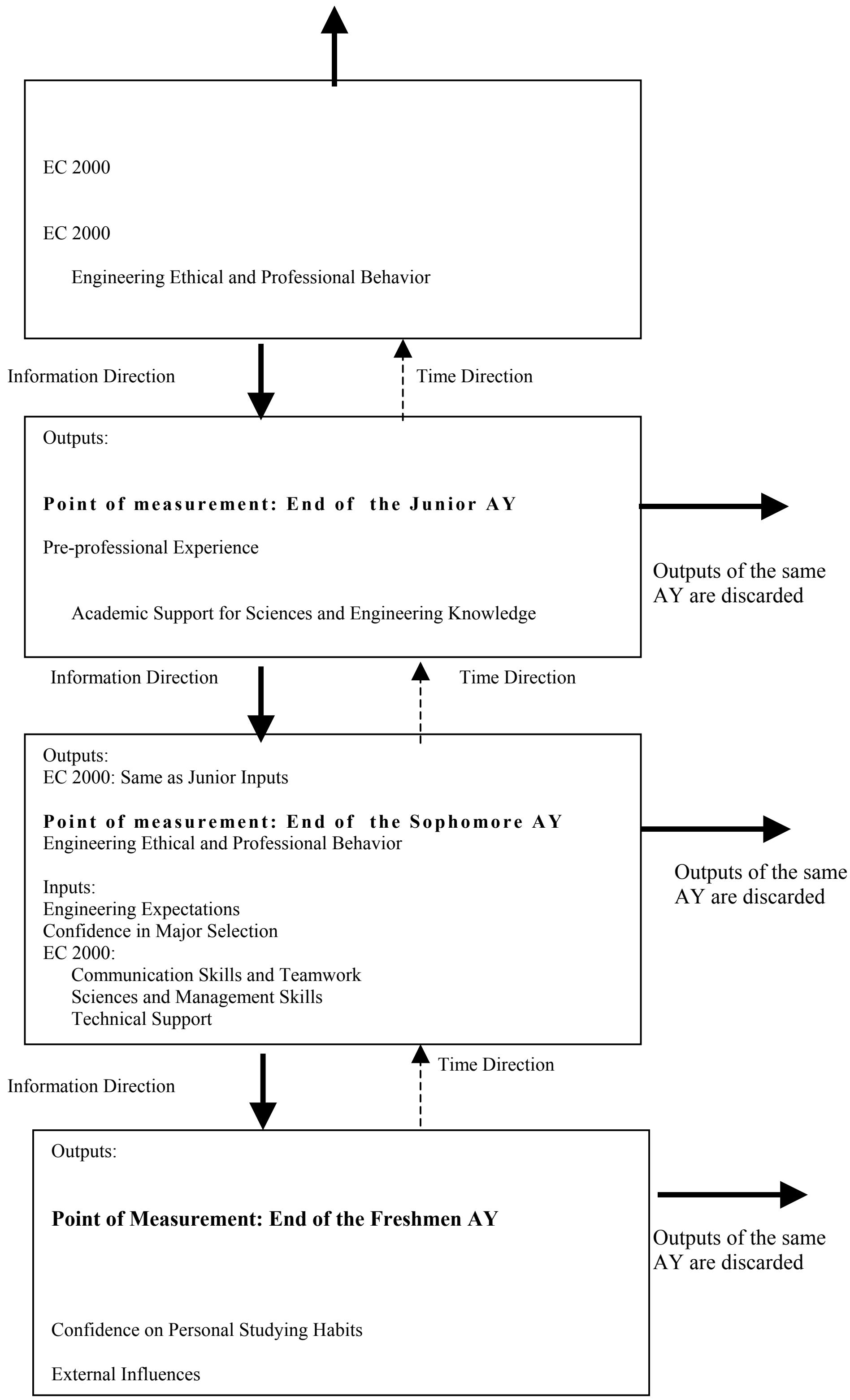



**Figure 6.6 Flow Chart of Outputs and Inputs per Level**

# 7.0 EFFICIENCY MEASUREMENT: METHODOLOGY

## 7.1 Introduction

The last part of this dissertation focuses on the development of a model to measure the relative efficiency of all the levels and programs schoolwide. Chapter 2 introduced the Data Envelopment Analysis (DEA) method as a way of measuring relative efficiency. In the original development DEA was restricted to be a linear program (LP).[(23)] It has been recently enhanced to include non-linear constraints as well. Specifically, in the model that will be developed here, some restrictions on characters (weights) of variables result in nonlinear constraints. After the analysis is performed, coefficients of efficiency are displayed in a chart or map to show the relative position of each level and program within the school. This efficiency map together with the Pitt-SW table constitutes the starting point for the investigation on best practices within the School of Engineering.

## 7.2 Procedure

An important motivation for benchmarking and measurement is found in Collier.[(25)]. A definition of benchmarking states that benchmarking is the search for industry best practices that lead to superior performance to pursue the best of class. Some generic questions are addressed by benchmarking studies such as: “who is the best of the class?,” “why is it the best?,” “which best practice determines the frontier?,” and “what are the rates of improvement over time?.” Thus by definition benchmarking requires a relative measure of efficiency.[(25)]

The next step is to develop the model for making the evaluation. The procedure is carried out as follows; first a set of equations is stated longitudinally for the four levels of a generic program. In the second step a model is constructed for the freshman level by using the freshman level equation from the previous model for each one of the programs. The freshman level is a common one within the School of Engineering for all undergraduate students. It has the same set of inputs for all the programs, and presents different outputs depending upon the program specifics. In the case where there is no common level across the institution it is suggested to that the freshmen level be used, because this is the starting level.

This first model is solved and the coefficients are used to scale the EC 2000 inputs of the set of equations of the sophomore level. The rationale is that in order to link the longitudinal study with the cross-sectional one the coefficients of the equations that correspond with the EC 2000 inputs of a given level are multiplied by the coefficient of efficiency of the previous level to include the relative position of the previous level. The process is repeated by constructing a second DEA model using the scaled inputs for the sophomore. The outcomes of this second model are used to scale the inputs of the junior level and a third model is constructed. The process is repeated once again for the senior level.

### 7.3 Relationship between Dea and the S.W. Table

A main requirement of the DEA method is the homogeneity of the units under assessment.[(23,32)] In general, the variables to be inputs for every DMU as well as the variables to be outputs for every DMU should be the same. In the specific case of this dissertation each level has the same set of variables across the programs. This requirement arises from the necessity to make comparisons over the same basis. Variables related to program specifics have not been considered in order to focus on common features.

It is very difficult to accomplish this homogeneity requirement in a longitudinal study. For the engineering educational system, the reasons are that perceptions and attitudes change as students' progress through the program. Chapter 6 gives support to this point when it is shown that the same perceptions and attitudes group differently along the levels of a program. This has been one of the objectives of Chapter 6: the homologation of variables along the programs. Here, outputs for the junior, sophomore and freshman level are taken in their totality, and with a few additions, from inputs of the next higher level.

It is proposed to use the Pitt-SW table categories to overcome the problem related to the lack of homogeneity. Categories have no dimension and may serve as a link between two consecutive levels. Therefore, DEA and the Pitt-SW analysis are related though the coefficients and weights used for the evaluation of efficiency. Variables are the set of answers considered as inputs and outputs. The amount of the contribution of a variable is given by a coefficient, which happens to be the largest proportion of the corresponding category in the Pitt-SW table. The character of the contribution of a given variable is represented by a category. The meaning of goodness is how favorable or unfavorable the attitudes or perceptions of the students related to a certain topic are. Categories are the same as the SW-Table. The character is quantified as a weight. Weights of Major Strengths/Weakness should be greater than those of Possible Strengths/Weakness categories and these last two should be greater than those of the Neutral category. If the weight represents a Major/Possible Strength the sign of the coefficient is positive, if it represents a Major/Possible Weakness the sign of the coefficient is negative. If the weight represents a Neutral the sign is left unrestricted and it is found by the solution of the system of equations.

Two consecutive or cross-sectional levels are allowed to have different weights. Therefore, each level adjusts its own weights with respect to itself and to the rest of the levels. Within certain tolerance ξ, weights (prices and costs) that represent the same category and the same level should be equal. These restrictions on the weights result in nonlinear constraints to be included in the model. Once it is detected which level or levels are the more efficient, other studies can be performed to improve the efficiency of the rest of the program/s.

For a given longitudinal cohort, there are different constraints that represent outputs and inputs of a specific level (freshmen, sophomore, junior and senior) but constraints and tolerances on the weights must be the same over the cohort. This way of setting the constraints together with the homologation makes it possible to relate the different levels of a program.

### 7.4 General Definitions

Generally an efficiency index $\varepsilon$ is defined to be

$$\varepsilon = \frac{\text{values of DMU i's outputs}}{\text{values of DMU i's inputs}}$$

The DEA approach uses the following restrictions and ideas to determine a DMU's efficiency.

No DMU can be more than 100% efficient. Thus the efficiency å of DMU *i* must be less than or equal to

1) For DMU *i* it is possible to write the same inequality as,

$$\frac{\text{values of DMU i's outputs}}{\text{values of DMU i's inputs}} \leq 1$$

Multiplying both sides of this inequality by the denominator and canceling,

values of DMU's inputs- values of DMU's outputs ≥ 0

2) Each category is weighted by a weight called price $t$ for the outputs and cost $w$ for the inputs. The linear equations aim to find the output prices and inputs costs that maximize efficiency.

3) To simplify computations input costs are scaled so that the total costs of inputs for DMU $i$ equals1. values of DMU's inputs = 1

4) The costs $w$ of each input and the price $t$ of each output must be strictly greater than 0, because if a cost or price is 0 DEA cannot detect an efficiency involving input or output $i$.

5) There is a group of variables that are inputs for one level and outputs for the next lower level, weights for those variables are considered independent from each other.

6) Weights (costs or prices) are the variables for the model.

## 7.5 Master Model

Decision Variables:

Define,

$t_j$ as the price of category $j$ of the Pitt-SW table

$w_j$ as the costs of category $j$ of the Pitt-SW table

$a_{ijkp}$ output $i$ that corresponds with category $j$ at level $k$ for program $p$

$b_{ijkp}$ input $i$ that corresponds with category $j$ at level $k$ For program $p$

$a_{ijk-1p} = b_{ijkp}$ inputs of one level are the outputs of the next lower one.

Where,

$j$ = 1 if Major Strength, 2 if Possible Strength, 3 if Neutral, 4 if Possible Weakness, 5 if Major Weakness

$k$ = 1 if freshmen, 2 if sophomore, 3 if junior , 4 if senior

$p= 1....n$, where $n$ is the number of programs within a school.

The objective, constraints and ideas are modeled though the following set of equations. For a given level $k$ and program $p$ they are stated as follows,

Objective Function:

a) In agreement with idea 2, maximize total price of outputs

$$\text{Max } z = \Sigma_i \Sigma_j a_{ijkp} t_j \quad (7.1)$$

This set of equations belongs only to one level. The sequence is:

Constraints:

b) In agreement to idea 1

$-(\Sigma_i \Sigma_j a_{ijkp} t_j)+(\Sigma_i \Sigma_j b_{ijkp} w_j) \geq 0$ (7.2)

c) In agreement with idea 3

To ensure that the efficiency coefficient is less than or equal to one, the sum of the inputs should be equal to 1, to scale the outputs

$(\Sigma_i \Sigma_j b_{ijkp} w_j) = 1$ (7.3)

d) In agreement with idea 4

To assure that every category makes a contribution

$t_j \geq 0.001$ for $j$=1,2,4,5.

$t_3$ unrestricted and $|t_3| \geq 0.001$ (7.4)

e) In agreement with idea 4 the same restrictions of point f are set on costs.

$w_j \geq 0.001$ for $j$=1,2,4,5.

$w_3$ unrestricted and $|w_3| \geq 0.001$ (7.5)

f) There is another set of constraints due to the characteristics of the system

g) The price of a major strength should be greater than the price of a possible strength,

$t_1 - t_2 > \xi$ (7.6)

h) The price of a possible strength should be greater than the absolute value of the price of a neutral,

$t_2 - |t_3| > \xi$ (7.7)

i) The price of a major weakness should be greater than the price of a possible weakness

$t_5 - t_4 > \xi$ (7.8)

j) The price of a possible weakness should be greater than the absolute value of the price of a neutral

$t_4 - |t_3| > \xi$ (7.9)

k) Due to the asymmetry of the SW- Table

$t_5 - t_1 > \xi$ and $t_4 - t_2 > \xi$ (7.10)

l) Same concepts of pointsg, *h*, *i, j, and k* are repeated to generate similar constraints for costs $w_j$

m) The difference between the cost and the price of the same category should be within a tolerance δ. This constraints relates to the difference in perceptions of inputs and an outputs, that should maintain the same relative position in the SW Table.

$$|w_j - t_j| < \delta \tag{7.11}$$

where ξ and δ are the same for each longitudinal cohort and are selected to assure the feasibility. The value of δ may change for different longitudinal cohorts. The last constraint defines a set of non-linear equations. The complete set of equations is repeated for the other levels *k* for each of the programs.

### 7.6 An Example

Four programs *A, B, C*, and *D* have been selected from the School of Engineering to test the model. The first step is to obtain the SW table for the four consecutive levels of the same program. The SW table has been obtained only for the variables that resulted from Chapter 6.

Table 7.1 shows the SW table for the outcomes of the sophomore level of Program B for the academic year 98-99. The values of the largest proportion used to classify categories in the table replace each one of the *Xs* . The proportions are added along each column. Results are the coefficients of the equations.

The equation of the outputs for the sophomore level of Program *B* is sated in the following way,

$$3.32*t1+5.556*t2+3.715*t3-0.571*t5$$

where $t_1$ is the weight for the Major Strengths category, $t_2$ is the one for Possible Strengths, $t_3$ for Neutral. The same steps are followed for the inputs (detailed computations are in Appendix C) .

When the inputs are added, the equation looks as follows,

$$-3.32*t1-5.56*t2-3.715*t3+0.571*t5 \\ +2.642w_1+6.583w_2+2.786w_3-1.142w_5>=0;$$

This equation is highlighted in Figure 7.1.

Following the same procedure a first set of equations for the longitudinal cohort of Program B is stated. The model is shown in Figure 7.1. The same set of equations is stated for all the programs involved in the measurement of efficiency.

```
-0.875*t1-10.625*t2+1.69*w1+10.50*w2+3.666*w3 >=0;                              (senior)
-.833*t1-7.752*t2-3.666*t3+699.8*w1+605.6*w2+4.834*w3-.571*w5>=0;                (junior)
-3.32*t1-5.556*t2-3.715*t3+.571*t5+2.642*w1+9.415w2+2.965*w3-1.142*w5>=0;        (sophomore)
-1.714*t1-8.91*t2-2.293*t3+1.142*t5+3.572*w1+3.686*w2+.363*w3>=0;                (freshman)
```

**Figure 7.1 Equations of the Freshmen-Senior Levels of Inputs and Outputs. Program B**

Four DEA models are then developed. Each one is related to one of the levels within the school. The first model is the application of DEA to the freshmen cross-sectional level. The set of equations related to weights are added. The model is shown in Figure 7.2

The program is solved by maximizing the outputs of each freshmen level at a time. Inputs are the same for all the freshmen levels. The same restrictions on weights are kept for all the solutions. The resulting coefficients of efficiency are shown in Table 7.2. These coefficients are multiplied by the EC 2000 inputs of the sophomore level of the respective program.

**Table 7.1 Sophomore Outputs. AY 1999-Program B**

| ***Academic support for sciences and engineering knowledge*** | **M S** | **PS** | **N** | **PW** | **M W** |
|---|---|---|---|---|---|
| *10. Ability to apply math concepts to solve engineering problems.* | **83.3** | | | | |
| *12.Ability to apply physics concepts to help solving engineering problems.* | | | **50** | | |
| *13.Ability to solve unstructured engineering problems.* | | **50** | | | |
| *14. Ability to analyze engineering data.* | | **50** | | | |
| *11.Ability to apply chemistry concepts to solve engineering problems* | **83.3** | | | | |
| ***Management skills*** | | | | | |
| *20. Technical writing ability: i.e to prepare engineering reports and papers.* | | | **66.7** | | |
| *21.Oral communication skills* | | | **66.7** | | |
| *22.Ability to function effectively in different team roles.* | | **66.7** | | | |
| *23.Ability to set goals and achieve them on time.* | **83.3** | | | | |
| *24.Ability to learn new things on my own.* | | **57.1** | | | |
| ***Problem solving and computer skills*** | | | | | |
| *15.Ability to design a device or process.* | | **50** | | | |
| *16.Ability to use proper laboratory procedures.* | | **60** | | | |
| *17.Computer programming skills.* | **83.3** | | | | |
| *18.Ability to use commercial software packages to solve engineering problems.* | | **50** | | | |
| ***Total sophomore due to junior input*** | **333.2** | **383.8** | **183.4** | **0** | **0** |
| *Confidence in Engineering Outcomes* | | | | | |
| *47. Using engineering concepts to solve relevant problems.* | | | **50** | | |
| *48.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | | | **57.1** |
| *54.Understanding the professional and ethical responsibilities of an engineer.* | | **71.8** | | | |
| *57. Effectively communicating engineering related ideas to others.* | | | **50** | | |
| *58. Listening to an impartially interpreting different viewpoints.* | | | **57.1** | | |
| *59. Understanding the potential risks and impacts that an engineering solution or design may have* | | **42.9** | | | |
| *60. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | | **30.8** | | |
| *61. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | **57.1** | | | |
| | **0** | **172** | **188** | **0** | **57.1** |
| *TOTAL* | **333** | **556** | **371** | **0** | **57.1** |

**Table 7.2 Freshmen Coefficient of Efficiency per Program**

| | **Index** |
|---|---|
| **A** | 0.8101 |
| **B** | 0.8749 |
| | 1 |
| | 0.9028 |

As an example, the sophomore equation for Program B from the first set of equations (Figure 7.1) is the following one,

-3.32*t1-5.556*t2-3.715*t3+.571*t5+2.642*w1+9.415w2+2.965*w3-1.142*w5>=0;

This equation is highlighted in Figure 7.3. The inputs of the sophomore level are scaled (penalized) by the factor 0.8749 from table 7.3. The same equation is the following one, also shown in Figure 7.3.

-3.32*t1-5.556*t2-3.715*t3+.571*t5+2.495*w1+8.30*w2+2.678*w3-.999*w5>=0;

Now, a second DEA model is developed for the sophomore level. Restrictions on weights are the same as the freshmen level. Changes for the sophomore level are shown in Figure 7.3.

```
MODEL:

Max = 0.833*t1+9.589*t2+1.374*t3-0.444*t4-0.667*t5;

3.572*w1+3.686*w2+0.363*w3=1;

-0.833*t1-9.589*t2-1.374*t3+0.444*t4+0.667*t5+3.572*w1+3.686*w2+0.363*w3 >=0; (freshman A)
-1.714*t1-8.91*t2-2.293*t3+1.142*t5+3.572*w1+3.686*w2+.363*w3>=0;               (freshman B)
-.9*t1-11.26*t2-1.26*t3+3.572*w1+3.686*w2+0.363*w3>=0;                           (freshman C)
-8.525*t2-3.635*t3+3.572*w1+3.686*w2+.363*w3>=0;                                  (freshman D)

t1>=0.001;
t2>=0.001;
@free(t3);
@abs(t3)>=0.001;
t4>=0.001;
t5>=0.001;
t1-t2>0.001;
t2-@abs(t3)>0.001;
t5-t4>0.001;
t4-@abs(t3)>0.001;
t5-t1>0.001;
t4-t2>0.001;
w1>=0.001;
w2>=0.001;
@free(w3);
@abs(w3)>=0.001;
w4>=0.001;
w5>=0.001;
w1-w2>0.001;
w2-@abs(w3)>0.001;
w5-w4>0.001;
w4-@abs(w3)>0.001;
@free (a);
@free(b);
@free(c);
@free(d);
@free(e);
a =w1-t1;
b=w2-t2;
c=w3-t3;
d=w4-t4;
e=w5-t5;
@abs(a)<0.0001;
@abs(b)<0.0001;
@abs(c)<0.0001;
@abs(d)<0.0001;
@abs(e)<0.0001;
end
```

**Figure 7.2 Lingo Model for the Freshmen Level**

```
MODEL:

Max=5.096*t2+5.235*t3-0.476*t4;

2.331*w1+9.935*w2+1.113*w3-0.36*w4-.54*w5=1;

-5.096*t2-5.235*t3+0.476*t4 +2.34*w1+8.985*w2+1.117*w3-0.36*w4-.54*w5>=0;
-3.33*t1-5.56*t2-371.5*t3+.571*t5+2.43*w1+8.34*w2+2.678*w3-.999*w5>=0;
-.818*t1-7.543*t2-4.252*t3+2.602*w1+12.65*w2+1.36*w3>=0;
-7.05*t2-3.607*t3+.944*t4+1.6*w1+8.64*w2+3.55*w3>=0;

t1>=0.001;
……….
@abs(e)<0.0001;
end
```

**Figure 7.3 Lingo Model for the Sophomore Level**

Coefficients of efficiency for the sophomore level are shown in Table 7.3.

**Table 7.3 Sophomore Coefficient of Efficiency per Program**

| Program | Index |
|---|---|
| A | 1 |
| B | 1 |
| C | 0.3776 |
| D | 0.4899 |

The process is repeated for the junior level. Inputs for the junior level related to the EC 2000 are scaled by the sophomore coefficients. The Lingo model for the junior level is shown in Figure 7.4 and the coefficients of efficiency are shown in Table 7.4.

```
MODEL:

Max= 4.178*t1+5.235*t2+0.47*t3-0.471*t4

0.813*w1+10.649*w2+5.491*w3-0.476*w4=1

-4.178*t1-5.382*t2-0.47*t3+0.471*t4+0.813*w1+10.649*w2+5.491*w3-0.476*w4>=0;
-.833*t1-7.75*t2-3.666*t3+.6.99*w1+6.056*w2+4.834*w3-.571>=0;
-5.363*t1-5.907*t2-0.91*t3+0.545*t5+3.75*w1+4.728*w2+2.01*w3>=0;
-5*t1-5.3*t2-1.2*t2+.4*t4+.5*t5+2.098*w1+6.352*w2+2.156*w3-.462*w4>=0;

t1>=0.001;
……….
@abs(e)<0.0001;
end
```

**Figure 7.4 Lingo Model for the Junior Level**

**Table 7.4 Junior Coefficient of Efficiency per Program**

| Program | Index |
|---|---|
| A | 0.9997 |
| B | 0.8477 |
| | 0.9939 |
| | 1 |

The coefficients are used to scale the EC 2000 input for the senior level. The last DEA model is developed for the senior level. The model is shown in Figure 7.5 and the coefficients are shown in Table 7.5.

```
MODEL:

Max= 6.955*t1+6.637*t2;

6.845*w1+6.095*w2+.47*w3-.471*w4=1;

-6.955*t1-6.637*t2+6.845*w1+6.095*w2+.47*w3-.471*w4>=0;
-0.875*t1-10.625*t2+1.433*w1+8.267*w2+3.10*w3 >=0;
-11.472*t1-3.395*t2+7.13*w1+7.39*w2+0.9*w3-0.54*w5>=0;
-7.011*t1-6.425*t2-.273*t3+5.879*w1+8.264*w2+1.20*w3-.4*w4-.5*w5>=0;

t1>=0.001;
……….
@abs(e)<0.0001;
end
```

**Figure 7.5 Lingo Model for the Senior Level**

**Table 7.5 Senior Coefficient of Efficiency per Program**

| Program | Index |
|---|---|
| A | 1 |
| B | 1 |
| C | 1 |
| D | 1 |

Table 7.6 shows the relative efficiency for the four programs. It is possible now to compare the relative efficiency along the same program and the relative efficiency at the school level.

**Table 7.6 Efficiency Coefficients AYs 1998-2001 Schoolwide**

| | Freshmen | Sophomore | Junior | Senior |
|---|---|---|---|---|
| **A** | 0.8101 | 1 | 0.9997 | 1 |
| **B** | 0.8749 | 1 | 0.8477 | 1 |
| **C** | 1 | 0.3776 | 0.9939 | 1 |
| **D** | 0.9028 | 0.4899 | 1 | 1 |

## 7.7 Efficiency Map

Table 7.6 can be deployed in a line chart. This chart constitutes a map that shows the relative position of the different programs and levels within the school of engineering, during a complete cycle of a student career. This chart is shown in Figure 7.6.

From Figure 7.6 Program *C,* particularly the freshman level appears to be more efficient in comparison with the rest of the freshman programs. Program *A* shows a very inefficient freshman level but it recovers for the next three levels. Program *C* needs to leverage its sophomore levels, and Program *D* its junior one.

It is important to notice that given that the map shows a relative efficiency once a level is improved the rest of the levels should be adjusted to this new state. This procedure forces the complete program to make an effort to improve all the levels at the same time.

It is important to notice that given that the map shows a relative efficiency once a level is improved the rest of the levels should be adjusted to this new state. This procedure forces the complete program to make an effort to improve all the levels at the same time.

Based on this map and the Pitt-SW Table, best practices can be addressed and spread across the institution. At this stage of the study no other conclusions can be drawn.

APPENDIX C shows the complete SW tables and equations for the models developed in this chapter.

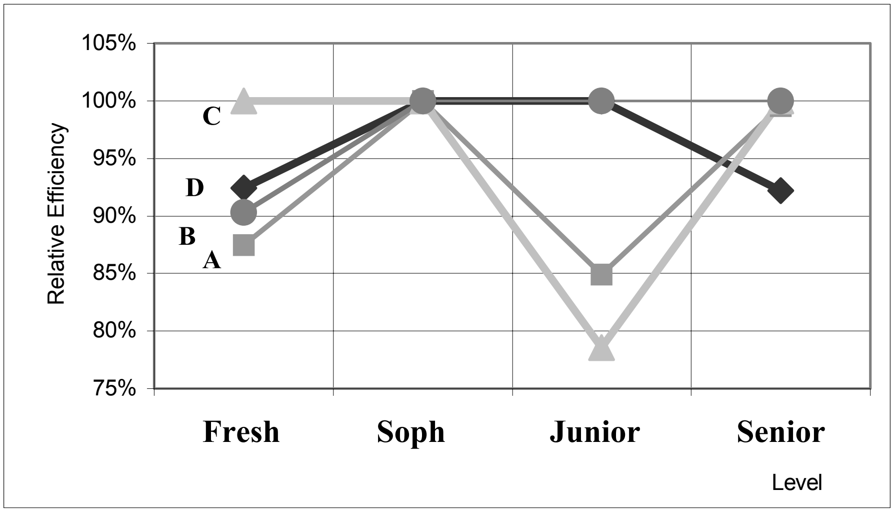



**Figure 7.6 Map of Relative Positions per Program and Level**

# 8.0 CONTRIBUTIONS AND FUTURE RESEARCH

This chapter highlights the main contributions of the SW analysis (Pitt-SW) and the DEA model developed in this dissertation. It also contains suggestions for future research.

## 8.1 Contributions

The Pitt-SW methodology attempts to fill a gap in the literature on service/quality management science. The method shows great versatility in measuring baselines and changes in self-confidence and attitudes in longitudinal cohorts. The core of this dissertation lies in framing the methodology in terms of selection of the category that holds the greatest proportion within a finite population. A set of tables with an estimated average probability of success *P[cs]* of correctly selecting the largest proportion has been developed. These tables are different from the tables for infinite populations in that it is necessary to construct a table for each population of size *N*. The category with the largest proportion is reclassified into one of several strength/weakness categories using the statistical techniques for ranking and selection.

Important differences exists between the SW analysis and other methods currently used to measure customer satisfaction. The differences highlight the power of the proposed method:

- No assumption about the continuum of the perception scale has been made. The method works with categories regardless of the type of the scale used. As a consequence it is possible to compare different and non-homogeneous cohorts.
- The SW table links satisfaction with strategic position. It allows a fast recognition of processes to which attention needs to be focused. They may either be doing very well which others may emulate or their performance may be substandard which needs management attention. This is expected to result in a more efficient allocation of resources and time effort.
- The SW technique assesses service quality without involving expectations. Absolute changes are measured through the movements from one category belonging to one level to another category of another level regardless of the natural increase in self-confidence of the individual resulting from the mastering of the acquired skills.
- It allows working with small populations and sample sizes.

- The methodology can be applied to a process whether it is repetitive or not.
- Cross-sectional and successive cohorts can be compared.
- The method has been developed to analyze any type of categorical data. Its application can be extended to analyze the quality dimensions of other existing service quality instruments.
- Besides the engineering educational service another system in which an application of this method might be useful the army, where a recruiter should satisfy requirements set by outside customers.
- The SW method saves time in the process of analyzing many different statements at the same time. It is not necessary to focus on plots or numbers and the results can be obtained in a day if special software is developed. It readily points out the areas, which are doing relatively well and those where it is necessary to make improvements.
- It gives a level of confidence for making a decision driven by customers perceptions per statement
- It prioritizes the decisions.

Another contribution of this dissertation has been an application of an operations research tool to measure the efficiency in creating self-confidence in the students towards meeting their goals. The method used is Data Envelopment Analysis (DEA). This technique has been applied level by level and results have been used to establish the relative efficiency of each program per level and to adjust the inputs of successive levels. This way of applying DEA iteratively resulted in a map or chart that displays the relative efficiency of each level and program schoolwide. An important conclusion has been obtained: a given level of relative efficiency does not guarantee the same level of efficiency the following year. Once a level improves its efficiency the rest of the levels should improve too in order to maintain the relative position.

## 8.2 Future Research

Topics recommended for future research as extensions of the work of this dissertation, are as follows:

a) Determination of the precision level of the complete SW table.

b) Given that some of the classifications are based on a 100% confidence level (Major Strengths), others are made by setting a preassigned confidence level (Possible Strengths/Weakness) and a category is based on a pragmatic decision making (Major Weakness) the idea is to find an overall probability of correct selection to assure a minimum overall level of confidence for decision-makers.

c) Determination of a confidence level along the four levels of a program

d) The same rationale as before is followed here but considering four consecutive levels individually. The main impact of this confidence statement will be on the calculation of the coefficients of efficiency as part of the homogeneity requirement of the DEA method.

e) Homologation of the alumni's set of surveys with the rest of the questionnaires of a given program

f) The Pitt-SW analysis is only one part of a SWOT analysis. A data driven OT (opportunities and threats) analysis would also need to investigate in external issues that influence students' satisfaction and to look for new ways of interlinking those external issues with the SW table. This will lead to work with alumni, who are the drivers of the success of any academic institution. By homologating the alumni survey with the rest of the questionnaires and then by including it in the calculation of the coefficient of efficiency it will be possible to find the gaps and advances between the perceptions of students and graduates. In contrast to the School level, a lower coefficient of efficiency will mean that the senior at exit will be well prepared to cope with labor market demands. On the other hand a high coefficient of efficiency related to alumni will mean that there is a big gap between skills demanded by the labor market and the skills provided to the graduates.

# APPENDICES

## APPENDIX A

## Fitted Probability of Making the Correct Selection

**Table A.1 Fitted Probability of Making the Correct Selection. N=10**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 9 | 8 | 7 | 6 | 5 |
| 1.00 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| 1.25 | 0.70 | 0.63 | 0.57 | 0.54 | 0.52 |
| 1.33 | 0.78 | 0.68 | 0.62 | 0.59 | 0.55 |
| 1.67 | 1.00 | 0.85 | 0.77 | 0.72 | 0.66 |
| 2.00 | | 1.00 | 0.90 | 0.83 | 0.76 |
| 2.33 | | | 1.00 | 0.92 | 0.84 |
| 3.00 | | | | 1.00 | 0.93 |
| 3.50 | | | | | 0.97 |
| 4.00 | | | | | 1.00 |

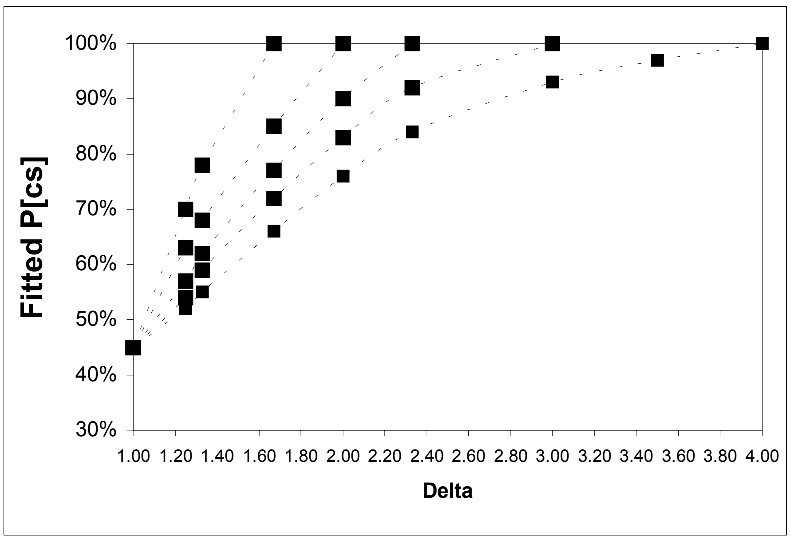



**Figure A.1 Fitted Probability of Making the Correct Selection. N=10**

**Table A.2 Fitted Probability of Making the Correct Selection. N=15**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 0 | 0 | 0 | 0 | 0 |
| 1.00 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| 1.17 | 0.72 | 0.63 | 0.60 | 0.57 | 0.54 |
| 1.20 | 0.77 | 0.67 | 0.63 | 0.60 | 0.56 |
| 1.33 | 0.95 | 0.78 | 0.72 | 0.66 | 0.62 |
| 1.40 | 1.00 | 0.83 | 0.75 | 0.69 | 0.64 |
| 1.50 | | 0.88 | 0.80 | 0.74 | 0.68 |
| 1.60 | | 0.93 | 0.84 | 0.77 | 0.72 |
| 1.75 | | 0.99 | 0.90 | 0.82 | 0.76 |
| 1.80 | | 1.00 | 0.92 | 0.83 | 0.77 |
| 2.00 | | | 0.97 | 0.88 | 0.82 |
| 2.25 | | | 1.00 | 0.93 | 0.87 |
| 2.50 | | | | 0.97 | 0.91 |
| 3.00 | | | | 1.00 | 0.96 |
| 3.30 | | | | | 0.98 |
| 3.67 | | | | | 1.00 |

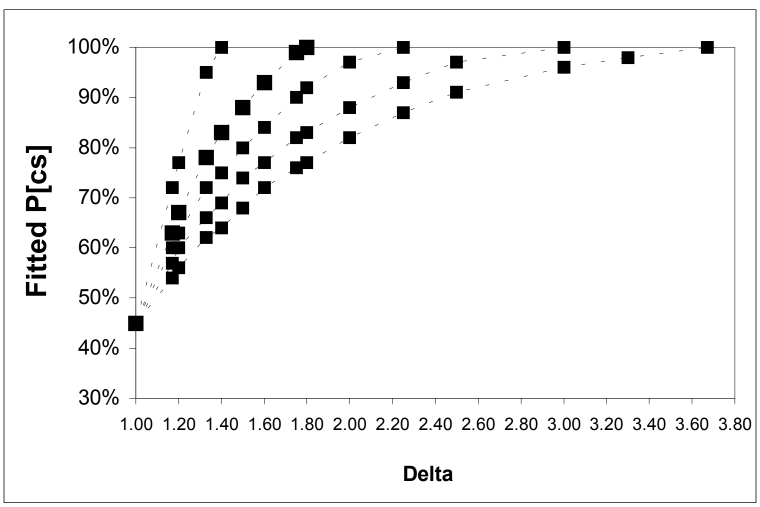



**Figure A.2 Fitted Probability of Making the Correct Selection. N=15**

Table A.3 Fitted Probability of Making the Correct Selection. N=20

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Del | 0 | 0 | 0 | 0 | 0 |
| | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| 1.13 | 0.65 | 0.6 | 0.57 | 0.53 | 0.51 |
| 1.14 | 0.69 | 0.64 | 0.59 | 0.55 | 0.52 |
| 1.25 | 0.82 | 0.74 | 0.69 | 0.62 | 0.58 |
| 1.29 | 0.86 | 0.77 | 0.71 | 0.64 | 0.60 |
| | 1.00 | 0.87 | 0.79 | 0.71 | 0.66 |
| | | 0.91 | 0.83 | 0.75 | 0.69 |
| 1.57 | | 0.94 | 0.86 | 0.78 | 0.72 |
| 1.67 | | 0.97 | 0.9 | 0.82 | 0.76 |
| 1.83 | | 1.00 | 0.94 | 0.87 | 0.81 |
| 2.00 | | | 0.97 | 0.92 | 0.86 |
| 2.20 | | | 1.00 | 0.95 | 0.9 |
| 2.40 | | | | 0.98 | 0.93 |
| 2.60 | | | | 1.00 | 0.95 |
| 3.00 | | | | | 0.99 |
| 3.25 | | | | | 1.00 |

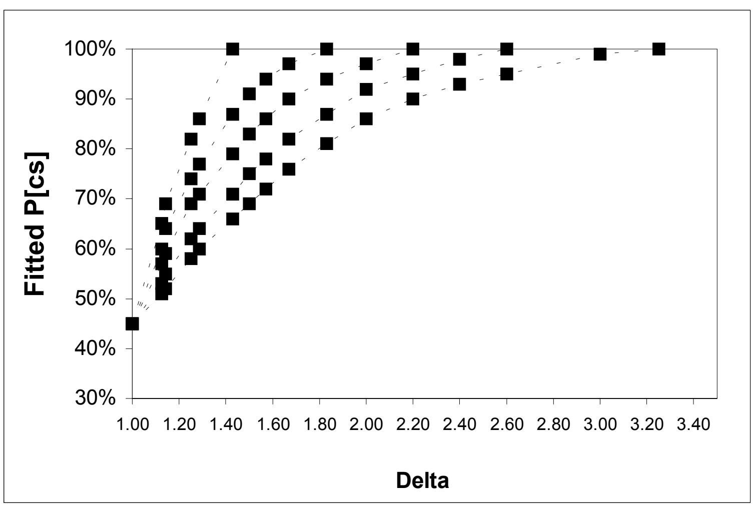



Figure A.3 Fitted Probability of Making the Correct selection. N=20

**Table A.4 Fitted Probability of Making the Correct Selection. N=25**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 0 | 0 | 0 | 0 | 0 |
| 1.00 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| | 0.65 | 0.59 | 0.56 | 0.54 | 0.52 |
| 1.13 | 0.67 | 0.61 | 0.57 | 0.55 | 0.53 |
| 1.25 | 0.85 | 0.77 | 0.69 | 0.64 | 0.6 |
| 1.33 | 0.95 | 0.85 | 0.76 | 0.70 | 0.65 |
| 1.38 | 1.00 | 0.89 | 0.8 | 0.74 | 0.68 |
| 1.50 | | 0.97 | 0.89 | 0.82 | 0.75 |
| 1.57 | | 1.00 | 0.93 | 0.86 | 0.78 |
| 1.63 | | | 0.96 | 0.89 | 0.81 |
| 1.71 | | | 1.00 | 0.93 | 0.85 |
| 1.75 | | | | 0.94 | 0.86 |
| 1.86 | | | | 0.98 | 0.9 |
| 2.00 | | | | 1.00 | 0.94 |
| 2.14 | | | | | 0.97 |
| 2.29 | | | | | 1.00 |

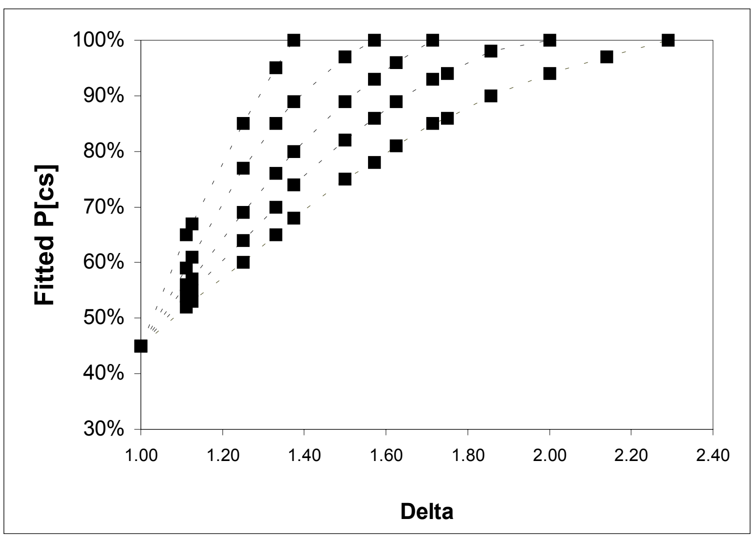



**Figure A.4 Fitted Probability of Making the Correct Selection. N=25**

**Table A.5 Fitted Probability of Making the Correct Selection. N=30**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 27 | 24 | 21 | 18 | 15 |
| 1.00 | 0.46 | 0.46 | 0.46 | 0.45 | 0.45 |
| 1.27 | 0.94 | 0.81 | 0.74 | 0.69 | 0.65 |
| 1.3 | 0.98 | 0.85 | 0.77 | 0.71 | 0.67 |
| 1.32 | 1.00 | 0.87 | 0.79 | 0.73 | 0.68 |
| 1.44 | | 0.95 | 0.88 | 0.81 | 0.76 |
| 1.56 | | 1.00 | 0.93 | 0.87 | 0.82 |
| 1.60 | | | 0.95 | 0.89 | 0.84 |
| 1.70 | | | 0.98 | 0.93 | 0.88 |
| 1.75 | | | 1.00 | 0.94 | 0.89 |
| 2.00 | | | | 1.00 | 0.95 |
| 2.13 | | | | | 0.98 |
| 2.25 | | | | | 1.00 |

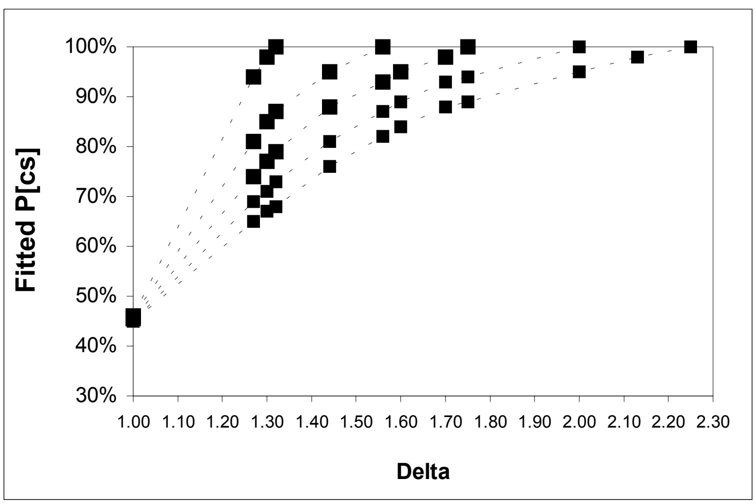



**Figure A.5 Fitted Probability of Making the Correct Selection. N=30**

**Table A.6 Fitted Probability of Making the Correct Selection. N=35**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 32 | 28 | 25 | 21 | 18 |
| 1.00 | 0.47 | 0.465 | 0.46 | 0.455 | 0.45 |
| 1.08 | 0.69 | 0.63 | 0.58 | 0.55 | 0.52 |
| 1.13 | 0.8 | 0.71 | 0.65 | 0.61 | 0.56 |
| 1.14 | 0.82 | 0.72 | 0.66 | 0.62 | 0.57 |
| 1.17 | 0.87 | 0.76 | 0.69 | 0.64 | 0.59 |
| 1.25 | 0.98 | 0.85 | 0.78 | 0.71 | 0.65 |
| 1.27 | 1.00 | 0.87 | 0.8 | 0.73 | 0.67 |
| 1.38 | | 0.96 | 0.88 | 0.81 | 0.75 |
| 1.45 | | 1.00 | 0.92 | 0.85 | 0.79 |
| 1.46 | | | 0.925 | 0.86 | 0.8 |
| 1.58 | | | 0.98 | 0.93 | 0.86 |
| 1.6 | | | 0.99 | 0.935 | 0.87 |
| 1.64 | | | 1.00 | 0.95 | 0.89 |
| 1.8 | | | | 1.00 | 0.945 |
| 1.81 | | | | | 0.95 |
| 1.88 | | | | | 0.97 |
| 1.91 | | | | | 0.98 |
| 2 | | | | | 1.00 |

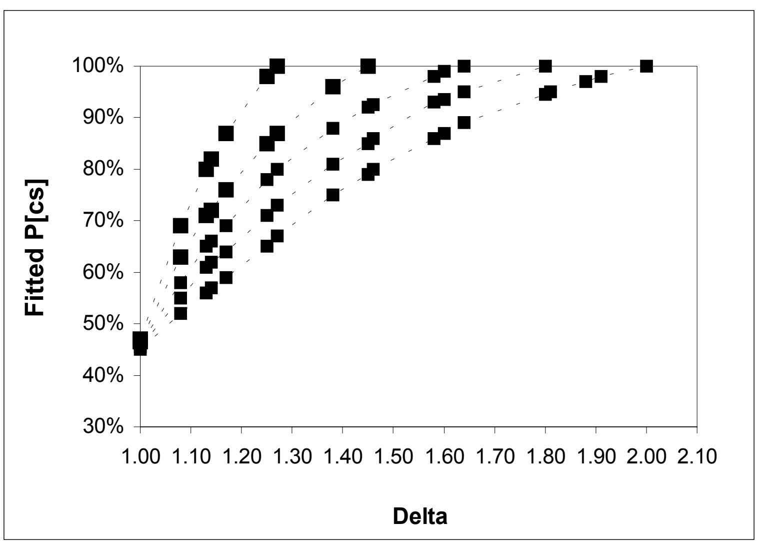



**Figure A.6 Fitted Probability of Making the Correct Selection. N=35**

**Table A.7 Fitted Probability of Making the Correct Selection. N=40**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 36 | 32 | 28 | 24 | 20 |
| 1.00 | 0.47 | 0.47 | 0.46 | 0.46 | 0.45 |
| 1.07 | 0.6 | 0.57 | 0.55 | 0.52 | 0.5 |
| 1.08 | 0.63 | 0.59 | 0.56 | 0.53 | 0.51 |
| 1.15 | 0.78 | 0.70 | 0.64 | 0.60 | 0.57 |
| 1.23 | 0.95 | 0.83 | 0.75 | 0.68 | 0.64 |
| 1.27 | 1.00 | 0.89 | 0.80 | 0.73 | 0.68 |
| 1.31 | | 0.93 | 0.85 | 0.77 | 0.72 |
| 1.33 | | 0.95 | 0.87 | 0.79 | 0.74 |
| 1.36 | | 0.97 | 0.90 | 0.82 | 0.76 |
| 1.42 | | 1.00 | 0.94 | 0.87 | 0.8 |
| 1.46 | | | 0.97 | 0.90 | 0.83 |
| 1.5 | | | 0.99 | 0.92 | 0.85 |
| 1.54 | | | 1.00 | 0.94 | 0.87 |
| 1.58 | | | | 0.96 | 0.89 |
| 1.62 | | | | 0.98 | 0.91 |
| 1.67 | | | | 1.00 | 0.93 |
| 1.73 | | | | | 0.96 |
| 1.75 | | | | | 0.97 |
| 1.82 | | | | | 1.00 |

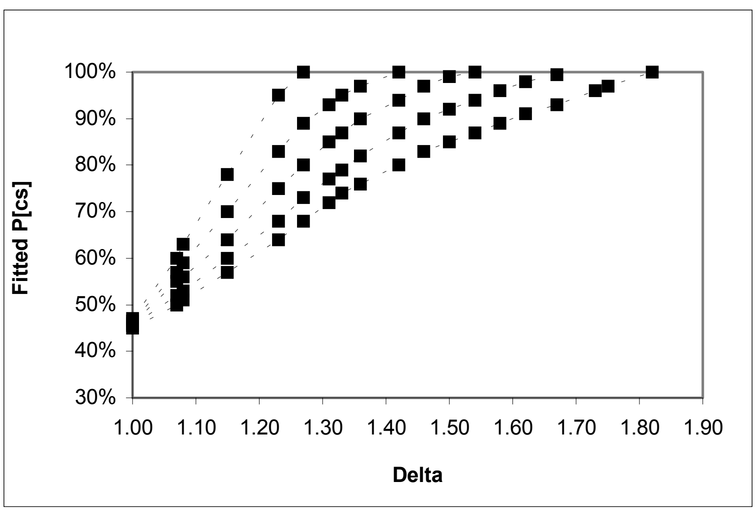



**Figure A.7 Fitted Probability of Making the Correct Selection. N=40**

**Table A.8 Fitted Probability of Making the Correct Selection. N=45**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| **Delta** | **41** | **36** | **32** | **27** | **23** |
| 1 | 0.47 | 0.47 | 0.46 | 0.46 | 0.45 |
| 1.06 | 0.63 | 0.56 | 0.54 | 0.51 | 0.5 |
| 1.07 | 0.64 | 0.58 | 0.56 | 0.52 | 0.51 |
| 1.13 | 0.78 | 0.67 | 0.63 | 0.59 | 0.56 |
| 1.21 | 0.94 | 0.82 | 0.75 | 0.7 | 0.64 |
| 1.27 | 1.00 | 0.89 | 0.82 | 0.75 | 0.69 |
| 1.29 | | 0.91 | 0.84 | 0.77 | 0.7 |
| 1.31 | | 0.94 | 0.87 | 0.79 | 0.73 |
| 1.40 | | 1.00 | 0.94 | 0.86 | 0.79 |
| 1.43 | | | 0.96 | 0.88 | 0.81 |
| 1.46 | | | 0.98 | 0.9 | 0.83 |
| 1.50 | | | 1.00 | 0.93 | 0.86 |
| 1.57 | | | | 0.97 | 0.9 |
| 1.62 | | | | 1.00 | 0.93 |
| 1.64 | | | | | 0.94 |
| 1.69 | | | | | 0.97 |
| 1.77 | | | | | 1.00 |

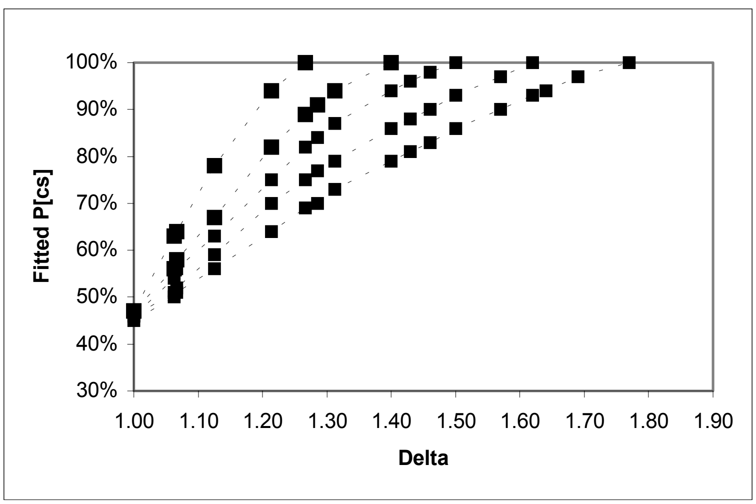



**Figure A.8 Fitted Probability of Making the Correct Selection. N=45**

**Table A.9 Fitted Probability of Making the Correct Selection. N=50**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 45 | 40 | 35 | 30 | 25 |
| 1.00 | 0.50 | 0.50 | 0.49 | 0.48 | 0.47 |
| 1.12 | 0.74 | 0.69 | 0.64 | 0.59 | 0.56 |
| 1.13 | 0.77 | 0.71 | 0.65 | 0.60 | 0.57 |
| 1.19 | 0.90 | 0.81 | 0.73 | 0.67 | 0.62 |
| 1.21 | 0.93 | 0.84 | 0.76 | 0.69 | 0.64 |
| 1.25 | 1.00 | 0.89 | 0.81 | 0.74 | 0.68 |
| 1.28 | | 0.92 | 0.84 | 0.77 | 0.71 |
| 1.29 | | 0.93 | 0.85 | 0.78 | 0.72 |
| 1.31 | | 0.95 | 0.87 | 0.80 | 0.74 |
| 1.4 | | 1.00 | 0.94 | 0.88 | 0.81 |
| 1.47 | | | 0.98 | 0.92 | 0.86 |
| 1.5 | | | 1.00 | 0.94 | 0.88 |
| 1.53 | | | | 0.96 | 0.90 |
| 1.6 | | | | 1.00 | 0.94 |
| 1.63 | | | | | 0.96 |
| 1.64 | | | | | 0.96 |
| 1.67 | | | | | 0.98 |
| 1.71 | | | | | 1.00 |

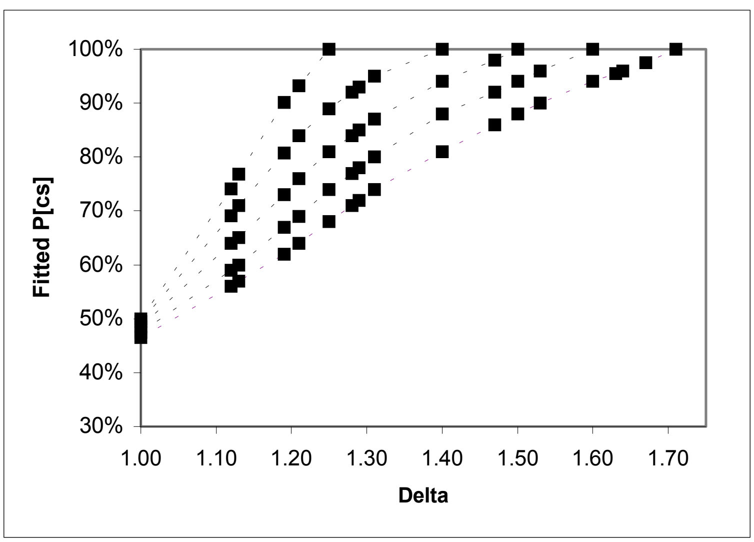



**Figure A.9 Fitted Probability of Making the Correct Selection. N=50**

**Table A.10 Fitted Probability of Making the Correct Selection. N=60**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 54 | 48 | 42 | 36 | 30 |
| 1.00 | 0.50 | 0.50 | 0.49 | 0.48 | 0.47 |
| 1.04 | 0.62 | 0.59 | 0.55 | 0.53 | 0.51 |
| 1.05 | 0.65 | 0.61 | 0.57 | 0.54 | 0.52 |
| 1.1 | 0.80 | 0.73 | 0.67 | 0.61 | 0.57 |
| 1.15 | 0.90 | 0.82 | 0.75 | 0.68 | 0.62 |
| 1.16 | 0.92 | 0.84 | 0.77 | 0.69 | 0.63 |
| 1.21 | 0.98 | 0.91 | 0.83 | 0.75 | 0.68 |
| 1.25 | 1.00 | 0.95 | 0.87 | 0.79 | 0.72 |
| 1.26 | | 0.96 | 0.88 | 0.80 | 0.73 |
| 1.27 | | 0.96 | 0.89 | 0.81 | 0.74 |
| 1.38 | | 1.00 | 0.95 | 0.89 | 0.83 |
| 1.43 | | | 0.98 | 0.92 | 0.87 |
| 1.44 | | | 0.98 | 0.93 | 0.87 |
| 1.45 | | | 0.99 | 0.93 | 0.88 |
| 1.5 | | | 1.00 | 0.96 | 0.91 |
| 1.53 | | | | 0.98 | 0.92 |
| 1.58 | | | | 1.00 | 0.95 |
| 1.61 | | | | | 0.97 |
| 1.68 | | | | | 1.00 |

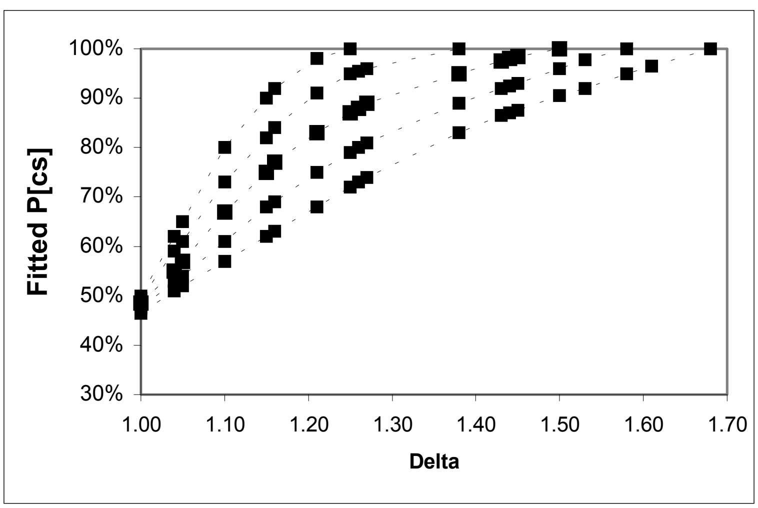



**Figure A.10 Fitted Probability of Making the Correct Selection. N=60**

**Table A.11 Fitted Probability of Making the Correct Selection. N=70**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 63 | 56 | 49 | 42 | 35 |
| 1.00 | 0.49 | 0.48 | 0.47 | 0.46 | 0.45 |
| | 0.72 | 0.65 | 0.62 | 0.58 | 0.56 |
| 1.11 | 0.81 | 0.72 | 0.68 | 0.63 | 0.60 |
| 1.12 | 0.83 | 0.75 | 0.70 | 0.65 | 0.61 |
| 1.13 | 0.85 | 0.77 | 0.71 | 0.66 | 0.63 |
| 1.14 | 0.87 | 0.79 | 0.73 | 0.68 | 0.64 |
| 1.22 | 1.00 | 0.915 | 0.85 | 0.78 | 0.73 |
| 1.23 | | 0.93 | 0.86 | 0.80 | 0.75 |
| 1.32 | | 1.00 | 0.94 | 0.88 | 0.82 |
| 1.38 | | | 0.98 | 0.92 | 0.86 |
| 1.41 | | | 1.00 | 0.94 | 0.88 |
| 1.50 | | | | 1.00 | 0.94 |
| 1.55 | | | | | 0.97 |
| 1.57 | | | | | 0.98 |
| 1.59 | | | | | 1.00 |

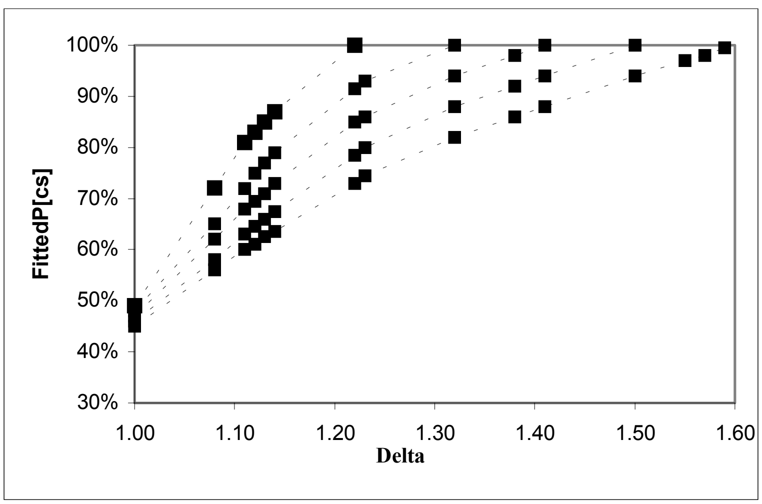



**Figure A.11 Fitted Probability of Making the correct Selection. N=70**

Table A.12 Fitted Probability of Making the Correct Selection. N=80

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 0 | 0 | 0 | 0 | 0 |
| 1.00 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| 1.03 | 0.57 | 0.54 | 0.52 | 0.50 | 0.49 |
| 1.07 | 0.71 | 0.65 | 0.60 | 0.56 | 0.55 |
| 1.12 | 0.85 | 0.77 | 0.69 | 0.65 | 0.62 |
| 1.19 | 0.97 | 0.88 | 0.81 | 0.75 | 0.70 |
| 1.22 | 1.00 | 0.92 | 0.85 | 0.79 | 0.73 |
| 1.32 | | 1.00 | 0.94 | 0.88 | 0.83 |
| 1.33 | | | 0.95 | 0.89 | 0.83 |
| 1.36 | | | 0.98 | 0.92 | 0.86 |
| 1.38 | | | 0.99 | 0.93 | 0.88 |
| 1.40 | | | 1.00 | | 0.89 |
| 1.44 | | | | 0.98 | 0.92 |
| 1.46 | | | | 1.00 | 0.94 |
| 1.54 | | | | | 1.00 |

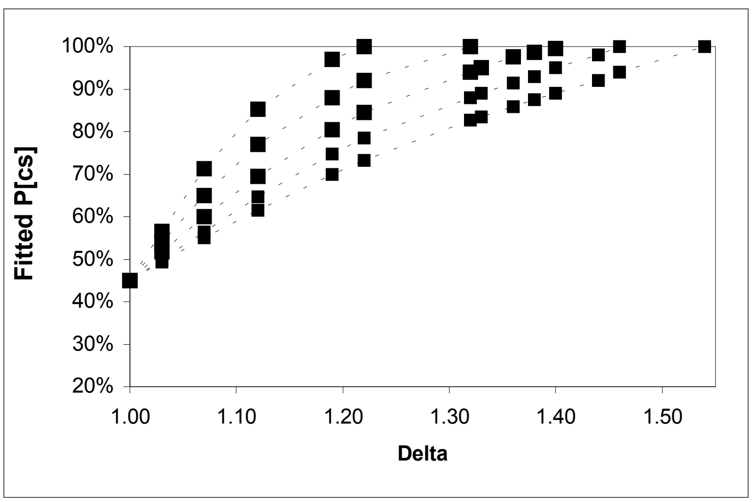



Figure A.12 Fitted Probability of Making the Correct Selection. N=80

Table A.13 Fitted Probability of Making the Correct Selection. N=90

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 81 | 72 | 63 | 54 | 45 |
| 1.00 | 0.48 | 0.47 | 0.46 | 0.45 | 0.44 |
| 1.06 | 0.67 | 0.61 | 0.58 | 0.55 | 0.53 |
| 1.10 | 0.80 | 0.71 | 0.66 | 0.62 | 0.59 |
| 1.14 | 0.90 | 0.80 | 0.74 | 0.68 | 0.64 |
| 1.21 | 1.00 | 0.91 | 0.84 | 0.78 | 0.73 |
| 1.25 | | 0.96 | 0.89 | 0.83 | 0.78 |
| 1.26 | | 0.97 | 0.90 | 0.84 | 0.79 |
| 1.28 | | 0.99 | 0.92 | 0.86 | 0.81 |
| 1.29 | | 1.00 | 0.93 | 0.87 | 0.82 |
| 1.39 | | | 1.00 | 0.96 | 0.90 |
| 1.41 | | | | 0.97 | 0.92 |
| 1.44 | | | | 0.99 | 0.94 |
| 1.45 | | | | 1.00 | 0.95 |
| 1.50 | | | | | 0.98 |
| 1.53 | | | | | 1.00 |

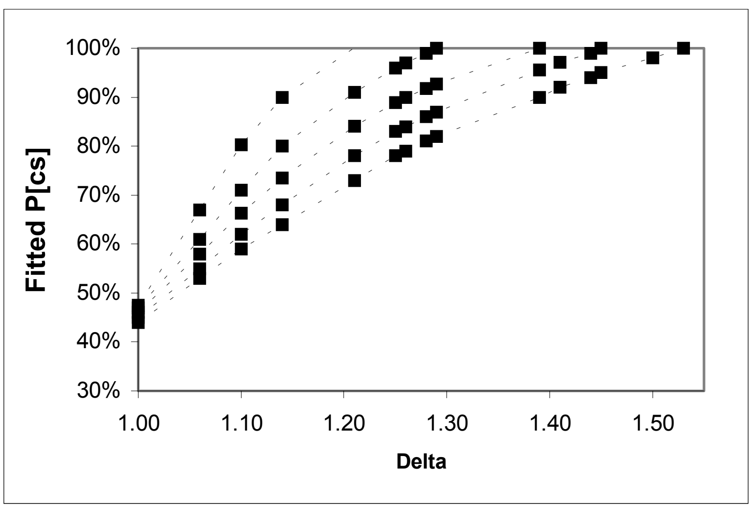



Figure A.13 Fitted Probability of Making the Correct Selection. N=90

**Table A.14 Fitted Probability of Making the Correct Selection. N=100**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 90 | 80 | 70 | 60 | 50 |
| 1.00 | 0.48 | 0.47 | 0.46 | 0.45 | 0.44 |
| 1.03 | 0.58 | 0.56 | 0.54 | 0.52 | 0.50 |
| 1.06 | 0.70 | 0.65 | 0.60 | 0.57 | 0.54 |
| 1.11 | 0.86 | 0.78 | 0.71 | 0.65 | 0.61 |
| 1.12 | 0.88 | 0.81 | 0.73 | 0.67 | 0.62 |
| 1.17 | 0.98 | 0.90 | 0.83 | 0.75 | 0.69 |
| 1.18 | 1.00 | 0.92 | 0.84 | 0.76 | 0.70 |
| 1.21 | | 0.96 | 0.89 | 0.81 | 0.74 |
| 1.24 | | 1.00 | 0.93 | 0.85 | 0.78 |
| 1.29 | | | 0.97 | 0.91 | 0.85 |
| 1.31 | | | 0.99 | 0.93 | 0.87 |
| 1.32 | | | 1.00 | 0.94 | 0.88 |
| 1.34 | | | | 0.96 | 0.90 |
| 1.39 | | | | 1.00 | 0.94 |
| 1.40 | | | | 1.00 | 0.95 |
| 1.48 | | | | | 1.00 |

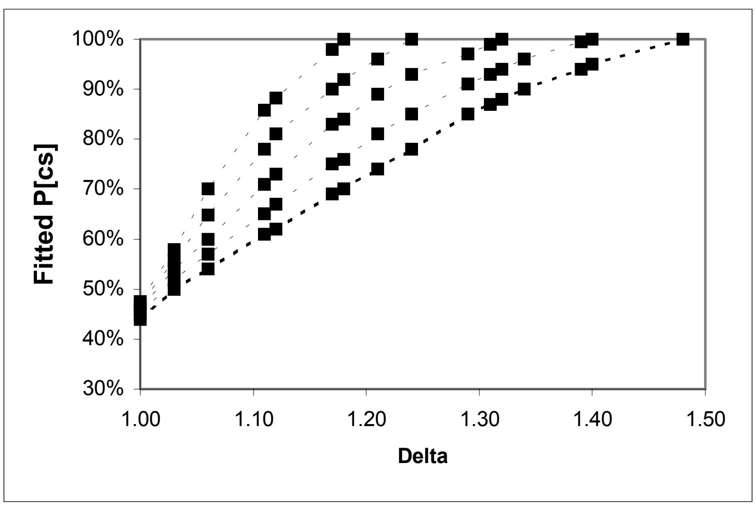



**Figure A.14 Fitted Probability of Making the Correct Selection. N=100**

**Table A.15 Fitted Probability of Making the Correct Selection. N=150**

| n | 90% | 80% | 70% | 60% | 50% |
|---|---|---|---|---|---|
| Delta | 135 | 120 | 105 | 90 | 75 |
| 1.00 | 0.48 | 0.47 | 0.46 | 0.45 | 0.44 |
| 1.02 | 0.58 | 0.56 | 0.56 | 0.52 | 0.51 |
| 1.06 | 0.74 | 0.69 | 0.66 | 0.62 | 0.59 |
| 1.09 | 0.84 | 0.77 | 0.72 | 0.68 | 0.64 |
| 1.14 | 0.95 | 0.88 | 0.81 | 0.76 | 0.72 |
| 1.18 | 1.00 | 0.94 | 0.87 | 0.82 | 0.78 |
| 1.23 | | 0.98 | 0.93 | 0.88 | 0.84 |
| 1.27 | | 1.00 | 0.96 | 0.92 | 0.88 |
| 1.28 | | | 0.97 | 0.93 | 0.89 |
| 1.32 | | | 1.00 | 0.96 | 0.92 |
| 1.34 | | | | 0.97 | 0.94 |
| 1.40 | | | | 1.00 | 0.97 |
| 1.47 | | | | | 1.00 |

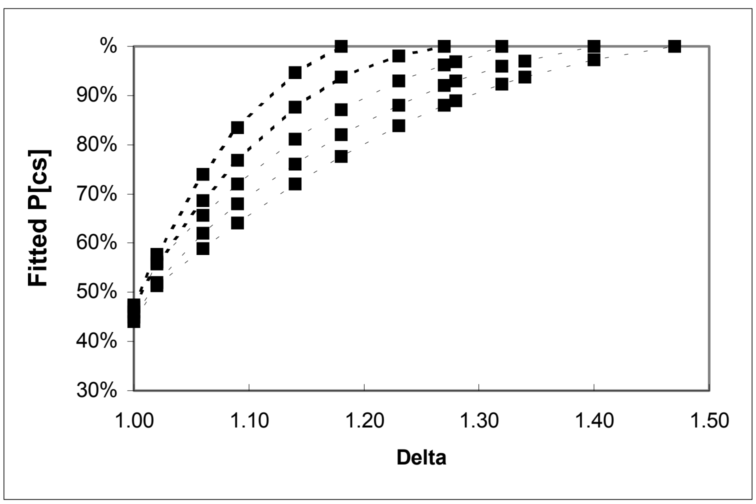



**Figure A.15 Fitted Probability of Making the Correct Selection. N=150**

# APPENDIX B

## Factor Analysis for Data Reduction for DEA

**Table B.1 FACTOR ANALYSIS FRESHMAN LEVEL - FIRST RESULTS OF INPUTS**

**Total Variance Explained**

| | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 9.649 | 19.691 | 19.691 | 9.649 | 19.691 | 19.691 | 6.703 | 13.680 | 13.680 |
| 2 | 3.790 | 7.734 | 27.425 | 3.790 | 7.734 | 27.425 | 3.537 | 7.218 | 20.898 |
| 3 | 3.095 | 6.316 | 33.742 | 3.095 | 6.316 | 33.742 | 2.838 | 5.792 | 26.690 |
| 4 | 2.075 | 4.234 | 37.976 | 2.075 | 4.234 | 37.976 | 2.339 | 4.773 | 31.463 |
| 5 | 1.870 | 3.817 | 41.793 | 1.870 | 3.817 | 41.793 | 2.163 | 4.414 | 35.876 |
| 6 | 1.819 | 3.712 | 45.505 | 1.819 | 3.712 | 45.505 | 2.132 | 4.350 | 40.227 |
| 7 | 1.735 | 3.541 | 49.046 | 1.735 | 3.541 | 49.046 | 1.998 | 4.078 | 44.304 |
| 8 | 1.495 | 3.050 | 52.096 | 1.495 | 3.050 | 52.096 | 1.990 | 4.062 | 48.366 |
| 9 | 1.356 | 2.767 | 54.863 | 1.356 | 2.767 | 54.863 | 1.974 | 4.028 | 52.394 |
| 10 | 1.241 | 2.532 | 57.395 | 1.241 | 2.532 | 57.395 | 1.685 | 3.439 | 55.833 |
| 11 | 1.197 | 2.442 | 59.837 | 1.197 | 2.442 | 59.837 | 1.475 | 3.009 | 58.842 |
| 12 | 1.113 | 2.272 | 62.110 | 1.113 | 2.272 | 62.110 | 1.360 | 2.775 | 61.617 |
| 13 | 1.023 | 2.088 | 64.197 | 1.023 | 2.088 | 64.197 | 1.264 | 2.580 | **64.197** |
| 14 | .972 | 1.984 | 66.182 | | | | | | |
| ……. | …………. | …………. | ………… | ………… … | ………… | ………….. | ………… … | ………….. | ………….. |
| 47 | .175 | .357 | 99.394 | | | | | | |
| 48 | .152 | .311 | 99.704 | | | | | | |
| 49 | .145 | .296 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

**Table B.2 FRESHMAN LEVEL - FIRST RESULTS OF INPUTS** . Rotated Component Matrix

| | Component | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| VAR3 | .817 | | | | | | | | | | | | |
| VAR1 | .803 | | | | | | | | | | | | |
| VAR2 | .800 | | | | | | | | | | | | |
| VAR4 | -.756 | | | | | | | | | | | | |
| VAR5 | .733 | | | | | | | | | | | | |
| VAR8 | -.680 | | | | | | | | | | | | |
| VAR7 | .633 | | | | | | | | | | | | |
| VAR6 | -.617 | | | | | | | | | | | | |
| VAR9 | -.595 | | | | | | | | | | | | |
| VAR42 | .539 | | | | | | | | | | | | |
| VAR18 | | | | | | | | | | | | | |
| VAR50 | | .776 | | | | | | | | | | | |
| VAR49 | | .734 | | | | | | | | | | | |
| VAR40 | | .637 | | | | | | | | | | | |
| VAR44 | | .611 | | | | | | | | | | | |
| VAR38 | | .522 | | | | | | | | | | | |
| VAR27 | | | | | | | | | | | | | |
| VAR30 | | | | | | | | | | | | | |
| VAR11 | | | .709 | | | | | | | | | | |
| VAR28 | | | .698 | | | | | | | | | | |
| VAR20 | | | .665 | | | | | | | | | | |
| VAR22 | | | .627 | | | | | | | | | | |
| VAR35 | | | | .773 | | | | | | | | | |
| VAR32 | | | | .720 | | | | | | | | | |
| VAR36 | | | | .541 | | | | | | | | | |
| VAR39 | | | | | -.844 | | | | | | | | |
| VAR46 | | | | | .831 | | | | | | | | |
| VAR29 | | | | | .480 | | | | | | | | |
| VAR31 | | | | | | | | | | | | | |
| VAR23 | | | | | | .781 | | | | | | | |
| VAR14 | | | | | | .606 | | | | | | | |
| VAR21 | | | | | | .546 | | | | | | | |
| VAR26 | | | | | | | | | | | | | |
| VAR47 | | | | | | | .822 | | | | | | |
| VAR48 | | | | | | | .775 | | | | | | |
| VAR43 | | | | | | | | .893 | | | | | |
| VAR37 | | | | | | | | -.871 | | | | | |
| VAR45 | | | | | | | | .506 | | | | | |
| VAR33 | | | | | | | | | .689 | | | | |
| VAR34 | | | | | | | | | .634 | | | | |
| VAR19 | | | | | | | | | .575 | | | | |
| VAR13 | | | | | | | | | -.574 | | | | |
| VAR24 | | | | | | | | | | .758 | | | |
| VAR16 | | | | | | | | | | .692 | | | |
| VAR25 | | | | | | | | | | | .624 | | |
| VAR12 | | | | | | | | | | | .533 | | |
| VAR10 | | | | | | | | | | | | .534 | |
| VAR17 | | | | | | | | | | | | .521 | |
| VAR41 | | | | | | | | | | | | | .820 |

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

**Table B.3 FINAL DIMENSIONS- FRESHMAN LEVEL Total Variance Explained**

| | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.658 | 24.167 | 24.167 | 2.658 | 24.167 | 24.167 | 2.090 | 19.004 | 19.004 |
| 2 | 1.576 | 14.331 | 38.498 | 1.576 | 14.331 | 38.498 | 2.090 | 19.002 | 38.005 |
| 3 | 1.126 | 10.239 | 48.737 | 1.126 | 10.239 | 48.737 | 1.141 | 10.369 | 48.374 |
| 4 | 1.035 | 9.405 | 58.142 | 1.035 | 9.405 | 58.142 | 1.074 | 9.768 | **58.142** |
| 5 | .993 | 9.031 | 67.173 | | | | | | |
| 6 | .771 | 7.008 | 74.181 | | | | | | |
| 7 | .706 | 6.416 | 80.597 | | | | | | |
| 8 | .686 | 6.234 | 86.830 | | | | | | |
| 9 | .578 | 5.254 | 92.085 | | | | | | |
| 10 | .493 | 4.484 | 96.569 | | | | | | |
| 11 | .377 | 3.431 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

**Table B.4 FINAL DIMENSIONS- FRESHMAN LEVEL . Rotated Component Matrix**

| | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| VAR25 | .736 | | | |
| VAR12 | .732 | | | |
| VAR22 | .714 | | | |
| VAR1 | .643 | | | |
| VAR44 | | .787 | | |
| VAR48 | | .725 | | |
| VAR40 | | .677 | | |
| VAR36 | | .604 | | |
| VAR24 | | | .800 | |
| VAR46 | | | .475 | |
| VAR37 | | | | .932 |

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 5 iterations.

Note:
Number order is based on the original questionnaire.

**Table B.5 FACTOR ANALYSIS SOPHOMORE LEVEL - FIRST RESULTS OF INPUTS**

**Total Variance Explained**

| | Initial Eigenval | | | Extraction Sums of Squared Loadings | | | Rotation Sum of Squares | | |
|---|---|---|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 8.701 | 20.716 | 20.716 | 8.701 | 20.716 | 20.716 | 3.966 | 9.442 | 9.442 |
| 2 | 3.510 | 8.356 | 29.072 | 3.510 | 8.356 | 29.072 | 2.876 | 6.848 | 16.291 |
| 3 | 2.673 | 6.365 | 35.437 | 2.673 | 6.365 | 35.437 | 2.863 | 6.817 | 23.108 |
| 4 | 2.307 | 5.492 | 40.929 | 2.307 | 5.492 | 40.929 | 2.806 | 6.681 | 29.789 |
| 5 | 1.729 | 4.116 | 45.045 | 1.729 | 4.116 | 45.045 | 2.255 | 5.369 | 35.158 |
| 6 | 1.489 | 3.546 | 48.591 | 1.489 | 3.546 | 48.591 | 2.225 | 5.297 | 40.455 |
| 7 | 1.331 | 3.169 | 51.760 | 1.331 | 3.169 | 51.760 | 1.989 | 4.735 | 45.190 |
| 8 | 1.323 | 3.149 | 54.909 | 1.323 | 3.149 | 54.909 | 1.941 | 4.622 | 49.812 |
| 9 | 1.232 | 2.932 | 57.841 | 1.232 | 2.932 | 57.841 | 1.930 | 4.596 | 54.408 |
| 10 | 1.129 | 2.688 | 60.529 | 1.129 | 2.688 | 60.529 | 1.852 | 4.409 | 58.817 |
| 11 | 1.106 | 2.632 | 63.161 | 1.106 | 2.632 | 63.161 | 1.475 | 3.512 | 62.330 |
| 12 | 1.049 | 2.498 | 65.659 | 1.049 | 2.498 | 65.659 | 1.398 | 3.330 | **65.659** |
| ……. | ……. | …….. | …….. | | | | | | |
| 42 | .134 | .319 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

**Table B.6 SOPHOMORE LEVEL - FIRST RESULTS OF INPUTS.Rotated Component Matrix**

| | Comp | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| VAR16 | .755 | | | | | | | | | | | |
| VAR15 | .742 | | | | | | | | | | | |
| VAR14 | .723 | | | | | | | | | | | |
| VAR17 | .672 | | | | | | | | | | | |
| VAR12 | .542 | | | | | | | | | | | |
| VAR20 | .520 | | | | | | | | | | | |
| VAR23 | | .793 | | | | | | | | | | |
| VAR24 | | .730 | | | | | | | | | | |
| VAR22 | | .720 | | | | | | | | | | |
| VAR13 | | | | | | | | | | | | |
| VAR43 | | | .777 | | | | | | | | | |
| VAR42 | | | .680 | | | | | | | | | |
| VAR38 | | | .604 | | | | | | | | | |
| VAR41 | | | .578 | | | | | | | | | |
| VAR39 | | | .577 | | | | | | | | | |
| VAR4 | | | | .747 | | | | | | | | |
| VAR6 | | | | .665 | | | | | | | | |
| VAR3 | | | | .613 | | | | | | | | |
| VAR7 | | | | .563 | | | | | | | | |
| VAR2 | | | | .561 | | | | | | | | |
| VAR1 | | | | | | | | | | | | |
| VAR34 | | | | | .833 | | | | | | | |
| VAR35 | | | | | .827 | | | | | | | |
| VAR26 | | | | | | .659 | | | | | | |
| VAR32 | | | | | | .636 | | | | | | |
| VAR25 | | | | | | .491 | | | | | | |
| VAR30 | | | | | | .458 | | | | | | |
| VAR10 | | | | | | | .711 | | | | | |
| VAR9 | | | | | | | .554 | | | | | |
| VAR8 | | | | | | | .530 | | | | | |
| VAR33 | | | | | | | | .700 | | | | |
| VAR31 | | | | | | | | .667 | | | | |
| VAR29 | | | | | | | | .516 | | | | |
| VAR28 | | | | | .473 | | | -.509 | | | | |
| VAR11 | | | | | | | | | .795 | | | |
| VAR05 | | | | | | | | | .750 | | | |
| VAR37 | | | | | | | | | | .873 | | |
| VAR40 | | | | | | | | | | -.821 | | |
| VAR19 | | | | | | | | | | | .691 | |
| VAR18 | | | | | | | | | | | .486 | |
| VAR21 | | | | | | | | | | | | .734 |
| VAR36 | | | | | | | | | | | | |

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

**Table B.7 SOPHOMORE LEVEL - FINAL DIMENSIONS. Total Variance Explained**

| | Initial Eigenval | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulativ % | Total | % of Variance | Cumulativ % | Total | % of Variance | Cumulativ % |
| 1 | 5.851 | 29.256 | 29.256 | 5.851 | 29.256 | 29.256 | 3.210 | 16.051 | 16.051 |
| 2 | 1.788 | 8.938 | 38.194 | 1.788 | 8.938 | 38.194 | 2.470 | 12.351 | 28.402 |
| 3 | 1.459 | 7.295 | 45.489 | 1.459 | 7.295 | 45.489 | 1.905 | 9.527 | 37.929 |
| 4 | 1.260 | 6.301 | 51.791 | 1.260 | 6.301 | 51.791 | 1.822 | 9.109 | 47.038 |
| 5 | 1.141 | 5.707 | 57.497 | 1.141 | 5.707 | 57.497 | 1.620 | 8.100 | 55.138 |
| 6 | 1.006 | 5.029 | 62.526 | 1.006 | 5.029 | 62.526 | 1.478 | 7.388 | **62.526** |
| ……… | …….. | …….. | ……. | | | | | | |
| 20 | .258 | 1.290 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

**Table B.8 SOPHOMORE LEVEL - FINAL DIMENSIONS. Rotated Component Matrix**

| | Component | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| VAR16 | .804 | | | | | |
| VAR17 | .790 | | | | | |
| VAR15 | .778 | | | | | |
| VAR20 | .724 | | | | | |
| VAR23 | | .809 | | | | |
| VAR24 | | .777 | | | | |
| VAR22 | | .748 | | | | |
| VAR32 | | | .731 | | | |
| VAR26 | | | .566 | | | |
| VAR14 | .473 | | .559 | | | |
| VAR12 | | | .487 | | | |
| VAR25 | | .485 | .486 | | | |
| VAR5 | | | | .680 | | |
| VAR1 | | | | .606 | | |
| VAR13 | | | | .598 | | |
| VAR3 | | | | | .780 | |
| VAR39 | | | | | .713 | |
| VAR28 | | | | | .543 | |
| VAR19 | | | | | | .745 |
| VAR18 | | | | | | .696 |

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 9 iterations.

**Table B.9 FACTOR ANALYSIS JUNIOR LEVEL - FIRST RESULTS OF INPUTS**

**Total Variance Explained**

| | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 10.230 | 20.058 | 20.058 | 10.230 | 20.058 | 20.058 | 4.452 | 8.730 | 8.730 |
| 2 | 4.673 | 9.162 | 29.221 | 4.673 | 9.162 | 29.221 | 3.653 | 7.163 | 15.893 |
| 3 | 2.838 | 5.564 | 34.785 | 2.838 | 5.564 | 34.785 | 3.477 | 6.817 | 22.710 |
| 4 | 2.104 | 4.126 | 38.911 | 2.104 | 4.126 | 38.911 | 3.088 | 6.056 | 28.766 |
| 5 | 1.911 | 3.748 | 42.659 | 1.911 | 3.748 | 42.659 | 2.861 | 5.609 | 34.375 |
| 6 | 1.734 | 3.400 | 46.059 | 1.734 | 3.400 | 46.059 | 2.794 | 5.478 | 39.853 |
| 7 | 1.599 | 3.136 | 49.195 | 1.599 | 3.136 | 49.195 | 2.400 | 4.706 | 44.559 |
| 8 | 1.476 | 2.895 | 52.090 | 1.476 | 2.895 | 52.090 | 1.933 | 3.790 | 48.348 |
| 9 | 1.458 | 2.859 | 54.949 | 1.458 | 2.859 | 54.949 | 1.756 | 3.443 | 51.792 |
| 10 | 1.328 | 2.604 | 57.553 | 1.328 | 2.604 | 57.553 | 1.738 | 3.408 | 55.200 |
| 11 | 1.225 | 2.401 | 59.954 | 1.225 | 2.401 | 59.954 | 1.613 | 3.163 | 58.363 |
| 12 | 1.127 | 2.211 | 62.165 | 1.127 | 2.211 | 62.165 | 1.366 | 2.679 | 61.042 |
| 13 | 1.048 | 2.055 | 64.220 | 1.048 | 2.055 | 64.220 | 1.317 | 2.583 | 63.625 |
| 14 | 1.011 | 1.983 | 66.203 | 1.011 | 1.983 | 66.203 | 1.315 | 2.578 | **66.203** |
| …. | …... | ….. | …… | | | | | | |
| 51 | .135 | .265 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

**Table B.10 JUNIOR LEVEL - FIRST RESULTS OF INPUTS. Rotated Component Matrix**

| | Comp | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| VAR31 | .794 | | | | | | | | | | | | | |
| VAR28 | .746 | | | | | | | | | | | | | |
| VAR26 | .736 | | | | | | | | | | | | | |
| VAR32 | .711 | | | | | | | | | | | | | |
| VAR30 | .671 | | | | | | | | | | | | | |
| VAR34 | .649 | | | | | | | | | | | | | |
| VAR27 | .602 | | | | | | | | | | | | | |
| VAR29 | .520 | | | | | | | | | | | | | |
| VAR23 | | .730 | | | | | | | | | | | | |
| VAR21 | | .701 | | | | | | | | | | | | |
| VAR22 | | .688 | | | | | | | | | | | | |
| VAR20 | | .677 | | | | | | | | | | | | |
| VAR24 | | .576 | | | | | | | | | | .457 | | |
| VAR16 | | .464 | | | | | | | .455 | | | | | |
| VAR13 | | | | | | | | | | | | | | |
| VAR05 | | | .841 | | | | | | | | | | | |
| VAR9 | | | .766 | | | | | | | | | | | |
| VAR6 | | | .675 | | | | | | | | | | | |
| VAR4 | | | .520 | | | | | | | | | | | |
| VAR7 | | | .474 | | | | | | | | | | | |
| VAR8 | | | | | | | | | | | | | | |
| VAR51 | | | | .727 | | | | | | | | | | |
| VAR47 | | | | .714 | | | | | | | | | | |
| VAR52 | | | | .673 | | | | | | | | | | |
| VAR50 | | | | .654 | | | | | | | | | | |
| VAR48 | | | | .554 | | | | | | | | | | |
| VAR17 | | | | | .759 | | | | | | | | | |
| VAR19 | | | | | .723 | | | | | | | | | |
| VAR18 | | | | | .551 | | | | | | | | | |
| VAR15 | | | | | .521 | | | | | | | | | |
| VAR38 | | | | | | -.838 | | | | | | | | |
| VAR40 | | | | | | -.795 | | | | | | | | |
| VAR37 | | | | | | .631 | | | | | | | | |
| VAR3 | | | | | | .514 | | | | | | | | |
| VAR44 | | | | | | | .738 | | | | | | | |
| VAR43 | | | | | | | .685 | | | | | | | |
| VAR45 | | | | | | | .613 | | | | | | | |
| VAR46 | | | | | | | | | | | | | | |
| VAR12 | | | | | | | | .777 | | | | | | |

**Table B.10 Continues**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VAR11 | | | | | | | | .506 | | | | | | |
| VAR10 | | | | | | | | .477 | | | | | | |
| VAR2 | | | | | | | | | .614 | | | | | |
| VAR1 | | | | | | | | | .527 | | | | | |
| VAR35 | | | | | | | | | | .742 | | | | |
| VAR36 | | | | | | | | | | .729 | | | | |
| VAR33 | | | | | | | | | | | .754 | | | |
| VAR49 | | | | | | | | | | | | .655 | | |
| VAR42 | | | | | | | | | | | | | .781 | |
| VAR41 | | | | | | | | | | | | | .544 | |
| VAR14 | | | | | | | | | | | | | | .468 |
| VAR39 | | | | | | | | | | | | | | |

**Table B.11 JUNIOR LEVEL - FINAL DIMENSIONS. Total Variance Explained**

| | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulativ % | Total | % of Variance | Cumulativ % | Total | % of Variance | Cumulativ % |
| 1 | 6.303 | 27.403 | 27.403 | 6.303 | 27.403 | 27.403 | 3.155 | 13.719 | 13.719 |
| 2 | 2.450 | 10.652 | 38.055 | 2.450 | 10.652 | 38.055 | 2.582 | 11.225 | 24.944 |
| 3 | 1.468 | 6.382 | 44.438 | 1.468 | 6.382 | 44.438 | 2.523 | 10.971 | 35.915 |
| 4 | 1.275 | 5.542 | 49.979 | 1.275 | 5.542 | 49.979 | 2.492 | 10.833 | 46.748 |
| 5 | 1.221 | 5.308 | 55.287 | 1.221 | 5.308 | 55.287 | 1.865 | 8.107 | 54.855 |
| 6 | 1.125 | 4.893 | 60.180 | 1.125 | 4.893 | 60.180 | 1.225 | 5.325 | **60.180** |
| …… | ……. | …….. | ……. | | | | | | |
| 23 | .242 | 1.053 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

**Table B.12 JUNIOR LEVEL - FINAL DIMENSIONS. Rotated Component Matrix**

| | Component | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| VAR21 | .775 | | | | | |
| VAR20 | .708 | | | | | |
| VAR23 | .687 | | | | | |
| VAR22 | .663 | | | | | |
| VAR12 | | .722 | | | | |
| VAR14 | | .581 | | | | |
| VAR01 | | .552 | | | .459 | |
| VAR10 | | .540 | | | | |
| VAR24 | .484 | .491 | | | | |
| VAR13 | | .480 | | | | |
| VAR28 | | | .844 | | | |
| VAR31 | | | .772 | | | |
| VAR26 | | | .769 | | | |
| VAR36 | | | .617 | | | |
| VAR17 | | | | .760 | | |
| VAR19 | | | | .743 | | |
| VAR18 | | | | .566 | | |
| VAR15 | | | | .507 | | |
| VAR16 | | | | .492 | | |
| VAR03 | | | | | .819 | |
| VAR05 | | | | | .630 | |
| VAR37 | | | | | .548 | |
| VAR11 | | | | | | .869 |

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 7 iterations.

**Table B.13 FACTOR ANALYSIS SENIOR LEVEL - FIRST RESULTS OF INPUTS**

**Total Variande Explained**

| | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 10.724 | 26.156 | 26.156 | 10.724 | 26.156 | 26.156 | 4.330 | 10.561 | 10.561 |
| 2 | 3.551 | 8.661 | 34.816 | 3.551 | 8.661 | 34.816 | 4.314 | 10.521 | 21.082 |
| 3 | 2.604 | 6.351 | 41.168 | 2.604 | 6.351 | 41.168 | 3.779 | 9.216 | 30.299 |
| 4 | 2.183 | 5.323 | 46.491 | 2.183 | 5.323 | 46.491 | 2.872 | 7.004 | 37.303 |
| 5 | 1.792 | 4.371 | 50.862 | 1.792 | 4.371 | 50.862 | 2.821 | 6.880 | 44.183 |
| 6 | 1.360 | 3.317 | 54.179 | 1.360 | 3.317 | 54.179 | 2.341 | 5.709 | 49.892 |
| 7 | 1.225 | 2.987 | 57.166 | 1.225 | 2.987 | 57.166 | 1.961 | 4.783 | 54.674 |
| 8 | 1.161 | 2.832 | 59.998 | 1.161 | 2.832 | 59.998 | 1.890 | 4.610 | 59.284 |
| 9 | 1.056 | 2.577 | 62.575 | 1.056 | 2.577 | 62.575 | 1.349 | 3.291 | **62.575** |
| …… | …… | …… | …… | | | | | | |
| 41 | 8.503E-17 | 2.074E-16 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

**Table B.14 SENIOR LEVEL - FIRST RESULTS OF INPUTS. Rotated Component Matrix**

Order reflects the matched questionnaire

| | Comp | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| VAR22F | .803 | | | | | | | | |
| VAR22A | .771 | | | | | | | | |
| VAR22E | .765 | | | | | | | | |
| VAR22G | .728 | | | | | | | | |
| VAR22C | .723 | | | | | | | | |
| VAR22D | .716 | | | | | | | | |
| VAR22B | .643 | | | | | | | | |
| VAR3G7 | | .864 | | | | | | | |
| VAR3H8 | | .861 | | | | | | | |
| VAR3A1 | | .764 | | | | | | | |
| VAR3E5 | | .730 | | | | | | | |
| VAR3D4 | | .526 | | | | | | | |
| VAR3F6 | | .519 | | | | | | | |
| VAR3C3 | | | | | | | | | |
| VAR1 | | | .875 | | | | | | |
| V152S | | | .875 | | | | | | |
| V172S | | | .646 | | | | | | |
| V16S | | | .552 | | | | | | |
| V17S | | | .519 | | | | | | |
| V15S | | | .495 | | | | | | |
| V18S | | | | | | | | | |
| VAR24BC | | | | .762 | | | | | |
| VAR24BE | | | | .759 | | | | | |
| VAR24BF | | | | .687 | | | | | |
| VAR24BA | | | | .683 | | | | | |
| VAR24BD | | | | .583 | | | | | |
| VAR24BB | | | | .562 | | | | | .534 |
| V000011 | | | | | .786 | | | | |
| VAR016 | | | | | .736 | | | | |
| VAR00017 | | | | | .691 | | | | |
| V22S | | | | | | .748 | | | |
| V23S | | | | | | .735 | | | |
| V232S | | | | | | .495 | | | |
| V24S | | | | | | .455 | | | |
| V14S | | | | | | | .750 | | |
| V13S | | | | | | | .552 | | |
| V12S | | | | | | | .503 | | |
| VAR018 | | | | | | | | .652 | |
| VAR019 | | | | | | | | .562 | |
| V233S | | | | | | | | | |
| VAR3B2 | | | | | | | | | .703 |

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 7 iterations.

**Table B.15 SENIOR LEVEL - FINAL DIMENSIONS. Total Variance Explained**

| | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulati % | Total | % of Variance | Cumulati % | Total | % of Variance | Cumulati % |
| 1 | 7.769 | 33.776 | 33.776 | 7.769 | 33.776 | 33.776 | 2.913 | 12.667 | 12.667 |
| 2 | 2.146 | 9.332 | 43.108 | 2.146 | 9.332 | 43.108 | 2.850 | 12.393 | 25.060 |
| 3 | 1.573 | 6.840 | 49.948 | 1.573 | 6.840 | 49.948 | 2.644 | 11.495 | 36.555 |
| 4 | 1.202 | 5.227 | 55.175 | 1.202 | 5.227 | 55.175 | 2.584 | 11.234 | 47.789 |
| 5 | 1.121 | 4.873 | 60.048 | 1.121 | 4.873 | 60.048 | 2.080 | 9.041 | 56.831 |
| 6 | 1.058 | 4.599 | 64.647 | 1.058 | 4.599 | 64.647 | 1.798 | 7.816 | **64.647** |
| ….. | …… | ….. | …… | | | | | | |
| 23 | 7.763E-17 | 3.375E-16 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

**Table B.16 SENIOR LEVEL - FINAL DIMENSIONS. Rotated Component Matrix**

Number reflects the original questionnaire

| | Component | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| VAR22A | .776 | | | | |
| VAR22F | .776 | | | | |
| V23g | .675 | | | | |
| V23d | .534 | | | | |
| V23j | .494 | | | | |
| V23e | .477 | | | | |
| V23h | .463 | | | | |
| V23i | .454 | | | | |
| V23f | .450 | | | | |
| V23o | | .923 | | | |
| V23p | | .923 | | | |
| V23k | | .801 | | | |
| V23q | | .797 | | | |
| VA23r | | .789 | | | |
| VA23n | | .788 | | | |
| VAR22D | | | .801 | | |
| VAR22C | | | .797 | | |
| VAR3A1 | | | .757 | | |
| V14S | | | | .835 | |
| V13S | | | | .554 | .547 |
| V12S | | | | .504 | |
| V23l | | | | | .769 |
| V23m | | | | | .717 |

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 11 iterations.

# APPENDIX C

## Coefficients for DEA Models

**Table C.1 FRESHMEN INPUTS 97-98**

**SW Table**

| | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *Expectations* | | | | | |
| *1.I expect that engineering will be a rewarding career.* | **94.4** | | | | |
| *22.Engineeers have contributed greatly to fixing problems in the world.* | **87.4** | | | | |
| *12.Engineers are innovative.* | **92.3** | | | | |
| *25.Engineers are creative* | **83.1** | | | | |
| *Confidence on personal study habits* | | | | | |
| *46.I am confident about my current study habits or routine* | | | **36.3** | | |
| *44. I am good at designing things.* | | **66.1** | | | |
| *48. I consider myself technically inclined* | | **69.2** | | | |
| *40. I have a strong problem solving skills.* | | **78.1** | | | |
| *36.I feel I know what an engineer does.* | | **72.2** | | | |
| *Team working habits* | | | | | |
| *37.Studing in a group is better than study by myself.* | | **43.1** | | | |
| *External expectations* | | | | | |
| *24.My parent(s) want me to be an engineer.* | | **39.9** | | | |
| *Total – Coefficients* | **357.2** | **368.6** | **36.3** | **0** | **0** |

**Table C.2 FRESHMAN OUTPUTS 97-98. Department A**

**SW Table**

| *Preparedness in engineering knowledge* | **M** | **PS** | **N** | **PW** | **MW** |
|---|---|---|---|---|---|
| *16. Ability to analyze engineering data.* | | **57** | | | |
| *15.Ability to solve unstructured engineering problems.* | | | **22.2** | | |
| *17.Ability to design a device or process.* | | | | **44.4** | |
| *20.Ability to use commercial software packages to solve engineering problems.* | | | **38.9** | | |
| *Communications skills and teamwork* | | | | | |
| *22. Technical writing ability: i.e to prepare engineering reports and papers.* | | | **33.3** | | |
| *23.Oral communication skills* | | | | | **66.7** |
| *24.Ability to be an effective team member.* | | **67.1** | | | |
| *Sciences and management skills* | | | | | |
| *12. Ability to apply math concepts to solve engineering problems.* | **83.3** | | | | |
| *13.Ability to apply chemistry concepts to solve engineering problems* | | **65** | | | |
| *14.Ability to apply physics concepts to help solving engineering problems.* | | **62.5** | | | |
| *25.Ability to set goals and achieve them on time.* | | **75.2** | | | |
| *26.Ability to learn new things on my own.* | | **73.5** | | | |
| *Technical Support* | | | | | |
| *18.Ability to use proper laboratory procedures.* | | **66.7** | | | |
| *19.Computer programming skills.* | | **50.6** | | | |
| *Total Output due to Sophomore Input* | **83.3** | **517.6** | **94.4** | **44.4** | **66.7** |
| *Confidence in Engineering Outcomes* | | | | | |
| *54. Using engineering concepts to solve relevant problems.* | | **58.8** | | | |
| *55.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | **43.5** | | |
| *62.Understanding the professional responsibilities of an engineer.* | | **64.7** | | | |
| *66. Effectively communicating engineering related ideas to others.* | | **67.5** | | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | **72.2** | | | |
| *68. Understanding the potential risks and impacts that an engineering solution or design may have* | | **59.5** | | | |
| *69. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | **56.4** | | | |
| *70. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | **62.2** | | | |
| | **0** | **441.3** | **43.5** | **0** | **0** |
| *TOTAL - Coefficients* | **83.3** | **958.9** | **137.9** | **44.4** | **66.7** |

**Table C.3 FRESHMAN OUTPUTS 97-98. Department B**

**SW Table**

| *Preparedness in engineering knowledge* | | PS | N | PW | M |
|---|---|---|---|---|---|
| *16. Ability to analyze engineering data.* | | | **65.8** | | |
| *15.Ability to solve unstructured engineering problems.* | | **52.9** | | | |
| *17.Ability to design a device or process.* | | | **60** | | |
| *20.Ability to use commercial software packages to solve engineering problems.* | | | **60** | | |
| *Communications skills and teamwork* | | | | | |
| *22. Technical writing ability: i.e to prepare engineering reports and papers.* | | | | | **57.1** |
| *23.Oral communication skills* | | | | | **57.1** |
| *24.Ability to be an effective team member.* | **85.7** | | | | |
| *Sciences and management skills* | | | | | |
| *12. Ability to apply math concepts to solve engineering problems.* | **85.7** | | | | |
| *13.Ability to apply chemistry concepts to solve engineering problems* | | **65.5** | | | |
| *14.Ability to apply physics concepts to help solving engineering problems.* | | **61** | | | |
| *25.Ability to set goals and achieve them on time.* | | **74.4** | | | |
| *26.Ability to learn new things on my own.* | | **78.6** | | | |
| | | | | | |
| *18.Ability to use proper laboratory procedures.* | | **66.7** | | | |
| *19.Computer programming skills.* | | **50.6** | | | |
| *Total Output due to Sophomore Input* | **1** | **44** | **185.8** | **0** | **114.2** |
| *Confidence in Engineering Outcomes* | | | | | |
| *54. Using engineering concepts to solve relevant problems.* | | **58.8** | | | |
| *55.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | **43.5** | | |
| *62.Understanding the professional responsibilities of an engineer.* | | **64.7** | | | |
| *66. Effectively communicating engineering related ideas to others.* | | **67.5** | | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | **72.2** | | | |
| *68. Understanding the potential risks and impacts that an engineering solution or design may have* | | **59.5** | | | |
| *69. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | **56.4** | | | |
| *70. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | **62.2** | | | |
| | **0** | **441.3** | **43.5** | **0** | **0** |
| *T* | **1** | **89** | **229.3** | **0** | **114.2** |

**Table C.4 FRESHMAN OUTPUTS 97-98. Department C**

**SW Table**

| *Preparedness in engineering knowledge* | **MS** | **PS** | **N** | | **MW** |
|---|---|---|---|---|---|
| *16. Ability to analyze engineering data.* | | **77.5** | | | |
| *15.Ability to solve unstructured engineering problems.* | | **57.5** | | | |
| *17.Ability to design a device or process.* | | **65.7** | | | |
| *20.Ability to use commercial software packages to solve engineering problems.* | | **62.5** | | | |
| *Communications skills and teamwork* | | | | | |
| *22. Technical writing ability: i.e to prepare engineering reports and papers.* | | **52.5** | | | |
| *23.Oral communication skills* | | **52.5** | | | |
| *24.Ability to be an effective team member.* | | | **61.5** | | |
| *Sciences and management skills* | | | | | |
| *12. Ability to apply math concepts to solve engineering problems.* | **90** | | | | |
| *13.Ability to apply chemistry concepts to solve engineering problems* | | **66.2** | | | |
| *14.Ability to apply physics concepts to help solving engineering problems.* | | **67.5** | | | |
| *25.Ability to set goals and achieve them on time.* | | **70** | | | |
| *26.Ability to learn new things on my own.* | | **75** | | | |
| *Technical Support* | | | | | |
| *18.Ability to use proper laboratory procedures.* | | **62.5** | | | |
| *19.Computer programming skills.* | | **70** | | | |
| *Total Output due to Sophomore Input* | **90** | **779.4** | **61.5** | **0** | |
| *Confidence in Engineering Outcomes* | | | | | |
| *54. Using engineering concepts to solve relevant problems.* | | **53.6** | | | |
| *55.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | **37.7** | | |
| *62.Understanding the professional responsibilities of an engineer.* | | **54.7** | | | |
| *66. Effectively communicating engineering related ideas to others.* | | | **27.5** | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | **65.2** | | | |
| *68. Understanding the potential risks and impacts that an engineering solution or design may have* | | **59.5** | | | |
| *69. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | **51.4** | | | |
| *70. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | **62.2** | | | |
| | **0** | **346.6** | **65.2** | **0** | |
| *TOTAL - Coeffiicients* | **90** | **1126** | **126.7** | **0** | |

**Table C.5 FRESHMAN OUTPUTS 97-98. Department D**

**SW Table**

| *Preparedness in engineering knowledge* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *16. Ability to analyze engineering data.* | | 72 | | | |
| *15.Ability to solve unstructured engineering problems.* | | 78 | | | |
| *17.Ability to design a device or process.* | | | 52 | | |
| *20.Ability to use commercial software packages to solve engineering problems.* | | 78 | | | |
| *Communications skills and teamwork* | | | | | |
| *22. Technical writing ability: i.e to prepare engineering reports and papers.* | | | 28 | | |
| *23.Oral communication skills* | | | 32 | | |
| *24.Ability to be an effective team member.* | | | 52 | | |
| *Sciences and management skills* | | | | | |
| *12. Ability to apply math concepts to solve engineering problems.* | | | 60 | | |
| *13.Ability to apply chemistry concepts to solve engineering problems* | | | 44 | | |
| *14.Ability to apply physics concepts to help solving engineering problems.* | | 70.9 | | | |
| *25.Ability to set goals and achieve them on time.* | | 74 | | | |
| *26.Ability to learn new things on my own.* | | 77 | | | |
| *Technical Support* | | | | | |
| *18.Ability to use proper laboratory procedures.* | | 56 | | | |
| *19.Computer programming skills.* | | | 32 | | |
| *Total Output due to Sophomore Input* | 0 | 505.9 | 300 | 0 | 0 |
| *Confidence in Engineering Outcomes* | | | | | |
| *54. Using engineering concepts to solve relevant problems.* | | 53.6 | | | |
| *55.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | 37.7 | | |
| *62.Understanding the professional responsibilities of an engineer.* | | 54.7 | | | |
| *66. Effectively communicating engineering related ideas to others.* | | | 27.5 | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | 65.2 | | | |
| *68. Understanding the potential risks and impacts that an engineering solution or design may have* | | 59.5 | | | |
| *69. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | 51.4 | | | |
| *70. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | 62.2 | | | |
| | 0 | 346.6 | | 0 | 0 |
| *TOTAL - Coefficietns* | 0 | 852.5 | 365.2 | 0 | 0 |

**Table C.6 SOPHOMORE INPUTS 98-99. Department A**

**SW Table**

| *Expectations* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *28. I expect that engineering will be a rewarding career.* | **83.3** | | | | |
| *39. I feel confident in my ability to succeed in engineering.* | **83.3** | | | | |
| *3. I am confident that I have chosen the right major* | | **50** | | | |
| *Confidence on career* | | | | | |
| *1.My freshman year prepared me for my sophomore year* | | **44.4** | | | |
| *5.My academic advisers have been helpful.* | | **55.6** | | | |
| | | | | | |
| *16. Ability to analyze engineering data.* | | **57** | | | |
| *15.Ability to solve unstructured engineering problems.* | | | **22.2** | | |
| *17.Ability to design a device or process.* | | | | **44.4** | |
| *20.Ability to use commercial software packages to solve engineering problems.* | | | **38.9** | | |
| *Communications skills and teamwork* | | | | | |
| *22. Technical writing ability: i.e to prepare engineering reports and papers.* | | | **33.3** | | |
| *23.Oral communication skills* | | | | | **66.7** |
| *24.Ability to be an effective team member.* | | **67.1** | | | |
| *agement skills* | | | | | |
| *12. Ability to apply math concepts to solve engineering problems.* | **83.3** | | | | |
| *13.Ability to apply chemistry concepts to solve engineering problems* | | **65** | | | |
| *14.Ability to apply physics concepts to help solving engineering problems.* | | **62.5** | | | |
| *25.Ability to set goals and achieve them on time.* | | **75.2** | | | |
| *26.Ability to learn new things on my own.* | | **73.5** | | | |
| *Technical Support* | | | | | |
| *18.Ability to use proper laboratory procedures.* | | **66.7** | | | |
| *19.Computer programming skills.* | | **50.6** | | | |
| *Confidence in Engineering Outcomes* | | | | | |
| *54. Using engineering concepts to solve relevant problems.* | | **53.6** | | | |
| *55.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | **43.5** | | |
| *62.Understanding the professional responsibilities of an engineer.* | | **54.7** | | | |
| *66. Effectively communicating engineering related ideas to others.* | | **57.5** | | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | **67.2** | | | |
| *68. Understanding the potential risks and impacts that an engineering solution or design may have* | | **59.5** | | | |
| *69. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | **51.4** | | | |
| *70. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | **62.2** | | | |
| *TOTAL* | **249.9** | **1073.7** | **137.9** | **44.4** | **66.7** |

**Table C.6 continues**

| | | | | | |
|---|---|---|---|---|---|
| *TOTAL Input from EC 2000 (a)* | **83.3** | **923.7** | **137.9** | **44.4** | **66.7** |
| *Coefficient of Efficiency Freshmen Level (b)* | **0.8101** | | | | |
| *(a) x (b) = ( c )* | **67.48** | **748.3** | **111.7** | **35.9** | **54.0** |
| *Total - a + c:* ***Coefficients*** | **234.0** | **898.3** | **111.7** | **35.9** | **54.0** |

**Table C.7 SOPHOMORE OUTPUTS 98-99. Department A**

**SW Table**

| *Academic support for sciences and engineering knowledge* | M S | PS | N | PW | M W |
|---|---|---|---|---|---|
| *10. Ability to apply math concepts to solve engineering problems.* | | 66.7 | | | |
| *12.Ability to apply physics concepts to help solving engineering problems.* | | | 50 | | |
| *13.Ability to solve unstructured engineering problems.* | | | 57.1 | | |
| *14. Ability to analyze engineering data.* | | 57.1 | | | |
| *11.Ability to apply chemistry concepts to solve engineering problems* | | | 57.1 | | |
| *Management skills* | | | | | |
| *20. Technical writing ability: i.e to prepare engineering reports and papers.* | | | 38.1 | | |
| *21.Oral communication skills* | | | 47.6 | | |
| *22.Ability to function effectively in different team roles.* | | 52.4 | | | |
| *23.Ability to set goals and achieve them on time.* | | 52.4 | | | |
| *24.Ability to learn new things on my own.* | | 57.1 | | | |
| *Problem solving and computer skills* | | | | | |
| *15.Ability to design a device or process.* | | | 47.6 | | |
| *16.Ability to use proper laboratory procedures.* | | 76.2 | | | |
| *17.Computer programming skills.* | | | | 47.6 | |
| *18.Ability to use commercial software packages to solve engineering problems.* | | 47.6 | | | |
| *Total sophomore due to junior input* | | | | | |
| *Confidence in Engineering Outcomes* | | | | | |
| *47. Using engineering concepts to solve relevant problems.* | | | 55.6 | | |
| *48.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | 50 | | |
| *54.Understanding the professional and ethical responsibilities of an engineer.* | | | 27.8 | | |
| *57. Effectively communicating engineering related ideas to others.* | | | 50 | | |
| *58. Listening to an impartially interpreting different viewpoints.* | | 66.7 | | | |
| *59. Understanding the potential risks and impacts that an engineering solution or design may have* | | 55.6 | | | |
| *60. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | | 44.4 | | |
| *61. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | 58.8 | | | |
| *TOTAL-Coefficients* | 0 | 590.6 | 525.3 | 47.6 | 0 |

**Table C.8 SOPHOMORE INPUTS 98-99. Department B**

**SW Table**

| *Expectations* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *28. I expect that engineering will be a rewarding career.* | **92.9** | | | | |
| *39. I feel confident in my ability to succeed in engineering.* | | **41.4** | | | |
| *3. I am confident that I have chosen the right major* | | **44.3** | | | |
| *Confidence on career* | | | | | |
| *1.My freshman year prepared me for my sophomore year* | | | **42.2** | | |
| *5.My academic advisers have been helpful.* | | | **25** | | |
| *Preparedness in engineering knowledge* | | | | | |
| *16. Ability to analyze engineering data.* | | | **65.8** | | |
| *15.Ability to solve unstructured engineering problems.* | | **52.9** | | | |
| *17.Ability to design a device or process.* | | | **60** | | |
| *20.Ability to use commercial software packages to solve engineering problems.* | | | **60** | | |
| *Communications skills and teamwork* | | | | | |
| *22. Technical writing ability: i.e to prepare engineering reports and papers.* | | | | | **57.1** |
| *23.Oral communication skills* | | | | | **57.1** |
| *24.Ability to be an effective team member.* | **85.7** | | | | |
| *Sciences and management skills* | | | | | |
| *12. Ability to apply math concepts to solve engineering problems.* | **85.7** | | | | |
| *13.Ability to apply chemistry concepts to solve engineering problems* | | **65.5** | | | |
| *14.Ability to apply physics concepts to help solving engineering problems.* | | **61** | | | |
| *25.Ability to set goals and achieve them on time.* | | **74.4** | | | |
| *26.Ability to learn new things on my own.* | | **78.6** | | | |
| *Technical Support* | | | | | |
| *18.Ability to use proper laboratory procedures.* | | **66.7** | | | |
| *19.Computer programming skills.* | | **50.6** | | | |
| *Confidence in Engineering Outcomes* | | | | | |
| *54. Using engineering concepts to solve relevant problems.* | | **53.6** | | | |
| *55.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | **43.5** | | |
| *62.Understanding the professional responsibilities of an engineer.* | | **54.7** | | | |
| *66. Effectively communicating engineering related ideas to others.* | | **57.5** | | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | **67.2** | | | |
| *68. Understanding the potential risks and impacts that an engineering solution or design may have* | | **59.5** | | | |
| *69. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | **51.4** | | | |
| *70. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | **62.2** | | | |

**Table C.8 continues**

| | | | | | |
|---|---|---|---|---|---|
| *TOTAL* | **264.3** | **941.5** | **296.5** | **0** | **114.2** |
| *TOTAL Input from EC 2000 (a)* | **171.4** | **855.8** | **229.3** | **0** | **114.2** |
| *Coefficient of Efficiency Freshmen Level (b)* | **0.8749** | | | | |
| *(a) x (b) = ( c )* | **14** | **748** | **200** | **0** | **9** |
| *Total - a + c: Coefficients* | **24** | **834.4** | **267.8** | **0** | **99.** |

**Table C.9 SOPHOMORE OUTPUTS 98-99. Department B**

**SW Table**

| *Academic support for sciences and engineering knowledge* | M S | PS | N | PW | M W |
|---|---|---|---|---|---|
| *10. Ability to apply math concepts to solve engineering problems.* | 83.3 | | | | |
| *12.Ability to apply physics concepts to help solving engineering problems.* | | | 50 | | |
| *13.Ability to solve unstructured engineering problems.* | | 50 | | | |
| *14. Ability to analyze engineering data.* | | 50 | | | |
| *11.Ability to apply chemistry concepts to solve engineering problems* | 83.3 | | | | |
| *Management skills* | | | | | |
| *20. Technical writing ability: i.e to prepare engineering reports and papers.* | | | 66.7 | | |
| *21.Oral communication skills* | | | 66.7 | | |
| *22.Ability to function effectively in different team roles.* | | 66.7 | | | |
| *23.Ability to set goals and achieve them on time.* | 83.3 | | | | |
| *24.Ability to learn new things on my own.* | | 57.1 | | | |
| *Problem solving and computer skills* | | | | | |
| *15.Ability to design a device or process.* | | 50 | | | |
| *16.Ability to use proper laboratory procedures.* | | 60 | | | |
| *17.Computer programming skills.* | 83.3 | | | | |
| *18.Ability to use commercial software packages to solve engineering problems.* | | 50 | | | |
| *Total sophomore due to junior input* | 333.2 | 383.8 | 183.4 | 0 | 0 |
| *onfidence in Engineering Outcomes* | | | | | |
| *47. Using engineering concepts to solve relevant problems.* | | | 50 | | |
| *48.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | | | 57.1 |
| *54.Understanding the professional and ethical responsibilities of an engineer.* | | 71.8 | | | |
| *57. Effectively communicating engineering related ideas to others.* | | | 50 | | |
| *58. Listening to an impartially interpreting different viewpoints.* | | | 57.1 | | |
| *59. Understanding the potential risks and impacts that an engineering solution or design may have* | | 42.9 | | | |
| *60. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | | 30.8 | | |
| *61. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | 57.1 | | | |
| | 0 | 171.8 | 187.9 | 0 | 57.1 |
| *efficients* | 333.2 | 555.6 | 371.3 | 0 | 57.1 |

**Table C.10 SOPHOMORE INPUTS 98-99. Department C**

**SW Table**

| *Expectations* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *28. I expect that engineering will be a rewarding career.* | **90.2** | | | | |
| *39. I feel confident in my ability to succeed in engineering.* | | **40** | | | |
| *3. I am confident that I have chosen the right major* | **80** | | | | |
| *Confidence on career* | | | | | |
| *1.My freshman year prepared me for my sophomore year* | | **40** | | | |
| *5.My academic advisers have been helpful.* | | | **31.9** | | |
| *Preparedness in engineering knowledge* | | | | | |
| *16. Ability to analyze engineering data.* | | **77.5** | | | |
| *15.Ability to solve unstructured engineering problems.* | | **57.5** | | | |
| *17.Ability to design a device or process.* | | **65.7** | | | |
| *20.Ability to use commercial software packages to solve engineering problems.* | | **62.5** | | | |
| *Communications skills and teamwork* | | | | | |
| *22. Technical writing ability: i.e to prepare engineering reports and papers.* | | **52.5** | | | |
| *23.Oral communication skills* | | **52.5** | | | |
| *24.Ability to be an effective team member.* | | | **61.5** | | |
| *Sciences and management skills* | | | | | |
| *12. Ability to apply math concepts to solve engineering problems.* | **90** | | | | |
| *13.Ability to apply chemistry concepts to solve engineering problems* | | **66.2** | | | |
| *14.Ability to apply physics concepts to help solving engineering problems.* | | **67.5** | | | |
| *25.Ability to set goals and achieve them on time.* | | **70** | | | |
| *26.Ability to learn new things on my own.* | | **75** | | | |
| *Technical Support* | | | | | |
| *18.Ability to use proper laboratory procedures.* | | **62.5** | | | |
| *19.Computer programming skills.* | | **70** | | | |
| *Confidence in Engineering Outcomes* | | | | | |
| *54. Using engineering concepts to solve relevant problems.* | | **53.6** | | | |
| *55.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | **43.5** | | |
| *62.Understanding the professional responsibilities of an engineer.* | | **54.7** | | | |
| *66. Effectively communicating engineering related ideas to others.* | | **57.5** | | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | **67.2** | | | |
| *68. Understanding the potential risks and impacts that an engineering solution or design may have* | | **59.5** | | | |
| *69. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | **51.4** | | | |
| *70. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | **62.2** | | | |
| *TOTAL* | **260.2** | **1265.5** | **136.9** | **0** | **0** |

**Table C.10 contimues**

| | | | | | |
|---|---|---|---|---|---|
| *TOTAL Input from EC 2000 (a)* | **90** | **1185.5** | **105** | **0** | **0** |
| *Coefficient of Eficiency Freshmen Level (b)* | **1** | | | | |
| *(a) x (b) = ( c )* | **90** | **1185.5** | **105** | **0** | **0** |
| *Total - a + c: Coefficients* | **260.2** | **1265.5** | **136.9** | **0** | **0** |

**Table C.11 SOPHOMORE OUTPUTS 98-99. Department C**

**SW Table**

| *Academic support for sciences and engineering knowledge* | M S | PS | N | PW | M W |
|---|---|---|---|---|---|
| *10. Ability to apply math concepts to solve engineering problems.* | | 78.4 | | | |
| *12.Ability to apply physics concepts to help solving engineering problems.* | | | 50 | | |
| *13.Ability to solve unstructured engineering problems.* | | 51.4 | | | |
| *14. Ability to analyze engineering data.* | | 75.7 | | | |
| *11.Ability to apply chemistry concepts to solve engineering problems* | | | 45.9 | | |
| *Management skills* | | | | | |
| *20. Technical writing ability: i.e to prepare engineering reports and papers.* | | | 45.9 | | |
| *21.Oral communication skills* | | | 45.9 | | |
| *22.Ability to function effectively in different team roles.* | | 54.1 | | | |
| *23.Ability to set goals and achieve them on time.* | | 75.7 | | | |
| *24.Ability to learn new things on my own.* | 81.1 | | | | |
| *Problem solving and computer skills* | | | | | |
| *15.Ability to design a device or process.* | | | 51.4 | | |
| *16.Ability to use proper laboratory procedures.* | | 70.3 | | | |
| *17.Computer programming skills.* | | | 40.5 | | |
| *18.Ability to use commercial software packages to solve engineering problems.* | | 67.7 | | | |
| *Total sophomore due to junior input* | 81.1 | 473.3 | 279.6 | | |
| *Confidence in Engineering Outcomes* | | | | | |
| *47. Using engineering concepts to solve relevant problems.* | | 57.5 | | | |
| *48.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | 57.7 | | |
| *54.Understanding the professional and ethical responsibilities of an engineer.* | | 65 | | | |
| *57. Effectively communicating engineering related ideas to others.* | | | 48.8 | | |
| *58. Listening to an impartially interpreting different viewpoints.* | | 46.3 | | | |
| *59. Understanding the potential risks and impacts that an engineering solution or design may have* | | 51.2 | | | |
| *60. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | | 39.1 | | |
| *61. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | 61 | | | |
| *TOTAL-Coefficients* | 81.1 | 754.3 | 425.2 | 0 | 0 |

**Table C.12 SOPHOMORE INPUTS 98-99. Department D**

**SW Table**

| *Expectations* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *28. I expect that engineering will be a rewarding career.* | **80** | | | | |
| *39. I feel confident in my ability to succeed in engineering.* | **80** | | | | |
| *3. I am confident that I have chosen the right major* | | **41** | | | |
| *Confidence on career* | | | | | |
| *1.My freshman year prepared me for my sophomore year* | | | **20** | | |
| *5.My academic advisers have been helpful.* | | | **25** | | |
| *Preparedness in engineering knowledge* | | | | | |
| *16. Ability to analyze engineering data.* | | **72** | | | |
| *15.Ability to solve unstructured engineering problems.* | | **78** | | | |
| *17.Ability to design a device or process.* | | | **52** | | |
| *20.Ability to use commercial software packages to solve engineering problems.* | | **78** | | | |
| *Communications skills and teamwork* | | | | | |
| *22. Technical writing ability: i.e to prepare engineering reports and papers.* | | | **28** | | |
| *23.Oral communication skills* | | | **32** | | |
| *24.Ability to be an effective team member.* | | | **52** | | |
| *Sciences and management skills* | | | | | |
| *12. Ability to apply math concepts to solve engineering problems.* | | | **60** | | |
| *13.Ability to apply chemistry concepts to solve engineering problems* | | | **44** | | |
| *14.Ability to apply physics concepts to help solving engineering problems.* | | **70.9** | | | |
| *25.Ability to set goals and achieve them on time.* | | **74** | | | |
| *26.Ability to learn new things on my own.* | | **77** | | | |
| *Technical Support* | | | | | |
| *18.Ability to use proper laboratory procedures.* | | **56** | | | |
| *19.Computer programming skills.* | | | **32** | | |
| *Confidence in Engineering Outcomes* | | **53.6** | | | |
| *54. Using engineering concepts to solve relevant problems.* | | **53.6** | | | |
| *55.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | **43.5** | | |
| *62.Understanding the professional responsibilities of an engineer.* | | **54.7** | | | |
| *66. Effectively communicating engineering related ideas to others.* | | **57.5** | | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | **67.2** | | | |
| *68. Understanding the potential risks and impacts that an engineering solution or design may have* | | **59.5** | | | |
| *69. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | **51.4** | | | |
| *70. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | **62.2** | | | |
| *TOTAL* | **160** | **953** | **388.5** | **0** | **0** |

**Table C.12 continues**

| | | | | | |
|---|---|---|---|---|---|
| *TOTAL Input from EC 2000 (a)* | **0** | **912** | **343.5** | **0** | **0** |
| *Coefficient of Eficiency Freshmen Level (b)* | **0.903** | | | | |
| *(a) x (b) = ( c )* | **0** | **823.4** | **310.1** | **0** | **0** |
| *Total - a + c: Coefficients* | **160** | **864.4** | **355.1** | **0** | **0** |

**Table C.13 SOPHOMORE OUTPUTS 98-99. Department D**

**SW Table**

| *Academic support for sciences and engineering knowledge* | M S | PS | N | PW | M W |
|---|---|---|---|---|---|
| *10. Ability to apply math concepts to solve engineering problems.* | | 69.4 | | | |
| *12.Ability to apply physics concepts to help solving engineering problems.* | | | 50 | | |
| *13.Ability to solve unstructured engineering problems.* | | | 57.1 | | |
| *14. Ability to analyze engineering data.* | | | 58.3 | | |
| *11.Ability to apply chemistry concepts to solve engineering problems* | | | | 47.2 | |
| *Management skills* | | | | | |
| *20. Technical writing ability: i.e to prepare engineering reports and papers.* | | 52.8 | | | |
| *21.Oral communication skills* | | | | 47.2 | |
| *22.Ability to function effectively in different team roles.* | | 45.7 | | | |
| *23.Ability to set goals and achieve them on time.* | | | 47.2 | | |
| *24.Ability to learn new things on my own.* | | 63.9 | | | |
| *Problem solving and computer skills* | | | | | |
| *15.Ability to design a device or process.* | | 44.4 | | | |
| *16.Ability to use proper laboratory procedures.* | | 44.4 | | | |
| *17.Computer programming skills.* | | | 36.1 | | |
| *18.Ability to use commercial software packages to solve engineering problems.* | | 44.4 | | | |
| *Total sophomore due to junior input* | 0 | 365 | 248.7 | 94.4 | 0 |
| *Confidence in Engineering Outcomes* | | | | | |
| *47. Using engineering concepts to solve relevant problems.* | | 56 | | | |
| *48.Designing an experiment to obtain measurements or gain additional knowledge about process.* | | 40 | | | |
| *54.Understanding the professional and ethical responsibilities of an engineer.* | | 52 | | | |
| *57. Effectively communicating engineering related ideas to others.* | | | 64 | | |
| *58. Listening to an impartially interpreting different viewpoints.* | | 52 | | | |
| *59. Understanding the potential risks and impacts that an engineering solution or design may have* | | 68 | | | |
| *60. Applying knowledge about current issues (economic, environmental, ) to engineering related problems.* | | | 48 | | |
| *61. Recognizing the limitations of my engineering knowledge and abilities when to seek additional information* | | 72 | | | |
| | 0 | 340 | 112 | 0 | 0 |
| *TOTAL- Coefficients* | 0 | 705 | 360.7 | 94.4 | 0 |

**Table C.14 JUNIOR INPUTS 99-00. Department A**

**SW Table**

| *Expectations* | M | PS | N | PW | MW |
|---|---|---|---|---|---|
| *37. I expect that engineering will be a rewarding career.* | | **71.4** | | | |
| *3. I am confident that I have chosen the right major* | | **57.1** | | | |
| *48.I feel confident in my ability to succeed in engineering.* | | **71.4** | | | |
| *5..My academic advisers have been helpful.* | | | **23.8** | | |
| *Academic support for sciences and engineering knowledge* | | | | | |
| *1.My sophomore year prepared me for my junior year* | | **61.9** | | | |
| *10. Ability to apply math concepts to solve engineering problems.* | | **66.7** | | | |
| *12.Ability to apply physics concepts to help solving engineering problems.* | | | **50** | | |
| *13.Ability to solve unstructured engineering problems.* | | | **57.1** | | |
| *14. Ability to analyze engineering data.* | | **57.1** | | | |
| *11.Ability to apply chemistry concepts to solve engineering problems* | | | **57.1** | | |
| *Pre-professional experience* | | | | | |
| *26. Increase my ability to succeed in engineering classes.* | | **62.5** | | | |
| *28.Provided me with the opportunity to pursue learning on my own.* | | **75** | | | |
| *31. Allowed me to work on a "real world" engineering problems.* | **83.1** | | | | |
| *36. Helped me to develop my communication skills.* | | **75** | | | |
| *Management skills* | | | | | |
| *20. Technical writing ability: i.e to prepare engineering reports and papers.* | | | **38.1** | | |
| *21.Oral communication skills* | | | **47.6** | | |
| *22.Ability to function effectively in different team roles.* | | **52.4** | | | |
| *23.Ability to set goals and achieve them on time.* | | **52.4** | | | |
| *24.Ability to learn new things on my own.* | | **57.1** | | | |
| *Problem solving and computer skills* | | | | | |
| *15.Ability to design a device or process.* | | | **47.6** | | |
| *16.Ability to use proper laboratory procedures.* | | **76.2** | | | |
| *17.Computer programming skills.* | | | | **47.6** | |
| *18.Ability to use commercial software packages to solve engineering problems.* | | **47.6** | | | |
| *Confidence in Engineering Outcomes* | | | | | |
| *56. Using engineering concepts to solve relevant problems.* | | | **55.6** | | |
| *57. Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | **50** | | |
| *63. Understanding the professional and ethical responsibilities of an engineer.* | | | **27.8** | | |
| *66. Effectively communicating engineering related ideas to others.* | | | **50** | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | **66.7** | | | |
| *68.Understanding the potential risks (to the public) and impacts that an engineering solution or design may have.* | | **55.6** | | | |
| *69 Applying knowledge about current issues (economic, environmental, political, societal, etc.) to engineering related problems.* | | | **44.4** | | |
| *70.Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information.* | | **58.8** | | | |

**Table C.14 continues**

| | | | | | |
|---|---|---|---|---|---|
| ***TOTAL*** | **83.1** | **1065** | **549.1** | **47.6** | **0** |
| *TOTAL Input from EC 2000 (a)* | **83.1** | **679.3** | **418.2** | **47.6** | **0** |
| *Coefficient of Eficiency Sophomore Level (b)* | **1** | | | | |
| *(a) x (b) = ( c )* | **83.1** | **679.3** | **418.2** | | **0** |
| *Total - a + c: Coefficients* | **83.1** | **1065** | **549.1** | **47.6** | **0** |

**Table C.15 JUNIOR OUTPUTS 99-00. Department A**

**SW Table**

| *Engineering Knowledge And Designing Skills* | MS | | N | PW | MW |
|---|---|---|---|---|---|
| *23g. Designing a device or process to satisfy a given set of specifications.* | | | **18** | | |
| *23d. Using my knowledge of engineering to solve relevant engineering problems.* | | **61** | | | |
| *23j. Using appropriate engineering techniques include software or lab equipment for problem solving.* | | **61** | | | |
| *23e. Designing and conducting an experiment to obtain measurements or gain additional knowledge about a process* | | **65** | | | |
| *23h. Functioning effectively in different team roles .* | | **61** | | | |
| *23i. Formulating unstructured engineering problems.* | | | **12** | | |
| *23f. Analyzing and interpreting set of data to find underlying meaning(s).* | **82** | | | | |
| *Engineering Professional And Ethical Behavior* | | | | | |
| *23o. Listening to and impartially interpreting different viewpoints.* | **82** | | | | |
| *23p. Understanding the potential risks and impacts that an engineering solution or design may have* | **82** | | | | |
| *23k. Understanding the professional and ethical responsibilities of an engineer.* | **88** | | | | |
| *23q. Applying knowledge about current issues(economics, environmental, political, social, etc.) to engineering-related problems* | | **61** | | | |
| *23r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | **82** | | | | |
| *23n. Effectively expressing engineering-related ideas to others.* | | **61** | | | |
| *Sciences Knowledge* | | | | | |
| *23a. Using my knowledge of mathematics to solve relevant engineering problems.* | | **65** | | | |
| *23b. Using my knowledge of chemistry to solve relevant engineering problems.* | | | **18** | | |
| *23c. Using my knowledge of physics to solve relevant engineering problems.* | | | | **47** | |
| *Communications Skills* | | | | | |
| *23l. Writing effectively.* | | **53** | | | |
| *23m. Making professional presentations.* | | **53** | | | |
| *TOTAL - Coefficients* | **418** | **538** | **47** | **47** | **0** |

**Table C.16 JUNIOR INPUTS 99-00. Department B**

**SW Table**

| *Expectations* | MS | PS | N | | MW |
|---|---|---|---|---|---|
| *37. I expect that engineering will be a rewarding career.* | **83.3** | | | | |
| *3. I am confident that I have chosen the right major* | **83.3** | | | | |
| *48.I feel confident in my ability to succeed in engineering.* | **100** | | | | |
| *5..My academic advisers have been helpful.* | | **50** | | | |
| *Academic support for sciences and engineering knowledge* | | | | | |
| *1.My sophomore year prepared me for my junior year* | | | **0** | | |
| *10. Ability to apply math concepts to solve engineering problems.* | **100** | | | | |
| 12.Ability to apply physics concepts to help solving engineering problems. | | | **45.4** | | |
| *13.Ability to solve unstructured engineering problems.* | | | **0** | | |
| *14. Ability to analyze engineering data.* | | | | | |
| *11.Ability to apply chemistry concepts to solve engineering problems* | | | **66.7** | | |
| *Pre-professional experience* | **83.3** | | | | |
| *26. Increase my ability to succeed in engineering classes.* | | | **50** | | |
| *28.Provided me with the opportunity to pursue learning on my own.* | | **50** | | | |
| *31. Allowed me to work on a "real world" engineering problems.* | | **50** | | | |
| *36. Helped me to develop my communication skills.* | **83.3** | | | | |
| *Management skills* | | | | | |
| *20. Technical writing ability: i.e to prepare engineering reports and papers.* | | | **66.7** | | |
| *21.Oral communication skills* | | | **66.7** | | |
| *22.Ability to function effectively in different team roles.* | | **66.7** | | | |
| *23.Ability to set goals and achieve them on time.* | **83.3** | | | | |
| *24.Ability to learn new things on my own.* | | **57.1** | | | |
| *Problem solving and computer skills* | | | | | |
| *15.Ability to design a device or process.* | | **50** | | | |
| *16.Ability to use proper laboratory procedures.* | | **60** | | | |
| *17.Computer programming skills.* | **83.3** | | | | |
| *18.Ability to use commercial software packages to solve engineering problems.* | | **50** | | | |
| *Confidence in Engineering Outcomes* | | | | | |
| *56. Using engineering concepts to solve relevant problems.* | | | **50** | | |
| *57. Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | | | **57.1** |
| *63. Understanding the professional and ethical responsibilities of an engineer.* | | **71.8** | | | |
| *66. Effectively communicating engineering related ideas to others.* | | | **50** | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | | **57.1** | | |
| *68.Understanding the potential risks (to the public) and impacts that an engineering solution or design may have.* | | **42.9** | | | |
| *69 Applying knowledge about current issues (economic, environmental, political, societal, etc.) to engineering related problems.* | | | **30.8** | | |
| *70.Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information.* | | **57.1** | | | |

**Table C.16 continues**

| | | | | | |
|---|---|---|---|---|---|
| ***TOTAL*** | **699.8** | **605.6** | **483.4** | **0** | **57.1** |
| *TOTAL Input from EC 2000 (a)* | **333.2** | **555.6** | **371.3** | **0** | **57.1** |
| *Coefficient of Eficiency Sophomore Level (b)* | **1** | | | | |
| *(a) x (b) = ( c )* | **333.2** | **555.6** | **371.3** | **0** | **57.1** |
| *Total - a + c: Coefficients* | **699.8** | **605** | **483.4** | **0** | **57.1** |

**Table C.17 JUNIOR OUTPUTS 99-00. Department B**

**SW Table**

| *Engineering Knowledge And Designing Skills* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *23g. Designing a device or process to satisfy a given set of specifications.* | 83.3 | | | | |
| *23d. Using my knowledge of engineering to solve relevant engineering problems.* | | 66.7 | | | |
| *23j. Using appropriate engineering techniques include software or lab equipment for problem solving.* | | 66.7 | | | |
| *23e. Designing and conducting an experiment to obtain measurements or gain additional knowledge about a process* | | 75 | | | |
| *23h. Functioning effectively in different team roles .* | | 66.7 | | | |
| *23i. Formulating unstructured engineering problems.* | | | 66.6 | | |
| *23f. Analyzing and interpreting set of data to find underlying meaning(s).* | | 75 | | | |
| *Engineering Professional And Ethical Behavior* | | | | | |
| *23o. Listening to and impartially interpreting different viewpoints.* | | 75 | | | |
| *23p. Understanding the potential risks and impacts that an engineering solution or design may have* | | 66.7 | | | |
| *23k. Understanding the professional and ethical responsibilities of an engineer.* | | 66.7 | | | |
| *23q. Applying knowledge about current issues(economics, environmental, political, social, etc.) to engineering-related problems* | | 75 | | | |
| *23r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | | 66.7 | | | |
| *23n. Effectively expressing engineering-related ideas to others.* | | 75 | | | |
| *Sciences Knowledge* | | | | | |
| *23a. Using my knowledge of mathematics to solve relevant engineering problems.* | | | 66.7 | | |
| *23b. Using my knowledge of chemistry to solve relevant engineering problems.* | | | 50 | | |
| *23c. Using my knowledge of physics to solve relevant engineering problems.* | | | 83.3 | | |
| *Communications Skills* | | | | | |
| *23l. Writing effectively.* | | | 50 | | |
| *23m. Making professional presentations.* | | | 50 | | |
| *TOTAL - Coefficients* | 83.3 | 775.2 | 366.6 | 0 | 0 |

**Table C.18 JUNIOR INPUTS 99-00. Department C**

**SW Table**

| *Expectations* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *37. I expect that engineering will be a rewarding career.* | **91.9** | | | | |
| *3. I am confident that I have chosen the right major* | 83.3 | | | | |
| *48.I feel confident in my ability to succeed in engineering.* | **83.3** | | | | |
| *5..My academic advisers have been helpful.* | | | **40.5** | | |
| *Academic support for sciences and engineering knowledge* | | | | | |
| *1.My sophomore year prepared me for my junior year* | | **79.3** | | | |
| *10. Ability to apply math concepts to solve engineering problems.* | **86.2** | | | | |
| *12.Ability to apply physics concepts to help solving engineering problems.* | | | | | |
| *13.Ability to solve unstructured engineering problems.* | | **79.3** | | | |
| *14. Ability to analyze engineering data.* | | | | | |
| *11.Ability to apply chemistry concepts to solve engineering problems* | | **75.7** | | | |
| | | | | | |
| *26. Increase my ability to succeed in engineering classes.* | | | **50** | | |
| *28.Provided me with the opportunity to pursue learning on my own.* | | **51.4** | | | |
| *31. Allowed me to work on a "real world" engineering problems.* | | **75.7** | | | |
| *36. Helped me to develop my communication skills.* | | | **45.9** | | |
| *Management skills* | | | | | |
| *20. Technical writing ability: i.e to prepare engineering reports and papers.* | | | **45.9** | | |
| *21.Oral communication skills* | | | **45.9** | | |
| *22.Ability to function effectively in different team roles.* | | **54.1** | | | |
| *23.Ability to set goals and achieve them on time.* | | **75.7** | | | |
| *24.Ability to learn new things on my own.* | **81.1** | | | | |
| *Problem solving and computer skills* | | | | | |
| *15.Ability to design a device or process.* | | | **51.4** | | |
| *16.Ability to use proper laboratory procedures.* | | **70.3** | | | |
| *17.Computer programming skills.* | | | **40.5** | | |
| *18.Ability to use commercial software packages to solve engineering problems.* | | **67.7** | | | |
| *Confidence in Engineering Outcomes* | | | | | |
| *56. Using engineering concepts to solve relevant problems.* | | **57.5** | | | |
| *57. Designing an experiment to obtain measurements or gain additional knowledge about process.* | | | **57.7** | | |
| *63. Understanding the professional and ethical responsibilities of an engineer.* | | **65** | | | |
| *66. Effectively communicating engineering related ideas to others.* | | | **48.8** | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | **46.3** | | | |
| *68.Understanding the potential risks (to the public) and impacts that an engineering solution or design may have.* | | **51.2** | | | |
| *69 Applying knowledge about current issues (economic, environmental, political, societal, etc.) to engineering related problems.* | | | **39.1** | | |
| *70.Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information.* | | **61** | | | |

**Table C.18 continues**

| | | | | | |
|---|---|---|---|---|---|
| ***TOTAL*** | **425.8** | **988.6** | **465.7** | **0** | **0** |
| *TOTAL Input from EC 2000 (a)* | **81.1** | **830** | **425.2** | **0** | **0** |
| *Coefficient of Eficiency Sophomore Level (b)* | **0.378** | | | | |
| *(a) x (b) = ( c )* | **30.62** | **313.4** | **160.6** | **0** | **0** |
| *Total - a + c : Coefficientw* | **375.3** | **472.0** | **201.1** | **0** | **0** |

**Table C.19 JUNIOR OUTPUTS 99-00. Department C**

**SW Table**

| *Engineering Knowledge And Designing Skills* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *23g. Designing a device or process to satisfy a given set of specifications.* | **91** | | | | |
| *23d. Using my knowledge of engineering to solve relevant engineering problems.* | | | **45.5** | | |
| *23j. Using appropriate engineering techniques include software or lab equipment for problem solving.* | | **72.7** | | | |
| *23e. Designing and conducting an experiment to obtain measurements or gain additional knowledge about a process* | | **63.6** | | | |
| *23h. Functioning effectively in different team roles .* | **90.9** | | | | |
| *23i. Formulating unstructured engineering problems.* | | **63.6** | | | |
| *23f. Analyzing and interpreting set of data to find underlying meaning(s).* | **90.9** | | | | |
| *Engineering Professional And Ethical Behavior* | | | | | |
| *23o. Listening to and impartially interpreting different viewpoints.* | **81.8** | | | | |
| *23p. Understanding the potential risks and impacts that an engineering solution or design may have* | | **72.7** | | | |
| *23k. Understanding the professional and ethical responsibilities of an engineer.* | | **72.7** | | | |
| *23q. Applying knowledge about current issues(economics, environmental, political, social, etc.) to engineering-related problems* | **81.8** | | | | |
| *23r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | | **72.7** | | | |
| *23n. Effectively expressing engineering-related ideas to others.* | **100** | | | | |
| *Sciences Knowledge* | | | | | |
| *23a. Using my knowledge of mathematics to solve relevant engineering problems.* | | **63.6** | | | |
| *23b. Using my knowledge of chemistry to solve relevant engineering problems.* | | | | | **54.5** |
| *23c. Using my knowledge of physics to solve relevant engineering problems.* | | | **45.5** | | |
| *Communications Skills* | | | | | |
| *23l. Writing effectively.* | | **63.6** | | | |
| *23m. Making professional presentations.* | | **45.5** | | | |
| *TOTAL - Coefficients* | **536.4** | **590.7** | **91** | **0** | **54.5** |

**Table C.20 JUNIOR INPUTS 99-00. Department D**

**SW Table**

| *Expectations* | **MS** | | **N** | **PW** | **M** |
|---|---|---|---|---|---|
| *37. I expect that engineering will be a rewarding career.* | **83.3** | | | | |
| *3. I am confident that I have chosen the right major* | | **75** | | | |
| *48.I feel confident in my ability to succeed in engineering.* | **83.3** | | | | |
| *5..My academic advisers have been helpful.* | | | **38.9** | | |
| *Academic support for sciences and engineering knowledge* | | | | | |
| *1.My sophomore year prepared me for my junior year* | | **77.8** | | | |
| *Ability to apply math concepts to solve engineering problems.* | | **70.4** | | | |
| *12.Ability to apply physics concepts to help solving engineering problems.* | | | | | |
| *13.Ability to solve unstructured engineering problems.* | | **66.7** | | | |
| *14. Ability to analyze engineering data.* | | | | | |
| *11.Ability to apply chemistry concepts to solve engineering problems* | **72.2** | | | | |
| *Pre-professional experience* | | **69.4** | | | |
| *26. Increase my ability to succeed in engineering classes.* | | | **50** | | |
| *28.Provided me with the opportunity to pursue learning on my own.* | | | **57.1** | | |
| *31. Allowed me to work on a "real world" engineering problems.* | | | **58.3** | | |
| *36. Helped me to develop my communication skills.* | | | | **47.2** | |
| *Management skills* | | | | | |
| *20. Technical writing ability: i.e to prepare engineering reports and papers.* | | **52.8** | | | |
| *21.Oral communication skills* | | | | **47.2** | |
| *22.Ability to function effectively in different team roles.* | | **45.7** | | | |
| *23.Ability to set goals and achieve them on time.* | | | **47.2** | | |
| *24.Ability to learn new things on my own.* | | **63.9** | | | |
| *Problem solving and computer skills* | | | | | |
| *15.Ability to design a device or process.* | | **44.4** | | | |
| *16.Ability to use proper laboratory procedures.* | | **44.4** | | | |
| *17.Computer programming skills.* | | | **36.1** | | |
| *18.Ability to use commercial software packages to solve engineering problems.* | | **44.4** | | | |
| *Confidence in Engineering Outcomes* | | | | | |
| *56. Using engineering concepts to solve relevant problems.* | | **56** | | | |
| *57. Designing an experiment to obtain measurements or gain additional knowledge about process.* | | **40** | | | |
| *63. Understanding the professional and ethical responsibilities of an engineer.* | | **52** | | | |
| *66. Effectively communicating engineering related ideas to others.* | | | **64** | | |
| *67. Listening to an impartially interpreting different viewpoints.* | | **52** | | | |
| *68.Understanding the potential risks (to the public) and impacts that an engineering solution or design may have.* | | **68** | | | |
| *69 Applying knowledge about current issues (economic, environmental, political, societal, etc.) to engineering related problems.* | | | **48** | | |
| *70.Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information.* | | **72** | | | |

**Table C.20 continues**

| | | | | | |
|---|---|---|---|---|---|
| ***TOTAL*** | **238.8** | **994.9** | **399.6** | **94.4** | **0** |
| *TOTAL Input from EC 2000 (a)* | **72.2** | **705** | **360.7** | **94.4** | **0** |
| *Coefficient of Eficiency Sophomore Level (b)* | **0.4899** | | | | |
| *(a) x (b) = ( c )* | **35.4** | **345.4** | **176.7** | **46.2** | **0** |
| *Total - a + c: Coefficients* | **201.9** | **635.3** | **215.6** | | **0** |

**Table C.21 JUNIOR OUTPUTS 99-00. Department D**

**SW Table**

| *Engineering Knowledge And Designing Skills* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *23g. Designing a device or process to satisfy a given set of specifications.* | | **60** | | | |
| *23d. Using my knowledge of engineering to solve relevant engineering problems.* | | **70** | | | |
| *23j. Using appropriate engineering techniques include software or lab equipment for problem solving.* | | **70** | | | |
| *23e. Designing and conducting an experiment to obtain measurements or gain additional knowledge about a process* | | **60** | | | |
| *23h. Functioning effectively in different team roles .* | **80** | | | | |
| *23i. Formulating unstructured engineering problems.* | | **70** | | | |
| *23f. Analyzing and interpreting set of data to find underlying meaning(s).* | **80** | | | | |
| *Engineering Professional And Ethical Behavior* | | | | | |
| *23o. Listening to and impartially interpreting different viewpoints.* | **80** | | | | |
| *23p. Understanding the potential risks and impacts that an engineering solution or design may have* | **90** | | | | |
| *23k. Understanding the professional and ethical responsibilities of an engineer.* | | **70** | | | |
| *23q. Applying knowledge about current issues(economics, environmental, political, social, etc.) to engineering-related problems* | | **60** | | | |
| *23r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | | | **60** | | |
| *23n. Effectively expressing engineering-related ideas to others.* | **80** | | | | |
| *Sciences Knowledge* | | | | | |
| *23a. Using my knowledge of mathematics to solve relevant engineering problems.* | | | **60** | | |
| *23b. Using my knowledge of chemistry to solve relevant engineering problems.* | | | | **40** | |
| *23c. Using my knowledge of physics to solve relevant engineering problems.* | | | | | **50** |
| *Communications Skills* | | | | | |
| *23l. Writing effectively.* | **90** | | | | |
| *23m. Making professional presentations.* | | **70** | | | |
| *TOTAL - Coefficients* | **500** | **530** | **120** | **40** | **50** |

**Table C.22 SENIOR INPUTS 00-01. Department A**

**SW Table**

| *Pre-professional engineering experience* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *22a. Solve engineering problems* | | 61.4 | | | |
| *23g. Designing a device or process to satisfy a given set of specifications.* | | | 17.6 | | |
| *22f. Understand engineering profession.* | 81 | | | | |
| *23d. Using my knowledge of engineering to solve relevant engineering problems.* | | 60.6 | | | |
| *23j. Using appropriate engineering techniques include software or lab equipment for problem solving.* | | 60.6 | | | |
| *23e. Designing and conducting an experiment to obtain measurements or gain additional knowledge about a process* | | 64.7 | | | |
| *23h. Functioning effectively in different team roles .* | | 60.6 | | | |
| *23i. Formulating unstructured engineering problems.* | | | 11.8 | | |
| *23f. Analyzing and interpreting set of data to find underlying meaning(s).* | 82.4 | | | | |
| *Engineering professional and ethical behavior* | | | | | |
| *23o. Listening to and impartially interpreting different viewpoints.* | 82.4 | | | | |
| *23p. Understanding the potential risks and impacts that an engineering solution or design may have* | 82.4 | | | | |
| *23k. Understanding the professional and ethical responsibilities of an engineer.* | 88.2 | | | | |
| *23q. Applying knowledge about current issues(economics, environmental, political, social, etc.) to engineering-related problems* | | 60.6 | | | |
| *23r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | 82.4 | | | | |
| *23n. Effectively expressing engineering-related ideas to others.* | | 60.6 | | | |
| *General pre-professional experience* | | | | | |
| *22c. Improve communication skills.* | 95.2 | | | | |
| *22d. Improve time management skills.* | | 71.5 | | | |
| *3a1. My undergraduate education has provided a solid background for my career.* | 90.5 | | | | |
| *Basic Sciences* | | | | | |
| *23a. Using my knowledge of mathematics to solve relevant engineering problems.* | | 64.7 | | | |
| *23b. Using my knowledge of chemistry to solve relevant engineering problems.* | | | 17.6 | | |
| *23c. Using my knowledge of physics to solve relevant engineering problems.* | | | | 47.1 | |

**Table C.22 continues**

| | | | | | |
|---|---|---|---|---|---|
| *Communication skills* | | | | | |
| *23l. Writing effectively.* | | **52.9** | | | |
| *23m. Making professional presentations.* | | **52.9** | | | |
| *Total* | **684.5** | **671.1** | **47** | **47.1** | **0** |
| *TOTAL Input from EC 2000 (a)* | **684.5** | | **47** | **47.1** | |
| *Coefficient of Eficiency Junior Level (b)* | **1** | | | | |
| *Total * c: Coefficients* | **684.3** | **609.5** | **46.99** | **47.09** | **0** |

**Table C.23 SENIOR OUTPUTS 00-01. Department A**

**SW Table**

| *Engineering professional and ethical behavior* | **MS** | | **N** | **P** | **MW** |
|---|---|---|---|---|---|
| *I.n. My ability to effectively express engineering related ideas to others.* | | **77.3** | | | |
| *1.o.My ability to listen and impartially interpret different viewpoints.* | **81.8** | | | | |
| *1.p. My understanding of potential risks and impact to the public of a proposed engineering solution.* | **81.8** | | | | |
| *1.k. My understanding of the professional and ethical responsibilities of an engineer.* | **95.5** | | | | |
| *1.q. My ability to apply knowledge about current issues to engineering-related problems* | | **54.5** | | | |
| *1.r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | **86.4** | | | | |
| *Engineering knowledge and skills* | | | | | |
| *1.a. My ability to use my knowledge of mathematics to solve relevant engineering problems.* | **90.9** | | | | |
| *1.d. My ability to use my knowledge of engineering to solve relevant problems.* | **81.8** | | | | |
| *I.e. My ability to design and conduct an experiment to obtain measurements or gain additional knowledge.* | | **77.3** | | | |
| *I.f. My ability to design and interpret a set of data to find underlying meaning.* | | **77.3** | | | |
| *I.g My ability to design a device or process to satisfy a given set of specifications.* | | **63.6** | | | |
| *1 I. My ability to formulate unstructured engineering problems.* | | **68.2** | | | |
| *1 j. My ability to use appropriate engineering techniques including software or lab equipment for problem solving.* | | **77.3** | | | |
| *1.l.My ability to write effectively.* | | **68.2** | | | |
| *Communication skills* | | | | | |
| *I. m. My ability to make effective presentations.* | **90.9** | | | | |
| *I.h. My ability to function effectively in different team roles.* | **86.4** | | | | |
| *Science knowledge* | | | | | |
| *1.b. My ability to use my knowledge of chemistry to solve relevant engineering problems.* | | **50** | | | |
| *1.c. My ability to use my knowledge of physics to solve relevant engineering problems.* | | **50** | | | |
| *TOTAL - Coefficients* | **695.5** | **663.7** | **0** | **0** | **0** |

**Table C.24 SENIOR INPUTS 00-01. Department B**

**SW Table**

| *Pre-professional engineering experience* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *22a. Solve engineering problems* | | 75 | | | |
| *23g. Designing a device or process to satisfy a given set of specifications.* | | 75 | | | |
| *22f. Understand engineering profession.* | 83.3 | | | | |
| *23d. Using my knowledge of engineering to solve relevant engineering problems.* | | 66.7 | | | |
| *23j. Using appropriate engineering techniques include software or lab equipment for problem solving.* | | 66.7 | | | |
| *23e. Designing and conducting an experiment to obtain measurements or gain additional knowledge about a process* | | 75 | | | |
| *23h. Functioning effectively in different team roles .* | | 66.7 | | | |
| *23i. Formulating unstructured engineering problems.* | | | 66.6 | | |
| *23f. Analyzing and interpreting set of data to find underlying meaning(s).* | | 75 | | | |
| *Engineering professional and ethical behavior* | | | | | |
| *23o. Listening to and impartially interpreting different viewpoints.* | | 75 | | | |
| *23p. Understanding the potential risks and impacts that an engineering solution or design may have* | | 66.7 | | | |
| *23k. Understanding the professional and ethical responsibilities of an engineer.* | | 66.7 | | | |
| *23q. Applying knowledge about current issues(economics, environmental, political, social, etc.) to engineering-related problems* | | 75 | | | |
| *23r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | | 66.7 | | | |
| *23n. Effectively expressing engineering-related ideas to others.* | | 75 | | | |
| *General pre-professional experience* | | | | | |
| *22c. Improve communication skills.* | | 62.5 | | | |
| *22d. Improve time management skills.* | | 62.5 | | | |
| *3a1. My undergraduate education has provided a solid background for my career.* | 85.7 | | | | |
| *Basic Sciences* | | | | | |
| *23a. Using my knowledge of mathematics to solve relevant engineering problems.* | | | 66.7 | | |
| *23b. Using my knowledge of chemistry to solve relevant engineering problems.* | | | 50 | | |
| *23c. Using my knowledge of physics to solve relevant engineering problems.* | | | 83.3 | | |

**Table C.24 continues**

| | | | | | |
|---|---|---|---|---|---|
| *Communication skills* | | | | | |
| *23l. Writing effectively.* | | | **50** | | |
| *23m. Making professional presentations.* | | | **50** | | |
| *Total* | **169** | **1050.2** | **366.6** | | **0** |
| *TOTAL Input from EC 2000 (a)* | **169** | **975.2** | **366.6** | | **0** |
| *Coefficient of Eficiency Junior Level (b)* | **0.8477** | | | | |
| *Total * c: Coefficients* | | **826.7** | **310.8** | | **0** |

**Table C.25 SENIOR OUTPUTS 00-01. Department B**

**SW Table**

| *Engineering professional and ethical behavior* | **MS** | | **N** | **PW** | |
|---|---|---|---|---|---|
| *I.n. My ability to effectively express engineering related ideas to others.* | | **50** | | | |
| *1.o.My ability to listen and impartially interpret different viewpoints.* | | **50** | | | |
| *1.p. My understanding of potential risks and impact to the public of a proposed engineering solution.* | **87.5** | | | | |
| *1.k. My understanding of the professional and ethical responsibilities of an engineer.* | | **62.5** | | | |
| *1.q. My ability to apply knowledge about current issues to engineering-related problems* | | **62.5** | | | |
| *1.r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | | **75** | | | |
| *Engineering knowledge and skills* | | | | | |
| *1.a. My ability to use my knowledge of mathematics to solve relevant engineering problems.* | | **75** | | | |
| *1.d. My ability to use my knowledge of engineering to solve relevant problems.* | | **75** | | | |
| *I.e. My ability to design and conduct an experiment to obtain measurements or gain additional knowledge.* | | **50** | | | |
| *I.f. My ability to design and interpret a set of data to find underlying meaning.* | | **75** | | | |
| *I.g My ability to design a device or process to satisfy a given set of specifications.* | | **62.5** | | | |
| *1 I. My ability to formulate unstructured engineering problems.* | | **62.5** | | | |
| *1 j. My ability to use appropriate engineering techniques including software or lab equipment for problem solving.* | | **75** | | | |
| *1.l.My ability to write effectively.* | | **50** | | | |
| *Communication skills* | | | | | |
| *I. m. My ability to make effective presentations.* | | **50** | | | |
| *I.h. My ability to function effectively in different team roles.* | | **75** | | | |
| *Science knowledge* | | | | | |
| *1.b. My ability to use my knowledge of chemistry to solve relevant engineering problems.* | | **62.5** | | | |
| *1.c. My ability to use my knowledge of physics to solve relevant engineering problems.* | | **50** | | | |
| *TOTAL - Coefficients* | **87.5** | **1062.5** | **0** | **0** | **0** |

## Table C.26 SENIOR INPUTS 00-01. Department C

### SW Table

| *Pre-professional engineering experience* | MS | PS | N | PW | M |
|---|---|---|---|---|---|
| *22a. Solve engineering problems* | | 66.7 | | | |
| *23g. Designing a device or process to satisfy a given set of specifications.* | | 76.7 | | | |
| *22f. Understand engineering profession.* | 91 | | | | |
| *23d. Using my knowledge of engineering to solve relevant engineering problems.* | | | 45.5 | | |
| *23j. Using appropriate engineering techniques include software or lab equipment for problem solving.* | | 72.7 | | | |
| *23e. Designing and conducting an experiment to obtain measurements or gain additional knowledge about a process* | | 63.6 | | | |
| *23h. Functioning effectively in different team roles .* | 90.9 | | | | |
| *23i. Formulating unstructured engineering problems.* | | 63.6 | | | |
| *23f. Analyzing and interpreting set of data to find underlying meaning(s).* | 90.9 | | | | |
| *Engineering professional and ethical behavior* | | | | | |
| *23o. Listening to and impartially interpreting different viewpoints.* | 81.8 | | | | |
| *23p. Understanding the potential risks and impacts that an engineering solution or design may have* | | 72.7 | | | |
| *23k. Understanding the professional and ethical responsibilities of an engineer.* | | 72.7 | | | |
| *23q. Applying knowledge about current issues(economics, environmental, political, social, etc.) to engineering-related problems* | 81.8 | | | | |
| *23r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | | 72.7 | | | |
| *23n. Effectively expressing engineering-related ideas to others.* | 100 | | | | |
| | | | | | |
| *22c. Improve communication skills.* | 86.6 | | | | |
| *22d. Improve time management skills.* | | 76.6 | | | |
| *3a1. My undergraduate education has provided a solid background for my career.* | 94.4 | | | | |
| *Basic Sciences* | | | | | |
| *23a. Using my knowledge of mathematics to solve relevant engineering problems.* | | 63.6 | | | |
| *23b. Using my knowledge of chemistry to solve relevant engineering problems.* | | | | | 54.5 |
| *23c. Using my knowledge of physics to solve relevant engineering problems.* | | | 45.5 | | |

**Table C.26 continues**

| | | | | | |
|---|---|---|---|---|---|
| *Communication skills* | | | | | |
| *23l. Writing effectively.* | | **63.6** | | | |
| *23m. Making professional presentations.* | | **45.5** | | | |
| *Total* | **717.4** | **810.7** | **9** | **0** | **54.5** |
| *TOTAL Input from EC 2000 (a)* | **717.4** | | **91** | **0** | **54.5** |
| *Coefficient of Eficiency Junior Level (b)* | **0.9939** | | | | |
| *Total * c : Coefficients* | **713.0** | | **90.5** | **0** | **54.2** |

## Table C.27 SENIOR OUTPUTS 00-01. Department C

### SW Table

| *Engineering professional and ethical behavior* | MS | PS | N | PW | MW |
|---|---|---|---|---|---|
| *I.n. My ability to effectively express engineering related ideas to others.* | | **71.1** | | | |
| *1.o.My ability to listen and impartially interpret different viewpoints.* | **94.7** | | | | |
| *1.p. My understanding of potential risks and impact to the public of a proposed engineering solution.* | **89.5** | | | | |
| *1.k. My understanding of the professional and ethical responsibilities of an engineer.* | **81.6** | | | | |
| *1.q. My ability to apply knowledge about current issues to engineering-related problems* | **86.8** | | | | |
| *1.r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | **89.5** | | | | |
| *Engineering knowledge and skills* | | | | | |
| *1.a. My ability to use my knowledge of mathematics to solve relevant engineering problems.* | **94.7** | | | | |
| *1.d. My ability to use my knowledge of engineering to solve relevant problems.* | **100** | | | | |
| *I.e. My ability to design and conduct an experiment to obtain measurements or gain additional knowledge.* | **81.6** | | | | |
| *I.f. My ability to design and interpret a set of data to find underlying meaning.* | **84.2** | | | | |
| *I.g My ability to design a device or process to satisfy a given set of specifications.* | **84.2** | | | | |
| *1 I. My ability to formulate unstructured engineering problems.* | **81.6** | | | | |
| *1 j. My ability to use appropriate engineering techniques including software or lab equipment for problem solving.* | | **78.9** | | | |
| *1.l.My ability to write effectively.* | | | | | |
| *Communication skills* | **97.3** | | | | |
| *I. m. My ability to make effective presentations.* | | **63.2** | | | |
| *I.h. My ability to function effectively in different team roles.* | | **68.4** | | | |
| *Science knowledge* | | | | | |
| *1.b. My ability to use my knowledge of chemistry to solve relevant engineering problems.* | | **57.9** | | | |
| *1.c. My ability to use my knowledge of physics to solve relevant engineering problems.* | **81.6** | | | | |
| *TOTAL - Coefficients* | **1147.3** | **339.5** | **0** | **0** | **0** |

**Table C.28 SENIOR INPUTS 00-01. Department D**

**SW Table**

| *Pre-professional engineering experience* | MS | P | N | P | M |
|---|---|---|---|---|---|
| *22a. Solve engineering problems* | | 71.4 | | | |
| *23g. Designing a device or process to satisfy a given set of specifications.* | | 71.4 | | | |
| *22f. Understand engineering profession.* | | 60 | | | |
| *23d. Using my knowledge of engineering to solve relevant engineering problems.* | | 70 | | | |
| *23j. Using appropriate engineering techniques include software or lab equipment for problem solving.* | | 70 | | | |
| *23e. Designing and conducting an experiment to obtain measurements or gain additional knowledge about a process* | | 60 | | | |
| *23h. Functioning effectively in different team roles .* | 80 | | | | |
| *23i. Formulating unstructured engineering problems.* | | 70 | | | |
| *23f. Analyzing and interpreting set of data to find underlying meaning(s).* | 80 | | | | |
| *Engineering professional and ethical behavior* | | | | | |
| *23o. Listening to and impartially interpreting different viewpoints.* | 80 | | | | |
| *23p. Understanding the potential risks and impacts that an engineering solution or design may have* | 90 | | | | |
| *23k. Understanding the professional and ethical responsibilities of an engineer.* | | 70 | | | |
| *23q. Applying knowledge about current issues(economics, environmental, political, social, etc.) to engineering-related problems* | | 60 | | | |
| *23r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | | | 60 | | |
| *23n. Effectively expressing engineering-related ideas to others.* | 80 | | | | |
| *General pre-professional experience* | | | | | |
| *22c. Improve communication skills.* | | 78.6 | | | |
| *22d. Improve time management skills.* | | 75 | | | |
| *3a1. My undergraduate education has provided a solid background for my career.* | 87.9 | | | | |
| *Basic Sciences* | | | | | |
| *23a. Using my knowledge of mathematics to solve relevant engineering problems.* | | | 60 | | |
| *23b. Using my knowledge of chemistry to solve relevant engineering problems.* | | | | 40 | |
| *23c. Using my knowledge of physics to solve relevant engineering problems.* | | | | | 50 |

**Table C.28 continues**

| | | | | | |
|---|---|---|---|---|---|
| *Communication skills* | | | | | |
| *23l. Writing effectively.* | **90** | | | | |
| *23m. Making professional presentations.* | | **70** | | | |
| *Total* | **587.9** | **826.4** | **120** | | **50** |
| *Coefficient of Eficiency Junior Level (b)* | **1** | | | | |
| *Total * c - Coefficients* | **587.9** | | **120** | **40** | **50** |

**Table C.29 SENIOR OUTPUTS 00-01. Department D**

**SW Table**

| *Engineering professional and ethical behavior* | **MS** | | **N** | **PW** | **MW** |
|---|---|---|---|---|---|
| *I.n. My ability to effectively express engineering related ideas to others.* | | **75.8** | | | |
| *1.o.My ability to listen and impartially interpret different viewpoints.* | | **75.8** | | | |
| *1.p. My understanding of potential risks and impact to the public of a proposed engineering solution.* | | **72.7** | | | |
| *1.k. My understanding of the professional and ethical responsibilities of an engineer.* | | **60.6** | | | |
| *1.q. My ability to apply knowledge about current issues to engineering-related problems* | **90.9** | | | | |
| *1.r. Recognizing the limitations of my engineering knowledge and abilities and knowing when to seek additional information* | **81.1** | | | | |
| *Engineering knowledge and skills* | | | | | |
| *1.a. My ability to use my knowledge of mathematics to solve relevant engineering problems.* | **87.7** | | | | |
| *1.d. My ability to use my knowledge of engineering to solve relevant problems.* | **93.9** | | | | |
| *I.e. My ability to design and conduct an experiment to obtain measurements or gain additional knowledge.* | | **78.8** | | | |
| *I.f. My ability to design and interpret a set of data to find underlying meaning.* | **84.8** | | | | |
| *I.g My ability to design a device or process to satisfy a given set of specifications.* | | **78.8** | | | |
| *1 I. My ability to formulate unstructured engineering problems.* | | **66.7** | | | |
| *1 j. My ability to use appropriate engineering techniques including software or lab equipment for problem solving.* | **84.4** | | | | |
| *1.l.My ability to write effectively.* | | **78.8** | | | |
| *Communication skills* | | | | | |
| *I. m. My ability to make effective presentations.* | **84.4** | | | | |
| *I.h. My ability to function effectively in different team roles.* | **93.9** | | | | |
| *Science knowledge* | | | | | |
| *1.b. My ability to use my knowledge of chemistry to solve relevant engineering problems.* | | | **27.3** | | |
| *1.c. My ability to use my knowledge of physics to solve relevant engineering problems.* | | **54.5** | | | |
| *TOTAL* | **701.1** | **642.5** | **27.3** | **0** | **0** |

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