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Enterprise Business Alignment Using Quality Function Deployment, Multivariate Data Analysis And Business Modeling Tools

Diala Gammoh
University of Central Florida

ENTERPRISE BUSINESS ALIGNMENT USING QUALITY FUNCTION DEPLOYMENT, MULTIVARIATE DATA ANALYSIS AND BUSINESS MODELING TOOLS

by

DIALA TAWFIG GAMMOH

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ABSTRACT

This dissertation proposes two novel ideas to enhance the business strategy alignment to customer needs. The proposed business alignment clock is a new illustration to the relationships between customer requirements, business strategies, capabilities and processes. To line up the clock and reach the needed alignment for the enterprise, a proposed clock mechanism is introduced.

The mechanism integrates the Enterprise Business Architecture (EBA) with the House of Quality (HoQ). The relationship matrix inside the body of the house is defined using multivariate data analysis techniques to accurately measure the strength of the relationships rather than defining them subjectively. A statistical tool, multivariate data analysis, can be used to overcome the ambiguity in quantifying the relationships in the house of quality matrix.

The framework is proposed in the basic conceptual model context of the EBA showing different levels of the enterprise architecture; the goals, the capabilities and the value stream architecture components. In the proposed framework, the goals and the capabilities are inputs to two houses of quality, in which the alignment between customer needs and business goals, and the alignment between business goals and capabilities are checked in the first house and the second house, respectively. The alignment between the business capabilities and the architecture components (workflows, events and environment) is checked in a third HoQ using the performance indicators of the value stream architecture components, which may result in infrastructure expansion, software development or process improvement to reach the needed alignment by the enterprise.

The value of the model was demonstrated using the Accreditation Board of Engineering and Technology (ABET) process at the Industrial Engineering and Management Systems department at the University of Central Florida. The assessment of ABET criteria involves an evaluation of the extent to which the program outcomes are being achieved and results in decisions and actions to improve the Industrial Engineering program at the University of Central Florida. The proposed framework increases the accuracy of measuring the extent to which the program learning outcomes have been achieved at the department. The process of continuous alignment between the educational objectives and customer needs becomes more vital by the rapid change of customer requirements that are obtained from both internal and external constituents (students, faculty, alumni, and employers in the first place).

To a friend indeed, a lover and a husband
Suleiman Alsweiss
Whose encouragement and care helped me achieve what I aimed for, who colored my life and taught me what “PURE LOVE” means

To my parents
Tawfig Gammoh & Afaf Owais
For bringing me to this life and teaching me all the values I need to live, love and succeed

To my lovely sisters
Fatina and Tala
For having a strong belief in my capabilities

To my beloved country
Jordan
Whom I promised to serve all my life with fidelity

And to all who thought I cannot do it…

I dedicate five years of determination, patience and passion

Yours
Diala

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LIST OF ACRONYMS/ABBREVIATIONS

ABET	Accreditation Board of Engineering and Technology
AHP	Analytical Hierarchy Process
ANP	Analytical Network Process
BOV	Business Operational View
CPP	Complex Product Planning
CR	Customer Requirements
CWQ	Customer Windows Quadrant
DARP	Dynamic Analysis Reduction Process
DFE	Design For Excellence
DFSS	Design For Six Sigma
DR	Design Requirements
EBA	Enterprise Business Architecture
EC	Engineering Characteristics
E-PAF	E-Business Planning and Analysis Framework
ET	Endo-Tracheal

FQFD	Fuzzy Quality Function Deployment
FSV	Functional Services View
HoQ	House of Quality
IE	Industrial Engineering
IEMS	Industrial Engineering and Management Systems
KE	Kansei Engineering
KMO	Kaiser-Mayor-Olkin
MC-ERP	Mass Customization-Enterprise Resource Planning
MoI	Method of Imprecision
MSA	Measuring of Sampling Adequacy
OEM	Original Equipment Manufacturer
PCA	Principal Component Analysis
QFD	Quality Function Deployment
RF	Relationship Factor
RF	Radio Frequency
SCM	Supply Chain Management

SQFD	Software Quality Function Deployment
STFN	Symmetrical Triangular Fuzzy Numbers
TimTM	Total Imagining Matrix
TQM	Total Quality Management
UML	Unified Modeling Language
VOC	Voice of the Customer
VSM	Value Stream Mapping

CHAPTER 1 INTRODUCTION

1.1 Introduction and Document Outline

The definition of quality to the consumer is the ability of a product or service to meet customer needs and expectations. Nowadays; meeting customer needs is not the target for most of the companies as consumers would like the companies to exceed their expectations. This is called customer satisfaction where a product or service can go beyond customer needs which in return create a feeling of brand loyalty toward the company.

Quality Function Deployment (QFD) was originally developed by Yoji Akao in 1966 in Japan, and used by many companies to assure that their products or services meet their customers' needs and expectations known as the voice of the customer (VOC). QFD translates the customer needs into engineering characteristics to help in the design of a new product or service.

QFD became popular as a tool to design for quality. For instance; QFD has been used in Toyota since 1977. Using 1977 as a base and upon introducing four new van-type vehicles, Toyota reported 20% reduction in start-up costs on the launch of a new van in October 1979, a 38% reduction in November 1982, and a cumulative 61% reduction in April 1984. (Baumer et al.)

QFD acts as a structured approach that helps companies understand the customers' requirements, their priorities, identify their relationships with the technical specifications and then evaluate the company's performance in comparison to its competitors in the market. At this point, business and market analysis can be done to assess the actual performance of producing a product or a process based on customer needs and desires. Identifying the company's selling points and deployment becomes a very crucial outcome of the HoQ that most of the companies are curious about.

Business enterprises have recognized quality as an important metric to maintain their strategic objectives. As the economy is randomly changing, there is no stable or predictable business. Business requirements and goals are changing in a pace that has to cope with the business strategic objectives. Nevertheless; customer expectations are in a rapid change which affects the way people are doing or maintaining business.

The companies that survived today's economical crisis have to make quick corrections to bridge the gap between their business plans, strategies and outcomes based on a real and accurate input. Yet amazingly, a mere 7% of employees today fully understand their company's business strategies and what's expected of them in order to help achieve the company goals. (Kaplan et al., 2001).

In their recent study; Berggren et al. (2006) found a strong relationship between a company's financial performance and an effective goal setting process as illustrated in Figure 1.1 44% of the stronger performers have almost 100% aligned goals at the managerial level while none of the weaker performers do.

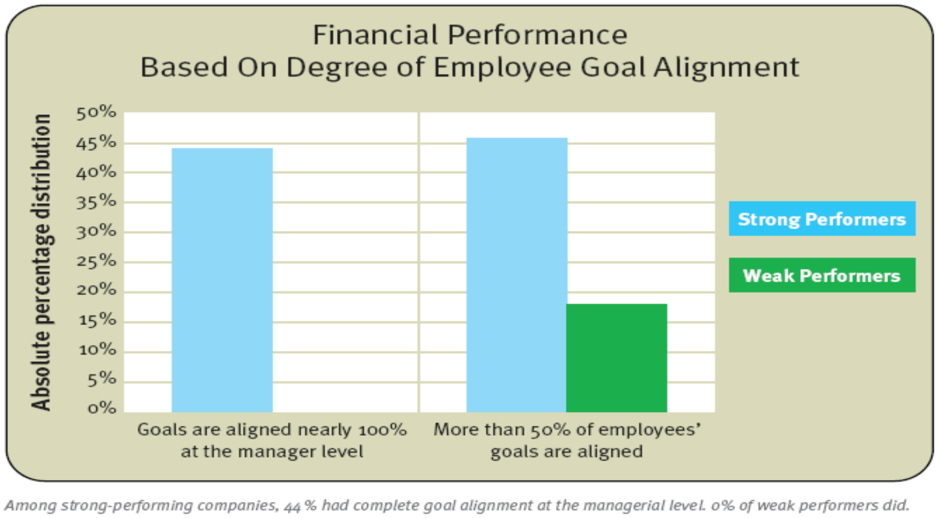


Figure 1.1 Financial performance based on degree of employee goal alignment (Berggren et al., 2006)

Companies like Dell, ING DIRECT, CEMEX, Wal-Mart, and others execute their strategy by first building their foundational architecture. The foundation for execution results from carefully selecting which processes and IT systems to standardize and integrate. They also embed technology in their processes so that they can efficiently and reliably execute their core operations. Their strength relies in their ability to decide which operations they must execute well; they implement IT systems to digitize those operations (Ross et al., 2006).

Ross et al. (2006) surveyed 103 U.S. and European companies about their IT-enabled business processes. Thirty-four percent of those companies have digitized their core processes. Relative to their competitors, those companies have achieved high profitability, experienced a faster time to market, and gotten more value from their IT investments.

Enterprise business architecture (EBA) is the organizing logic for business processes and IT infrastructure, reflecting the integration and standardization requirements of the company's operating model. The enterprise architecture provides a long-term view of a company's processes, systems, and technologies so that individual projects can build capabilities – not just fulfill immediate needs (Ross et al., 2006).

This research proposes a novel methodology that integrates EBA with the HoQ to enhance the business strategy alignment to customer needs. The relationship matrix inside the body of the house is defined using a multivariate data analysis technique to accurately measure the strength of the relationships rather than defining them subjectively which is the most common critique about QFD in the literature. To project the changes that occur within the IT related business processes, an intermediate interface between business strategy and its deployment is needed. The Unified Modeling Language (UML), an extension to the EBA, can be utilized to serve as a realization to this interface to enhance the alignment in IT-enabled business processes. However; the scope of this research work does not include the UML implementation, it just refers to its importance in the enterprise business alignment in section 3.2.

1.2 Research Problem Statement

Companies need a business strategy that is operational, evolving and periodically updated to reflect any changes in customer needs in the market place; this raised an opportunity for improvement. Business enterprises lack accurate measures and clear understanding for the enterprise holistically that can keep it aligned in all of its complex dimensions with customer requirements.

1.3 The Need of a New Framework

In business enterprises, there is a need to create a holistic framework that helps provide an accurate business alignment to the enterprise business strategy to ensure that the capabilities of the business meet the customers' needs and demands. Companies must realize that EBA is a modeling tool that has a customer focus based on an overall view of the enterprise. Figure 1.2 demonstrates unclear relationships represented by the arrows between the customer requirements, strategies and processes; it doesn't group the processes according to their value to the customer or to their relationships to the enterprise strategic goals. The relationships are vague and confuse management to decide on the degree of alignment between customer needs, strategic goals and processes.

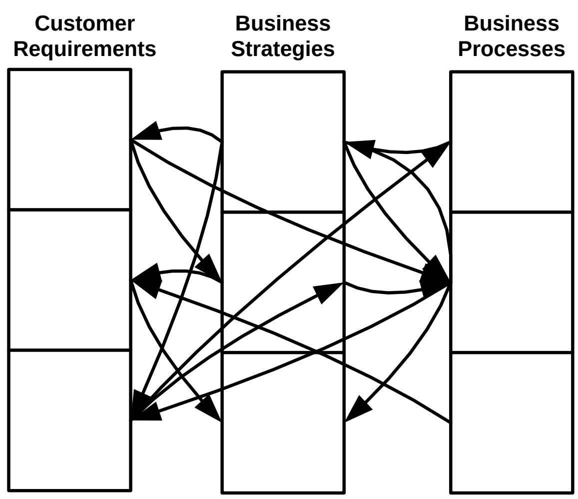


Figure 1.2 Relationship between customer requirements to strategies and processes

This research work defines a unique framework of integrating business architecture with QFD to reach an optimal level of alignment between business strategy and customer expectations. However, QFD still needs an enhancement in identifying its relationships matrix; it has to use a quantitative approach especially in enterprises with many interrelated dependent variables that affect the outcome results of a certain product or process. A statistical tool such as multivariate data analysis can be used to overcome the ambiguity in the house of quality matrix.

Business enterprises with IT initiatives can use UML as part of their framework as a unified modeling language to build IT- related models that are precise, unambiguous and complete, and map it into a programming language such as Java, C++, or Visual Basic, or even to tables in a relational database or as persistent store of an object-oriented database. UML implementation is not in the scope of this research work; however its importance and relationship to our proposed framework is described in section 3.2.

1.4 Objectives of this Research

- Develop a framework that:
    - Enhances the alignment of business strategy to customer expectations using quality function deployment in the basic conceptual model context of the enterprise business architecture (explained in section 3.2.2); this means that the framework takes the same flow of the enterprise business architecture. However; building the architecture is not in the scope of this research work.
    - Uses multivariate data analysis as a statistical tool to quantify the relationships in the house of quality matrix.

- Validate the proposed framework using a real application.

1.5 Contributions of this Research

- A novel business alignment clock to represent two states of the alignment between enterprise strategic goals, capabilities, processes and customer requirements
- A dynamic mechanism that uses quantitative houses of quality to provide enterprises with accurate guidance about the requirements needed to align their strategies with customer requirements.
- Incorporation of the enterprise business architecture basic conceptual model in the proposed framework (explained in section 3.2.2).

1.6 Value of Research

The value of this research derives from the importance of introducing an evolving and operational framework that accurately measures the degree of alignment between enterprises' strategies, capabilities and processes based on a change in customer demands. This increases the efficiency of quality assurance in business enterprises since the use of a quantified house of quality in a business architecture context leads to more precise decisions about the requirements incorporated in the design of a process or a product. Using UML can increase the efficiency of translating this design into IT architecture at the lowest level of the framework implementation.

Investment in the design of quality will pay off to the business enterprise on the short and long run. UML implementation is not in the scope of this research work; however its importance and relationship to our proposed framework is described in the section 3.2.

1.7 Document Outline

This document has been divided into six chapters. The first chapter presents the introduction, problem statement and contribution of this research work. Chapter two is a literature review on QFD, EBA and UML applications in addition to the approaches used to quantify customer and technical requirements. The novel business alignment clock along with its mechanism is presented in Chapter three while chapter four shows an implementation of the framework. Chapter 5 integrates the components of the proposed mechanism and provides the final results while Chapter 6 provides the conclusions, next steps and future work of this research work.

CHAPTER 2 LITERATURE REVIEW

This literature is divided into three sections; the first section reviews QFD applications in which the house of quality has been deployed, the second section presents the quantitative approaches that have been used in the HoQ matrix, the third section presents the applications in which the EBA has been used along with QFD to map business architecture in enterprises that use software solutions.

2.1 Quality Function Deployment Applications

QFD also known as the house of quality is a technique that has been evolving since 1966, it was originally developed by Yoji Akao in Japan. Its main purpose is to deploy the voice of the customer throughout the design stages of a product planning or a process development. It allows the enterprise to organize its information as an initiative to projects with high level of quality. Figure 2.1 presents the general structure of the HoQ matrix.

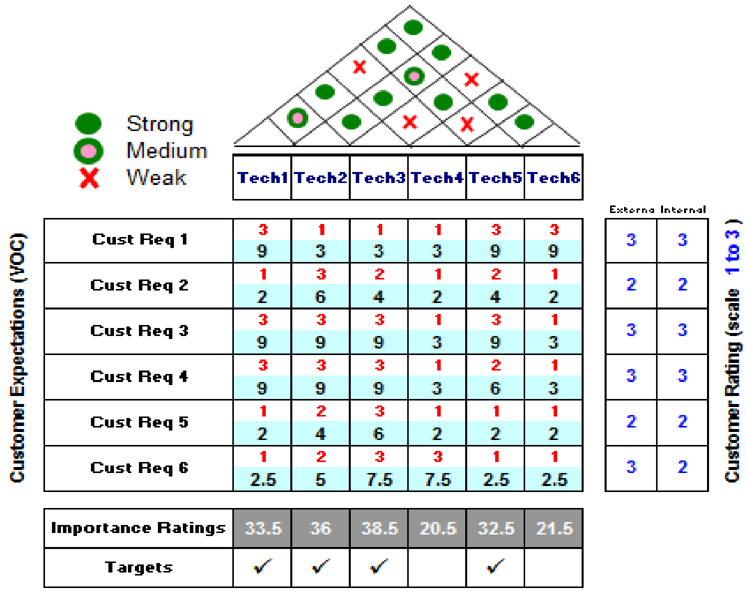


Figure 2.1 General structure of the HoQ (QFD)

The main components of the HoQ are the technical requirements and the customer requirements denoted as the HOWs and the WHATs respectively which are prioritized according to their importance. The relationship between the customer requirements and the technical requirements are identified in the body of the house, while the relationships between the technical requirements are identified in the roof of the house.

A benchmarking analysis could be done in the house comparing customer requirements among peer competitors in the market and to evaluate the actual performance of the company to the classified requirements. The columns weights at the very bottom of the house represent the most important technical requirement that has to be tackled first.

Some of the most common usage of QFD is due to its ability of providing structured information about a product; it allows engineers to prioritize technical and engineering design characteristics Teck Khim et al. (2000). However; literature has mentioned many difficulties in its application, Chan et al. (2005) addressed the difficulty in defining the correlations between the desired quality by the customer (the WHATs) and the technical requirements (the HOWs), they think that most of the information generated in the HoQ relies on human beings' perceptions that are imprecise in terms of breadth of meaning. Ambiguity appears in both the "voice of the customer" and "the voice of the technicians".

Ramasamy et al. (2004) described the weights given to the engineering characteristics (EC) which are a translation of the voice of the customer as crisp; those crisp weights can lead to a wrong prioritization of the engineering characteristics (EC) which is not reliable for the HoQ design. However; Martins et al. (2001) found the difficulty in working in groups which don't have enough knowledge about using the method could lead to unreliable use of the HoQ results. These difficulties acted as barriers that prevented the use of the HoQ in many companies. Additionally; Camevalli et al. (2008) described the benefits of the HoQ application as intangible benefits that are related to improvements in the project management only; this discourages the use of HoQ since tangible benefits may or may not occur with QFD applications.

However; QFD has been used tremendously as an effective tool in many applications, among them is to develop a strategy ; Dikmen et al. (2005) study's findings showed a successful implementation of QFD in housing projects as they used it to facilitate marketing decisions. In the construction industry, usually the client needs and requirements are not treated systematically and they are neglected as the project goes on. QFD was able to track client expectations from the start till the end of the project and reduced uncertainty. Jalham et Al, (2006) used QFD in the manufacturing strategy formulation process to provide the basis for selection between options in each of the formulation stages. They also extended the use of QFD from identifying a manufacturing strategy into deploying it into action plans and tasks. A full documentation of the whole process was able to bridge the gap between manufacturing and business strategy.

QFD was also used to help implant methods, norms, etc. For instance, Ramaswamy et al. (2002) showed in their study to just-in-time implementation in small and medium enterprises that QFD can be implemented successfully through helping the enterprise formulate an action plan for improving system performance and they suggested that the QFD is best carried out at regular intervals as situation changes over time. Yang el al (2006) used QFD to determine critical ERP (Enterprise Resource Planning) implementation items in a semiconductor related industry in Taiwan; they used it additionally as a tool to evaluate the strengths and weaknesses of a semiconductor.

Moreover, QFD has been used for product and service development. In product development; Booysen (2006) used QFD to develop a medical product which is a device for fixing an Endo-tracheal (ET) tube in a patient during an aesthesia, as it is common for an ET tube to move and/or become dislodged due to various extraneous reasons. If the tube deviates from the correct position it can cause one or both lungs to collapse, which can be fatal. Implementing QFD to improve this medical device helped in holding an ET tube in place in a more secure manner.

As for service development; González el al (2008) applied the combination of Kansei Engineering (KE) with QFD to improve e-banking services, they thought that allowing the use of both tools will enable the organization to provide the exact e-commerce services needed by the customer to achieve the highest level of customer satisfaction. Kansei is a Japanese term which means a psychological feeling or image of a product. Kansei engineering refers to the translation of consumers' psychological feeling about a product into perceptual design elements. Kansei engineering is also sometimes referred to as "sensory engineering" or "emotional usability." (Ergosoft laboratories, 2009).

Bier et al. (2001) used QFD to construct a higher education curriculum that meets the customer needs at RainStar University. To ensure that the curriculum incorporated all the required competencies of its customers, they measured the following:

1. How strongly each course addressed the terminal competencies,
2. Whether there were sufficient learning experiences for the students to master each competency,
3. How important each competency was in the overall curriculum,
4. and how important each course was in the curriculum.

RainStar University used six steps to completing a QFD matrix: identify the customers, define the terminal competencies of the product, place the competencies into the first column of the matrix, have the panel of experts rank each competency, place each course in the curriculum into a double column, and examine each competency and assign a relationship factor (RF) to each course. RainStar believes QFD matrices can not only help design the curriculum, but also keep an entire academic unit focused on the importance of each course in the final product.

Bolt et al. (1999) applied QFD; they called it Jurrasic QFD, to integrate service and product quality function deployment. Their studies showed how QFD can be customized to a specific project, especially to design a tangible product, an animatronics dinosaur to be used in a service operation (theme park attraction). Their goal was to incorporate the spoken and unspoken needs of their customers who are the theme park visitors into their HoQ matrix.

They thought of using the Kano's model, a theory of product development and customer satisfaction developed in 1980's, to gather customer requirements as it was one of the most tools used in literature for classifying customer requirements which are the normal requirements, the expected requirements and the exciting requirements, but Kano found that the exciting needs which are most tied to adding value are invisible to the customer and provider, further they change over time, technology, market segment, etc. Kano's model for customer requirements is shown in Figure 2.2.

Bolt et al. think that understanding the customer requirements is best done by the QFD team who are going to observe, listen and record problems that customers experience and the opportunities they wish to seize.

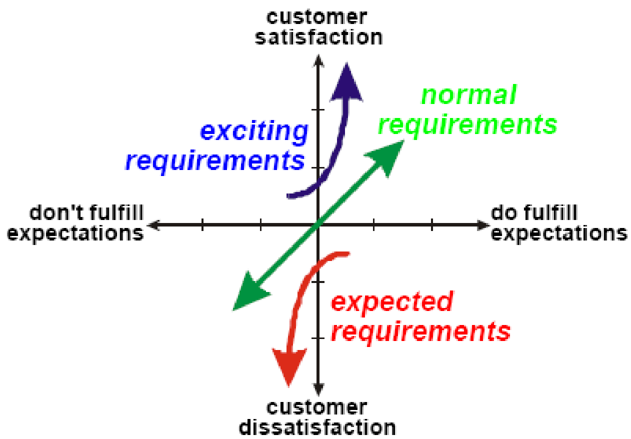


Figure 2.2 Kano's model of customer (Bolt et al., 1999)

Another domain in which QFD has been applied is software development. For instance; Buyukozhan et al., (2005) used QFD to develop word processing software based on customer needs. The customer requirements hierarchy was decided by the development experts while software users (three focus groups, namely secretarial, business and home computer users) evaluate the customer requirements based on their needs.

Liu et al. (2006) presented an innovative quantitative method of setting technical targets in Software QFD (SQFD) to enable analysis of impact of unachieved target values on customer satisfaction. It was based on assessment of the impact of technical attributes on satisfaction of customer requirements.

QFD was also used in the literature as a planning tool. Milan et al. (2003) used QFD in planning soil tillage, they were able to define that the most important characteristics to attend seedling demands were the furrow width and depth, and clod sizes.

Jiang et al. (2007) used QFD as an architecture that integrates six sigma and design for excellence to enable manufacturers to differentiate a product in terms of quality prior to the actual production process. Design for Excellence (DFE) can integrate with QFD in converting demanded qualities into quality characteristics while Design for Six Sigma (DFSS) can integrate with QFD in the design process of a product.

2.2 Quantitative Approaches Used to Enhance QFD

Many critiques were directed to the methods used in identifying relationships and priorities in the HoQ matrix. Gilb (2008) has criticized QFD as the customer requirements are not usually well defined, and the target value is not well specified. He summarized the QFD weaknesses as follows:

- Lack of a clearly defined scale of measure.
- Lack of information about when the level must be delivered.
- Lack of information about whether the level needs to be delivered to the entire system or on to some critical components only.
- Lack of clarity of whether this target value is a constraint or a desired level.
- The "technical evaluation" is vague, subjective, and unhelpful and the "importance rating" of the designs seems a useless subjective stipulation.
- The "interactions" roof of the house of quality that is subjectively defined and not informative.
- QFD does not identify the many stakeholders who have requirements including the noncustomer/user stakeholders.

Consequently QFD cannot include all critical to success stakeholders requirements. However; literature showed so many successful implementations of the HoQ in different applications as shown in the first section of chapter two.

The aim of this section of the literature review is to address the feasibility of different schemes used to quantify the HoQ matrix relationships and priorities as many doubts on the decisions made based on the HoQ matrix were mentioned in the literature. Since most of the relationships and prioritization techniques were subjectively defined, seeking a quantitative approach that can be used to quantify those relationships is crucial. This section includes the quantitative approaches that were used in any application that relies on getting customer requirements.

Fuzzy logic either alone or in combination with other methods and tools inside the quality matrix was used to prioritize or identify the importance of the demanded quality as one of the recommendations in the literature review of QFD in addition to identifying the relationships between customer and technical requirements. Chen el al (2008) considered not only the inherent fuzziness in the relationships between customer requirements (CRs) and design requirements (DRs), but also those among DRs.

Chan et al., (2005) suggested using a symmetrical triangular fuzzy numbers (STFNs) to capture the vagueness in people’s linguistic assessments. Instead of using the quite subjective sales-point concept, an entropy method is introduced to conduct competitive analysis and derive competitive priority ratings. They implemented a 9-step house of quality model; those steps are summarized in Figure 2.3.

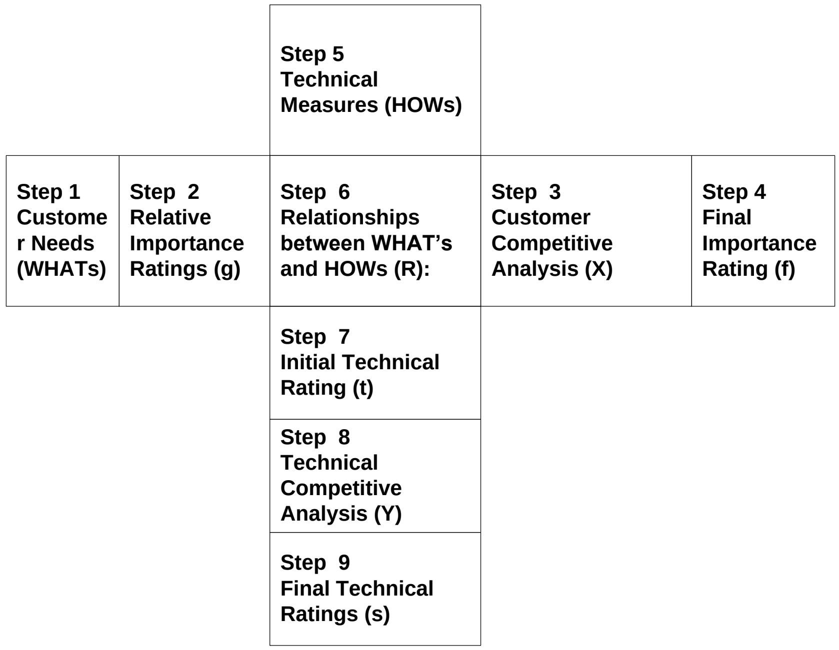


Figure 2.3 A 9-step house of quality (HoQ) – quantitative description (re-illustrated figure) (Chan et al., 2005)

Another trend found is the use of the Analytic Hierarchy Process (AHP) method and the Analytic Network Process (ANP) in the HoQ. Patrovi (2006) used AHP to determine the strength of the relationship between the row and column variables of each matrix and used ANP to determine the strength of synergistic effects among column variables. Patrovi implemented QFD at ABC Inc, which was a world's leading manufacturer of all digital mass measurement products for industrial use.

Patrovi model integrates AHP and ANP in a modified HoQ, the main purpose of this model is to help in the facility location decision taking into consideration both external (customer wants, status of competition, and characteristics of location) and internal criteria (critical internal processes) that sustain competitive advantage. The model does not eliminate subjectivity completely but it adds quantitative precision to an otherwise ad-hoc decision-making process.

Additionally, in contrast to other recently developed quantitative models, competitors' status were included for facility location analysis. Figure 2.4 represents the proposed model by Patrovi.

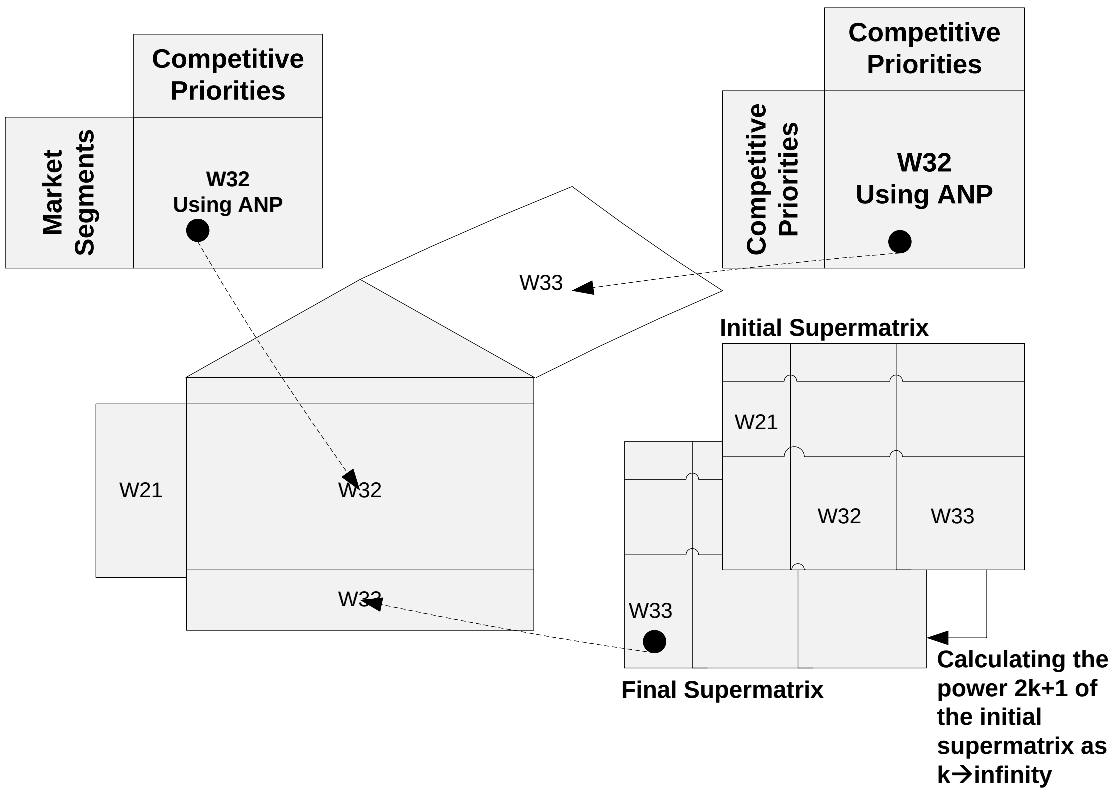


Figure 2.4 Integrating AHP, super matrix into modified QFD (re-illustrated figure) (Patrovi, 2006)

Prioritizing the customer requirements is very important in the QFD process, Wasserman (1993) proposed a linear programming model to prioritize customer requirement in the HoQ matrix. Kwong et al. (2002) used a fuzzy AHP with an extent analysis approach to determine the importance weights for the customer requirements. They used this approach in a hair dryer design; they converted the customer assessments into a set of triangular fuzzy numbers. However, triangular fuzzy numbers may not be applicable in all industry applications.

Khoo et al. (1996) proposed a fuzzy quality function deployment (FQFD) to study the basic design requirements of a flexible manufacturing system, their approach used the possibility theory and a fuzzy arithmetic to build the HoQ matrix, the authors claim that this approach is capable of removing ambiguity and uncertainty in the prioritization and correlation process. The framework of the proposed fuzzy QFD system is demonstrated in Figure 2.5

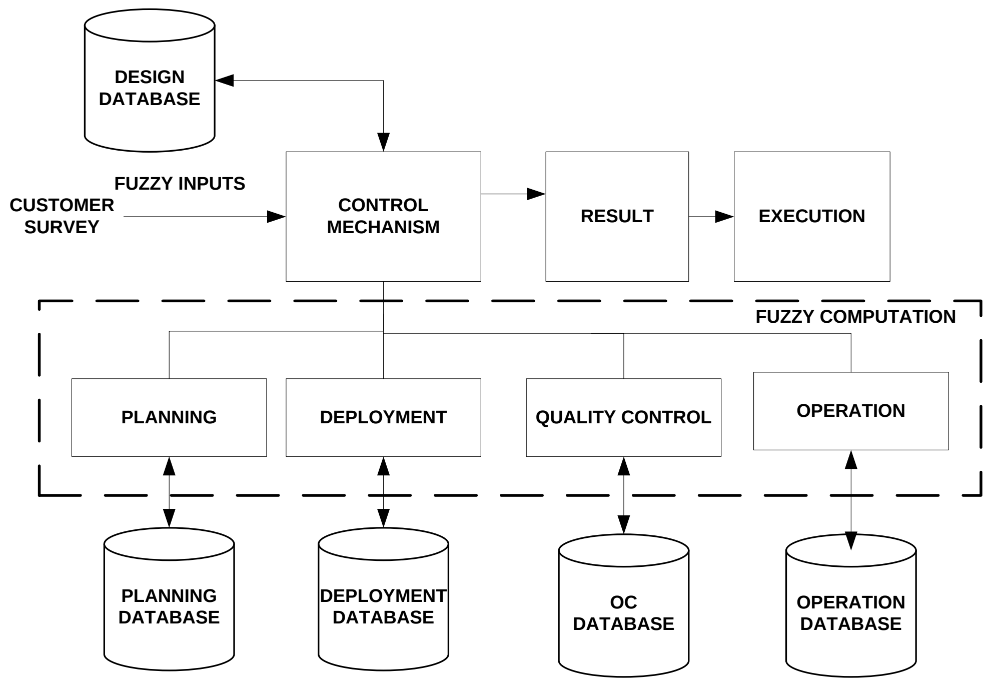


Figure 2.5 The framework of the fuzzy QFD system (re-illustrated figure) (Khoo, 1996)

Chen et al. (2008) built a fuzzy QFD program modeling approach using the method of imprecision. Fuzzy set theory was embedded into a QFD framework and a novel fuzzy QFD program modeling approach to complex product planning (CPP) was proposed to optimize the values of EC by taking the design uncertainty and financial considerations into account, this was done because the current QFD approaches were unable to cope with CPP characterized by involving multiple ECs associated with significant uncertainty. In the proposed methodology, fuzzy set theory was used to account for design uncertainty; the method of imprecision (MoI) was employed to perform multiple-attribute synthesis to generate a family of synthesis strategies by varying the value of s, which indicated the different compensation levels among ECs. The proposed methodology allowed QFD practitioners to control the distribution of their development budget by presetting the value of “s” to determine the compensation levels among ECs. Figure 2.6 represents a flowchart of this methodology:

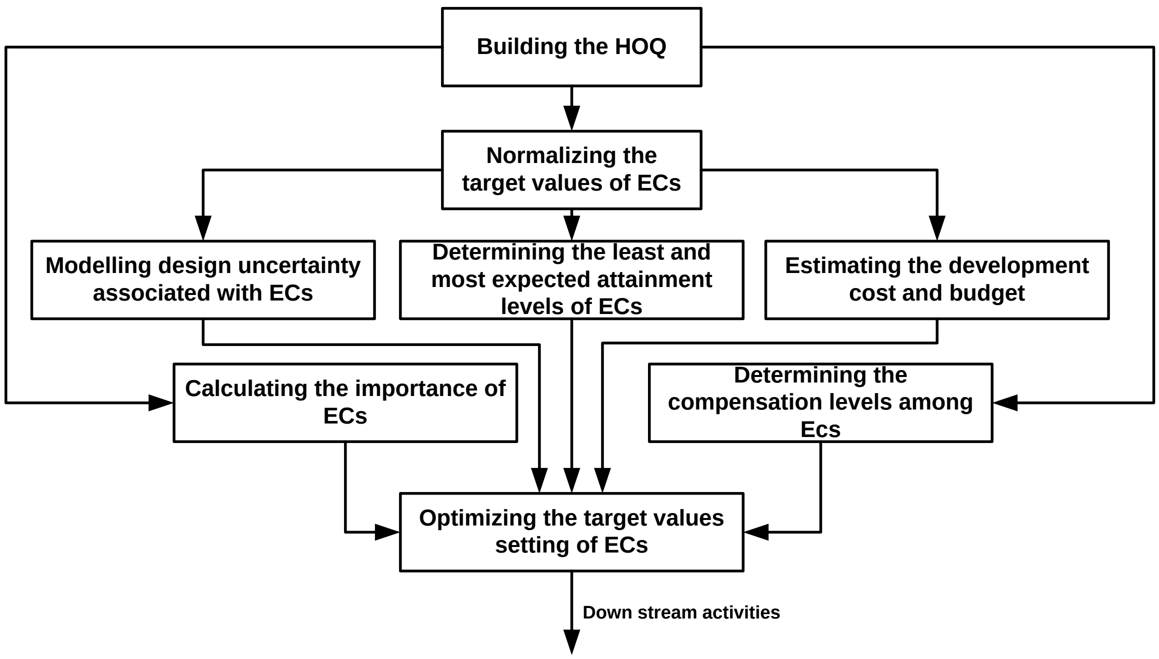


Figure 2.6 Flowchart of the proposed methodology (re-illustrated figure) (Chen et al., 2008)

Kazmar et al. (2001) suggested a qualitative reasoning for decision synthesis to better utilize qualitative models that engineers already develop to support dynamic decision making processes.

Researchers introduced an alternative to QFD which utilizes the approximate relationship matrix to quantitatively develop a global feasible region for the decision problem. The method can be viewed as an extension of monotonicity analysis to develop a normalized system model with specifications, solve the global feasible space, and identify globally desirable settings for the decision variables and the performance attributes. The method also enabled the generation of correlation matrices between multiple decision variables and multiple performance attributes.

Unlike other traditional decision support approaches, changes in the importance weightings to tighten or loosen performance specification can significantly change the set of active constraints and the topology of the solution. The development of the qualitative reasoning approach required generation and normalization of qualitative decision models. An extensive simplex method was then described to generate the global feasibility solution.

Trappey et al. (1996) developed a formal QFD to improve retail services which helps retails to structure their knowledge and information for decision making processes. The QFD was built based on a computer based algorithms, they developed an object-oriented prototype which incorporates new algorithms for prioritizing the VOC items. The retail HoQ practice procedure is shown in Figure 2.7.

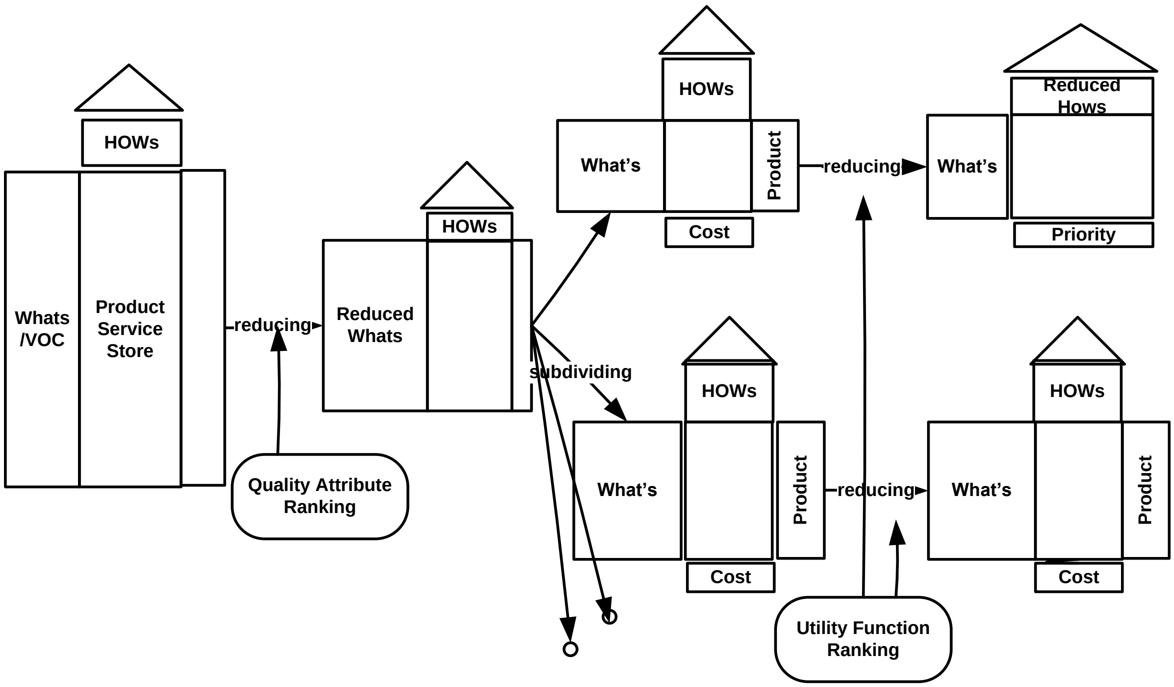


Figure 2.7 A retail HoQ practice procedure (re-illustrated figure) (Trappey et al., 1996)

The two ranking methods that are incorporated in this study is the quality attribute ranking method and the utility function ranking method as shown in Figure 2.7.

The quality attribute ranking is developed to accurately measure the VOC, structuring the customer's needs and rating the priorities of these needs. This methodology assumes that a multi-attribute questionnaire is used to record the VOC and a subset of the most critical attributes is created (the WHATs). The utility function ranking method is used to rank and reduce the HOWs to provide the greater customer satisfaction within the allowed cost. The advantage of using the reduced HoQ is to allow managers to focus on the critical requirements.

Trappey et al. (1996) implemented the proposed HoQ using an interactive software environment to automate the decision process by selecting the object-oriented programming environment. One concern about this automated approach is that it requires accurate data input from various sources.

Yan et al. (2005) used neural network techniques to improve conventional QFD technique in terms of effective design knowledge handling in product concept development.

Teck Khim et al. (2000) used the factor analysis technique to quantify the relationships among the technical requirements in a house of quality built for device modeling. They studied the correlation among the various parameters in a device as their values were generated from the device model. Factor analysis technique is one of the common and effective methods for such analysis; it has three major phases, factor extraction, factor rotation and factor score computation. This technique helps in identifying the smallest number of common factors that best explains or accounts for the correlation among the characteristics using the computed correlation matrix; it also helps in identifying the pattern, communalities and the unique variances of the characteristic. Through the use of factor analysis to analyze further on the "roof" selection of the HoQ, it was possible to reduce and identify the more dominating characteristics that are detrimental to the performance of the device.

Gonzalez et al. (2008) used QFD along with benchmarking analysis and other innovative quality tools to develop a new customer-centered undergraduate curriculum in supply chain management (SCM). They used QFD and benchmarking to develop a VOC matrix. Using information from the matrix, a new customer-oriented SCM undergraduate program was designed.

The research methodology was implemented through three phases; the first phase was to gather and analyze the information using survey distributed among a group of companies that hire professionals in the area of supply chain management and logistics, researchers used statistical analysis such as dynamic analysis and factor analysis in order to classify, reduce and rank the customer expectations gathered in the survey. The outcome of this phase was the grouping of customer expectations into common customer requirement categories.

The second phase was to build the house of quality with the benchmarking analysis; they used the dynamic analysis reduction process (DARP) as a tool to reduce the number of variables. This tool considers the interrelationship among variables and groups similar variables using the direct and indirect influences in the main variable. The customer windows quadrant (CWQ) was used as analytical tool to cluster and classify customer expectation from the customer's perspective.

Parkin et al. (2002) used statistical techniques with the HoQ such as half-normal plots, correlations, principal component analysis (PCA) and factor analysis. They described those as extremely flexible techniques that help in decision making at various stages of the development process. They applied these techniques in their study to the original equipment manufacturer (OEM) company which was able to establish aspects for improvement within their process and plan accordingly.

Glen et al. (2005) applied QFD to Lifestyle Company for producing pens. They built a hierarchy diagram which represents the transition from the qualitative study of lifestyle to the quantitative study of how best to achieve it with the new product. To quantify the HoQ, they used the powerful analytical tools common in market research which is the multivariate analysis.

Quantification helps in explaining which of the lifestyle words best represents the market segment, which design elements best explain the lifestyle words, and which specification or performance level of those design elements optimizes the lifestyle experience.

Krieg et al., (2002) used qualitative and quantitative approaches in order to get a comprehensive understanding of the market requirements to a new technological solution at Siemens for the MAGENTOM Avanto product which is the first MR scanner with TimTM Technology and Audio Comfort (TimTM is an abbreviation of Total Imaging Matrix). This technology allows seamless integration of 76 local radio frequency (RF) antennas with 32 receiver channels.

The qualitative methods are for example customer focus groups, sales advisory boards and interviews, while quantitative studies like surveys or a conjoint analysis which can provide representative statistics. Conjoint analysis was described as an excellent tool to determine the customer's value system. The challenge with conjoint methods for MR systems and probably for other products as well, was the limited amount of features and attributes levels to describe such a complex product. The authors think that the integration between the HoQ and conjoint analysis add adequacy to the decision based process but they were restricted to the processes with few attributes.

Pullman et al. (2002) did a thorough comparison for the use of quality function deployment and the conjoint analysis in a new product design, each method was implemented separately to compare the advantages of using one over the other. Many of the optimal design features were the same using QFD and conjoint analysis; there were also some strengths of using one over the other.

According to Pullman et al. (2002) study, the conjoint analysis strengths were summarized as follows:

- Conjoint analysis was easier to compare the most preferred features that maximize sales to profit maximizing features and also to develop designs that optimize product line sales or profits.
- Conjoint analysis better captured customers' current preferences for product features.
- Conjoint analysis usually does a better job of representing current customer preferences than QFD:
    - Consumer preferences or choices were directly decomposed into consumer utilities for features in conjoint analysis as opposed to a more indirect route where design team judgment was used to convert consumer needs to engineering characteristics, then to design features in QFD.
    - Individual-level modeling used by conjoint analysis substantially reduce the “fallacy of the majority” problems where group averages can mask important difference in either the importance or the desired level of a feature.

The QFD strengths were as follows:

- QFD used to highlight the fact that certain engineering characteristics or design features had both positive and negative aspects which represents the degree of correlation.
- QFD also highlighted the importance of starting explicitly with customer needs, regardless of which method is used.
- QFD captured what product developers thought would best satisfy customer needs.

However; the strengths and weaknesses of these approaches (QFD, Conjoint Analysis) suggest that they are complements rather than substitutes. Both QFD and conjoint analysis can be viewed as complementary approaches that should be conducted simultaneously; each providing feedback to the other. QFD's ability to generate creative or novel solutions should be combined with conjoint analysis' ability to forecast market reaction to design changes.

For example, conjoint analysis could be used first to determine the most important features for a subsequent QFD study. Alternatively, after QFD has screened the problem down to a smaller number of features, conjoint analysis could be used to refine feature levels and improve predictions. It is recommended to use both in a hybrid approach that would start with an elicitation of customer needs and then simultaneously do a pilot conjoint analysis and proceed through the first two houses of QFD somewhat independently.

2.3 Enterprise Business Architecture (EBA)

Business enterprises face a problem in aligning their business strategies especially when they have several systems running simultaneously. They use business architecture to understand and assess the business processes, understand opportunities and indicate requirements to achieve the desired business goals.

Whittle et al. (2005) defined EBA in their book (Enterprise Business Architecture) as a modeling tool that has a customer focus based on a holistic view of the enterprise, and it helps in evolving and deriving other architectures from the EBA base and improve the critical performance measures.

The basic purpose of EBA is to unify the enterprise, improve its effectiveness and efficiency and produce the value-creating system as defined in the corporate strategy. Its framework consists of the architecture (static model), workflow (dynamic model) and the event diagram. It defines the enterprise value streams and their relationships to all external entities and other enterprise value streams and the events that trigger instantiations, it serves as central plexus of the enterprise.

The questions that EBA tries to answer in most of its cases are:

- Does the enterprise have a strategy?
- Is it operational, evolving and periodically updated to reflect opportunities and changes in the market place?
- Is the enterprise aligning the initiatives with the strategy using the metrics and measures as guidance?
- How does it achieve the corporate objectives?

The answers most of the time are vague, there is no understanding for the enterprise holistically that can keep it aligned in all of its complex dimensions.

To find an answer, one must cobble together a solution in an ad hoc fashion from several functional organizations and departments. Today's enterprises, for the most part, are not integrated, aligned or able to effectively or efficiently answer these questions (Whittle et al., 2005).

However; QFD has been used in the literature as a planning and strategic tool to help businesses map their architecture in a more structured way. For instance, Erder et al. (2003) used QFD to ensure that the new design in an enterprise IT architecture project fully implements functional and nonfunctional requirements so that planned IT systems can support the business. They identified the need to develop an enterprise IT architecture to define the organization's guiding principles and standards, develop blueprints, build common services and create a road map to an IT future state.

The main challenge in the enterprise architecture is to provide traceability between business drivers and architectural decisions. QFD in their study was used as a technique to let architects correlate how well the design criteria will meet the customer needs. It can be used during the architecture development process to prioritize user requirements, translating these requirements into an architecture design and plan architecture releases. Figure 2.8 represents the leveraging of QFD during architecture design.

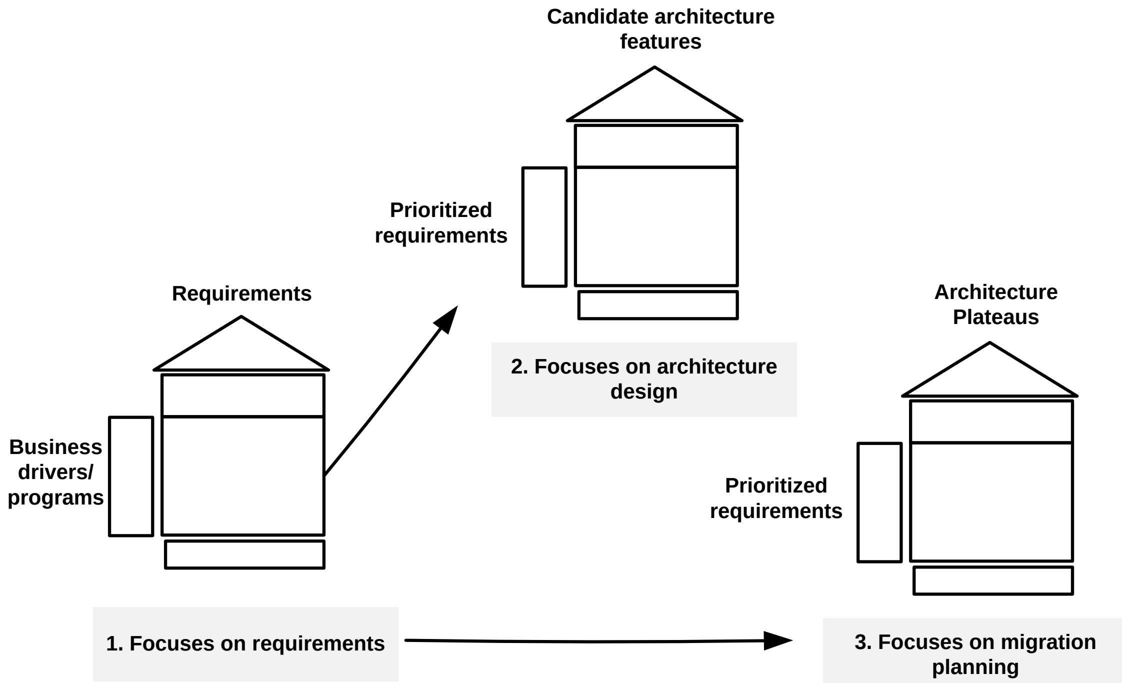


Figure 2.8 Leveraging QFD during architecture design (re-illustrated figure) (Erder et al., 2003)

Crowe et al. (1996) described how the traditional QFD concepts and methods can be used in the formulation of manufacturing strategy to ensure alignment with business strategy. They presented a case study at a powdered metals manufacturer to show how the QFD methodology can be adapted for use in manufacturing strategy formulation. Their proposed plan of action is summarized as follows:

- Step 1. Define the business environment.
- Step 2. Functional strategies formulation stage.
- Step 3. Manufacturing priorities formulation stage.
- Step 4. Action plans formulation stage.
- Step 5. Detail tasks formulation stage.
- Step 6. Feedback and revision stage.

Clegg et al. (2007) produced a new framework which integrates the balanced scorecard, value chain and quality function deployment techniques into an integrated framework known as the E-Business Planning and Analysis Framework (E-PAF), their purpose was to show how QFD can be part of a structured planning and analysis methodology for micro-sized enterprises to build-up their e-business capabilities.

Figure 2.9 represents E-PAF scheme which is structured as follows:

- Step1: Using balanced score cards (BSC) to develop "WHATs" for QFD Matrix I.
- Step2: Using value chain analysis (VCA) to develop "HOWs" in QFD Matrix I.
- Step 3: Completing correlation of "WHATs" and "HOWs" in QFD Matrix I.
- Step 4: Identification of critical business processes from QFD Matrix I.

- Step 5: Inputting critical business processes to the “WHATs” of QFD Matrix II.
- Step 6: List of potential candidate e-business applications to support the “HOWs” in QFD Matrix II.
- Step 7: Completing correlation of “WHATs” and “HOWs” in QFD Matrix II.
- Step 8: Identification of critical e-business applications from QFD Matrix II.

The authors emphasize the integration of the three design tools, business score card, value chain analysis and quality function deployment since it was proved to be very successful in developing e-business capability maturity levels.

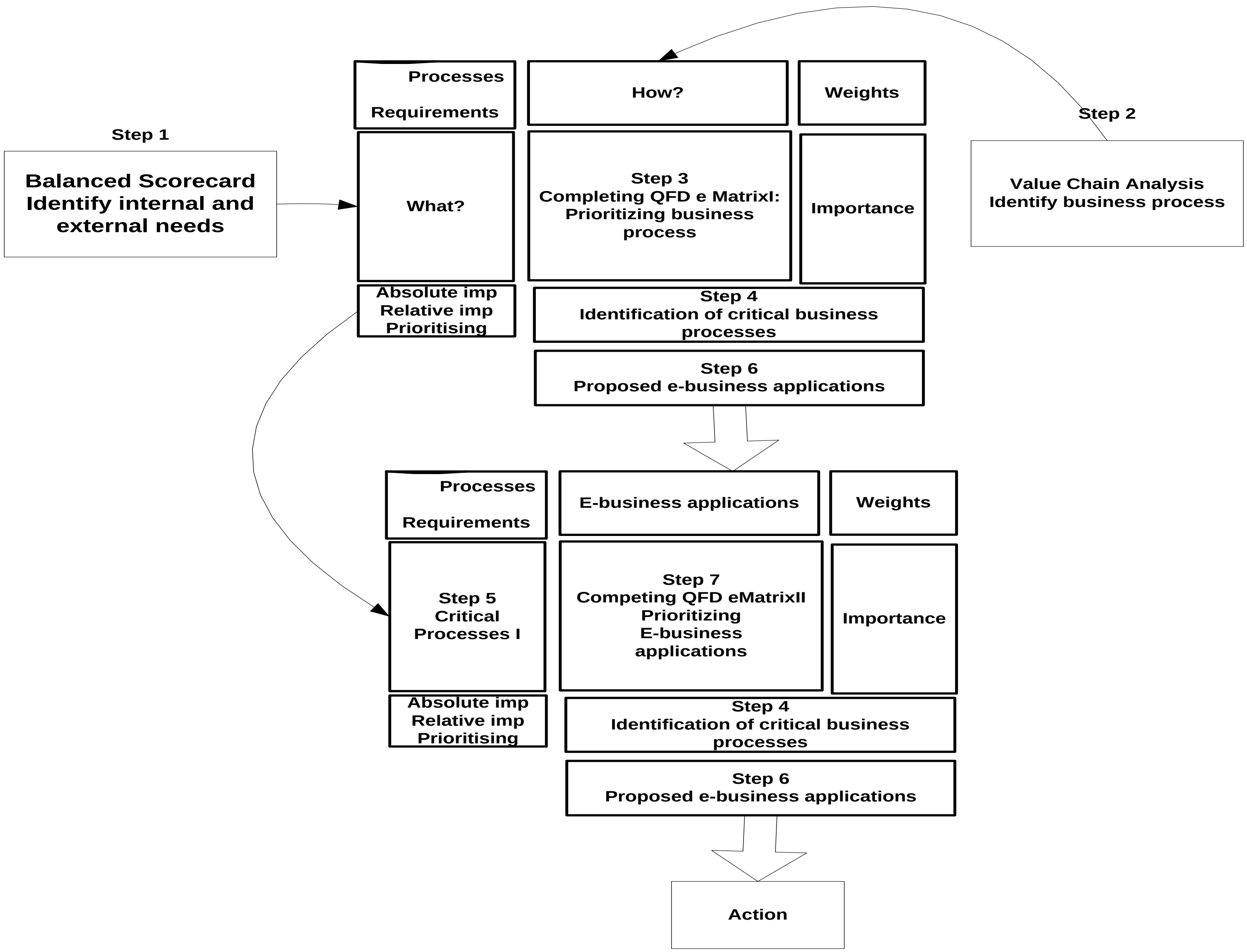


Figure 2.9 E-business planning and analysis framework (re-illustrated figure) (Cleg et al., 2007)

Yu et al. (2003) utilized the method of QFD to link the business requirement with the function structure of information system. Figure 2.10 represents the conversion process from business model to information system model.

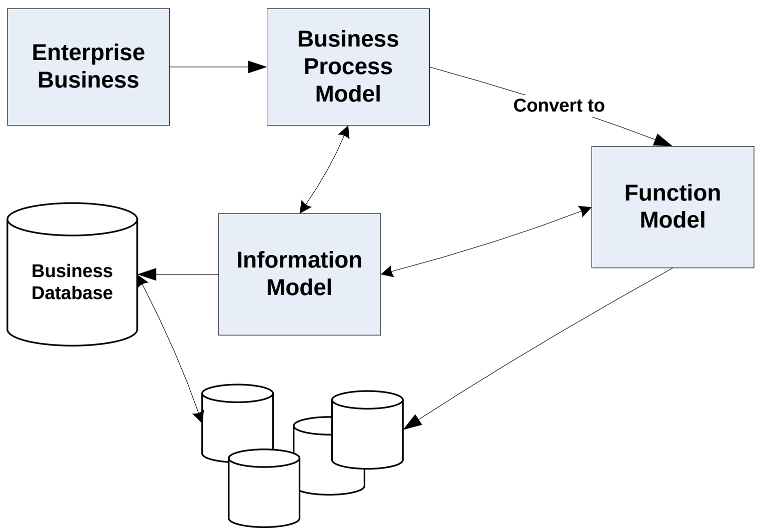


Figure 2.10 The conversion process from business model to information system model (re-illustrated figure). (Yu et al., 2003)

This model uses the HoQ matrix as an intermediate between the enterprise business and the information system, QFD is used as a communication diagram between the business engineering and the software engineering. The whole process of information engineering utilizing enterprise modeling with QFD is shown in Figure 2.11. The missing part in this model is the steps and tools used to build their enterprise model and the linkage between QFD and information system.

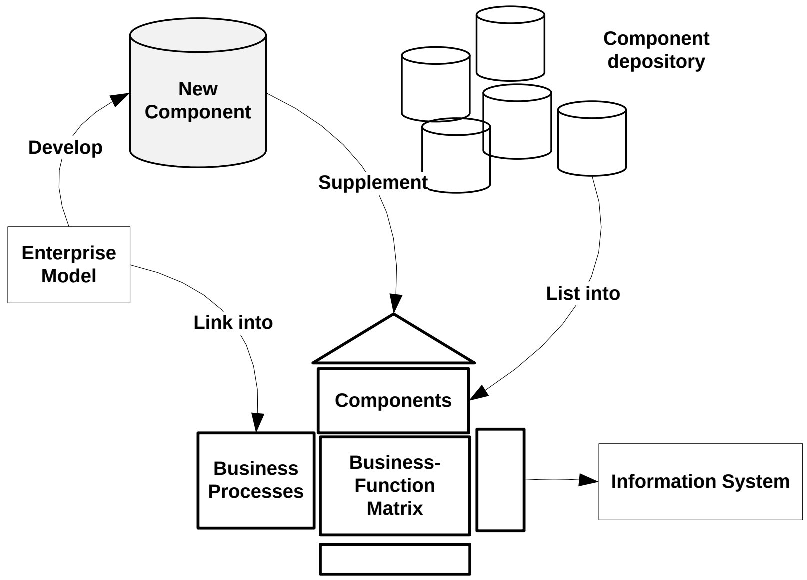


Figure 2.11 The whole process of information engineering utilizing enterprise modeling with QFD (re-illustrated figure). (Yu et al., 2003)

Zhao et al. (2007) proposed an implementation framework of mass customization-enterprise resource planning (MC-ERP) based on three principles of mass customization (principle of similarity, principle of reuse, and principle of globalization). Those principles are integrated with enterprise modeling technology, workflow technology, component technology, integrated platform technology and knowledge management technology. Figure 2.12 represents the proposed MC-ERP framework. The fundamental of the MC-ERP framework is the enterprise total solution based on the enterprise modeling shown in Figure 2.13.

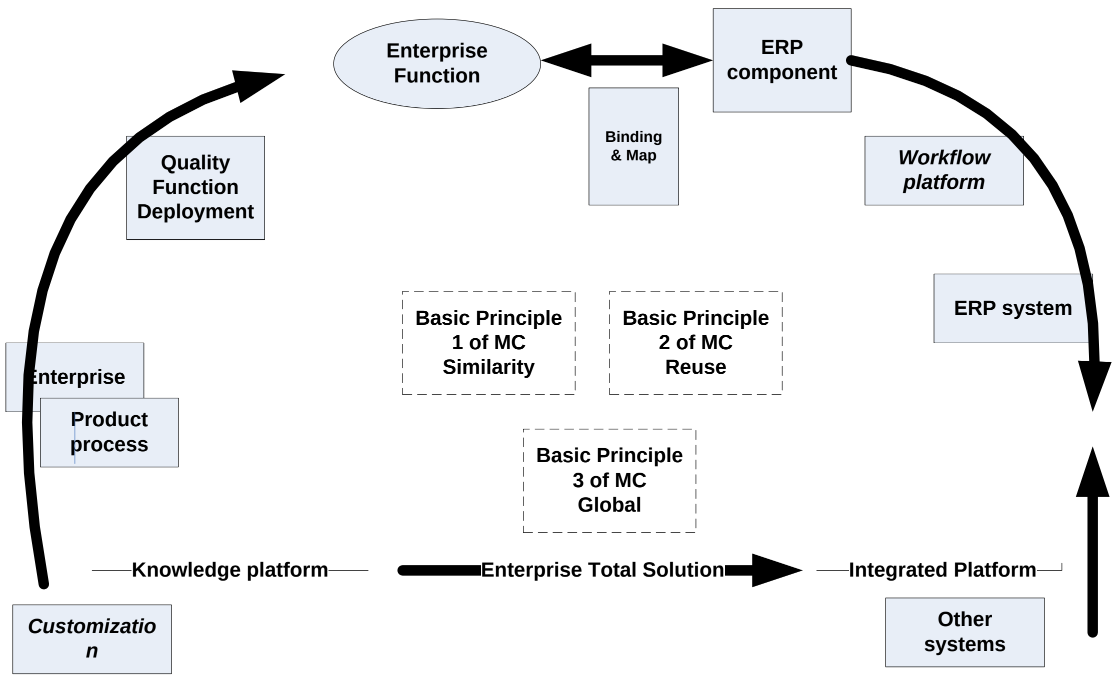


Figure 2.12 Implementation framework of MC-ERP (re-illustrated figure). (Zhao et al., 2007)

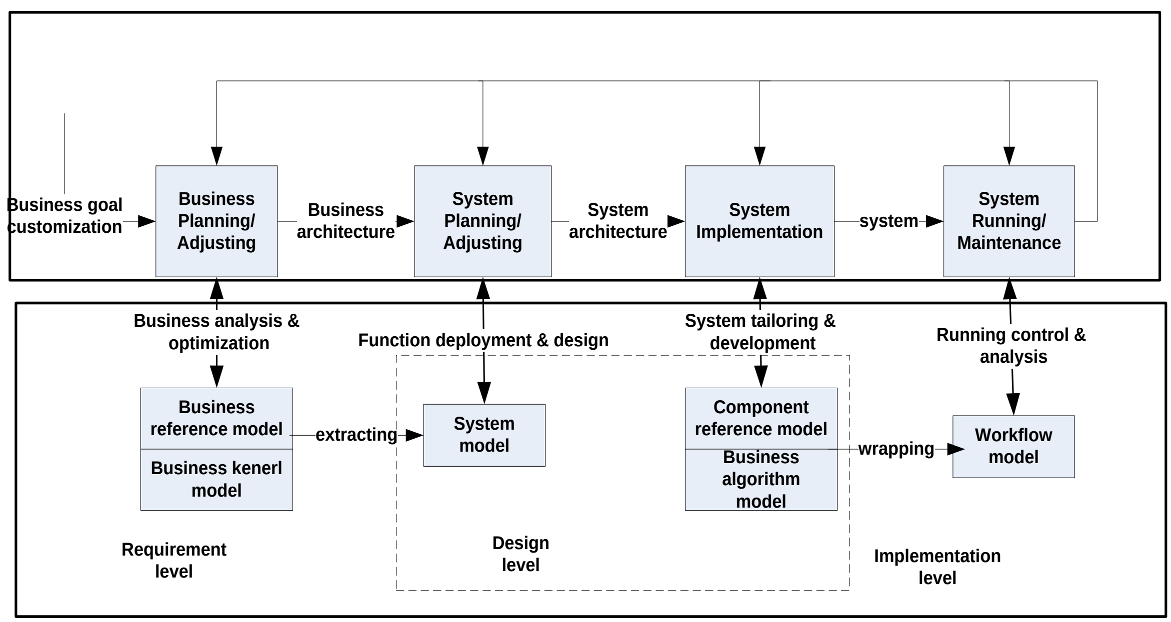


Figure 2.13 Enterprise total solution based on the enterprise modeling (re-illustrated figure). (Zhao et al., 2007)

In order to validate the MC-ERP framework, an architecture of a toolset for implementation was also proposed using the kernel package (enterprise modeling tool).

Ongoing research is continuing in this area, future work could be including the interaction between ERP components and business processes; ERP components interface standards on the workflow platform, the component family modeling and so on. The missing part in the previous model is on the approach used to find the relationships inside the HoQ matrix.

Jin et al. (2008) presented a business oriented 8-Stage service design and management methodology that integrates Total Quality Management (TQM) techniques such as the HoQ matrices to help quantify qualitative service management parameters. Figure 2.14 shows the 8-stage service design and management methodology.

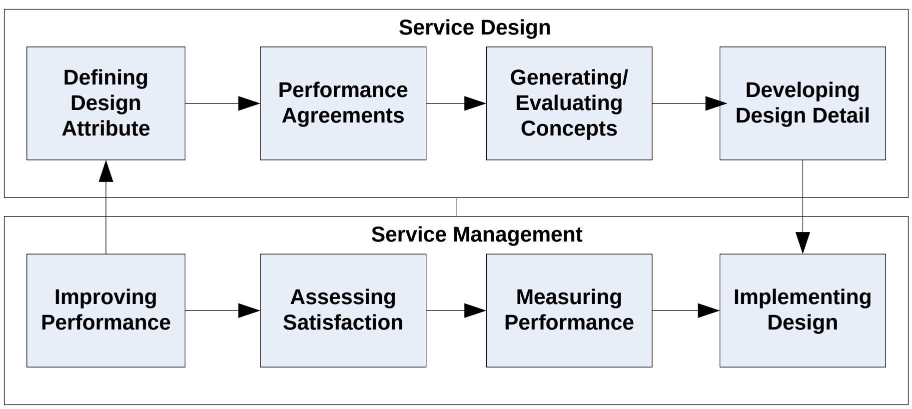


Figure 2.14 8-Stage model (re-illustrated figure). (Jin et al., 2008)

The HoQ matrix is used in the first stage to define the design attributes, the study has shown that it is possible to map existing business processes in an organization to the 8-stage service management model that would help design service management solutions irrespective of the type of business or the type of the technological infrastructure.

The literature showed that all of the integrated enterprise architectures are described logically; meaning that each describes its purpose and does not describe the physical implementation that achieves the logical requirement. Additionally, all of the models presented the view from a functional perspective and had nothing to do with the customer's perspective. This issue causes business enterprises to find a difficulty in aligning what is done vs. what is produced. This research works intends to fill the gap by proposing a mechanism that is based on the basic conceptual model of EBA to reach the needed alignment while incorporating the customer needs.

EBA was created as a solution to help in answering questions about the business alignment problem. It is characterized in two areas which are the business/unit area or the value stream. However there is still a lack of integration and connectivity that exists in each of those areas.

Whittle et al. (2005) focused on the importance of the value stream architecture to put integrated high-level business architecture together. Value stream was defined in their book as: "*An end-to-end collection of activities that created a result for a customer, who may be the ultimate customer or an internal end user of the value stream. The value stream has a clear goal: to satisfy or to delight the customer*." Whittle et al., page 31 (2005).

Value stream mapping (VSM) has been used as a tool to map business processes. For instance; Seith et al. (2005) used VSM for lean operation and cycle time reduction in XYZ Company. VSM was implemented successfully as a technique to achieve productivity improvement at supplier end for an auto industry.

Dixon (2008) defined the value stream mapping (VSM) as a tool that helps ensuring that the enterprise is working on the right improvements at the right time, where the "right" improvements are those that promise to make the business better at serving the most important customers while reducing costs and improving profitability. Learning to use VSM consistently over time can set the stage for the best possible use of other Lean tools.

For business enterprises with IT initiatives, it is important to develop and evolve the business enabling software and supporting organizational roles into a single integrated system. The transition from business design to the Unified Modeling Language (UML) or to packaged software is more predictable and formal. This is an AND approach, a collaborative approach that adds a new dimension to the enterprise way of thinking.

Booch et al. (1999) defined UML in their book (Unified Modeling Language User Guide) as a standard language for software blueprints, it provides a vocabulary and rules for combining words in that vocabulary for the purpose of communication. It focuses on the conceptual and physical representation of a system. UML is a model for constructing; meaning that it is possible to map from a model in the UML to a programming language such as Java, C++, Visual Basic, tables in a relational database, or as a persistent store of an object-oriented database.

The UML addresses the documentation of a system's architecture and all of its details; it also provides a language for expressing requirements. However, UML still has some limitations when applied in a software development domain even though it has been the general purpose standard technique, for this reason, there were some initiatives to employ QFD (Quality Function Deployment) and other effective methods to enhance UML so that a high quality software can be delivered with avoiding failures of software projects, the QFD-style matrix is employed to capture, organize and analyze customer non-functional requirements in order to represent them into UML diagram and notations.

Zhou et al. (2004) integrated the HoQ with UML to enhance the use of UML in software projects. They addressed the limitations of UML in which the integration of QFD with UML was an enhancement to the use of UML. UML limitations are:

- Problem 1:
  - UML cannot communicate with customers.
  - UML lacks techniques for requirements modeling.
  - UML lacks techniques for domain modeling.
  - UML is short in describing the system performance.
- Problem 2: UML cannot effectively direct designers to programs.
- Problem 3: UML cannot describe the software system completely.

These limitations might affect the quality of a software design or might cause failure of the project.

The use of QFD with UML came as a solution to those problems, since QFD gives a systematic and quantifiable approach to determine what is valuable to customers. QFD is an effective tool in the initial stages of the software development; it understands the needs of the customer and then translates them into design specifications.

Dorn et al. (2009) presented an overview of approaches, methodologies, specifications and technologies in B2B e-commerce. They classified them into a model with four layers: business models, business processes, deployment artifacts and software environments. Those four layers have to be addressed in a top-down approach. Figure 2.15 shows the classifications.

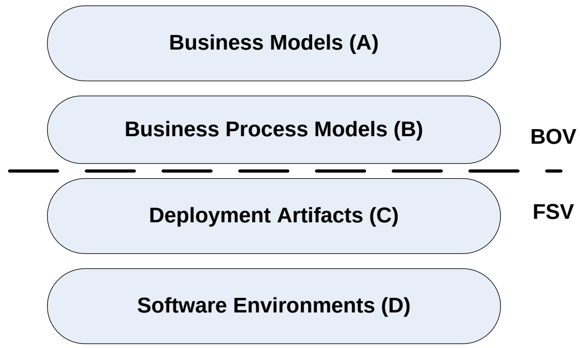


Figure 2.15 Classification scheme based on refinement of the Open-edi reference model (re-illustrated figure). (Dorn et al., 2009)

BOV and FSV in Figure 2.15 denote business operational view and functional services view respectively. Dorn et al. do not elaborate information modeling being part of business process models and do not discuss software environments. Figure 2.16 gives an overview of the business and implementation-related specifications. They differentiate between the business model which is the exchange of values (goods, services, and money) between business partners on an abstract level with the overall goal to generate benefits for each participant while business process models are located on the next lower layer.

Figure 2.17 represents the transformation that occurs from the business models to the web services. The upper layer A represents the business perspective, providing and defining services, organizational units, business rules and resources. It may also include business objectives and corresponding measurement values (e.g., profit or number of customers). Layer B represents the business processes which will be semi-automatically selected and adapted in order to implement the defined services, considering business rules and objectives. Decision points in the process will typically access the mentioned measurement values. Layers C and D are set of Web services that can be used to implement the activities from A and B.

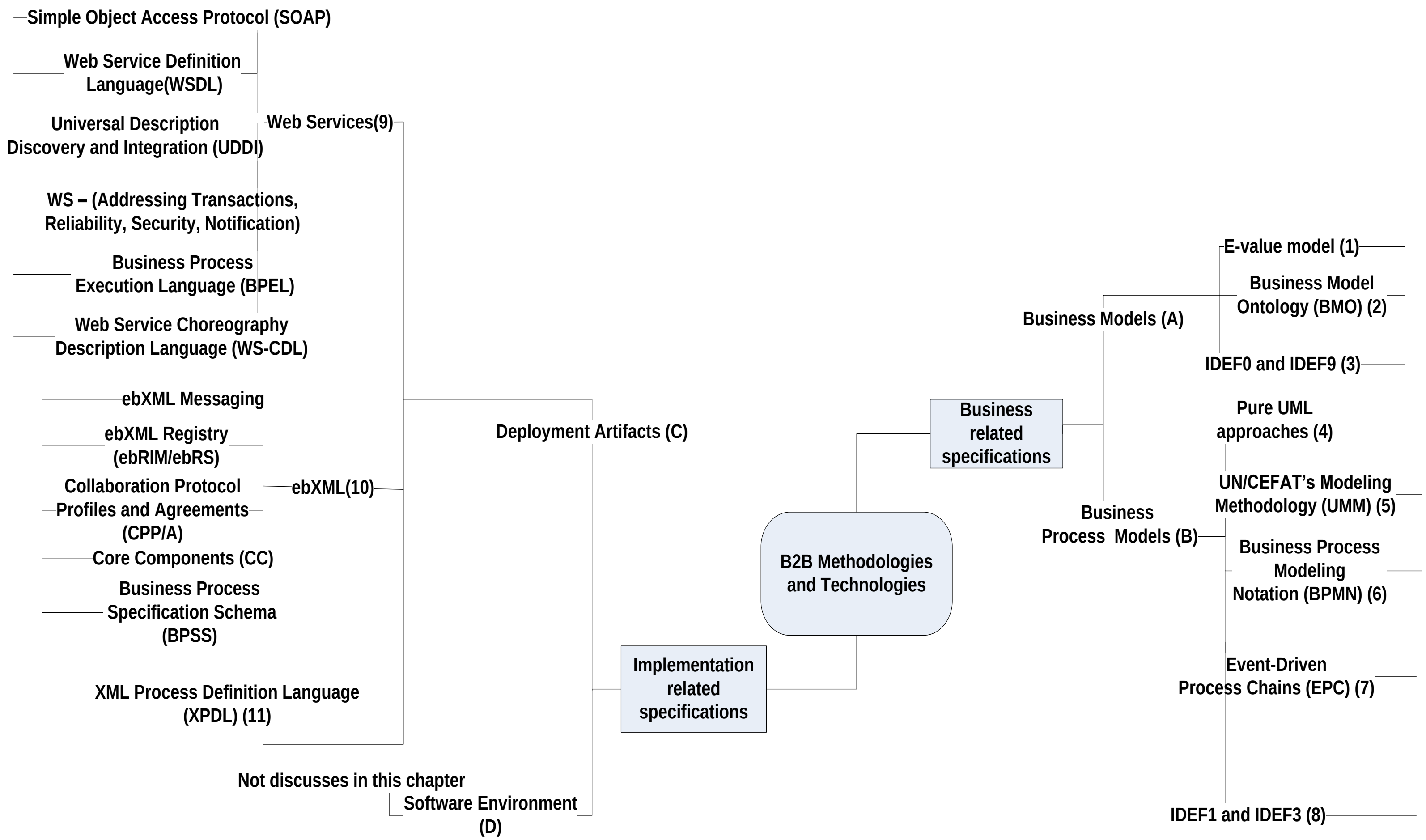


Figure 2.16 Overview of business and implementation and related B2B specifications (re-illustrated figure). (Dorn et al., 2009)

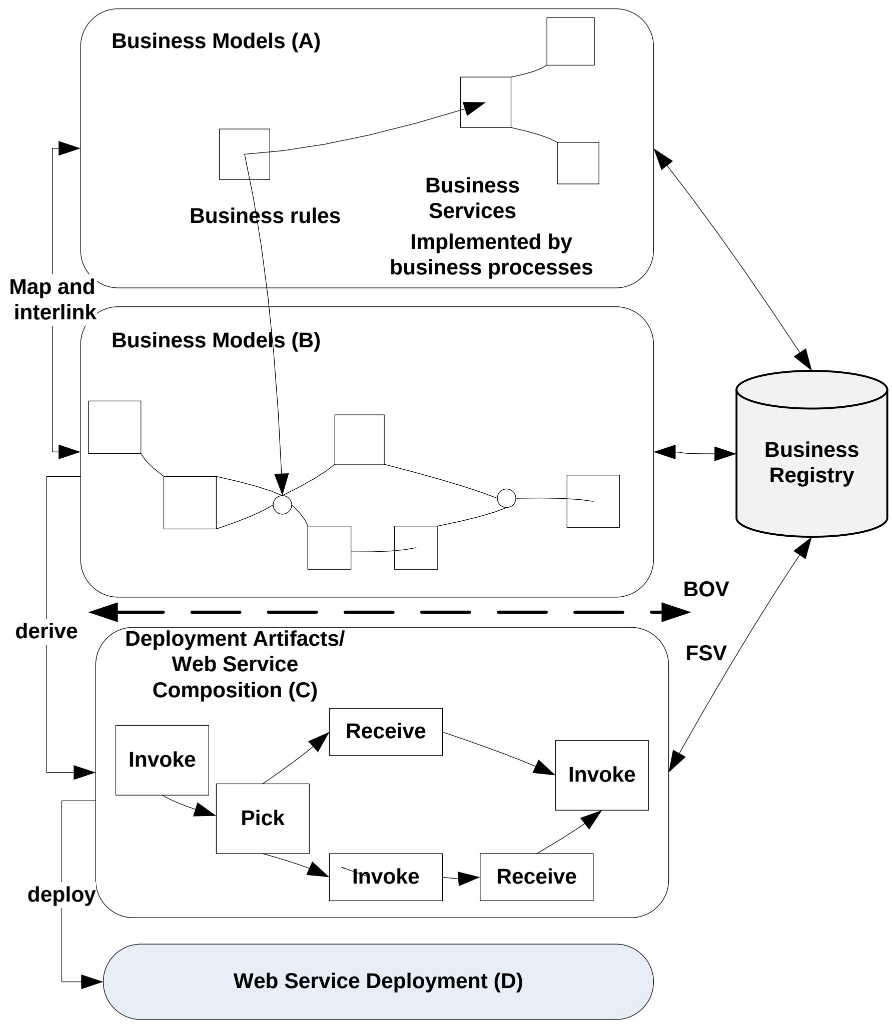


Figure 2.17 B2B transformation process: from business models to Web services (re-illustrated figure). (Dorn et al., 2009)

Appendix A summarizes the contributions of different authors in the literature, highlighting the key points that were addressed in each approach, and what are the points that were left out. In conclusion of that, it is obvious that more research is needed to be done to bridge the gaps existing in the body of literature. For instance; the integration between QFD, UML, EBA and multivariate analysis could be an approach to design a holistic view of the process based on value stream mapping.

CHAPTER 3 PROPOSED METHODOLOGY

This research proposed a novel framework that introduces the use of a quantified house of quality in the context of the basic conceptual model of the enterprise business architecture. The implementation of the framework provides an accurate measure of the degree of alignment between the business strategy and all of the enterprise complex dimensions. The alignment might be needed as a result of a change in the customer requirements.

Enterprise business architecture was used in several applications. However; not many researchers have shown a clear integration between EBA and QFD, most of them showed the benefits of using EBA and QFD tools together without describing a clear mapping for this integration.

3.1 Research Workflow

The flow of this research started by studying the fields in which the HoQ was used, identifying its weaknesses and gaps. Many researchers have criticized the subjective relationship matrix in the HoQ. However; other researchers used several quantitative approaches that were mentioned in the previous section. Going more specific into the field of business enterprises and their use of QFD, this research has led to questioning the availability of a common tool which all business enterprises can use in order to reach the desired level of understanding of their business strategy.

However; an integration of QFD, EBA, UML and multivariate data analysis is proposed in this research to satisfy business enterprises and help them align their business strategy. Figure 3.1 and Figure 3.2 represents this research process map. The implemented work is marked by the red star in the two figures.

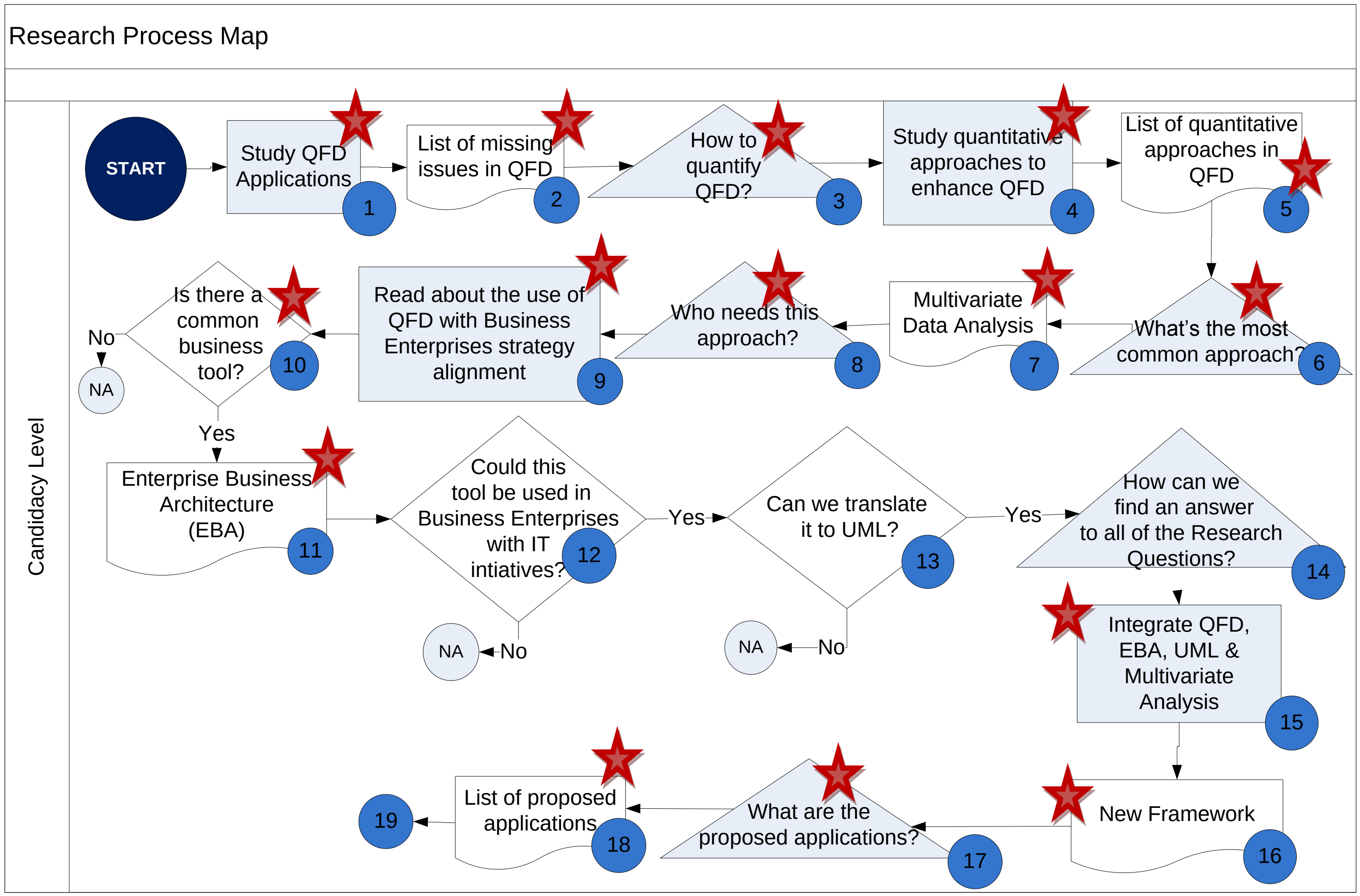


Figure 3.1 Research process map – candidacy Level

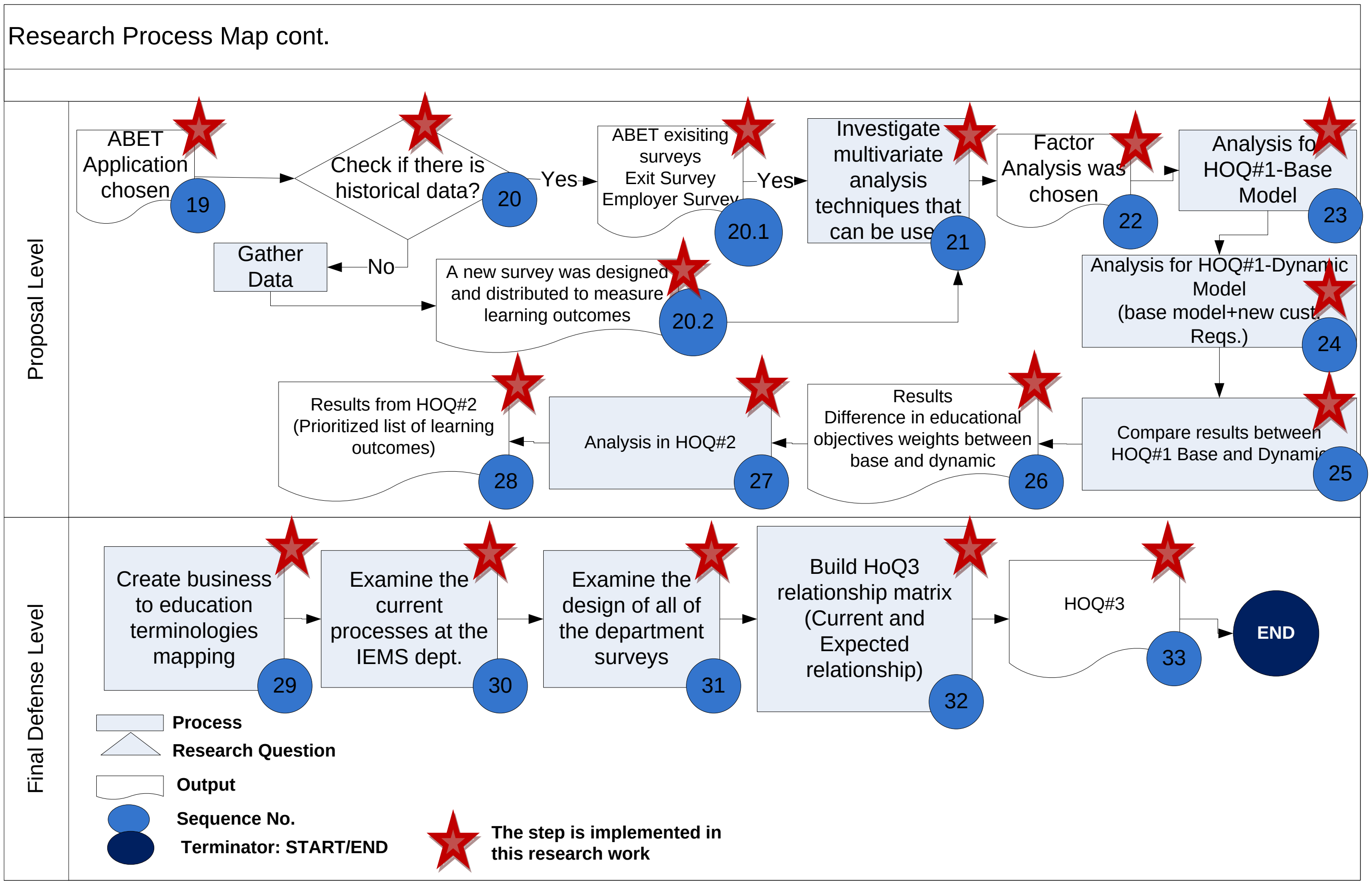


Figure 3.2 Research Process map – proposal and final defense Level

3.2 Proposed Methodology

Business strategy is the direction and the scope that enterprises set over the long term assuring that customer expectations are met during different phases of the business implementation and within the enterprise resources. As customer requirements change rapidly, business enterprises have to stay tuned to those changes that might affect their business strategic goals and processes.

Business strategy evolves periodically and in most of the cases, this change is slower than the change in the customer requirements. Hence; business capabilities or processes can evolve faster to cope with the pace of change in the customer requirements taking into consideration the scope and the direction of the enterprise business strategy.

Building a structured business architecture acts as a foundation to the business strategy execution, it leads to a smoother and leaner transition in any change in the processes of the enterprise as a result of the change in the customer requirements.

This research work intends to develop a unique framework to enhance the business alignment by integrating business architecture, QFD, multivariate analysis and UML to reach the needed alignment by the enterprise.

3.2.1 Proposed business alignment clock

The business alignment clock is a novel representation of the change that occurs in business enterprises in different dimensions: business strategy, business capabilities, business processes and customer requirements. It was developed as a tool to facilitate understanding the dynamic elements of the business enterprise model and how they change over time. To better understand the proposed work, Table 3.1 provides basic definitions of the main terminologies that are used in this chapter.

The three dimensions are the arms of the proposed business clock, they represent the following:

- Business strategy is the slowest clock arm (the hours' arm that moves slowly).
- Customer requirements arm is the fastest (the seconds' arm that moves quickly).
- Business capabilities and processes arm (the minutes' arm) moves faster than the strategy but slower than the customer requirements to cope with the change in customer expectations.

Table 3.1 Business definitions

Quality in business alignment	Ensure that all of the business activities generate the values that the business needs (Ross et al., p119, 2006).
Enterprise Business Architecture	A foundational architecture that links up all of the business complex dimensions; workflows, events and environment to the business strategy (Whittle et al., 2005)
Enterprise Capability	The ability to handle uncertainty and respond positively to change, to create and implement new ideas and ways of doing things, and to make reasonable risk/reward assessments and act upon them in one's personal and working life (Davies H., 2002).
Business Capabilities	The tangible and intangible assets that the enterprises use to develop and implement their strategies (Ray et al., 2004).

Enterprise Business Processes	A specific ordering of work activities across time and place, with a beginning and end, and clearly defined inputs and outputs (Whittle et al., 2005).
Customer Requirements	The needs and the demands of the customer and are also called the Voice of the Customer (VoC) (Büyüközkan et al., 2005).
Business Strategy	The long term goals of the enterprise (Jalham et al., 2006).
An architecture	The structure of components, their relationships, and the principles and guideline governing their design and evolution over time (IEEE, 1990). **It is a static model that shows relationships between workflows and do not illustrate flows or sequences** (Whittle et al., 2005).
Enterprise Entity Model	The highest level model of the enterprise. It illustrates the relationships between all external entities such as its customers, suppliers, stakeholders, service providers, regulatory agencies, and infrastructure providers. It identifies all external inputs and outputs with their respective sources and destinations. It decomposes into a single enterprise aggregate model (Whittle et al., 2005).
Enterprise Aggregate Model	The enterprise aggregate represents the first level of decomposition. It illustrates the relationships between all group aggregate models and identifies all external inputs and outputs with their respective sources and destinations. The enterprise decomposes into the group aggregate models(Whittle et al., 2005).
Group Aggregate	The encapsulation or consolidation of some group of value streams for some specific purpose (Whittle et al., 2005).
A value stream	An end-to-end collection of activities that creates results for a customer, who may be the ultimate customer or an internal end user of the value stream. The value stream has a clear goal: to satisfy or to delight the customer (Martin, 1995).
An enterprise business architecture (EBA)	The enterprise value streams and their relationships to all external entities and other enterprise value streams and the events that trigger instantiation. It is a definition of what the enterprise must produce to satisfy its customers, compete in a market, deal with its suppliers, sustain operations, and care of its employees. It is composed of models of architectures, workflows and events (Whittle et al., 2005)
Workflows	Graphically portray how inputs are transformed to outputs for the enterprise. Workflows illustrate the flow of control, delays, sequencing, and which entity performs the activity. **Workflows are dynamic models that require activation by an event** (Whittle et al., 2005)**.**
Events	Events initiate workflows in the architecture. **Events trigger actions or processes in the enterprise** (Whittle et al., 2005).
Environment	Shows all of the sources and destinations of all of the external inputs and outputs of the value stream (Whittle et al., 2005).

The snapshots shown in Figure 3.3 represent two states of the enterprise business alignment during the evolvement of the business clock which occurs when there is a change in the customer requirements. To ensure quality in business alignment; business capabilities, processes and customer requirements must be aligned to the business strategy. The alignment has to be checked by the time the business enterprise is fed with new customer requirements; the clock dials that align the three arms are QFD, multivariate analysis, EBA and UML.

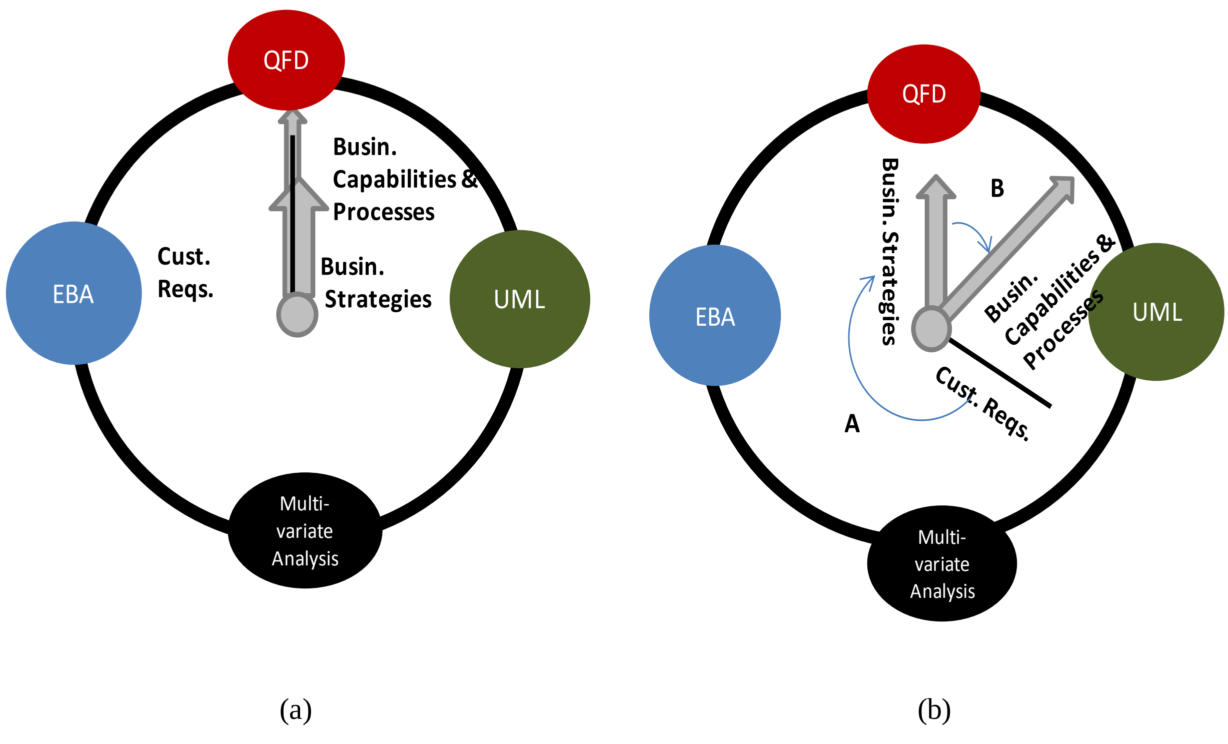


Figure 3.3 Proposed business alignment clock (a) Alignment is 100%, (b) Alignment < 100% Checking the alignment is needed (customer requirements have changed)

The two cases in the proposed business clock are:

3.2.1.1 <u>The Ideal Case</u>

Business enterprises would like to reach a stable flow of processes that exceed customer satisfaction and meet the enterprise strategic goals. Large companies start executing their strategy by building their foundation (architecture) in which they believe it structures the enterprise in all of its complex dimensions; the environment, workflows and the events. This structure creates a holistic overview of the enterprise and facilitates tracking all the inputs and outputs associated with any changes. Figure 3.3.a represents an ideal case where the customer requirements, capabilities and processes are aligned with the business strategy (the three arms are lined up); this means our processes are capable of meeting the customer requirements as well as matching the enterprise strategic goals. The direction of the arms indicates the role of the QFD in achieving a hundred percent alignment.

3.2.1.2 Alignment Needed Case

Ideal case is not the actual case in most of the times especially when a change in customer requirements creates a conflict in business strategic goals. Alignment between the business strategic goals, capabilities, processes, and the new customer requirements is needed to reflect any necessary changes on the enterprise work flows, environment and events. Figure 3.3.b represents the case where there is a need to check the enterprise strategic goals against its capabilities and processes. Step A represents the alignment between the customer requirements and business strategies while step B represents the alignment between the business strategies, capabilities and processes. The proposed mechanism for the two steps is described in section 3.2.2.

This research proposes an integration between four core elements, EBA, UML, QFD and multivariate data analysis, to achieve the needed alignment. Multivariate data analysis along with

QFD is responsible to check the degree of alignment in response to a change in customer requirements which in return gives the management an accurate measure to the current state of the enterprise strategy. The gathering of new customer requirements initiates the movement of the seconds' arm during which the QFD with the multivariate data analysis checks the effect of the new customer requirements on the priorities of the business strategic goals, capabilities and processes. The EBA and UML support the QFD alignment by providing information about the important processes on which the enterprise has to focus to optimize the alignment needed.

The rotation of the clock arms indicates a change in the customer requirements that need to be investigated. Hence; when a change occurs in the customer requirements, the four core tools contribute to line up the clock.

3.2.2 Proposed Clock Mechanism

To allow the business alignment clock to line up, this research proposes a mechanism that is built in the context of EBA basic conceptual model. EBA basic conceptual model is shown in Figure 3.4. This basic structure illustrates how all of the enterprise dimensions fit together to form a harmonious whole for the enterprise and it allows the enterprise to focus on specific components for analysis while understanding their relationships to the rest of the enterprise. To understand the basic conceptual model, important definitions are provided in Table 3.1.

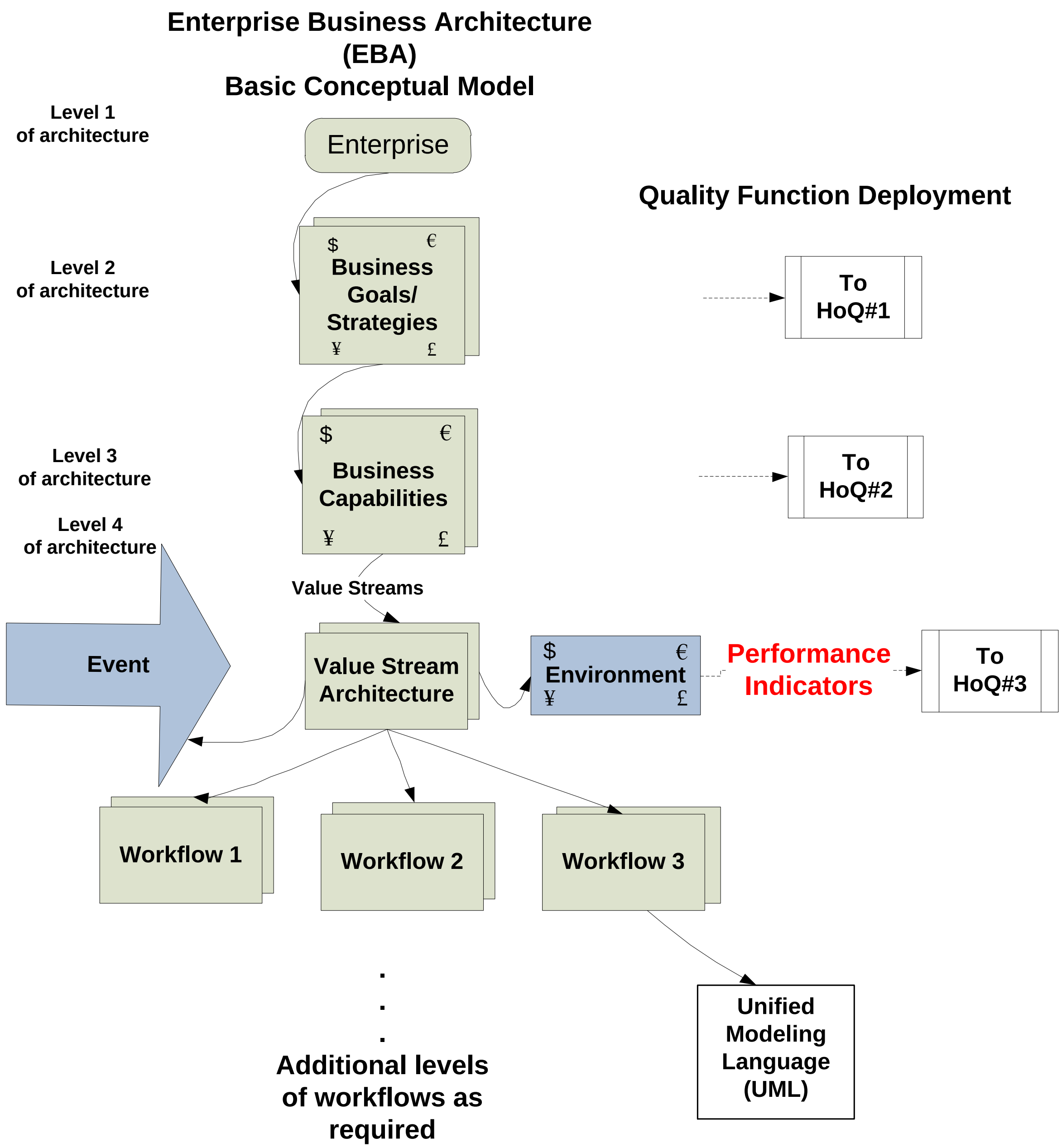


Figure 3.4 Re-illustrated figure of the basic conceptual structure of the EBA. (Whittle et al., 2005)

Whittle et al. (2005) defined EBA as a foundational architecture that links up to the corporate strategy, process initiatives and software development domains. Figure 3.4 is a high level depiction of the basic EBA structure which provides a conceptual overview of the major components and the integration schema. The EBA approach allows the enterprise to focus on specific models for analysis while understanding the relationships to the rest of the enterprise. For example; the enterprise may decide to focus on one specific strategic objective based on a change in the customer requirements. Since all of the strategic goals are linked to the enterprise capabilities with supporting metrics and measures; the enterprise has to analyze the value streams that affect a specific goal and what improvements are needed to meet the strategic expectations.

As a result, the business enterprise may require process improvement, infrastructure expansion, or software development in one or more of the business capabilities. The improvements are reflected in the business processes (workflows), events or environment and become an input to the business goals (strategies). The enterprise may have any combination of project tasks associated with process improvement, infrastructure expansion or software development. Each task is driven from the enhanced workflows (processes) in the EBA; EBA determines the requirements of each task which will result in an integration from strategy to results. The summarized benefits delivered from the EBA are (Whittle et al., 2005):

1. Strategic alignment.
2. Customer-centric focus.
3. Strategy to results connectivity.
4. Speed to market.

5. Team synergy.
6. Less work and waste.
7. Continuous improvement and feedback.

To line up the proposed business clock, this research proposes a novel mechanism which is divided into two phases and three houses of quality. The phases are:

3.2.2.1 Phase I: Analysis Phase

HoQ#1 and HoQ#2 are part of the analysis phase, and they are shown in the proposed mechanism in Figure 3.5. The analysis phase is responsible for checking the change in the strategic goals' weights according to a change in the customer requirements. HoQ#1 is responsible of prioritizing the strategic goals. The difference between strategic goals' weights will be investigated to check if this change has to be reflected on the current business capabilities in HoQ#2, and thus, if a corrective action is needed in HoQ#3.

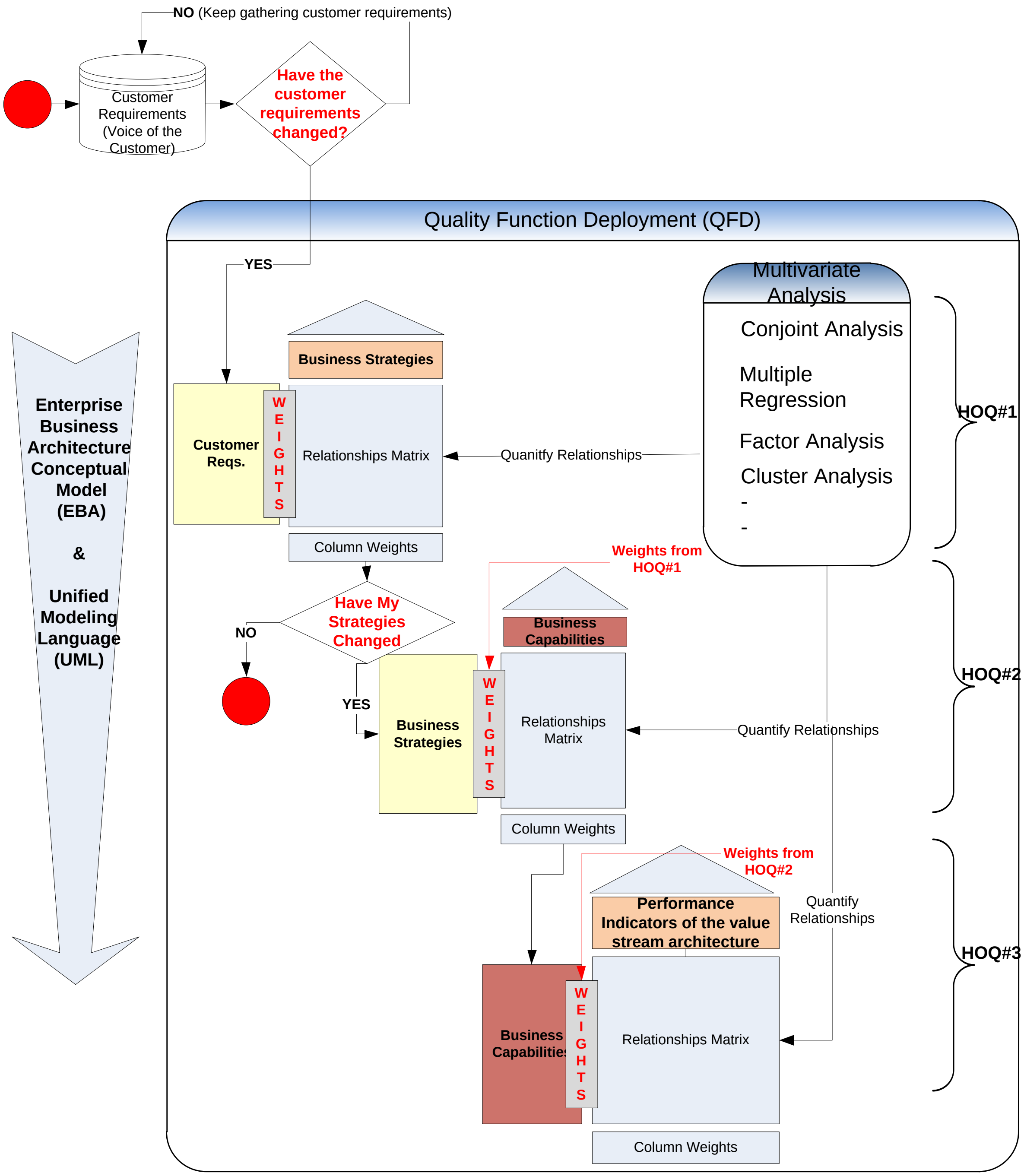


Figure 3.5 Mechanism to line up the proposed business clock

- House of Quality # 1: Aligning customer requirements with business strategic goals
    - Input:
        - Customer requirements are gathered and prioritized through surveys, customer complaints, interviews, focus groups, etc.; they represent the WHATs in HoQ#1.

          The initiation phase of HoQ#1 is called the base model where the house is fed with customer requirements for the first time. However; after feeding the house with new customer requirements; we refer to the house with the dynamic model.

          A comparison of the strategies' weights between the base and dynamic model has to be done to decide on moving to HoQ#2.
        - Business strategies are the strategic goals at the company and they represent the HOWs in HoQ#1.
        - Quantitative relationships inside the body of the house using the appropriate multivariate data analysis technique.
    - Output:
        - Prioritized list of business strategic goals based on column weights; the column weights are the summations of the column values. Each value equals the multiplication of the importance of the customer requirement by its strength with the strategic goal.

** ***A checkpoint after HoQ#1:***
Have the strategies' weights changed between the base and the dynamic models?
***IF** yes **THEN** Proceed to HoQ#2*
ELSE
go back and keep checking new customer requirements

- House of Quality # 2: Aligning business strategies with business capabilities
    - Input:
        - Prioritized business strategies from HoQ#1 (the WHATs).
        - Business capabilities (the HOWs).
        - Relationships inside the relationship matrix are quantitatively defined using the appropriate multivariate data analysis technique.
    - Output:
        - Prioritized list of critical business capabilities.

Multivariate data analysis is used to quantify the relationships matrix inside the body of HoQ#1 and HoQ#2. It refers to all statistical techniques that simultaneously analyze multiple measurements on individuals or objects under investigation (Hair et al., 2006). Multivariate data analysis techniques are:

1. Structural equation modeling.
2. Canonical correlation analysis.
3. Multivariate analysis of variance.
4. Conjoint analysis.
5. Multiple discriminant analysis.
6. Linear Probability models.

7. Exploratory factor analysis.
8. Cluster analysis.
9. Multidimensional scaling.
10. Correspondence analysis.

The selection of the multivariate analysis technique relies on the type of relationship among variables that are being examined; if the variables can be classified into dependent and independent, this means that the underlying structure among the variables is clearly identified, thus; the selection of the technique is limited to the options between number 1 to number 6 in the list shown above. However; if the underlying structure is not clear and we cannot classify the variables into dependent and independent; the selection of the techniques will be limited to the options between numbers 7 to number 10.

If the researcher is comparing variables, exploratory factor analysis is appropriate, if the researcher is comparing cases/respondents; the cluster analysis is the technique to be chosen while multidimensional scaling and correspondence analysis is more appropriate if the researcher is comparing objects. The selection among the latest two techniques depends on the type of data under analysis (metric or non-metric). A detailed demonstration for a multivariate analysis technique is provided in Chapter 4. However; researchers may use any other multivariate technique according to the application in which the proposed framework is used, type of data and relationships.

3.2.2.2 Phase II: Correction Phase

This phase is a reflection of the change in the priorities of the strategic goals and business capabilities on the business architecture (processes, events or environment); it represents the corrective actions that the enterprise should adopt to account for this change. HoQ#3 is responsible for examining the current processes (workflows), events or environment and their relationships toward the prioritized business capabilities using the performance indicators of the value stream architecture components.

The current relationship between each performance indicator and capability is examined versus the expected relationship. The highest gap indicates that more attention has to be paid to a certain process or event which may result in process improvement, infrastructure expansion, or software development in one or more of the business capabilities.

The Unified Modeling Language helps modify or add any IT-related process since it provides the technical team (programmers) with a clear set of diagrams (class, use case, sequence diagrams…etc) that help them accommodate for the change occurred.

- House of Quality # 3: Aligning business capabilities to the value stream architecture components through the business performance indicators
    - Input:
        - Prioritized list of critical business capabilities from HoQ#2 (the WHATs).
        - Performance indicators of the business processes (workflows), event or environment (the HOWs).
        - The differences between the current and expected relationships inside the body of the house are defined by a team of experts or quantitatively, if possible.

- Output:
  - Processes improvement, infrastructure expansion, or software development in one or more of the business capabilities.
  - Tasks associated with process improvement, infrastructure expansion or software development.

To conduct a process improvement or business process reengineering initiative, the EBA is the source of analysis and provides insight into performance improvements. Some of these initiatives require some sort of software development or enhancement support.

The Unified Modeling Language (UML), an extension to EBA, can be utilized to serve as a realization to this interface to enhance the alignment in IT-enabled business processes. UML translates the business model into IT model. The feedback loop from the IT architectures to the business architectures results in continued creativity and additional process improvement ideas. For example; some enterprises may want to run some simulations of the new processes to test and predict the results of the new improvements, since the enterprise has the inputs and outputs modeled along with the events, most of the information required by a simulation product or tool is already located in the EBA. The EBA serves as the single repository of enterprise information required by most strategic initiatives. However; UML implementation is not in the scope of this work, its importance and relationship to the proposed framework is only introduced.

CHAPTER 4 MODEL IMPLEMENTATION

4.1 Case Description

The business alignment clock and mechanism are novel research ideas that are proposed to all executives in business enterprises - senior managers, strategists, operational managers, financial managers and IT managers - who care about achieving superior execution of their strategies. However; some terminologies may differ from one field to another, for example; managers in business sectors may use some terminologies that are different than what managers use in service providers, educational systems or governmental agencies.

In this dissertation, we used the educational system at the department of Industrial Engineering and Management System (IEMS) at the University of Central Florida (UCF) to demonstrate the value of the proposed work for the following reasons:

1. Management support; top management support is a key factor for the successful implementation of the proposed framework.
2. Accessibility of data; the IEMS department provided a full access to surveys and responses for analysis.
3. Flexibility; the IEMS department was flexible in distributing new surveys and examining students' and faculty's perceptions.

4. Validity: the IEMS department allowed us to validate the efficiency of the proposed framework, by conducting a current to expected situation mapping and highlight the processes that need more attention.

On the other hand; business enterprises and industry limit the implementation of the proposed framework. Executives and managers are cautious about providing data, and exposing their architecture and processes to an outside researcher, for they believe that this reveals critical information to their competitors in the market. Hence; adopting the educational system at the IEMS department at UCF was more feasible to show a full implementation of our proposed research work.

The Accreditation Board of Engineering and Technology (ABET) process at the IEMS department was chosen for demonstration; it includes criteria that measures the department educational objectives, learning outcomes and continuous improvement initiatives which can be mapped accordingly to business terminologies. Business to education terminologies' mapping is provided in Figure 4.1.

ABET Inc., the recognized accreditor for college and university programs in applied science, computing, engineering, and technology, is a federation of 30 professional and technical societies representing these fields. Among the most respected accreditation organizations in the U.S., ABET has provided leadership and quality assurance in higher education for over 75 years.

As of 2008, ABET accredits 2,800 programs at more than 600 colleges and universities nationwide. Over 1,500 dedicated volunteers participate annually in ABET activities. (ABET Inc., 2008). ABET evaluation occurs every six years, in which the institution has to maintain ABET accreditation standards established by ABET Inc.

The IEMS department at UCF has gone through stages of continuous improvement since 2002 that emphasize system design and integration, product development, and experiential learning.

In recognition to the importance of ABET accreditation, the IEMS department has formed an ABET committee to provide program assessment and to set guidelines to faculty on issues such as developing performance, initiating efforts to ensure the compliance with ABET criteria, and developing the roadmap for achieving excellence in the delivery of courses. (ABET self-study report, 2008).

ABET requires 8 criteria to achieve the accreditation for the institution, the eight main criteria focus on students, program educational objectives, program learning outcomes, continuous improvement, curriculum, faculty, facilities and support.

Criterion 2, 3 and 4 of the ABET self-study report focus on measuring the educational objectives, learning outcomes set by the IEMS department and the continuous improvement initiatives that the department follows to provide high quality of its educational system.

Program educational objectives are broad statements that describe the career and professional accomplishments that the program is preparing the graduates to achieve. The current educational objectives at the IEMS department are:

1. To produce graduates who assume challenging or satisfying positions in the private and public sectors.
2. To produce graduates who achieve professional growth through advanced studies and/or career development activities.

3. To produce industrial engineering professionals who recognize that engineering is a global service profession that must be practiced ethically with integrity, honesty, and objectivity.

The program learning outcomes are narrower statements that describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire in their matriculation through the program. The current learning outcomes are:

1. Students will be able to apply mathematics, science and engineering fundamentals in classroom and real world projects.
2. Students will be able to make responsible decisions and exhibit integrity and ethics in classroom and real world projects.
3. Students will be able to collect, analyze, and interpret data in classroom and project settings as well as drawing meaningful conclusions and developing sound recommendations.
4. Students will effectively utilize industrial engineering design and problem-solving skills in classroom and real world projects.
5. Students will communicate effectively, orally and in writing, to peers and superiors in classroom and real world projects.
6. Students will be able to work with persons of varied backgrounds in classroom and real world projects.
7. Students will incorporate contemporary issues into the practice of industrial engineering.

8. Students will be able to measure the impact of global and societal issues on industrial engineering solutions to modern practical problems.
9. Students will explore options for professional growth, including graduate study, conference attendance, and professional society participation.
10. Students will utilize tools and techniques of industrial engineering to effectively and efficiently design systems, products and processes that meet the needs of the society.

Assessment of criterion 2 and criterion 3 involves one or more processes that identify, collect, and prepare data to evaluate the achievement of program outcomes. Evaluation determines the extent to which program outcomes are being achieved and results in decisions and actions to improve the program.

The ten learning outcomes that are mentioned above have been modified by the IEMS department to comply with the ABET a-k quality standards for engineering and technology that are set by the ABET Inc.; The ABET a-k criteria are:

a. An ability to apply knowledge of mathematics, science and engineering.
b. Design and conduct experiments as well as to analyze and interpret data.
c. Design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
d. An ability to function on multi-disciplinary teams.
e. An ability to identify, formulate and solve engineering problems.
f. An understanding of professional and ethical responsibility.

g. Ability to communicate effectively.
h. Ability to understand the impact of engineering solutions in a global, economic, environmental and social context.
i. Recognition of the need for and an ability to engage in life-long learning.
j. Knowledge of contemporary issues.
k. An ability to use techniques, skills, and the modern engineering tools for engineering practice.

To map the a-k criteria to the program educational objectives, and learning outcomes, a set of relationships' matrices are needed. However; the strength of these relationships has been subjectively defined and evaluated by the IEMS ABET committee members through the last years of accreditation. The matrices' results have been qualitatively assessed, thus; they were biased toward the committee members' desires and experiences.

A need for a quantitative approach has been raised to increase the accuracy of measuring the extent to which the program learning outcomes have been achieved at the department. This need becomes more vital by the rapid change of customer requirements that are obtained from both internal and external constituents (students, faculty, alumni and employers in the first place). Both internal and external program constituencies are susceptible to changes in emerging circumstances such as societal and economical needs.

The IEMS department at UCF needs to evaluate the degree of alignment between its educational objectives and learning outcomes as a result of a change in its customer requirements. Consequently; the processes to achieve the learning outcomes might be subject to change.

This research is envisioned to help the IEMS department measure accurately the alignment between the educational objectives and learning outcomes in a changing environment of customer requirements.

A business to education terminologies mapping is provided in Figure 4.1 along with its relationship with the basic conceptual model of the EBA to clarify the implementation of the proposed framework in educational systems.

The terminologies are mapped as follows:

1. Program educational objectives represent the business goals (also known as business strategies); which correspond to the enterprise aggregate defined in Chapter 3.
2. Program learning outcomes represent the business capabilities; which correspond to the group aggregates defined in Chapter 3.
3. Value stream architecture components (workflows, events and environment) correspond respectively to processes, stakeholders' feedback and culture.
    - The processes in the value stream architecture represent the sequence of operational or instructional activities, e.g. curriculum revising, facilities checking, database maintenance… etc.
    - The stakeholders' feedback is the event that initiates a process to start. Stakeholders' feedback is the voice of the customer which the department has to listen to in order to continuously improve the program. This is usually done by several surveys distributed by the industrial department, e.g.; program specific exit, alumni, faculty, employer, senior design mentors surveys.

- The environment is the supporting culture in the department to find opportunities for improvement along with improvement activities and corrective actions.

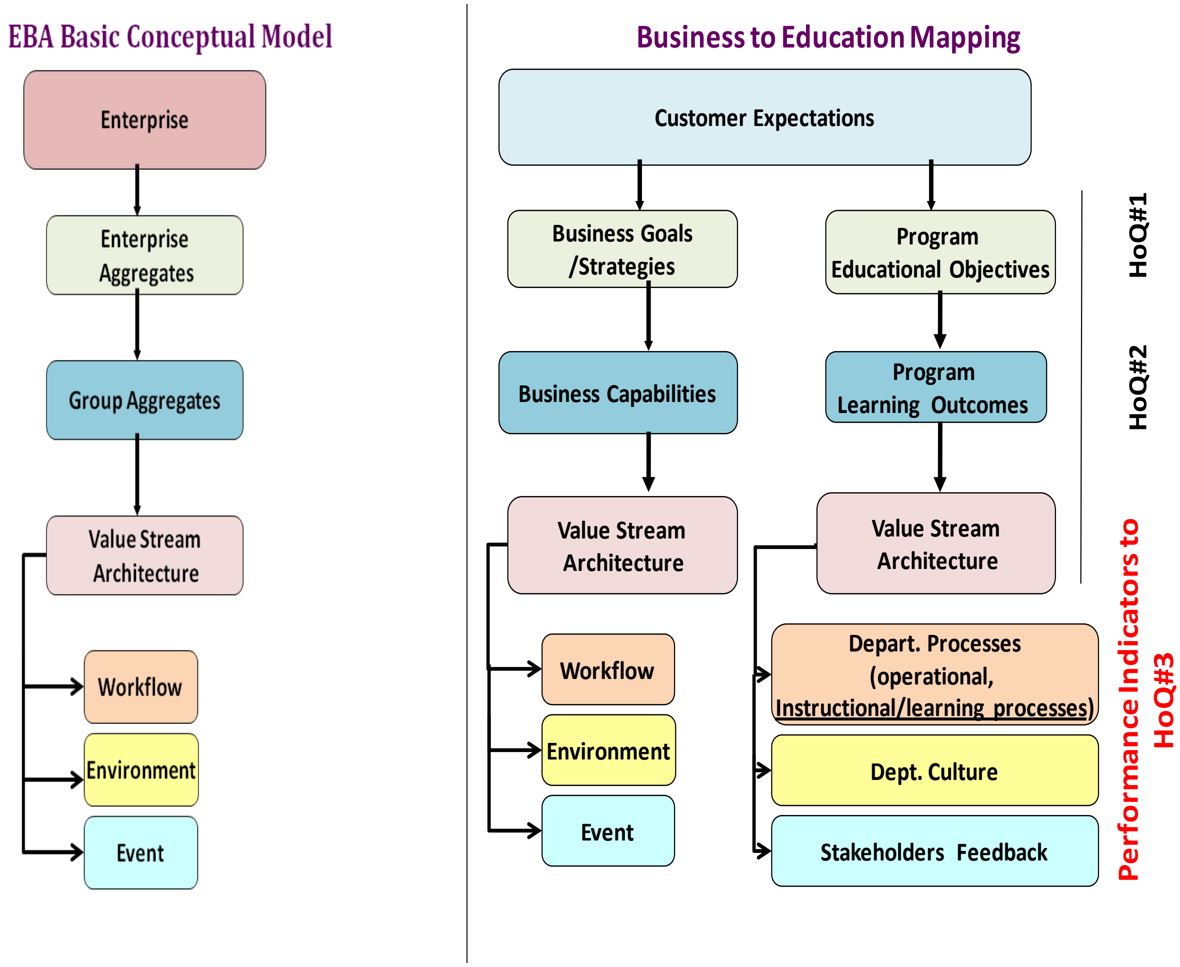


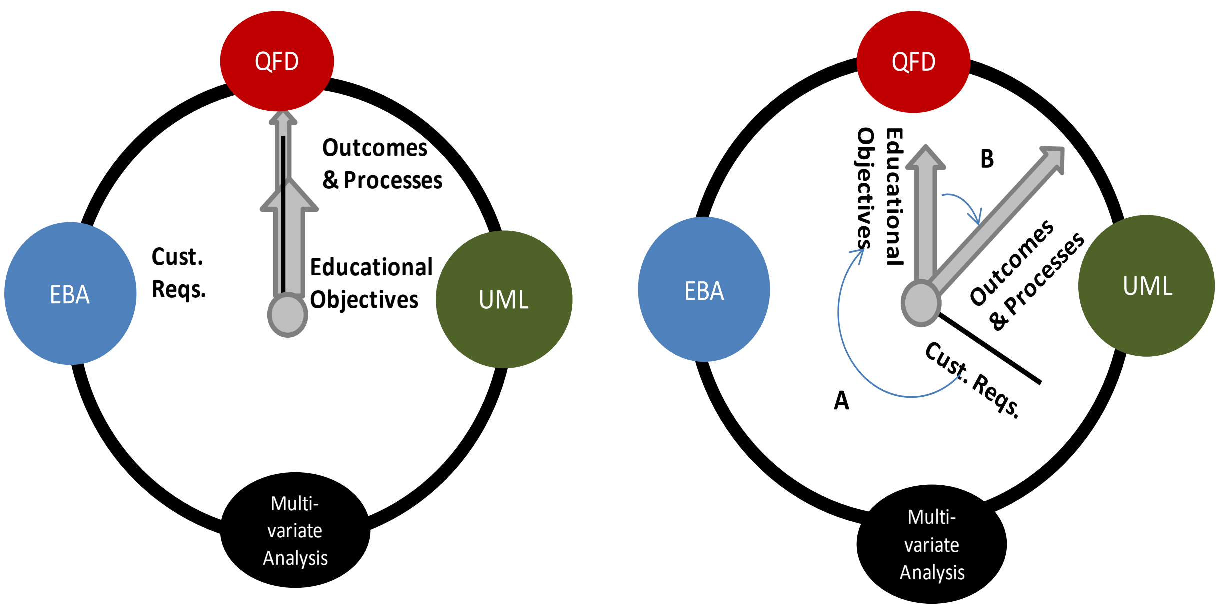
Figure 4.1 Business to education terminologies mapping and its relationship to EBA

Figure 4.2 (a) is a projection of the ABET case on the ideal case of the proposed business clock explained earlier in this document (Figure 3.3 (a))

- Educational objectives clock arm is the slowest (the hours' arm that moves slowly).
- Customer requirements arm is the fastest (the seconds' arm that moves quickly).

- Learning outcomes and processes arm move faster than the educational objectives but slower than the customer requirements to cope with the change in customer expectations (the minutes' arm).

Figure 4.2(b), shows the two alignment steps. Step A represents the alignment between the customer requirements and the educational objectives which occurs in HoQ#1 in the proposed methodology, while step B represents the alignment between the educational objectives, learning outcomes and the components of the value stream architecture which occurs in HoQ#2 and HoQ#3 in the proposed methodology. Figure 4.3 shows the proposed mechanism to line up the clock as applied to the ABET accreditation process.



(a) (b)

Figure 4.2 Business alignment clock - ABET application, (a) alignment is 100%, (b) alignment < 100% checking the alignment is needed (customer requirements have changed)

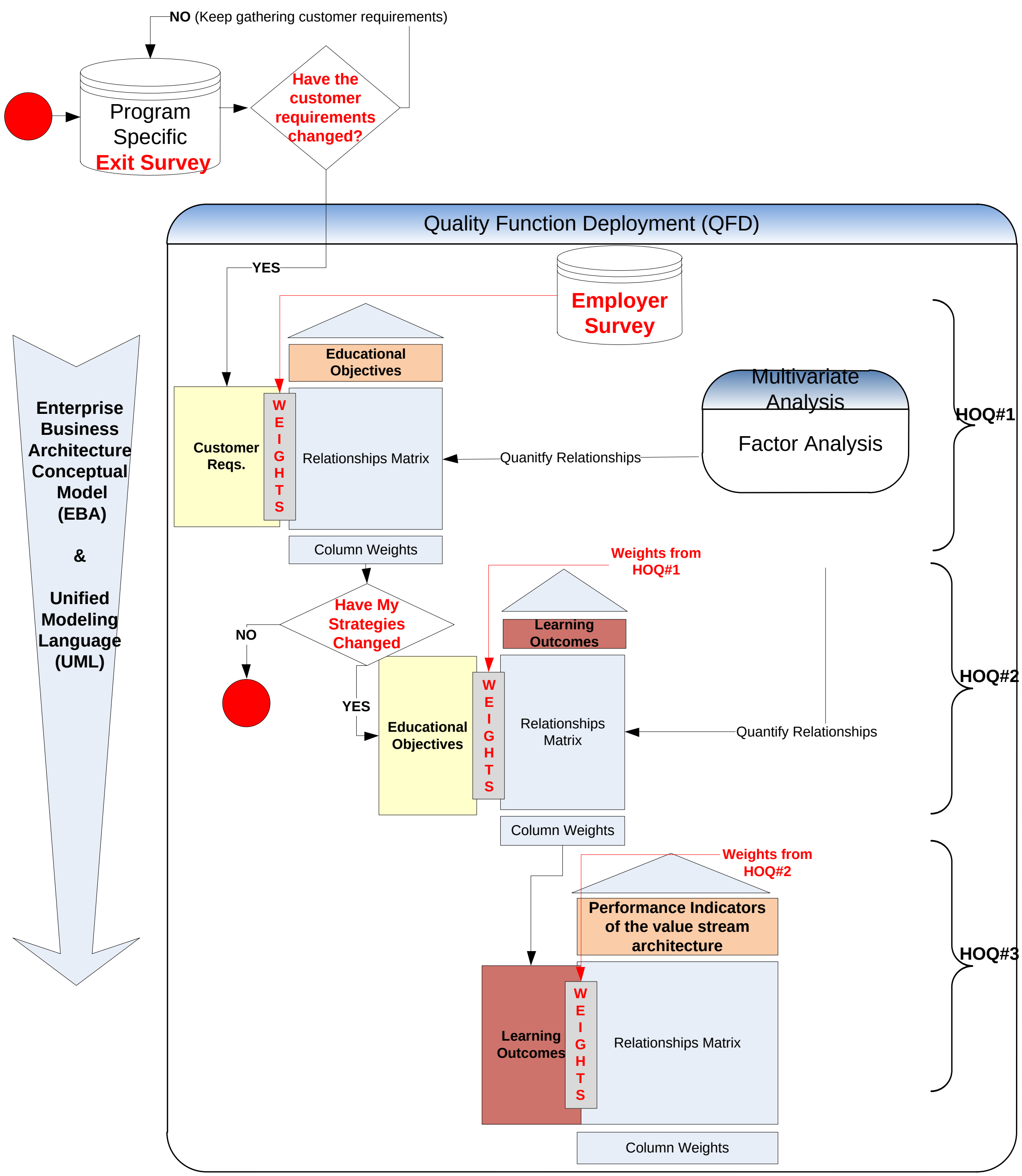


Figure 4.3 Mechanism to line up the proposed business clock - ABET application

4.2 Surveys and Data Collection

The assessment tools that are used to measure the customer requirements, educational objectives and learning outcomes are divided into two types:

1. Indirect measurement tools: include existing surveys results and a new survey designed to measure the learning outcomes.
2. Direct measurement tools: includes students' grades from the fundamentals exam (FE) or senior design projects (SE) or specific courses to directly measure the learning outcomes at the IEMS department.

The measurement tools used in each of the houses are described in this section as follows:

4.2.1 House of Quality #1 (HoQ#1) Inputs, Outputs and Limitations

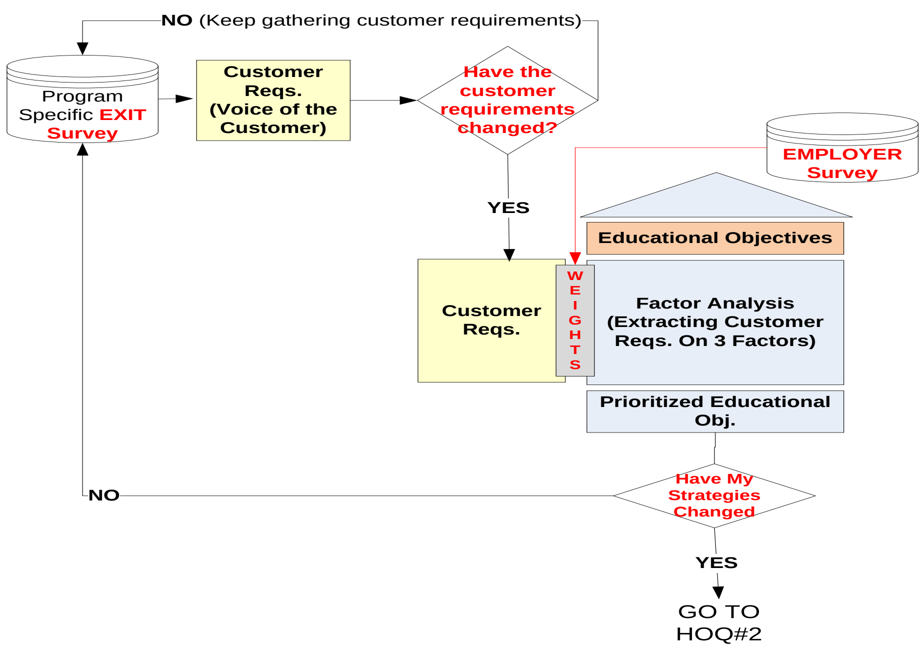


Figure 4.4 House of Quality #1 in ABET – close look

Inputs:

To measure the IEMS educational objectives; we incorporated the voice of the customers from two perspectives; our students at the graduation semester and the employers who deal with the newly graduate professionals.

As shown in Figure 4.4; the students' voice is gathered through the exit survey conducted every semester when the students fill the 'intent to graduate' form, while the employer voice is gathered through the employer survey that is distributed every two or three years. The current exit and employer surveys' questions are shown in Appendix B and Appendix C respectively.

Factor analysis was used to analyze the exit survey; questions were grouped into variables (customer requirements) and variables were extracted into three factors which are mapped to the current three educational objectives. Factor analysis in HoQ#1 is explained in details in Chapter 5. Another input to HoQ#1 is the quantitative relationships inside the body of the house between customer requirements and educational objectives as a result of using factor analysis technique.

The employer survey was used as an input to HoQ#1 to prioritize the customer requirements. The grouping of the questions into variables is shown in Table 4.1. Cronbach's alpha test for grouping the questions into variables is shown in this chapter as statistical evidence.

Table 4.1 Variables in exit survey

Variable Name	Corresponding Survey Questions
Technical Skills	2,3,4,5,6
Communication Skills	7,8,9
Team Skills	10,11,12
Contemporary Issues	13,14

Outputs:

- Prioritized list of the educational objectives as a result of multiplying the relationship matrix in the body of the house by the importance of variables from the employer survey. The summation of each column will result in a prioritized list of factors (educational objectives).

HoQ#1 was run twice:

1. The first run, the base model, used the exit survey data from 2002 until 2004 as an initiation to the proposed framework, 2005 and 2006 years were excluded from the analysis because the survey had a different set of questions. The employer survey input was replaced by weights coming from the ABET Advisory Board comments in the 2002 ABET self study report since there was no data provided about employer surveys at that time.
2. The second run, the dynamic model, used new customer requirements coming from the exit survey data in 2007 and 2008. Feeding the framework with new customer requirements trigger the business alignment seconds' arm to move and check for the alignment between the strategies, capabilities and the value stream architecture components which correspond to the educational objectives, learning outcomes and the IEMS value stream architecture components.

The sample size of the exit survey was 110 between 2002 and 2004 while the sample size for the exit survey was 68 in 2007 and 2008. The employer survey that was distributed in 2008 was used as an input to prioritize the importance of the customer requirements in the dynamic model.

The results of the two houses are compared to check if the weights of the educational objectives have changed to move to HoQ#2 to study the alignment between the educational objectives and the learning outcomes. This comparison is shown in the decision box shown

Figure 4.4; the IEMS department has to set a threshold at which a change in its educational objectives' weights creates the need to move to the second and third HoQ.

A normal probability plot was drawn against the two exit surveys data to test for normality. Figure 4.5 shows the normal probability plot against the exit survey variables (Technical, Communication, Team and Contemporary issues) in the base model, while Figure 4.6 shows the normal probability plot against the exit survey variables in the dynamic model. We notice that the data is not normally distributed because it is built using surveys based on a Likert scale (1-5), however; the normality assumption is not critical for exploratory factor analysis when the purpose is to understand the relationships between variables (Tabachnick and Fidell, 2001). Critical assumptions for factor analysis are tested in Chapter 5.

Having a discrete shape of the responses since it is based on a Likert scale is a limitation to HoQ#1; the purpose of combining the survey questions into variables is to convert the data into a continuous nature.

This research work is constrained with a limited number of questions measuring a certain variable, for instance; the technical skills variable in Figure 4.5 and Figure 4.6 is a summation of 5 questions in the exit survey which makes the data more continuous and closer to normality than the contemporary issues variable. The contemporary issues variable is a summation of only two questions which shows the data in a discrete nature and far away from the normal probability plot.

A new design of the exit survey is provided in Appendix F in which each variable is measured with at least three questions.

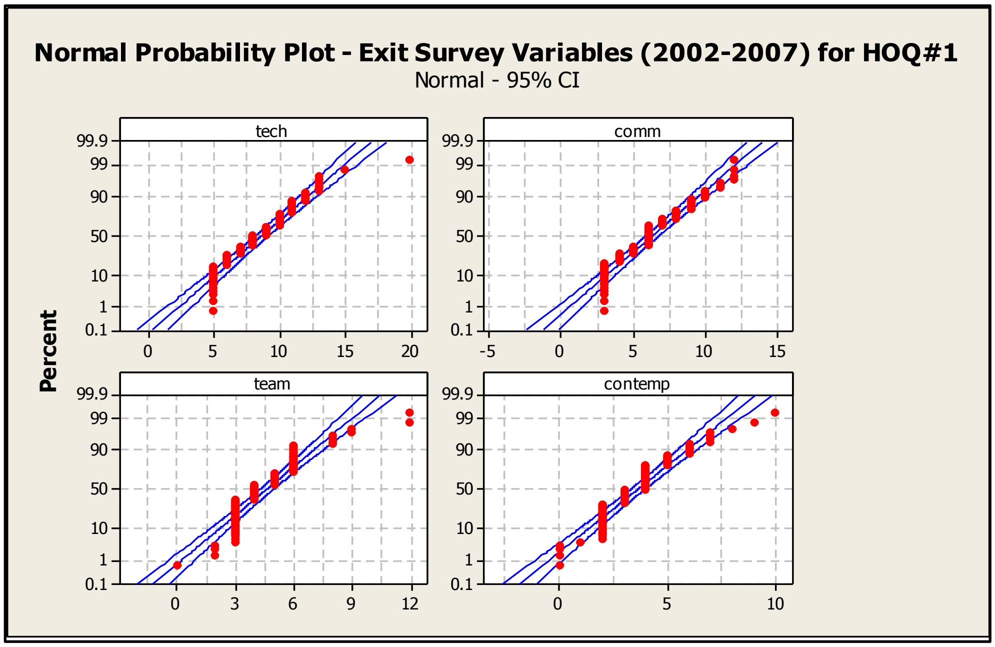


Figure 4.5 Normal probability plot - exit survey variables (2002-2004) for HoQ#1-base model

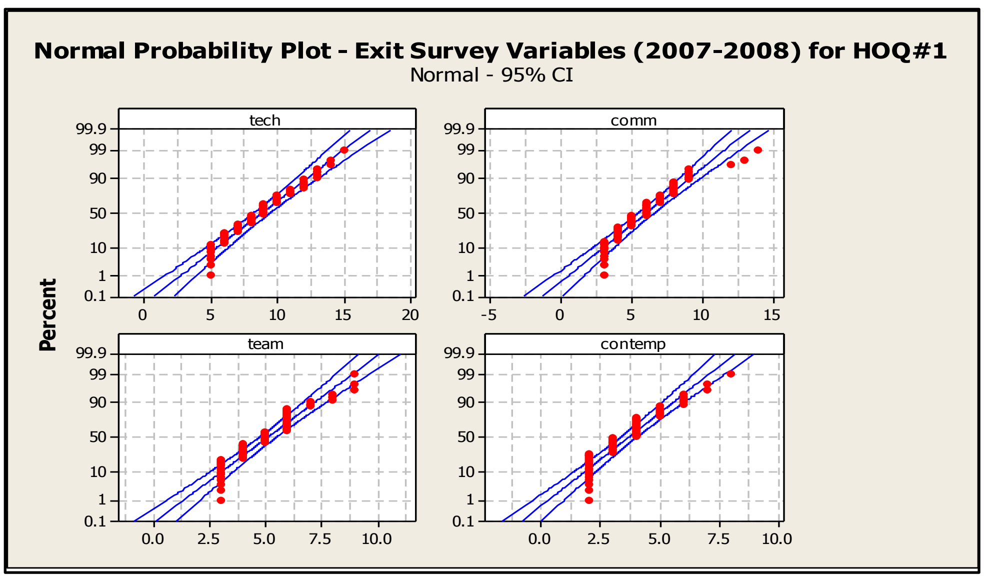


Figure 4.6 Normal probability plot - exit survey variables (2007-2008) for HoQ#1-dynamic Model

HoQ#1 – Statistical Evidence of grouping the questions into variables:

The grouping of the questions into variables was based on faculty members' expertise. To statistically support the grouping of the questions into variables; a Cronbach's alpha test, a reliability test, was conducted for the questions themselves in the base and dynamic model.

A diagnostic measure to assess the reliability is the reliability coefficient (Cronbach's alpha). The objective is to ensure that the responses of the grouped questions are not too varied so that the summated scale of the questions' responses is reliable. The typical lower limit for a Cronbach's alpha is 0.70 and it may decrease to 0.60 in exploratory research (Hair et al., 2006). Cronbach's alpha test among variables is going to be explained in Section 4.3.5.

Table 4.2 and Table 4.3 provide the Cronbach's alpha results for all the questions related to each variable in the base and dynamic model of HoQ#1 respectively. The Cronbach's alpha for the four variables (Technical Skills, Communication Skilles, Team Skills and Contemporary Issues) was 0.803, 0.841, 0.841 and 0.710 for the base model and 0.813, 0.849, 0.684 and 0.525 for the dynamic model; they are acceptable values of the Cronbach's alpha. None of the deleted questions in each variable result in a higher Cronbach's alpha, hence; none of questions is excluded from any of the variables. However; the deletion of any of the questions in the contemporary issues results in a negative Cronbach's alpha value which violates reliability model assumptions. This is due to the small number of questions that form the contemporary issue variable as mentioned in HoQ#1 limitations section. This problem can be overcome by increasing the number of questions related to one variable in the new designed survey which is provided in Appendix F.

Table 4.2 Cronbach's Alpha test of the base model questions for each variable (Technical, Communication, Team, Contemporary Issues)

Reliability Statistics

Cronbach's Alpha	N of Items
.803	5

Technical Skills Questions - Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
q2	6.8440	5.170	.551	**.777**
q3	6.9908	5.139	.641	**.754**
q4	6.6972	4.991	.543	**.780**
q5	7.0550	4.682	.694	**.732**
q6	6.8349	4.639	.543	**.786**

Reliability Statistics

Cronbach's Alpha	N of Items
.841	3

Communication Skills Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
q7	3.9909	2.651	.738	**.749**
q8	4.2909	2.979	.694	**.791**
q9	4.2273	3.095	.691	**.795**

Reliability Statistics

Cronbach's Alpha	N of Items
.841	3

Team Skills Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
q10	3.1887	1.678	.651	**.830**
q11	3.0849	1.450	.746	**.738**
q12	3.0849	1.602	.723	**.763**

Reliability Statistics

Cronbach's Alpha	N of Items
.710	2

Contemporary Issues Questions-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
q13	2.0680	1.084	.567	.[a]
q14	1.6893	.667	.567	.[a]

a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

Table 4.3 Cronbach's Alpha test of the dynamic model questions for each variable (Technical, Communication, Team, Contemporary Issues)

Reliability Statistics

Cronbach's Alpha	N of Items
.813	5

Technical Skills Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
q2	6.90	4.550	.646	**.764**
q3	7.01	4.318	.666	**.757**
q4	6.82	4.331	.570	**.792**
q5	7.10	4.731	.581	**.783**
q6	7.21	5.016	.570	**.788**

Reliability Statistics

Cronbach's Alpha	N of Items
.849	3

Communication Skills Questions-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
q7	4.00	2.418	.815	**.692**
q8	4.01	2.522	.799	**.710**
q9	3.99	3.149	.559	**.929**

Reliability Statistics

Cronbach's Alpha	N of Items
.684	3

Team Skills Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
q10	3.43	1.442	.460	**.638**
q11	3.35	1.336	.540	**.537**
q12	3.34	1.272	.497	**.594**

Reliability Statistics

Cronbach's Alpha	N of Items
.525	2

Contemporary Issues Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
q13	1.85	1.083	.386	.[a]
q14	1.76	.481	.386	.[a]

a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

4.2.2 House of Quality #2 (HoQ#2) Inputs and Outputs

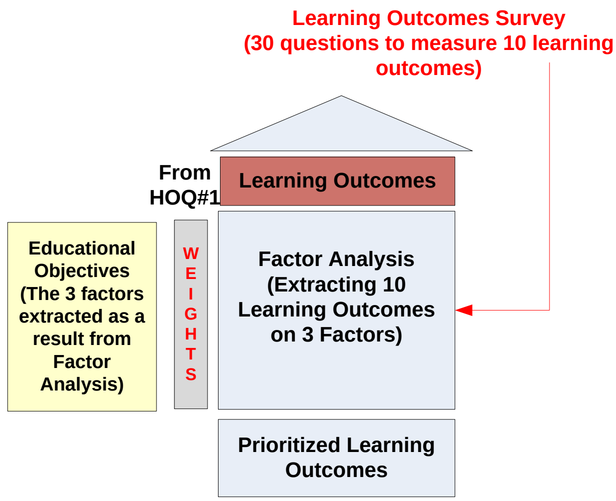


Figure 4.7 House of Quality #2 in ABET – close Look

A closer look at House of Quality #2 in ABET is shown in Figure 4.7, its inputs and outputs are explained as follows:

Inputs:

- A survey consists of 30 questions was designed to measure the 10 learning outcomes at the IEMS department. Each learning outcome was measured by at least three questions. Approximately 100 juniors and seniors were targeted to fill the survey at the department; 90 students filled the survey which indicates a valid response rate (90%).
- The learning outcomes are treated as variables that consist of survey questions. The learning outcomes survey is shown in Appendix D. The grouping of the questions into variables (learning outcomes) is shown in Table 4.4. Learning outcome 1 and 10 are

similar to each other for which we combined their questions. Cronbach’s alpha test for grouping the questions into variables is shown in this chapter as statistical evidence.

- A prioritized list of the educational objectives from HoQ#1.
- Quantitative relationships between the learning outcomes and the educational objectives as a result of extracting the 10 learning outcomes into 3 factors using factor analysis.

Table 4.4 Variables in learning outcomes survey

Variable name	Corresponding Survey Questions
Learning Outcome 1 & 10 (LO1)	1,2, 29,30
Learning Outcome 2 (LO2)	3,4,5,6
Learning Outcome 3 (LO3)	7,8,9
Learning Outcome 4 (LO4)	10,11,12
Learning Outcome 5 (LO5)	13,14,15
Learning Outcome 6 (LO6)	16,17,18
Learning Outcome 7 (LO7)	19,20,21,22
Learning Outcome 8 (LO8)	23,24,25
Learning Outcome 9 (LO9)	26,27,28

Outputs:

- Prioritized list of the learning outcomes as a result of multiplying the relationship matrix in the body of the house by the average importance of factors that came from HoQ#1. The summation of the columns will result in a prioritized list of the learning outcomes.

HoQ#2 – Statistical Evidence of grouping the questions into variables:

The grouping of the questions into variables was based on faculty members’ expertise. To statistically support the grouping of the questions into variables; a Cronbach’s alpha test (a reliability test) was conducted for the questions themselves. Cronbach's alpha test was conducted for all of the learning outcomes' questions to check for reliability.

Table 4.5 provides the Cronbach's alpha results for all the questions related to each variable in the HoQ#2. The Cronbach's alpha for the nine variables was higher than 0.7 in most of the cases which indicate a reliable grouping of the questions.

The deletion of any of the questions in each variable didn't result in a higher Cronbach's alpha, hence; none of questions is excluded from any of the variables.

Table 4.5 Cronbach's alpha test for the learning outcomes' questions

Reliability Statistics

Cronbach's Alpha	N of Items
.823	4

Learning Outcome 1 and 10 Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
lo1_1	5.5222	4.252	.624	**.788**
lo1_2	5.5667	4.338	.642	**.781**
lo10_1	5.4556	4.183	.619	**.791**
lo10_2	5.5222	3.893	.708	**.748**

Reliability Statistics

Cronbach's Alpha	N of Items
.686	4

Learning Outcome 2 Questions--Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
lo2_1	5.8778	4.356	.684	**.484**
lo2_2	5.2222	5.119	.272	**.767**
lo2_3	6.0444	5.301	.498	**.613**
lo2_4	5.9889	4.618	.503	**.599**

Reliability Statistics

Cronbach's Alpha	N of Items
.819	3

Learning Outcome 3 Questions-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
lo3_1	3.2667	1.546	.664	**.761**
lo3_2	3.3444	1.667	.716	**.711**
lo3_3	3.2333	1.664	.641	**.781**

Reliability Statistics

Cronbach's Alpha	N of Items
.868	3

Learning Outcome 4 Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
lo4_1	3.7000	2.212	.746	**.822**
lo4_2	3.4333	1.844	.783	**.783**
lo4_3	3.5778	2.022	.726	**.836**

Reliability Statistics

Cronbach's Alpha	N of Items
.851	3

Learning Outcome 5 Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
lo5_1	3.4444	3.059	.689	**.822**
lo5_2	3.4333	2.698	.721	**.793**
lo5_3	3.6333	2.729	.756	**.757**

Reliability Statistics	
Cronbach's Alpha	N of Items
.848	3

Learning Outcome 6 Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
lo6_1	3.4444	2.654	.666	**.835**
lo6_2	3.3778	2.170	.753	**.752**
lo6_3	3.4889	2.298	.737	**.767**

Reliability Statistics	
Cronbach's Alpha	N of Items
.866	4

Learning Outcome 7 Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
lo7_1	7.0000	8.652	.667	**.847**
lo7_2	7.0889	8.149	.697	**.836**
lo7_3	7.1444	7.541	.762	**.809**
lo7_4	7.0000	8.247	.739	**.819**

Reliability Statistics	
Cronbach's Alpha	N of Items
.748	3

Learning Outcome 8 Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
lo8_1	3.7333	2.153	.636	**.590**
lo8_2	4.0222	2.202	.627	**.602**
lo8_3	4.3111	2.779	.474	**.772**

Reliability Statistics	
Cronbach's Alpha	N of Items
.852	3

Learning Outcome 9 Questions -Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
lo9_1	3.5667	2.967	.719	**.803**
lo9_2	3.5444	3.217	.731	**.784**
lo9_3	3.9778	3.573	.731	**.793**

The Normal probability plot for the l0 learning outcomes is shown in Figure 4.8. Removing the points that are extremely deviated from the confidence limits didn't affect the analysis results for which we decided to keep them.

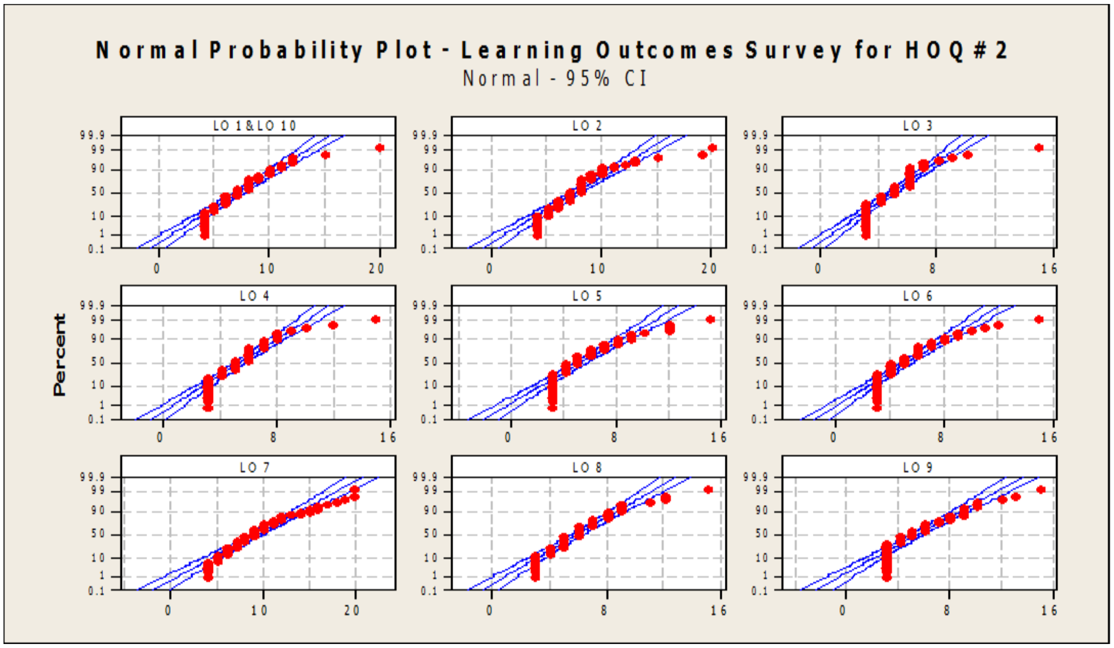


Figure 4.8 Normal probability plot - learning outcomes survey for HoQ#2

4.2.3 House of Quality #3 (HoQ#3) Inputs and Outputs

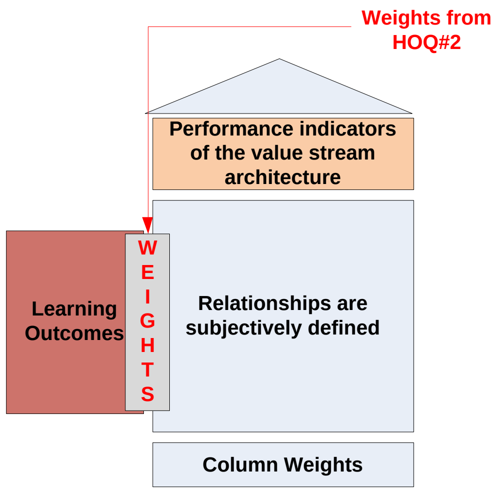


Figure 4.9 HoQ#3 in ABET - close look

HoQ#3, Figure 4.9, is a reflection of the change in the priorities of the educational objectives and learning outcomes on the department architecture including processes, events or culture; it represents the corrective actions that the industrial engineering department should adopt to account for this change. The performance indicators of the architecture components are used to study the relationships between the architecture components and the learning outcomes.

HoQ#3 is responsible for examining the current processes (workflows), the surveys that the department uses to collect the stakeholders' feedback (event), and the department culture (environment). HoQ#3 studies the relationships of all of the value stream architecture components toward the prioritized learning outcomes through the components' performance indicators. The current relationship between each process and each learning outcome is examined versus the expected relationship, the differences between the two are used to fill the relationship matrix inside the body of the house. The highest gap indicates that more attention has to be paid to a certain process or event which may result in process improvement, infrastructure expansion, or software development.

There is a difference in the way the researcher reads the third house than the first and second house. The researcher has to read the house horizontally and specify the learning outcome for which the department needs to check its processes, events or culture.

By examining the department processes (current and expected relationship) toward the most important learning outcomes (as an input from HoQ#2), the researcher will be able to identify the need for process improvement initiatives for a specific learning outcome.

Input:

- Prioritized list of critical learning outcomes from HoQ#2 (the WHATs).

- Performance indicators of the instructional or operational processes (workflows), stakeholders' feedback (events) or culture (environment) from the business architecture (the HOWs).
- Current and expected relationships inside the body of the house are defined by a team of expertise (faculty).

Output:

- Processes improvement, infrastructure expansion, or software development for one or more of the learning outcomes
- Tasks associated with process improvement, infrastructure expansion or software development.

To conduct a process improvement or business process reengineering initiative, the value stream architecture is the source of analysis and provides insight into performance improvements. Some of these initiatives require some sort of software development or enhancement support. UML may be used to enhance some of the operational processes conducted at the department. For instance; UML class diagrams can be used to create and maintain a relational database for all the surveys and data gathering processes. However; UML is not used for demonstration in this dissertation.

In this dissertation, we limited our scope to one instructional process which is the curriculum revising process in addition to the surveys used to get the stakeholders' feedback. The course control document (syllabus) and the surveys are used as performance indicators of the curriculum revision process and the stakeholders' feedback which are components of the value stream architecture.

The current relationships of the courses toward the learning outcomes are collected from the 2008 ABET self study report while the expected relationships are collected from the faculty. A matrix with all of the learning outcomes vs. all of the courses taught by each professor was distributed to all the faculty members to fill out the expected relationship of the courses they teach with each learning outcome.

However, the current and expected relationships between the surveys and the learning outcomes were identified by a Six Sigma team who worked on designing a Six Sigma project for the ABET process at the IEMS department in Fall 2009. The detailed analysis of the surveys is provided in HoQ#3 results in Chapter 5.

The difference between the current and expected relationship was calculated for each course versus each learning outcome to identify the highest gap that the department has to pay more attention to and used as an input to fill in the relationship matrix inside the body of HoQ#3.

4.3 Factor Analysis

Thus; for the application addressed in this research (ABET), the multivariate data analysis technique used was the exploratory factor analysis for the following main two reasons:

1. We care about grouping variables not cases/respondents or objects.

2. The underlying structure among the variables (IEMS educational objectives, learning outcomes and the customer requirements) is not clearly identified.

The steps undertaken to complete the factor analysis are presented in details in this chapter while the results for each step in each house is presented in Chapter 5. The five steps to conduct factor analysis are:

1. Assessing assumptions
2. Factors extractions
3. Factors rotation
4. Factors evaluation and interpretations
5. Assessing the reliability (internal consistency) of the instrument (survey)
6. Labeling the factors

4.3.1 Assessing Assumptions

A basic assumption of the exploratory factor analysis is the existence of underlying factors within a set of variables that can explain the interrelationships among those variables (Kim & Mueller, 1978). Factor analysis is performed using Pearson product moment correlations, taking into consideration the needed assumptions for this analysis, such as large sample size, continuous distributions and linear relationships among items. Tabachnick and Fidell (2001) argue that normality of distributions is not critical if the research objective is to explore, summarize and describe the underlying relationships among variables, but normality is an issue that needs to be considered if the research objective is to identify the number of factors.

In ABET application, the objective is to understand the relationships among learning outcomes and customer requirements, not to identify the number of factors; the number of factors is predetermined since it represents the number of the current educational objectives for the IEMS department (currently three). In our case; customer requirements and learning outcomes are extracted based on three factors in HoQ#1 and HoQ#2 respectively.

Figure 4.10 represents the flowchart describing the sequence of the critical assumptions needed for factor analysis.

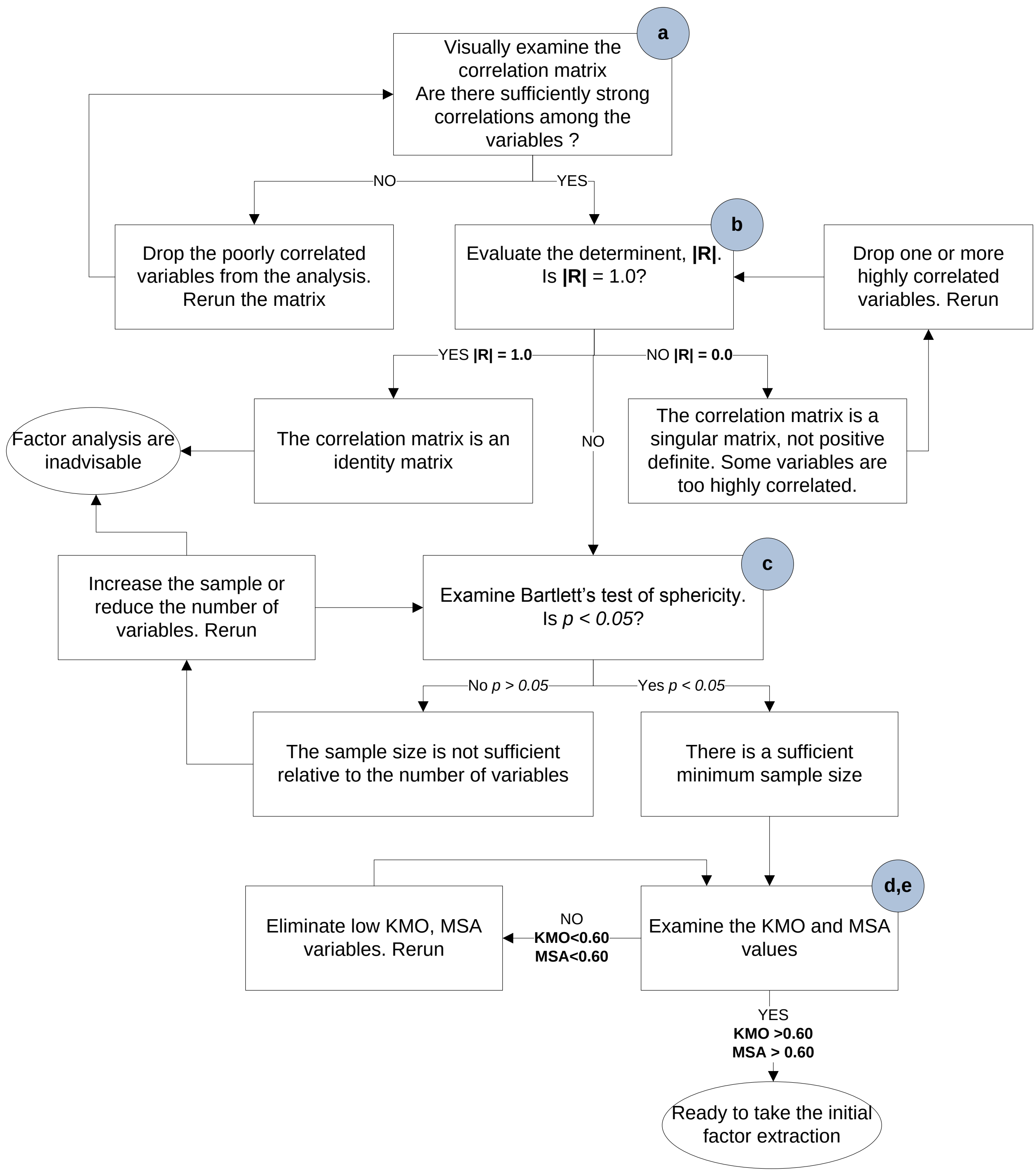


Figure 4.10 Assessing assumptions flow chart (Pett et al., 2003)

a) Examine the correlation among variables

Pett, (1997) suggested a rule of thumb to evaluate the strength of the relationship between two variables based on Pearson correlation. Table 4.6 shows the rule of thumb.

Table 4.6 Suggested rule of thumb for evaluating the strength (Pett, 1997)

Absolute Value of r	R^2	**Strength of Relationship**
.00-.29	.00-.08	Weak
.30-.49	.09-.24	Low
.50-.69	.25-.48	Moderate
.70-.89	.49-.80	Strong
0.90-1.00	0.81-1.00	Very strong

The significance level of the null hypothesis of no association exists between two variables has to be checked to satisfy a basic assumption of the availability of some common factors that describe the interrelationship among the variables.

b) Evaluate the determinant of the correlation matrix

The determinant of a square matrix determines whether or not a given matrix will have an inverse, which is important for the mathematical manipulations of the correlation matrix in factor analysis. If the determinant equals to zero; it means there is no inverse associated with the matrix which will make the mathematical manipulations in factor analysis indivisible.

c) Bartlett's Test of Sphericity

Bartlett's test of sphericity tests the null hypothesis that the correlation matrix is an identity matrix (i.e. no relationships among variables). The null hypothesis states that the correlation matrix is an identity matrix. Bartlett's test is a chi-square test that takes on the following form (Pedhazur & Schmelkin, 1991):

$$X^2 = -\left[(N-1) - \left(\frac{2k+5}{6}\right)\right]\log_e |R|$$

Where,

X^2 = calculated chi-square value for Bartlett's test

N = sample size

K= number of variables in the matrix

$\log_e$ = natural logarithm

|R| = determinant of the correlation matrix

The degrees of freedom (df) for this chi-square can be calculated as: df = k (k-1) / 2.

d) Kaiser-Meyer-Olkin Test (KMO)

KMO is a measure of the overall sampling adequacy that compares the magnitudes of the calculated correlation coefficients to the magnitudes of the partial correlation coefficients; it is a second indicator about the strength of the relationship among variables. KMO can be expressed as (Pett et al., 2003):

$$KMO = \frac{\sum (correlations)^2}{\sum (correlations)^2 + \sum (partialcorrelations)^2}$$

Kaiser (1974, p.35) suggests using the following criteria for the KMO values:

a. Above 0.90 is "marvelous".

b. In the 0.80s is “meritorious”.

c. In the 0.70s is just “middeling”.

d. Less than 0.60 is “mediocre”,”miserable”, or “unacceptable”.

e) Individual Measures of Sampling Adequacy (MSA)

In addition to the overall KMO, a measure of sampling adequacy can be computed for each individual variable using only the simple and partial correlation coefficients involving the particular item under consideration. The MSA for an individual item indicates how strongly that item is correlated with other items in the matrix (Pett et al., 2003). The same interpretation for standards of excellence outlined above for the KMO (Kaiser, 1974) can also be applied to the individual MSAs.

4.3.2 Factors Extraction

The factors extraction step is to determine the initial number of factors that represent the construct that is being measured. There is no one simple solution for the number of factors to be extracted, different researchers may select different number of factors to represent the construct of research. However; some guidelines are available to help the researcher when to stop extracting factors. Figure 4.11 shows the sequence of the three steps of factors extraction.

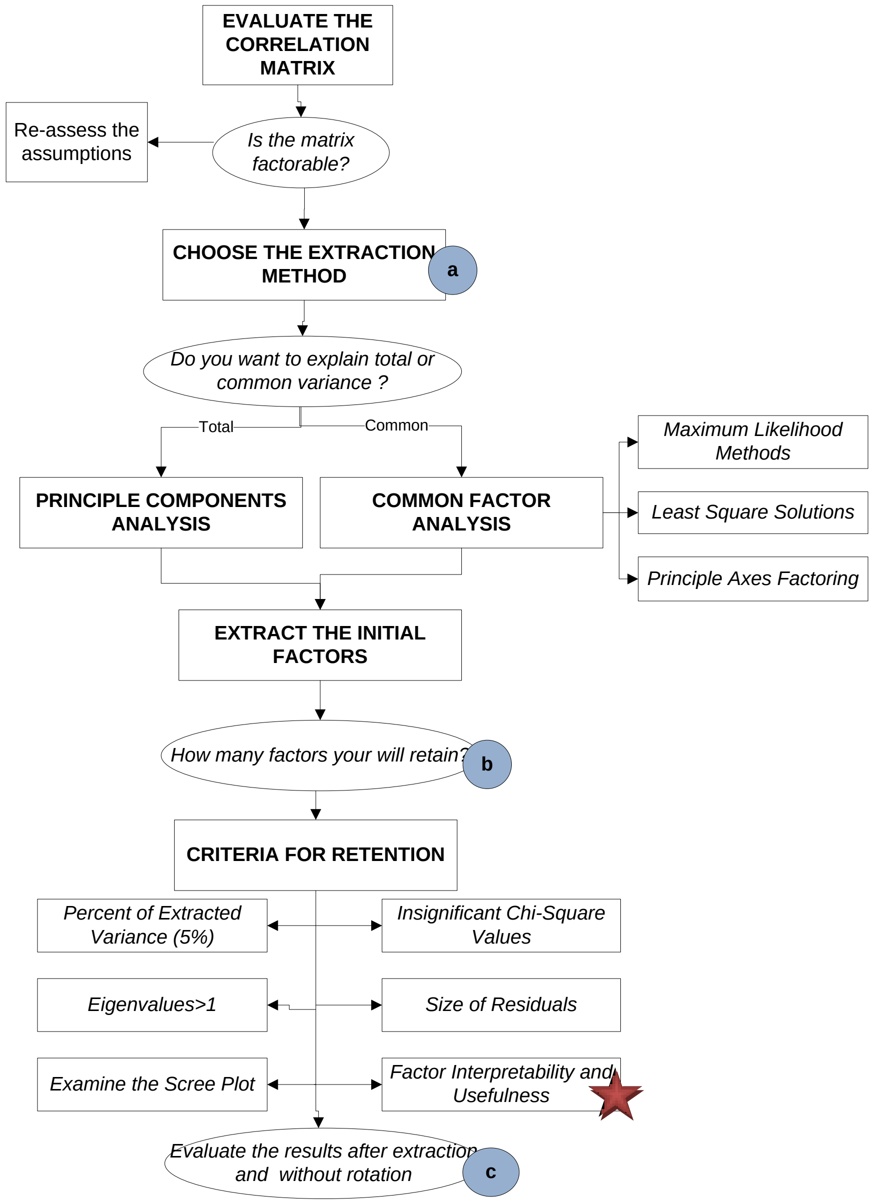


Figure 4.11 Extraction flow chart (Pett et al., 2003)

Factors extraction steps and results are explained in this section as follows:

a) Selecting a factor method

The extraction process begins with providing an initial estimate of the total amount of variance in each individual variable that is explained by the extracted factors (Pett et al., 2003).

The explained variance is referred to as the communality of an item which ranges from 0 to 1.0, higher values explain that the factors being extracted explain more of the variance of an individual variable. The total variance of any variable can be partitioned into three types (Hair et al., 2006):

1) Common variance: is the variance in a variable that is shared with all other variables, the variable communality is the estimate of a variable's shared or common variance among the variables as represented by the extracted factors.
2) Specific variance (unique variance): is that variance associated with only a specific variable. This variable is not explained by the correlations to the other variables but is associated with an individual variable.
3) Error variance: is also a variance that cannot be explained by the correlations with other variables, but it is due to unreliability in the data-gathering process, measurement error, or a random component in the measured phenomenon.

The total variance of any variable is composed of its common, specific and error variances. If a variable is highly correlated with one or more variables, the communality for this variable will increase.

To select the factor method, the researcher has to decide whether a total variance or a common variance needs to be analyzed. There are two available options (Hair et al., 2006):

1) Principle Component Analysis (PCA): considers the total variance and derives factors that contain small portions of unique variance and in some instances, error variance. It is appropriate when:
    - Data reduction is a primary concern, focusing on the minimum number of factors needed to account for the maximum portion of the total variance represented in the original set of variables
    - Prior knowledge suggest that specific and error variance represent a relatively small portion of the total variance
2) Common Factor Analysis (Maximum Likelihood methods, Least Squares Solutions, Principle Axis Factoring): considers only the common or shared variance assuming that both the unique and error variance are not of interest in defining the structure of the variables. It is most appropriate when:
    - The primary objective is to identify the latent dimensions or constructs represented in the original variables, and
    - The researcher has a little knowledge about the amount of specific and error variance and therefore wishes to eliminate this variance.

The default and most commonly used approach is the principle component analysis which we used in our analysis since we have a predetermined decision to extract three factors that represent the educational objectives of the IEMS department at UCF.

b) Determine the number of factors

There is no one precise solution for the number of factors to be extracted, different researchers may select different number of factors to represent the construct of research. However; some guidelines are available to help the researcher when to stop extracting factors (Pett et al., 2003):

1) Latent Root (Eigen values > 1): select only factors that have Eigen values > 1.00, this means that those factors will have more than their share of the total variance in the items. This method is most accurate when there are fewer than 40 variables, the sample size is large and the number of factors is expected to be between [n/5] and [n/3], where n is the number of variables included in the analysis.
2) Percent of variance extracted: the researcher terminates the factor extraction process when a threshold for maximum variance extracted (75%-80%) has been achieved. The advantage of this approach is that it would ensure practical significance of the factors.
3) Examining the scree plot: plot the extracted factors against their Eigen values in descending order of magnitude to identify distinct breaks in the slope of the plot. The point at which the curve first begins to straighten out is considered to indicate the maximum number of factors to extract.

   Cattell (1966) provided a general rule that the scree test results in at least one and sometime two or three more factors being considered for inclusion than does the latent root criterion (Eigen values greater than one).

4) Statistical significance of the extracted factors

   Examine the Chi-Square values to test the goodness-of-fit test. The statistic tests the null hypothesis that the fit of the data with the number of factors chosen (k) is adequate. In this test, the researcher is looking for the minimum number of factors that would results in a non-significant X^2 value. An assumption with this test is the normality; each variable in the correlation matrix has to be normally distributed.

5) Factor Interpretability and Usefulness

   Nunally and Bernstein (1994) caution the researcher against using rigid guidelines for determining the best number of factors to extract. The statistical solution that the researcher uses should be combined with theoretical sense. The best criteria for determining the number of factors are factor interpretability and usefulness during the initial extraction and after the factors have been rotated to achieve more clarity.

Pett (2003) suggests examining several solutions, Eigen values, explained variance, and Scree plot; then decide on the range of possible factors to extract; run different solutions and examine the loadings on the factors.

c) Examine the initial solution of the extracted factors without rotation

The researcher has to examine the initial factor matrix of loadings. Factor Loadings are the correlation of each variable and the factor. Loadings indicate the degree of correspondence between the variable and the factor, with higher loadings making the variable representative of the factor (Hair et al., 2006). If the initial solution doesn't show a clear clustering of the variables among factors, the researcher has to rotate the factors. In most cases, rotation of the factors improves the interpretation by reducing the ambiguities that often accompany the initial un-rotated factor solution.

4.3.3 Factors Rotation

The un-rotated factor solution indicated in Section 4.3.2 extracts factors in the order of their variance extracted. The first factor tends to be a general factor with almost every variable loading significantly, and it accounts for the largest amount of variance. The second and subsequent factors are then based on the residual amount of variance. Each accounts for successively smaller portions of variance. By rotating the factors, the reference axes of the factors are turned around the origin until some other position has been reached. Figure 4.12 shows the orthogonal rotation; one type of rotation methods.

The ultimate effect of rotating the factor matrix is redistributing the variance from earlier factors to later ones to achieve a simpler, theoretically more meaningful pattern. There are two types of rotations; Orthogonal Factor Rotation in which the angle between the axes is 90 degrees while the angle is not constrained in the Oblique Factor Rotation (Hair et al., 2006).

The selection of orthogonal or oblique approach is based on how the researcher suspects the factors to be correlated. The orthogonal approach assumes that the factors are not correlated and independent, hence; the cosine of the angle θ between the two factors' axes is equal to zero and the angle is 90^o. The oblique approach assumes somehow a high correlation among the factors; and the angle between the two factors' axes is determined according to the strength of the correlation by taking the inverse cosine (arc) of the correlation between the two factors ($cos^{-1}(r)$). For example; for correlated factors with r = 0.43, the angle θ could be $\cos^{-1}(0.43)$ = 64° and for r = -0.191, the angle could be 101°.

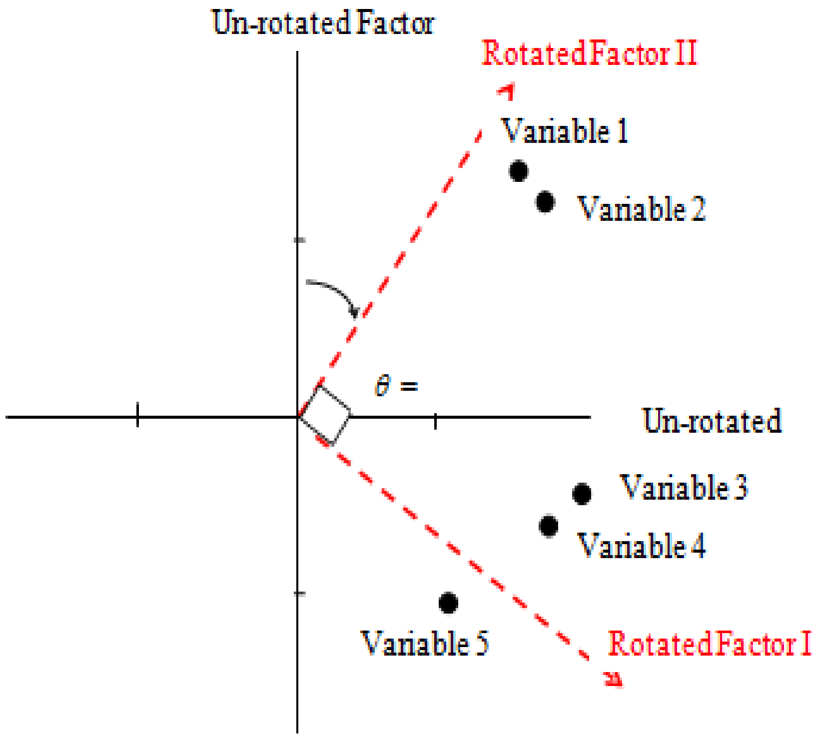


Figure 4.12 Orthogonal factor rotation (Hair et al., 2006)

Figure 4.13 represents the flowchart for Factors Rotation.

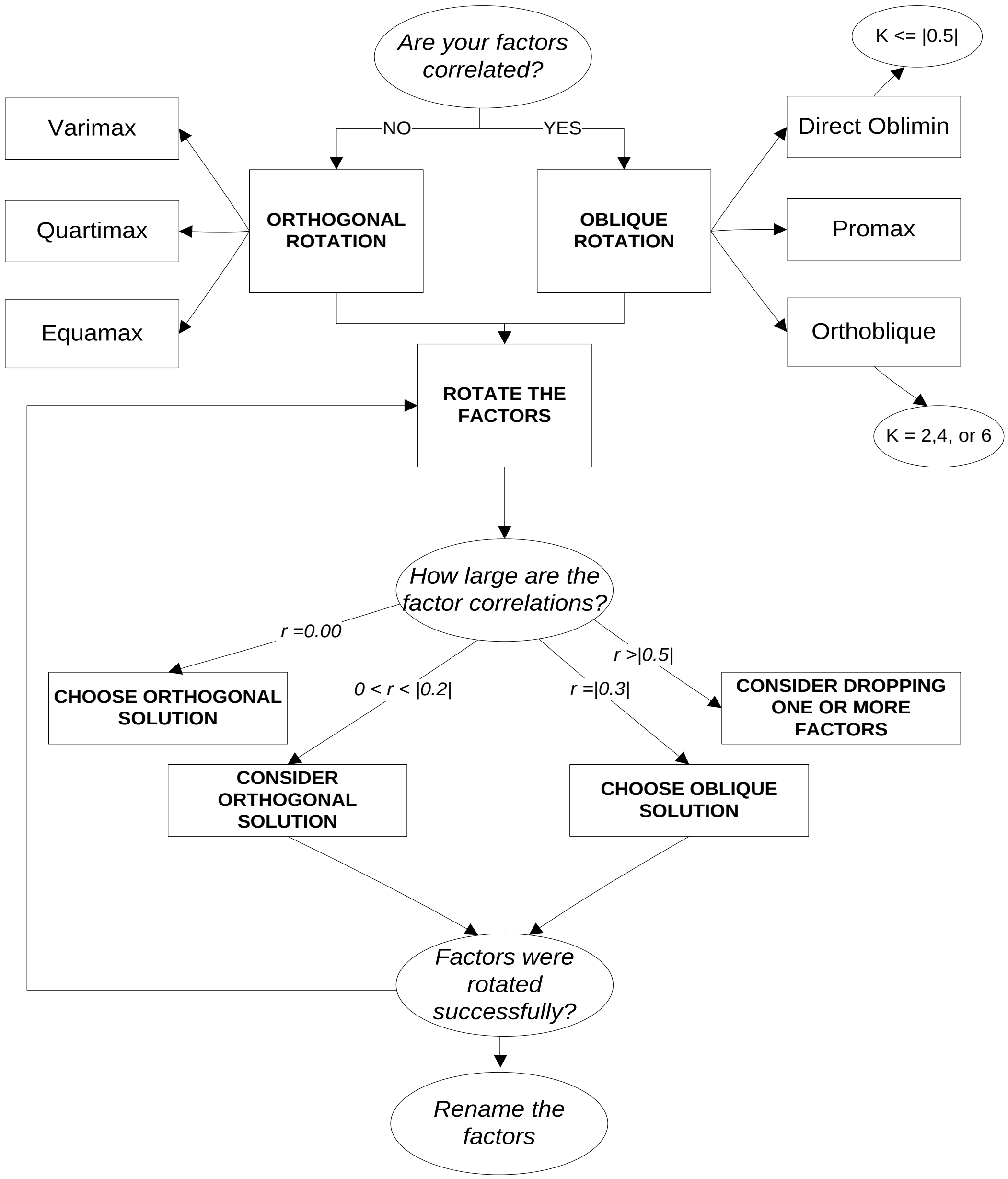


Figure 4.13 Factors rotation flowchart (Pett et al., 2003)

4.3.4 Factors Evaluations and Interpretation

As a final process, we should evaluate the factor loadings on each factor, the evaluation may result in:

1) Deletion of one or more of the variables.
2) Employing a different rotational approach.
3) Extracting different number of factors.
4) Changing the extraction method.
5) Ignore the variables that cause problems

The evaluations steps are:

a) Judging the significance of the factor loadings

   Hair et al., page 128 (2006) proposed some guidelines to assess the significance of a factor loading on a certain factor based on the sample size. The guidelines are shown in the following table.

Table 4.7 Guidelines for identifying significant factor loadings based on sample size significance is based on a 0.05 significance level (Hair et al., 2006)

Factor Loading	**Sample Size Needed for Significance**[a]
0.30	350
0.35	250
0.40	200
0.45	150
0.50	120
0.55	100
0.60	85
0.65	70
0.70	60
0.75	50

b) Assessing the communalities of the variables after the rotation

One simple approach that Hair et al., (2006) suggest is examining the variable's communality, representing the amount of variance accounted for by the factor solution for each variable. They suggest excluding the variable(s) that does not have sufficient explanation of the variance; this implies any communality less than 0.50.

After assessing the significance of loadings and the communalities, we have to check the availability of any of the following:

1) A variable that doesn't have any significant loading on any of the factors.
2) Cross loading problem: when a variable is significant on more than one factor.

4.3.5 Assessing the reliability (internal consistency) of the instrument (survey)

The reliability refers to the degree of consistency between multiple measurements of a variable. A commonly used measure to assess the reliability of a survey is to check its internal consistency which applies to the consistency among the variables in a summated scale. A diagnostic measure to assess the reliability is the reliability coefficient (Cronbach's alpha), the typical lower limit for Cronbach's alpha is 0.70 and it may decrease to 0.60 in exploratory research (Hair et al., 2006). The equation for the Cronbach's alpha as mentioned in Pett et al., (2003) is:

$$r_{kk} = \frac{k}{k-1}(1-\frac{\sum \sigma_i^2}{\sigma_x^2})$$

Where

r_{kk} = coefficient alpha

k = number of variables in the scale

$\sum \sigma_i^2$ = sum of the variances of the individual variables

σ_x^2 = variance for the composite scale

A flow chart that describes step 4 and 5 is shown Figure 4.14.

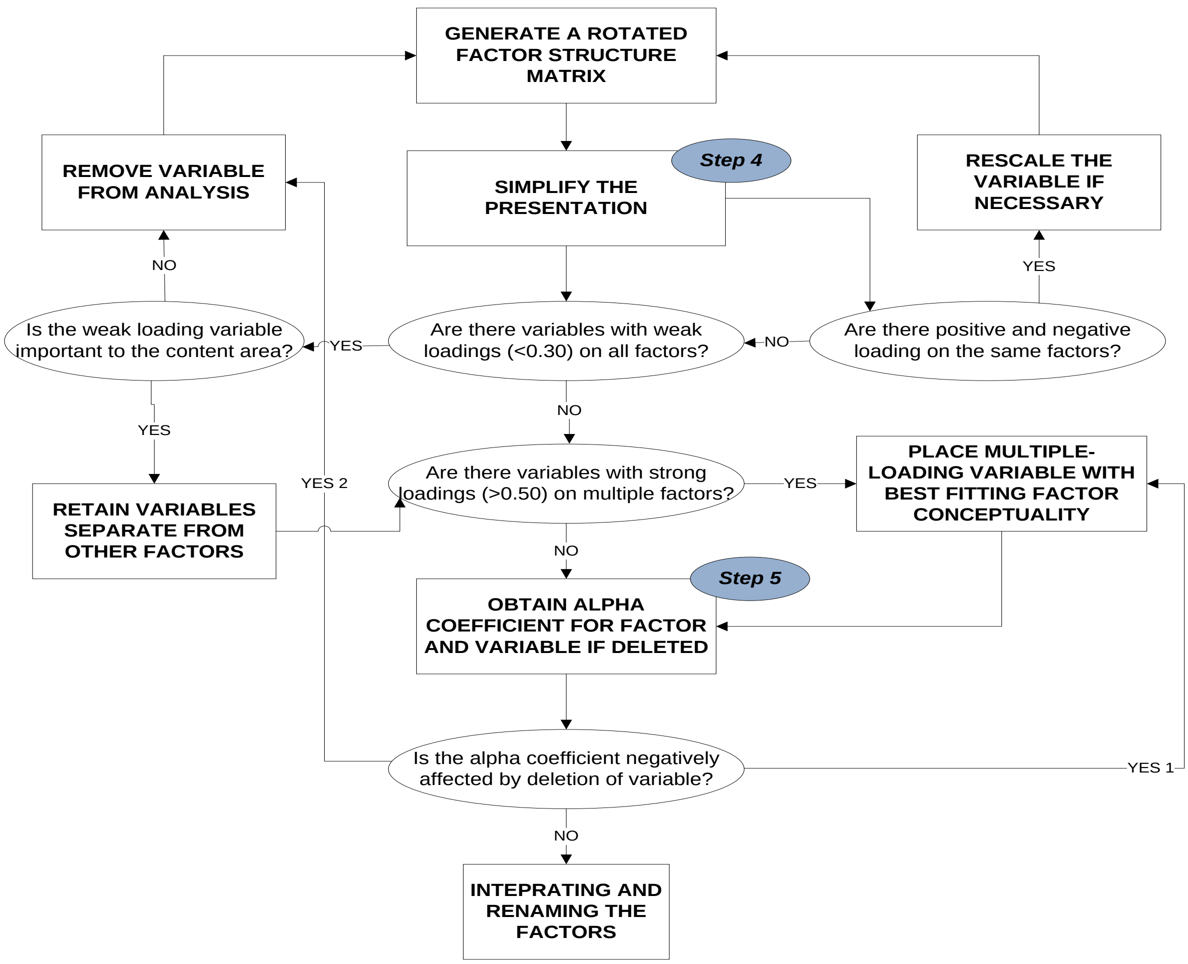


Figure 4.14 Refining the factors & evaluate internal consistency (Pett et al., 2003)

4.3.6 Labeling the Factors

When the researcher reaches an acceptable factor solution, he/she tries to assign some meaning to the pattern of factor loadings. Variables with higher loadings should have greater influence on the name selected to represent a factor. The name of the factor is not derived or assigned by the factor analysis computer program; the name is intuitively developed by the researcher based on its appropriateness for representing the underlying dimensions of a particular factor.

CHAPTER 5 INTEGRATION AND RESULTS

The proposed mechanism in this research work is built in the basic conceptual model context of EBA. This basic structure illustrates how all of the industrial engineering department dimensions fit together to form a harmonious whole for the department and it allows the department to focus on specific components for analysis while understanding their relationships to the whole department architecture.

Figure 5.1 illustrates the basic conceptual model of the IEMS architecture.

The educational objectives represent the business strategies, learning outcomes are the business capabilities while the value stream architecture components are mapped as follows:

- The event is represented by the stakeholders' feedback.
- The environment is represented by the culture in the department.
- The workflows are represented using two types of processes, instructional processes and operational processes. The curriculum revision process and the facilities checking are used as examples of the instructional processes, while the database maintenance is used as an example to the operational processes.

The performance indicators of the curriculum revision process (syllabus) and stakeholders' feedback (surveys) are selected to demonstrate the proposed framework in this work.

This chapter discusses the integration between the three houses proposed in this research. HoQ#1 and HoQ#2 were built using an input from the ABET surveys and the factor analysis while HoQ#3 was built using the performance indicators of the architecture processes, events and environment. The faculty input to HoQ#3 was to identify the expected strength of the relationships between the architecture components and the learning outcomes while the current strength was identified using the 2008 ABET self study report. A gap analysis between the current and the expected relationships is done, by taking the difference between the two, to decide to which architecture component the department has to pay more attention. The higher the gap is, the more attention the department has to pay to the corresponding architecture component.

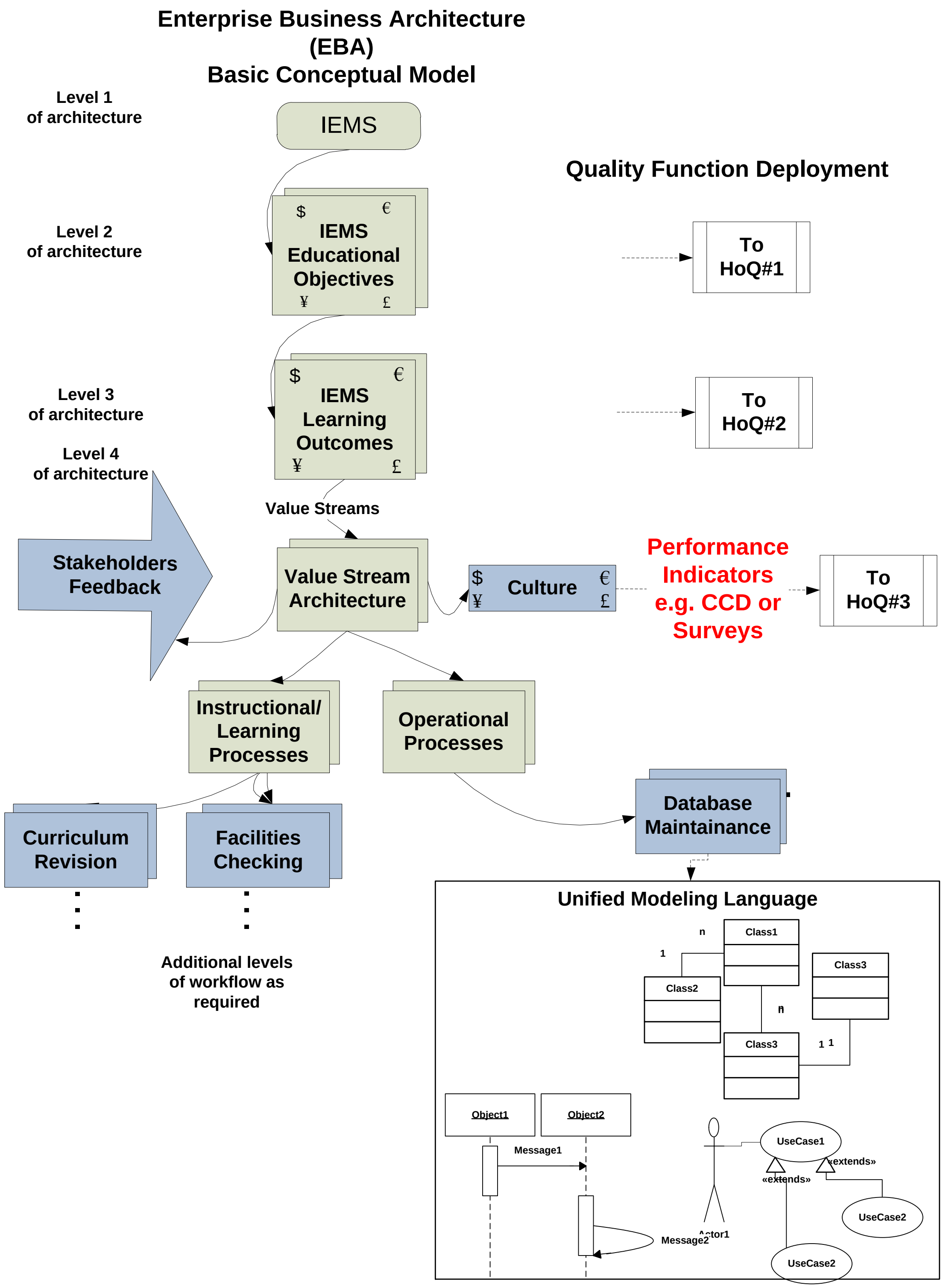


Figure 5.1 Basic conceptual model of the architecture at the IEMS department

5.1 HoQ#1 Results – Base Model (2002 to 2004 data) – HoQ#1

5.1.1 Assessing Assumptions

In this section we will assess the ability of the data used for the HoQ # 1 in the base model (initiation phase) to be factorable. The base model HoQ#1 is shown in Figure 5.2.

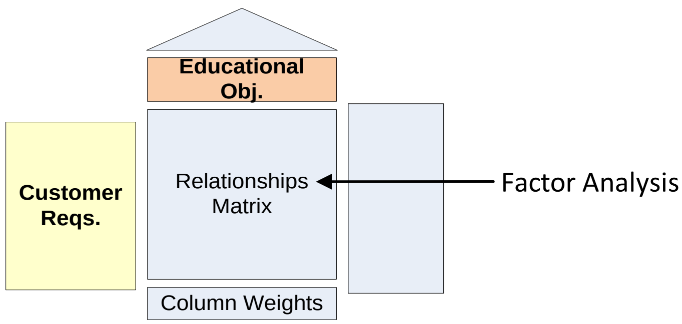


Figure 5.2 Base model in ABET - HoQ#1

The customer requirements are gathered using the industrial engineering (IE) program specific exit survey shown in Appendix B .Questions 2 through 14 only were included in the analysis; the correlations among them were examined by inspection and grouped into 4 variables as shown in Table 5.1. The grouping of the questions into variables was statistically proved using the Cronbach's alpha as shown previously in Section 4.2.

The value of each variable corresponds to the summation of the responses of the related questions to make the data more continuous and as close as possible to normality, although, normality is not critical when the objective is to understand the relying structure among variables, which represents the case here.

Figure 4.10 presents the flowchart describing the sequence of the critical assumptions needed for factor analysis. The assumptions results in ABET application for the first run of HoQ#1 (base model) are as follows:

a) Examine the correlation among variables

Table 5.1 Pearson correlation (r) among variables for the base Model - HoQ#1

Descriptive Statistics

	Mean	Std. Deviation	N
tech	8.6182	2.69890	110
comm	6.2545	2.46233	110
team	4.5636	1.88440	110
contemp	3.5818	1.76813	110

Correlations

		tech	comm	team	contemp
tech	Pearson Correlation	1	.643**	.472**	.362**
	Sig. (2-tailed)		.000	.000	.000
	N	110	110	110	110
comm	Pearson Correlation	.643**	1	.370**	.284**
	Sig. (2-tailed)	.000		.000	.003
	N	110	110	110	110
team	Pearson Correlation	.472**	.370**	1	.490**
	Sig. (2-tailed)	.000	.000		.000
	N	110	110	110	110
contemp	Pearson Correlation	.362**	.284**	.490**	1
	Sig. (2-tailed)	.000	.003	.000	
	N	110	110	110	110

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.1 shows descriptive statistics and the correlations among the variables in HoQ#1 for the base model. A visual examination of the Pearson correlation table shows that none of the variables has a weak correlation ($0.00 < r^2 < 0.08$) or very strong one ($0.81 < r^2 < 1.0$).The coefficient of determination (r^2) is used to assess the strength of a relationship between two variables. It represents the proportion of variance in one variable that is associated with another one. A rule of thumb suggested by (Pett, 1997) for evaluating the strength of the relationship is presented previously in Table 4.6.

Moreover; the significance levels in Table 5.1 are almost equal to zero which means at alpha=0.05 we would reject the null hypothesis H_0 of no association between two variables. Significant correlation exists to satisfy the basic assumption of the availability of some common factors that describe the interrelationship among the variables.

b) Evaluate the determinant of the correlation matrix

The determinant for our correlation matrix was calculated using SPSS statistical software and it equals to 0.333 which confirms the existence of correlation among variables.

The Bartlett's test value equals to 117.56 calculated using SPSS and shown in Table 5.2 is greater than the critical value obtained from the Chi-Square table which equals to 12.5916 (df=6). Additionally, the p-value is zero (less than alpha = 0.05) which indicates that we should reject the null hypothesis of no relationships among variables and indicates that our correlation matrix is not an identity matrix.

Table 5.2 KMO and Bartlett's test for the base model - HoQ#1

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.690**
Bartlett's Test of Sphericity	Approx. Chi-Square	**117.560**
	df	6
	Sig.	.000

c) Kaiser-Meyer-Olkin Test (KMO)

Table 5.2 shows that the size of KMO in our analysis equals to 0.690 which meets the "middeling" criteria suggested by Kaiser (1974, p.35).

d) Individual Measures of Sampling Adequacy (MSA)

The underlined values in Table 5.3 are the measures of sampling adequacy (MSA) for the four individual variables, technical skills, communication skills, team skills and contemporary issues. MSA for those variables is close to 0.7 which meets the "middeling" criteria.

Table 5.3 Individual measure of sampling adequacy for the base model - HoQ#1

Anti-image Matrices

		tech	comm	team	contemp
Anti-image Covariance	tech	.516	-.308	-.148	-.074
	comm	-.308	.580	-.048	-.024
	team	-.148	-.048	.656	-.267
	contemp	-.074	-.024	-.267	.737
Anti-image Correlation	tech	**.659**[a]	-.563	-.255	-.121
	comm	-.563	**.661**[a]	-.077	-.036
	team	-.255	-.077	**.733**[a]	-.384
	contemp	-.121	-.036	-.384	**.735**[a]

a. Measures of Sampling Adequacy(MSA)

Our conclusions based on the above analysis for HoQ#1 in the base model are:

- According to Bartlett's test, the correlation matrix is not an identity matrix.
- The KMO statistic suggests that we have a sufficient sample size relative to the number of items in our scale.
- The MSA statistics indicate that the correlations among the individual items are good to suggest that the correlation matrix is factorable.

5.1.2 Factors Extraction

As we have seen in step 1, the four variables satisfy the factor analysis assumptions; hence they are factorable.

a) Selecting a factor method

   The default and most commonly used approach is the principle component analysis which we used in our analysis.

b) Determine the number of factors

   In this research, we extracted the four variables into three factors since we have a predetermined decision to extract three factors that represent the educational objectives of the IEMS department at UCF.

   However; to statistically support the selection of three factors, we used the following guidelines:

   1) Examining the scree plot:

Although the number of factors that have an Eigen value greater than one is only one factor. The scree plot in Figure 5.3 shows that the slope of the line becomes smaller after extracting three factors than one or two only. As we mentioned earlier in this document, Cattell (1966) provided a general rule that the scree test results in at least one and sometime two or three more factors being considered for inclusion than does the latent root criterion (Eigen values greater than one).Extracting three factors is still acceptable according to Cattell (1966).

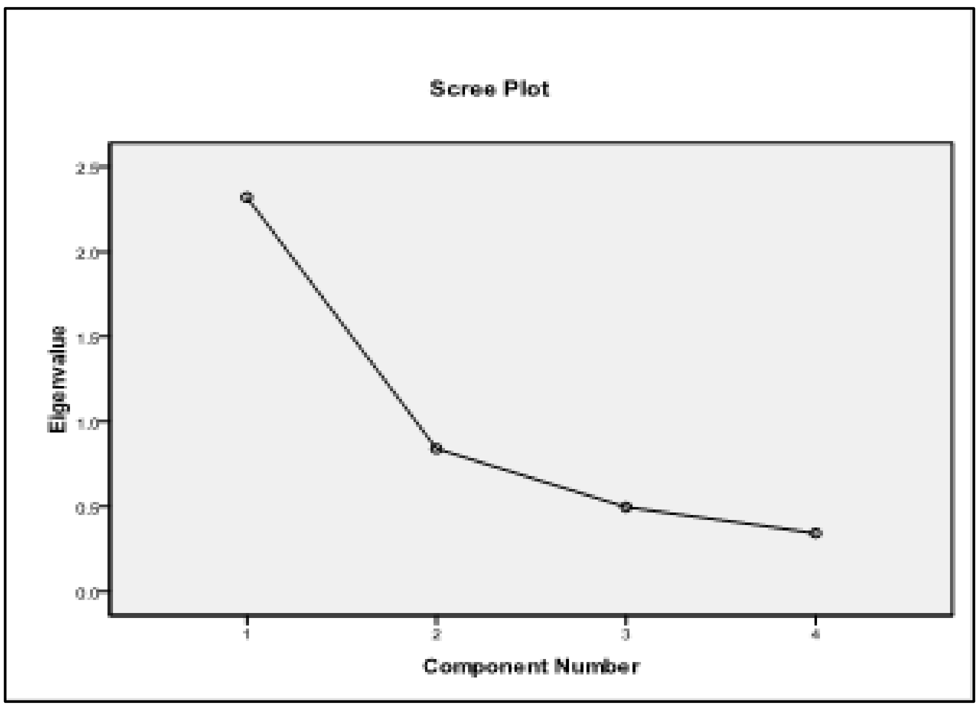


Figure 5.3 Scree plot of the four variables in HoQ#1 - base model

2) Percent of variance extracted:

The cumulative percentage of variance explained by the variables and after extracting three factors (components) equals to 91.411 % as shown in Table 5.4. This indicates a practical significance of the factors being extracted (greater than 80%).

Table 5.4 Total variance explained for the HoQ#1 in the base model

Total Variance Explained

Component	Initial Eigen values			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.319	57.983	57.983	2.319	57.983	57.983
2	.840	21.000	78.983	.840	21.000	78.983
3	.497	12.428	91.411	.497	12.428	**91.411**
4	.344	8.589	100.000			

Extraction Method: Principal Component Analysis.

c) Examine the initial solution of the extracted factors without rotation

The initial un-rotated factor matrix (3 factors extracted) using principle component analysis is computed and shown in Table 5.5. The values in the table represent the factor loadings of each variable on each factor.

The initial solution does not show clear clustering for the four variables; the four variables have significant loadings (>0.5) on the first factor. However; the solution doesn’t appear to make the most sense theoretically and intuitively. Thus; we will employ a rotational method (explained in step 3) to achieve simpler and theoretically more meaningful factor solutions.

Table 5.5 Three UNROTATED factors extracted using principle component analysis

Component Matrix[a]

	Component		
	1	2	3
tech	.832	-.336	.001
comm	.765	-.506	.144
team	.764	.348	-.534
contemp	.677	.592	.438

Extraction Method: Principal Component Analysis.
a. 3 components extracted.

5.1.3 Factors Rotation

Since the three factors in our HoQ#1 in the base model should represent the three educational objectives set by the IEMS department, we assume that each educational objective targets one goal; this implies independence between the educational objectives. Thus; the orthogonal rotation approach is used for the ease of analysis. There are three orthogonal approaches (VARIMAX, QUARTIMAX and EQUIMAX); each approach differs in the goal of achieving orthogonal rotation and in the angle of rotation (not the angle between the factors axes). The VARIMAX is the default orthogonal approach in most of the orthogonal rotations and its goal is to maximize the variances of the loadings within the factors in addition to maximize the differences between the high and low loadings on a particular factor (Pett et al., 2003). QUARTIMAX focuses on simplifying the rows of the factor loading matrix while EQUIMAX combines both goals of VARIMAX and QUARTIMAX. The resulted rotated matrix is shown in Table 5.6 Factors plot in rotated space is shown in Figure 5.4.

Table 5.6 Rotated factor loading matrix using VARIMAX for HoQ#1 in the base model

Rotated Component Matrix[a]

	Component		
	1	2	3
comm	**<u>.917</u>**	.095	.113
tech	**<u>.829</u>**	.303	.164
team	.235	**<u>.935</u>**	.245
contemp	.166	.230	**<u>.959</u>**

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

Component Plot in Rotated Space

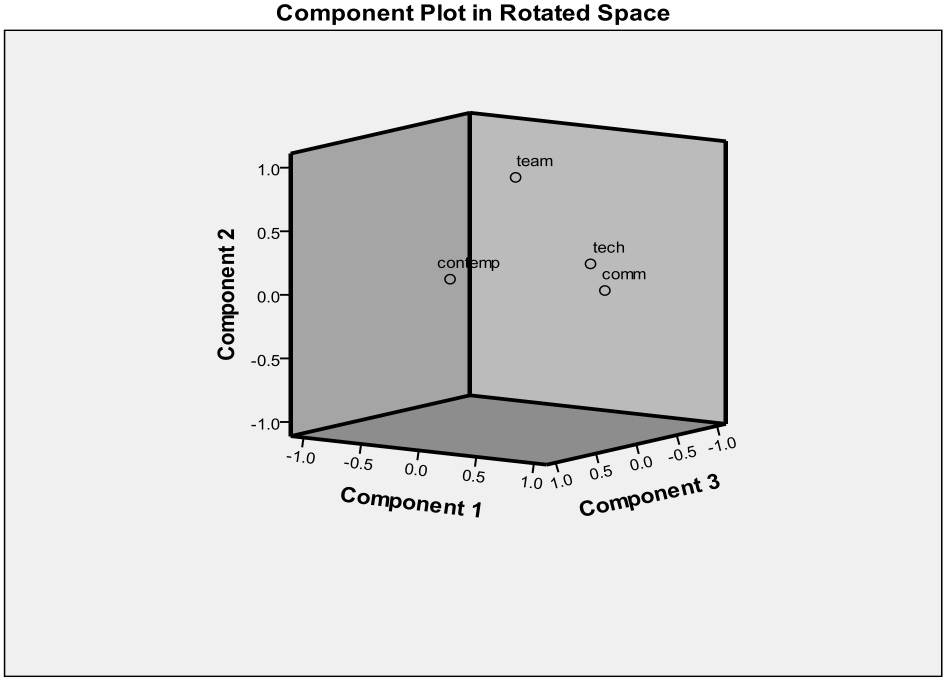


Figure 5.4 Factors (components) plot in rotated space for HoQ#1 in the base model

5.1.4 Factors Evaluations and Interpretation

In our application, we started with the following decision to evaluate our factor loading matrix:

1. Judging the significance of the factor loadings

   The number of responses (sample size) gathered toward the exit survey for HoQ#1 in the base model was 103 after ignoring 7 responses for their missing answers; this implies to 0.5 significance level on α = 0.05, Hail et al., page 128 (2006). Table 5.6 shows significant loadings of the "technical and communication skills" on factor 1, "team skills" on factor 2, and "contemporary & global" issues on factor 3.

2. Assessing the communalities of the variables after the rotation

   Table 5.7 shows that none of the variables has to be excluded since all of their communalities are greater than 0.5 which means they have sufficient explanation of the variance.

Table 5.7 Communalities after extracting 3 factors for the HoQ#1 in the base model

Communalities

	Initial	Extraction
tech	1.000	.805
comm	1.000	.862
team	1.000	.989
contemp	1.000	1.000

Extraction Method: Principal Component Analysis.

In our application, after extracting four variables into three factors using the principle component analysis and rotating the factors using the VARIMAX, we have the best solution that makes sense theoretically and intuitively which is shown in Table 5.6.

5.1.5 Assessing the reliability (internal consistency) of the instrument (survey)

Table 5.8 and Table 5.9 show all the values needed to calculate the Cronbach's alpha value for the four variables in HoQ#1 in the base model.

K=4,

$$\sum \sigma_i^2 = (2.69)^2 + (2.46)^2 + (1.88)^2 + (1.76)^2 = 19.22$$

$$\sigma_x^2 = 46$$

The calculated Cronbach's alpha shown in Table 5.10 equals to 0.753 which indicates an internal consistency of the survey that has been conducted.

Table 5.8 Descriptive statistics of the four variables in HoQ#1 in the base model

Variables Statistics

	Mean	Std. Deviation	N
tech	8.6182	2.69890	110
comm	6.2545	2.46233	110
team	4.5636	1.88440	110
contemp	3.5818	1.76813	110

Table 5.9 Statistics summary of the summated scale of four variables in HoQ31 in the base model

Summary Variable Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Variables Means (Mean of the means)	5.755	3.582	8.618	5.036	2.406	4.863	4
Variables Variances	5.006	3.126	7.284	4.158	2.330	3.986	4
Inter-Item Covariances	2.165	1.236	4.272	3.037	3.457	1.097	4
Inter-Item Correlations	.437	.284	.643	.359	2.265	.015	4

Scale Statistics			
Mean	Variance	Std. Deviation	N of Items
23.0182	46.000	6.78231	4

Table 5.10 Cronbach's alpha

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.753	.756	4

Table 5.11 shows that how Cronbach's alpha changes when we delete any of the variables.

Results show that none of the variables' deletion will result in a higher Cronbach's alpha value. Our conclusion is that our coefficient alpha is strong (0.753), or 75.3% of the variance of the total scores on this subscale can be attributed to reliable, or systematic variance.

Table 5.11 Variable-total Statistics for the four variables in HoQ#1 (base model)

Variable-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
tech	14.4000	21.912	.665	.484	**.628**
comm	16.7636	25.485	.581	.420	**.678**
team	18.4545	30.947	.549	.344	**.702**
contemp	19.4364	33.679	.448	.263	**.747**

5.1.6 Labeling the Factors

Since we have only four variables in HoQ#1 in the base model and they are grouped into three factors, naming them should be related to the variables in each factor. The three factors should be related to the educational objectives that the IEMS department at UCF is assessing. The results of our analysis are:

1. Factor 1: includes communication skills and technical skills variables; factor 1 is labeled with the name of the variable that has the highest loading among the variables that have significant loadings. Thus; factor 1 is named “Communication”.
2. Factor 2: includes one variable which is team skills.
3. Factor 3: includes one variable which is contemporary issues.

However; the three factors resulted from our analysis are not clearly mapped (one to one mapping) to the three current educational objectives at the IEMS department listed below:

1. Educational Objective 1:“To produce graduates who assume challenging or satisfying positions in the private and public sectors.”
2. Educational Objective 2: “To produce graduates who achieve professional growth through advanced studies and/or career development activities.”
3. Educational Objective 3: “To produce industrial engineering professionals who recognize that engineering is a global service profession that must be practiced ethically with integrity, honesty, and objectivity.”

This indicates that the assessment tool (exit survey) that has been distributed before 2007 is not well structured to measure the three educational objectives.

None of the questions in the exit survey measures the second educational objective which addresses the preparation of the students for professional growth i.e., enrollment in graduate studies, conferences or professional organizations.

A new design of the exit survey is provided in Appendix F.

The base model of HoQ#1 prioritized the three factors generated from the factor analysis performed on the exit survey distributed from 2002 until 2004. The weight given to each educational objective indicates its importance. HoQ#1 (base model) results are shown in Figure5.5.

	Business Strategy (Educational Objectives) / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Weight according to Advisory Weight Input - ABET Report	Factor 1 Technical + Communication	Factor 2 Team	Factor 3 Contemporary Issues
			+	+	+
			Factor Loading	Factor Loading	Factor Loading
1	Communication (5)	5	0.917	0.095	0.113
			4.585	**0.475**	**0.565**
2	Technical (4)	4	0.829	0.303	0.164
			3.316	**1.212**	**0.656**
3	Team (5)	5	0.235	0.935	0.245
			1.175	**4.675**	**1.225**
4	Contemporary (3)	3	0.166	0.230	0.959
			0.498	**0.690**	**2.877**
	TOTAL		9.57	7.05	5.32
	RELATIVE IMPORTANCE		44%	32%	24%

Figure 5.5 HoQ#1 base model combined results (2002-2004)

5.2 Factor Analysis Results – Dynamic Model (2007 and 2008) – HoQ#1

NOTE: This section shows the results with the reflective statements. The importance of each step and its explanation are described earlier in the Section 4.3.

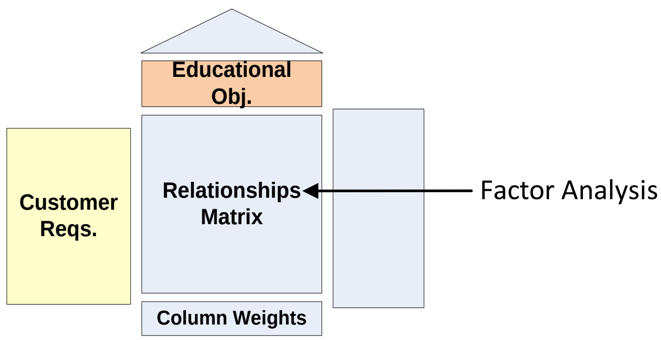


Figure 5.6 Dynamic model - HoQ#1

5.2.1 Assessing assumptions

In this section we will be assessing the data used for the HoQ#1 in the dynamic model, Figure 5.6, which is fed with new customer requirements.

The customer requirements are gathered using IEMS program specific exit survey shown in Appendix B (including 2007 and 2008 data only). Questions 2 through 14 only were included in the analysis, the correlations among them were examined visually and grouped similar to the groupings in Table 4.1. The grouping of the questions into variables was statistically proved using the Cronbach's alpha as shown previously in Section 4.2.

The values of each variable correspond to the summation of the responses of the variable related questions to make the variable values as close as possible to normality. However; as mentioned earlier, normality is not critical when the objective is to understand the relying structure among variable.

a) Examine the correlation among variables

Table 5.12 Dynamic model - HoQ#1: pearson correlation among variables

Correlations

		tech	comm	team	contemp
tech	Pearson Correlation	1	.435**	.641**	.523**
	Sig. (2-tailed)		.000	.000	.000
	N	68	68	68	68
comm	Pearson Correlation	.435**	1	.500**	.397**
	Sig. (2-tailed)	.000		.000	.001
	N	68	68	68	68
team	Pearson Correlation	.641**	.500**	1	.459**
	Sig. (2-tailed)	.000	.000		.000
	N	68	68	68	68
contemp	Pearson Correlation	.523**	.397**	.459**	1
	Sig. (2-tailed)	.000	.001	.000	
	N	68	68	68	68

**. Correlation is significant at the 0.01 level (2-tailed).

- None of the correlations between the variables in Table 5.12 has a weak correlation ($0.00 < r^2 < 0.08$) or very strong correlation ($0.81 < r^2 < 1.0$).
- The significance levels are all almost equal to zero, which means at alpha=0.05 we would reject the null hypothesis H_0 of no association between the two variables.

However; significant correlation exists to satisfy the basic assumption of the availability of some common factors that describe the interrelationship among the variables.

b) Evaluate the determinant of the correlation matrix

- The determinant for the correlation matrix was calculated using SPSS and it was found to be 0.291. This confirms the existence of correlation among the variables.

c) Bartlett's Test of Sphericity

We should reject the null hypothesis of no relationships among variables for the following reasons:

- The Barlteltt's test value equals to 79.973 calculated using SPSS and shown in Table 5.13 is greater than the critical value obtained from the Chi-Square table which equals to 12.5916 (df=6).
- Additionally, the p-value equals to zero (less than alpha = 0.05) which indicates that our correlation matrix is not an identity matrix.

Table 5.13 KMO and Bartlett's test

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.764
Bartlett's Test of Sphericity	Approx. Chi-Square	79.973
	df	6
	Sig.	.000

d) Kaiser-Meyer-Olkin Test (KMO)

The overall adequacy; measured by the size of KMO; is close to the "meritorious" criteria Kaiser (1974, p.35). The size of KMO in our analysis equals to 0.764 as shown in Table 5.13.

e) Individual Measures of Sampling Adequacy (MSA)

The individual adequacy; measured by MSA; meets the “meritorious” criteria, Kaiser (1974, p.35). MSA for the four variables are above 0.7 as shown in Table 5.14 (underlined values).

Table 5.14 Individual measure of sampling adequacy

Anti-image Matrices

		tech	comm	team	contemp
Anti-image Covariance	tech	.517	-.065	-.245	-.184
	comm	-.065	.706	-.176	-.119
	team	-.245	-.176	.520	-.076
	contemp	-.184	-.119	-.076	.680
Anti-image Correlation	tech	**.725**[a]	-.108	-.472	-.310
	comm	-.108	**.826**[a]	-.291	-.172
	team	-.472	-.291	**.729**[a]	-.128
	contemp	-.310	-.172	-.128	**.819**[a]

a. Measures of Sampling Adequacy(MSA)

We conclude from the above analysis for the HoQ#1 in the Dynamic model:

- According to Bartlett’s test, the correlation matrix is not an identity matrix.
- The KMO statistic suggests that we have a sufficient sample size relative to the number of items in our scale.
- The MSA statistics indicate that the correlations among the individual items are good to suggest that the correlation matrix is factorable.

5.2.2 Factors Extraction

a) Selecting a factor method

- Principle component analysis method was used.

b) Determine the number of factors

In this research, we extracted the four variables into three factors since we have a predetermined decision to extract three factors that represent the educational objectives of the IEMS department at UCF.

However; to statistically support the selection of three factors, we used the following guidelines:

1. Examining the scree plot:

   The number of factors that have an Eigen value greater than one is only one factor as shown in Figure 5.7. However; taking extra two or three points are still acceptable according to Cattell (1996).

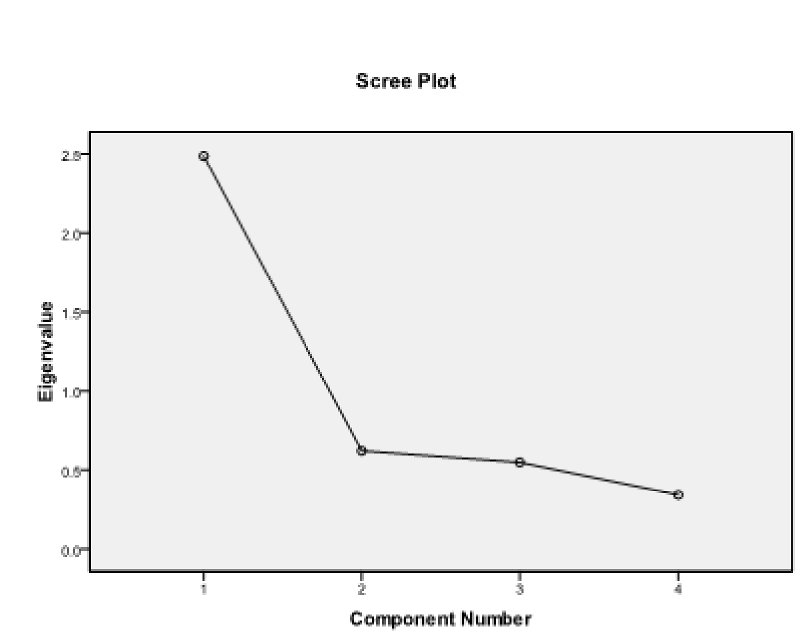


Figure 5.7 Scree plot of the four variables in HoQ#1 - dynamic model

2. Percent of variance extracted:

   The cumulative percentage of variance explained by the variables and after extracting three factors (components) equals to 91.427 as shown in Table 5.15. This indicates a practical significance of the factors being extracted (greater than 80%).

Table 5.15 Total variance explained for the HoQ#1 in the dynamic model

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.486	62.143	62.143	2.486	62.143	62.143
2	.622	15.551	77.694	.622	15.551	77.694
3	.549	13.733	91.427	.549	13.733	**91.427**
4	.343	8.573	100.000			

Extraction Method: Principal Component Analysis.

c) Examine the initial solution of the extracted factors without rotation

The initial un-rotated factor matrix (3 factors extracted) using principle component analysis is computed and shown in Table 5.16.

The initial solution doesn't show clear clustering for the four variables. Thus; we will employ a rotational method (explained in step 3) to achieve simpler and theoretically more meaningful factor solutions.

Table 5.16 Three UNROTATED factors extracted using principle component analysis

Component Matrix[a]

	Component		
	1	2	3
tech	.837	-.204	-.305
team	.837	.056	-.374
contemp	.747	-.439	.489
comm	.727	.621	.279

Extraction Method: Principal Component Analysis.
a. 3 components extracted.

5.2.3 Factors Rotation

The default Orthogonal VARIMAX rotation approach is used assuming that the three educational objectives are independent of each other (each educational objective (factor) has a different goal). The resulted rotated matrix is shown in Table 5.17. Factors plot in rotated space is shown in is shown in Figure 5.8.

Table 5.17 Rotated factor loading matrix using VARIMAX for HoQ#1 in the dynamic model

Rotated Component Matrixa

	Component		
	1	2	3
team	**.851**	.139	.315
tech	**.840**	.335	.130
contemp	.270	**.940**	.181
comm	.254	.178	**.946**

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

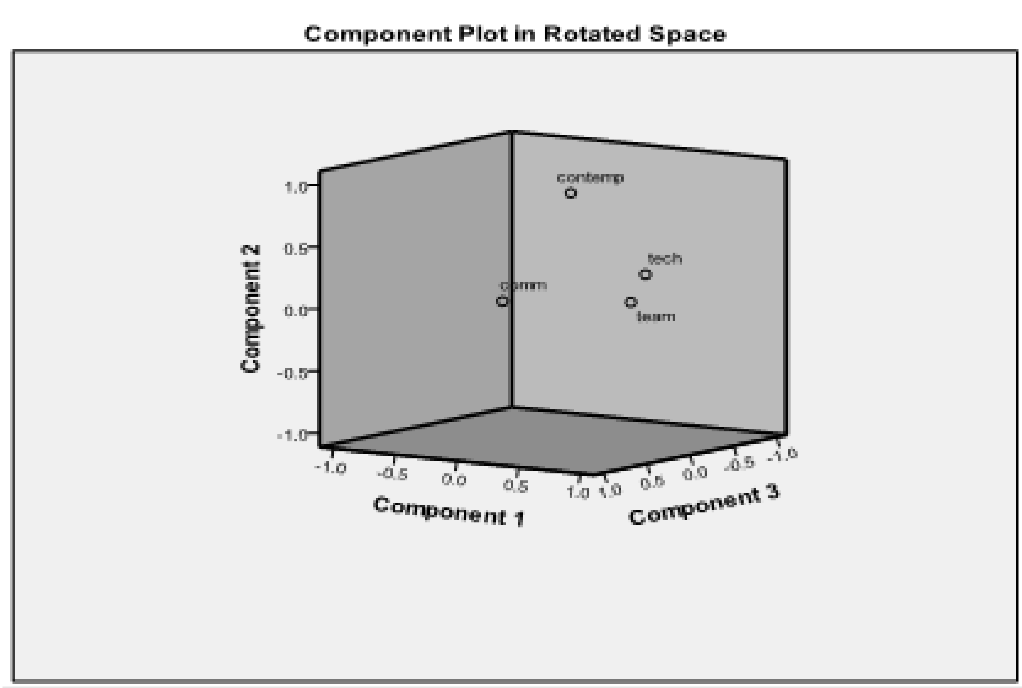


Figure 5.8 Factors (components) plot in rotated space for HoQ#1 in the dynamic model

5.2.4 Factors Evaluations and Interpretation

a) Judging the significance of the factor loadings

In our application, the number of responses (sample size) gathered in the exit survey for HoQ#1 in the dynamic model were 67; this implies a significance level of 0.65 for factor loadings on α = 0.05, Hail et al., page 128 (2006).

Table 5.17 shows significant loadings of the “technical skills” and “team skills” on factor 1, “communication skills” on factor 2, and “contemporary & global” issues on factor 3. However; technical skills is tied to team skills in factor 1 in HoQ#1 in the dynamic model while factor 1 has technical skills tied to communication skills in HoQ#1 in the base model. This is due to lack of clarity in the design of the assessment tool (exit survey). The exit survey was not structured clearly to target the three educational objectives by the IEMS department at UCF. The new design of the Exit survey is provided in Appendix F.

b) Assessing the communalities of the variables after the rotation

Table 5.18 shows that none of the variables has to be excluded since all of their communalities are greater than 0.5 which means that they have sufficient explanation of the variance.

Table 5.18 Communalities after extracting 3 factors for the HoQ#1 in the dynamic model

Communalities

	Initial	Extraction
tech	1.000	.835
comm	1.000	.991
team	1.000	.842
contemp	1.000	.989

Extraction Method: Principal Component Analysis.

In our application, after extracting three factors on four variables using the principle component analysis and rotating the factors using the VARIMAX, we have the best solution that makes sense theoretically and intuitively which is shown in Table 5.17.

5.2.5 Assessing the reliability (internal consistency) of the instrument

- The calculated Cronbach's alpha equals to 0.77 which indicates an internal consistency of the instrument that has been used.

  Table 5.19 and Table 5.20 shows all the values needed to calculate the Cronbach's alpha value for the four variables in HoQ#1 in the dynamic model.

Table 5.19 Descriptive statistics of the four variables in HoQ#1 in the dynamic model

Item Statistics

	Mean	Std. Deviation	N
tech	8.81	2.627	68
comm	6.00	2.375	68
team	5.06	1.620	68
contemp	3.62	1.456	68

Table 5.20 Statistics summary of the summated scale of the four variables in HoQ#1 in the dynamic model

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	5.871	3.618	8.809	5.191	2.435	4.795	4
Item Variances	4.322	2.120	6.903	4.783	3.256	5.379	4
Inter-Item Covariances	1.971	1.083	2.728	1.645	2.520	.414	4
Inter-Item Correlations	.493	.397	.641	.244	1.615	.007	4

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
23.49	40.940	6.398	4

Table 5.21 shows how the Cronbach's alpha value will change if we delete any of our variables. Results show that none of the variables' deletion will result in a higher Cronbach's alpha value. Our conclusions is that our coefficient alpha is strong (0.77), or 77.00% of the variance of the total scores on this subscale can be attributed to reliable, or systematic variance.

Table 5.21 Item-total Statistics for the four variables in HoQ#1(dynamic model)

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
tech	14.68	19.147	.648	.483	.686
comm	17.49	23.268	.525	.294	.749
team	18.43	26.845	.683	.480	.681
contemp	19.87	29.908	.560	.320	.739

5.2.6 Labeling the Factors

The results of our analysis are:

1. Factor 1: includes team skills and technical skills variables; factor 1 is labeled with the name of the variable that has the highest loading among the variables that have significant loadings. Thus; factor 1 is named "Team".
2. Factor 2: includes communication skills.
3. Factor 3: includes contemporary and global issues.

However; as we mentioned in Section 5.2.4; technical and team skills load together on one factor in HoQ#1 in the dynamic model while technical skills loads with communication skills together on one factor in HoQ#1 in the base model. This leads to an ambiguity in labeling the three factors which might be due to lack of clarity in the design of the exit survey that targets the current three educational objectives. Moreover; the three factors resulted from our analysis are not clearly mapped (one to one mapping) to the three current educational objectives at the IEMS department. The results of HoQ#1 (dynamic model) are shown in Figure 5.9.

	Business Strategy (Educational Objectives) / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Employer Survey 2008	Factor 1 team+ technical	Factor 2 contemporary	Factor 3 communication
			+	+	
			Factor Loading	Factor Loading	Factor Loading
1	Team (3)	3	0.851	0.139	0.315
			2.553	**0.417**	**0.945**
2	Technical (4)	4	0.840	0.335	0.130
			3.360	**1.340**	**0.520**
3	Contemporary (3)	3	0.270	0.940	0.181
			0.810	**2.820**	**0.543**
4	Communication (2)	2	0.254	0.178	0.946
			0.508	**0.356**	**1.892**
	TOTAL		7.23	4.93	3.90
	RELATIVE IMPORTANCE		45%	31%	24%

Figure 5.9 HoQ#1 dynamic model combined results (2007-2008)

A comparison between the educational objectives' weights in HoQ#1 base and dynamic model is shown in Table 5.22. Figure 5.10 shows another illustration of the differences in weights; the three factors weights are drawn against three axes, where each triangle head represents a factor with its associated weight. The two triangles represent the base and the dynamic model, the figure shows that the two triangles are not identical which indicates a change in the priorities of the three factors. This change needs to be investigated in HoQ#2 and check if the current learning outcomes still meet the current educational objectives.

Table 5.22 HoQ#1 base and dynamic weights comparison

	HoQ#1 (base)	**HoQ#1(dynamic)**	**Difference in weights = Δω** **Δω ≠ 0**
Communication factor	44%	24%	**-20%**
Team factor	32%	45%	**-13%**
Contemporary factor	24%	31%	**7%**

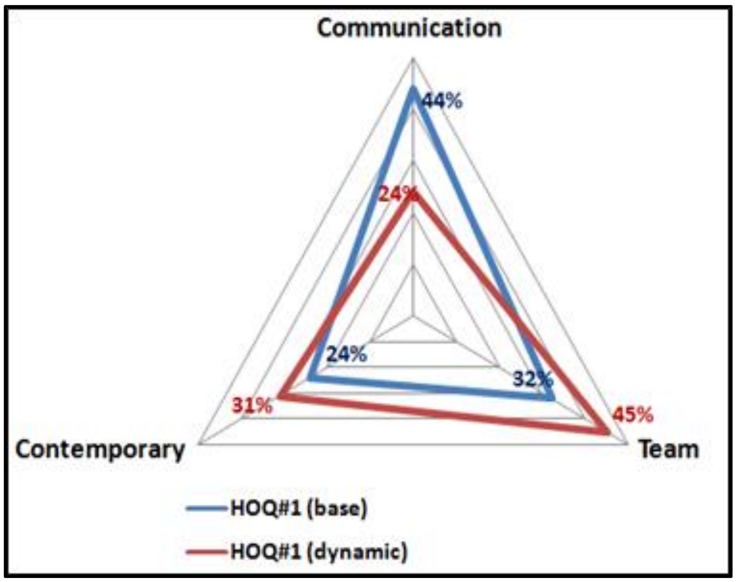


Figure 5.10 Illustration graph for the difference in weights between base and dynamic HoQ#1

5.3 Factor Analysis Results – HoQ#2

NOTE: This section shows the results with the reflective statements. The importance of each step and its explanation are the same as described in details in Chapter 4.

5.3.1 Assessing assumptions

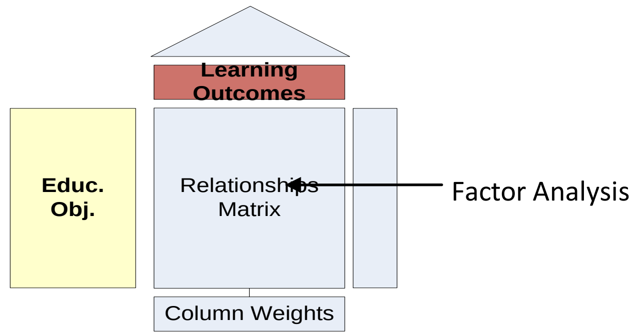


Figure 5.11 HoQ#2

HoQ#2 as shown in Figure 5.11 maps the prioritized educational objectives from HoQ#1 toward the learning outcomes. The IEMS learning outcomes were extracted into three factors using factor analysis, the three factors represent the three educational objectives which are prioritized from HoQ#1. Each learning outcome has been treated as a variable that has the summated value of the questions that measure this variable. The grouping of the questions into variables is shown previously in Table4.4. The learning outcomes survey questions are shown in Appendix D.

a) Examine the correlation among variables

Table 5.23 HoQ#2: Pearson correlation among variables

Correlations

		lo2	lo3	lo4	lo5	lo6	lo7	lo8	lo9	lo1_and_10
lo2	Pearson Correlation	1	.606**	.598**	.689**	.722**	.572**	.688**	.500**	.645**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000	.000
lo3	Pearson Correlation	.606**	1	.794**	.627**	.667**	.456**	.614**	.484**	.730**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000	.000
lo4	Pearson Correlation	.598**	.794**	1	.665**	.644**	.502**	.610**	.424**	.677**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000
lo5	Pearson Correlation	.689**	.627**	.665**	1	.763**	.617**	.672**	.535**	.583**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000
lo6	Pearson Correlation	.722**	.667**	.644**	.763**	1	.627**	.799**	.619**	.686**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000
lo7	Pearson Correlation	.572**	.456**	.502**	.617**	.627**	1	.643**	.482**	.504**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.000
lo8	Pearson Correlation	.688**	.614**	.610**	.672**	.799**	.643**	1	.546**	.639**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000
lo9	Pearson Correlation	.500**	.484**	.424**	.535**	.619**	.482**	.546**	1	.616**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000
lo1_and_10	Pearson Correlation	.645**	.730**	.677**	.583**	.686**	.504**	.639**	.616**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	

**. Correlation is significant at the 0.01 level (2-tailed).

- None of the correlations in Table 5.23 shows a weak correlation ($0.00 < r^2 < 0.08$) or very strong correlation ($0.81 < r^2 < 1.0$).
- The significance levels equal to zero which means at alpha=0.05 we would reject the null hypothesis H_0 of no association between two variables.

However; significant correlation exists to satisfy the basic assumption of the availability of some common factors that describe the interrelationship among the variables.

b) Evaluate the determinant of the correlation matrix

- The determinant for our correlation matrix was calculated using SPSS statistical software and it equals to 0.001 which confirms the existence of correlation among the variables.

c) Bartlett's Test of Sphericity

We should reject the null hypothesis of no relationships among variables for the following reasons:

- The Bartlett's test value equals to 594.03 calculated using SPSS and shown in Table 5.24 is greater than the critical value obtained from the Chi-Square table. The critical value at 36 degrees of freedom (df = ((9-1)*9)/2), and alpha = 0.05 is between 43.7729 and 55.7585.
- Additionally, the p-value equals to zero (less than alpha = 0.05) which indicates that our correlation matrix is not an identity matrix.

Table 5.24 KMO and Bartlett's Test - HoQ#2

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.922
Bartlett's Test of Sphericity	Approx. Chi-Square	594.030
	df	36
	Sig.	.000

d) Kaiser-Meyer-Olkin Test (KMO)

- The overall adequacy; measured by the size of KMO; is close to the “meritorious” criteria Kaiser (1974, p.35). The size of KMO in our analysis equals to 0.922 as shown in Table 5.24.

e) Individual Measures of Sampling Adequacy (MSA)

- The individual adequacy; measured by MSA; meets the “marvelous” and the “meritorious” criteria Kaiser (1974, p.35). MSA for the 9 variables are above 0.7 as shown in Table 5.25 (underlined values).

Table 5.25 Individual measure of sampling adequacy - HoQ#2

Anti-image Matrices

		Io2	Io3	Io4	Io5	Io6	Io7	Io8	Io9	Io1_and_10
Anti-image Covariance	Io2	.382	-.012	-.002	-.077	-.045	-.039	-.054	.017	-.066
	Io3	-.012	.289	-.151	-.015	-.025	.039	-.011	-.005	-.092
	Io4	-.002	-.151	.306	-.074	.004	-.029	-.017	.057	-.055
	Io5	-.077	-.015	-.074	.323	-.085	-.075	.002	-.046	.043
	Io6	-.045	-.025	.004	-.085	.227	-.019	-.107	-.063	-.027
	Io7	-.039	.039	-.029	-.075	-.019	.503	-.094	-.052	-.008
	Io8	-.054	-.011	-.017	.002	-.107	-.094	.305	-.010	-.018
	Io9	.017	-.005	.057	-.046	-.063	-.052	-.010	.524	-.135
	Io1_and_10	-.066	-.092	-.055	.043	-.027	-.008	-.018	-.135	.326
Anti-image Correlation	Io2	**.957**[a]	-.037	-.007	-.219	-.153	-.089	-.159	.039	-.186
	Io3	-.037	**.895**[a]	-.510	-.049	-.098	.103	-.036	-.013	-.299
	Io4	-.007	-.510	**.892**[a]	-.236	.014	-.075	-.056	.143	-.175
	Io5	-.219	-.049	-.236	**.926**[a]	-.313	-.186	.005	-.111	.133
	Io6	-.153	-.098	.014	-.313	**.918**[a]	-.055	-.409	-.184	-.100
	Io7	-.089	.103	-.075	-.186	-.055	**.950**[a]	-.239	-.101	-.019
	Io8	-.159	-.036	-.056	.005	-.409	-.239	**.930**[a]	-.025	-.056
	Io9	.039	-.013	.143	-.111	-.184	-.101	-.025	**.924**[a]	-.327
	Io1_and_10	-.186	-.299	-.175	.133	-.100	-.019	-.056	-.327	**.918**[a]

a. Measures of Sampling Adequacy(MSA)

We conclude from the above analysis for HoQ#1 in the dynamic model:

- According to Bartlett's test, the correlation matrix is not an identity matrix.
- The KMO statistic suggests that we have a sufficient sample size relative to the number of items in our scale.
- The MSA statistics indicate that the correlations among the individual items are strong to suggest that the correlation matrix is factorable.

5.3.2 Factors Extraction

a. Selecting a factor method
   - Principle component analysis method was used.
b. Determine the number of factors

We extracted the nine variables (learning outcome 1 and 10 questions are combined in one variable) into three factors since we have a predetermined decision to extract three factors that represent the educational objectives of the IEMS department at UCF.

However; to statistically support the selection of three factors, we used the following guidelines:

1. Examining the scree plot:
   The number of factors that have an Eigen value great than one is only one factor as shown in Figure 5.12.

However, taking two or three extra points are still acceptable according to Cattell (1996).

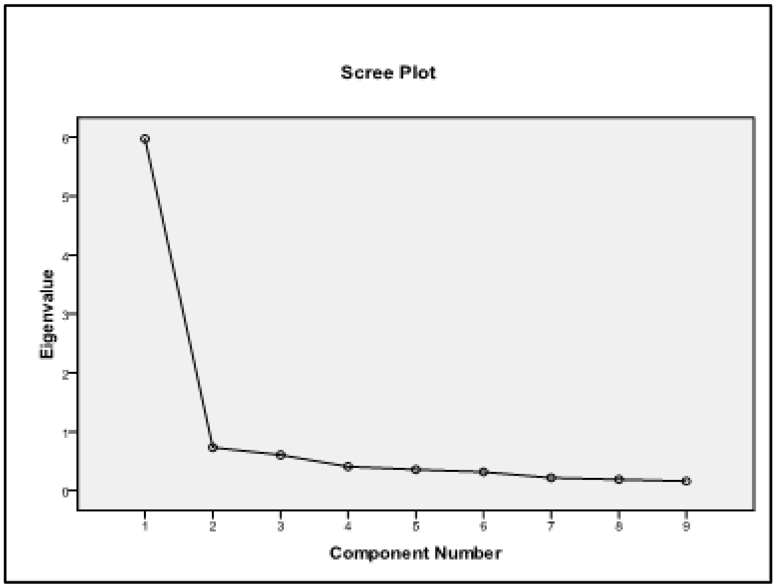


Figure 5.12 Scree plot of the four variables in HoQ#2

2. Percent of variance extracted:

Table 5.26 shows that the cumulative percentage of variance explained by the variables and after extracting three factors (components) equals to 81.302 %. This indicates a practical significance of the factors being extracted (greater than 80 %).

Table 5.26 Total variance explained for the HoQ#2

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.970	66.334	66.334	5.970	66.334	66.334	3.032	33.691	33.691
2	.737	8.189	74.523	.737	8.189	74.523	2.762	30.690	64.381
3	.610	6.779	81.302	.610	6.779	81.302	1.523	16.921	**81.302**
4	.414	4.603	85.905						
5	.363	4.028	89.933						
6	.322	3.583	93.516						
7	.223	2.481	95.997						
8	.196	2.173	98.170						
9	.165	1.830	100.000						

Extraction Method: Principal Component Analysis.

c. Examine the initial solution of the extracted factors without rotation

The initial un-rotated factor matrix (3 factors extracted) using principle component analysis is computed and shown in Table 5.27.

The initial solution doesn’t show clear clustering for the nine variables. Thus; we will employ a rotational method to achieve simpler and theoretically more meaningful factor solutions.

Table 5.27 : Three UNROTATED factors extracted using principle component analysis

Component Matrix[a]

	Component		
	1	2	3
lo6	.896	.128	-.020
lo8	.852	.173	-.110
lo5	.843	.087	-.190
lo1_and_10	.831	-.213	.280
lo2	.825	.073	-.140
lo3	.820	-.451	.027
lo4	.811	-.426	-.142
lo7	.733	.420	-.251
lo9	.702	.268	.616

Extraction Method: Principal Component Analysis.
a. 3 components extracted.

5.3.3 Factors Rotation

The default Orthogonal VARIMAX rotation approach is used assuming that the three educational objectives (factors) are independent of each other. Each educational objective (factor) has a different goal. The resulted rotated matrix is shown in Table 5.28. Factors plot in rotated space is shown in is shown in Figure 5.13.

Table 5.28 Rotated factor loading matrix using VARIMAX for HoQ#2

Rotated Component Matrix[a]

	Component		
	1	2	3
lo7	**.848**	.140	.197
lo8	**.719**	.400	.301
lo5	**.704**	.466	.204
lo6	**.679**	.459	.385
lo2	**.660**	.464	.237
lo3	.280	**.861**	.237
lo4	.371	**.844**	.093
lo1_and_10	.298	**.670**	.527
lo9	.316	.197	**.897**

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

a. Rotation converged in 4 iterations.

Component Plot in Rotated Space

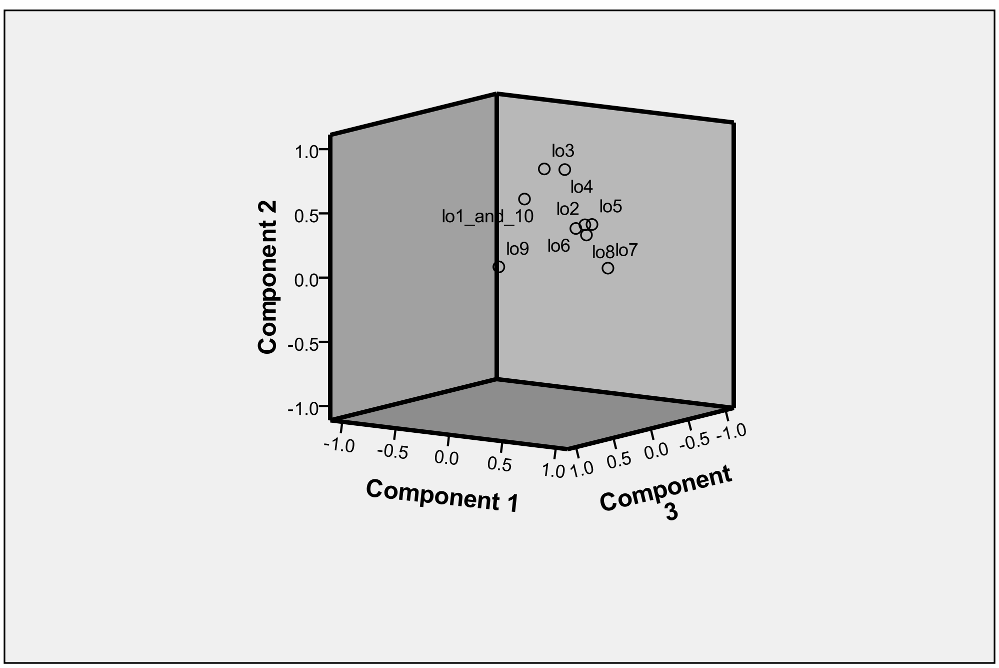


Figure 5.13 Component plot in rotated space for HoQ#2

5.3.4 Factors Evaluations and Interpretation

a) Judging the significance of the factor loadings

In our application, the number of responses (sample size) gathered toward the learning outcomes survey for HoQ#2 was 90; this implies an almost 0.57 significance level for factor loadings on $\alpha = 0.05$, Hail et al., page 128 (2006). Table 5.28 shows significant loadings of learning outcomes 7, 8, 5, 6, 2 on factor 1, learning outcomes 3, 4, 1 and 10 on factor 2 and learning outcome 9 on factor 3.

b) Assessing the communalities of the variables after the rotation

Table 5.29 shows that none of the variables has to be excluded from the analysis. All of the variables have sufficient explanation of the variance (communality greater than 0.50).

Table 5.29 Communalities after extracting 3 factors for the HoQ#2

Communalities

	Initial	Extraction
lo2	1.000	.706
lo3	1.000	.875
lo4	1.000	.858
lo5	1.000	.754
lo6	1.000	.820
lo7	1.000	.777
lo8	1.000	.768
lo9	1.000	.944
lo1_and_10	1.000	.815

Extraction Method: Principal Component Analysis.

In our application, after extracting nine variables into three factors using the principle component analysis and rotating the factors using the VARIMAX, we have the best solution that makes sense theoretically and intuitively which is shown in shown in Table 5.28.

5.3.5 Assessing the Reliability (internal consistency) of the Instrument

The calculated Cronbach's alpha equals to 0.925 which indicates an internal consistency of the instrument that is been used.

Table 5.30 and Table 5.31 show all the values needed to calculate the Cronbach's alpha value for the seven variables in HoQ#2.

Table 5.30 Descriptive statistics of the four variables in HoQ#2

Variable Statistics

	Mean	Std. Deviation	N
Io2	7.7111	2.79343	90
Io3	4.9222	1.83124	90
Io4	5.3556	2.06801	90
Io5	5.2556	2.43366	90
Io6	5.1556	2.22807	90
Io7	9.4111	3.72328	90
Io8	6.0333	2.17984	90
Io9	5.5444	2.61010	90
Io1_and_10	7.3556	2.64495	90

Table 5.31 Statistics summary of the summated scale of the four variables in HoQ#1 in the dynamic model

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	6.305	4.922	9.411	4.489	1.912	2.327	9
Item Variances	6.527	3.353	13.863	10.509	4.134	9.605	9

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
56.7444	331.181	18.19838	9

Table 5.32 shows how the Cronbach's alpha value will change if we delete any of our variables. The deletion of any of the variables won't result in a higher Cronbach's alpha.

Table 5.32 Item-total Statistics for the four variables in HoQ#2

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Io2	49.0333	254.819	.769	.618	.914
Io3	51.8222	281.766	.749	.711	.918
Io4	51.3889	276.150	.738	.694	.917
Io5	51.4889	262.725	.793	.677	.913
Io6	51.5889	264.110	.858	.773	.910
Io7	47.3333	240.135	.669	.497	.929
Io8	50.7111	268.725	.807	.695	.913
Io9	51.2000	269.802	.636	.476	.923
Io1_and_10	49.3889	258.780	.769	.674	.914

Our conclusion is that our coefficient alpha is strong (0.925), or 92.5% of the variance of the total scores on this subscale can be attributed to reliable, or systematic variance.

5.3.6 Labeling the Factors

The results of our analysis are:

1. Factor 1: includes learning outcomes 7, 8, 5, 6 and 2; the five learning outcomes measure the ability of students to incorporate contemporary issues into the practice of engineering.
2. Factor 2: includes learning outcomes 3, 4, 1 and 10; the four learning outcomes measure the ability of students to apply engineering technical skills.
3. Factor 3: includes learning outcome 9 which measures the ability of students to explore options for professional growth, including graduate study, conference attendance, and professional society participation.

We notice that the three factors extracted can be mapped to the current three educational objectives at the IEMS department as follows:

1. Factor 1 is mapped to educational objective 3

   "To produce industrial engineering professionals who recognize that engineering is a global service profession that must be practiced ethically with integrity, honesty and objectivity.
2. Factor 2 is mapped to educational objective 1

   "To produce graduates who assume challenging or satisfying positions in the private and public sectors".
3. Factor 3 is mapped to educational objective 2

"To produce graduates who achieve professional growth through advanced studies and/or career development activities".

The three factors extracted from HoQ#2 are clearly mapped to the current educational objectives, unlike the three factors extracted from HoQ#1(base and dynamic model); this is due to the measurement tool that is used in HoQ#2 which covers the three aspects of the educational objectives. The exit survey used in HoQ#1 was not well designed to cover the second educational objective (professional growth) for which we assigned its weight (0.6) to be higher than educational objective 3 and 1 in HoQ#2 to emphasize on its importance. HoQ#2 results are shown in Figure 5.14.

Business Capabilities (Learning Outcomes) / Business Strategies (Educational Objectives)	Weight from HOQ#1 Dynamic	Outcome 1. &10 Apply math and science and use industrial engineering to design systems and products for real life projects and to meet the needs of the society	Outcome 2. Students will make responsible decisions and exhibit integrity and ethics in classroom and real world projects.	Outcome 3. Students will be able to collect, analyze, and interpret data in classroom and project settings as well as drawing meaningful conclusions and developing sound recommendations.	Outcome 4. Students will effectively utilize industrial engineering design and problem-solving skills in classroom and real world projects.	Outcome 5. Students will communicate effectively, orally and in writing, to peers and superiors in classroom and real world projects	Outcome 6. Students will be able to work with persons of varied backgrounds in classroom and real world projects.	Outcome 7. Students will incorporate contemporary issues into the practice of industrial engineering.	Outcome 8. Students will be able to measure the impact of global and societal issues on industrial engineering solutions to modern practical problems.	Outcome 9. Students will explore options for professional growth, including graduate study, conference attendance, and professional society participation.
		+	+	+	+	+	+	+	+	+
Factor 1 (Educational Objective3): Contemporary	0.31	0.298	**0.660**	0.280	0.371	**0.704**	**0.679**	**0.848**	**0.719**	0.316
		0.092	0.205	0.087	0.115	0.218	0.210	0.263	0.223	0.098
Factor2 (Educational Objective 1): Engineering Skills	0.45	**0.670**	0.464	**0.861**	**0.844**	0.466	0.459	0.140	0.400	0.197
		0.302	0.209	0.387	0.380	0.210	0.207	0.063	0.180	0.089
Factor 3 (Educational Objective 2): Professional Growth	0.60	0.527	0.237	0.237	0.093	0.204	0.385	0.197	0.301	**0.897**
		0.316	0.142	0.142	0.056	0.122	0.231	0.118	0.181	0.538
TOTAL		**0.710**	**0.556**	**0.616**	**0.551**	**0.550**	**0.648**	**0.444**	**0.583**	**0.725**
RELATIVE IMPORTANCE		**13.2%**	**10.3%**	**11.5%**	**10.2%**	**10.2%**	**12.0%**	**8.2%**	**10.8%**	**13.5%**

Figure 5.14 HoQ# 2 combined results

5.4 HoQ#3 Results

The input for HoQ#3 is a prioritized list of learning outcomes from HoQ#2. In this research; we mapped the prioritized learning outcomes to the course control document (syllabus) as a performance indicator of the curriculum revision process (one of the instructional processes), in addition to the surveys as a performance indicator for the stakeholders' feedback. Both the instructional processes (workflows) and the stakeholders' feedback (events) are components of the value system architecture.

The strength of the relationship between each learning outcome and each architecture component inside the body of the house represents the difference in weight between the current and the expected relationship. The larger the difference is, the more attention the department has to pay for a specific architecture component. This may result in an enhancement in one or more of the department courses, design of new surveys or a different culture embracing continuous improvement initiatives.

As we mentioned earlier in Chapter 4, the current and expected relationships between the surveys and the learning outcomes were identified by a six sigma team in an initiative for a design for six sigma projects at the IEMS department in fall 2009 which is part of this research work. Table 5.33 shows summarized results of the current surveys distributed in the department versus the learning outcomes; the numbers inside the cells represent the number of questions in a certain survey measuring a specific learning outcome. A detailed analysis of the surveys is provided in Appendix E.

The expected relationships were identified by a six sigma project initiative (part of this research work). The expected relationships between the surveys and the learning outcomes are analyzed in Table 5.34. The number inside each cell indicates the number of questions expected to be in each survey that satisfy a certain learning outcome. These expectations are based on a set of clear and concise questions that were designed to measure the learning outcomes. Each learning outcome is measured by at least three questions.

The survey that has more than three questions in both the expected and the current relationship matrix has been given the code number (3), (2) if it has two questions, (1) if it has one question, (0) if it doesn't have any question measuring a certain learning outcome.

A gap analysis between the current and expected relationships for the surveys has been done using the coded numbers. For example, the exit survey has 5 questions measuring learning outcome 3 in the current situation (code = 3) and 3 questions in the expected situation (code = 3). Consequently; the number that is entered in HoQ#3 is zero as shown in Figure 5.17 indicating that the current relationship meets the expected relationship between the exit survey and learning outcome 3. Table 5.33 and Table 5.34 show the current and expected relationships, respectively, between the surveys and the learning outcomes.

However; the current strength of the relationship between each course and each learning outcome is identified based on information from the 2008 ABET self-study report while the expected relationship is identified by the faculty members. A matrix with all of the learning outcomes vs. all of the courses taught by each professor was distributed to all the faculty members to fill out the strength of the relationship between the course and the learning outcome. On a scale of 0 to 3, where 0 indicates that there is no expected relationship between the course and the learning outcome while 3 indicates that the course is expected to strongly satisfy the learning outcome.

A gap analysis for the current and expected relationships for both the curriculum revising process and the surveys is shown in HoQ#3 three parts, Figure 5.15, Figure 5.16 and Figure 5.17.

Table 5.33 Survey vs. learning outcomes analysis - summarized results of the current situation

Learning Outcomes 1-8	Outcome 1 & 10	Outcome 2	Outcome 3	Outcome 4	Outcome 5	Outcome 6	Outcome 7	Outcome 8	Outcome 9
	Students will be able to apply mathematics, science and engineering fundamentals in classroom and real world projects. Students will utilize tools and techniques of industrial engineering to effectively and efficiently design systems, products and processes that meet the needs of the society.	Students will make responsible decisions and exhibit integrity and ethics in classroom and real world projects.	Students will be able to collect, analyze, and interpret data in classroom and project settings as well as drawing meaningful conclusions and developing sound recommendations.	Students will effectively utilize industrial engineering design and problem-solving skills in classroom and real world projects.	Students will communicate effectively, orally and in writing, to peers and superiors in classroom and real world projects.	Students will be able to work with persons of varied backgrounds in classroom and real world projects.	Students will incorporate contemporary issues into the practice of industrial engineering.	Students will be able to measure the impact of global and societal issues on industrial engineering solutions to modern practical problems.	Students will explore options for professional growth, including graduate study, conference attendance, and professional society participation.
Exit Survey	5	1	5	5	4	3	1	1	0
Alumni Survey	3	1	3	3	1	1	0	1	2
Employer Survey	2	1	2	3	2	3	3	3	0
Student Satisfaction Survey	1	1	4	4	1	1	1	2	1
Senior Design Industrial Mentor	0	0	2	0	3	1	0	0	0
Faculty Survey	1	1	5	3	3	1	6	6	0

Table 5.34 Expected number of questions in the surveys needed to measure the learning outcomes

SURVEY	Specific Questions									
	Learning Outcome 1	Learning Outcome 2	Learning Outcome 3	Learning Outcome 4	Learning Outcome 5	Learning Outcome 6	Learning Outcome 7	Learning Outcome 8	Learning Outcome 9	Learning Outcome 10
Exit Survey	2	4	3	3	3	3	4	3	3	2
Alumni	2	4	3	3	3	3	4	3	3	2
Employer	2	4	3	3	3	3	4	3	3	2
Student Satisfaction	2	4	3	3	3	3	4	3	0	2
Senior Design Industrial Mentors	2	0	3	3	3	0	0	0	0	2
Faculty Survey	2	4	3	3	3	3	4	3	3	2

Educational System Architecture / Business Capabilities (Learning Outcomes)	From HoQ #2	Instructional Processes																	
		Performance Indicators of the Curriculum Revision Process																	
		EGN3613 Engineering Economics Analysis	EGN4624 Engineering Administration	EGN5858 Prototyping and Product Realization	STA3032 Probability & Statistics for Engineers	EIN3000 Introduction to IE and MS	EIN3314C Work Measurement and Design	EIN3354 Principles of Cost Engineering	EIN4191C Engineering Leadership Seminar I	EIN4192 Engineering Leadership Seminar II	EIN4214 Safety Engineering and Administration	EIN4243C Human Engineering	EIN4333C Industrial Control Systems	EIN4364C Industrial Planning and Design	EIN4391C Manufacturing Engineering	EIN4516C Systems Analysis and Design	EIN4891C IE Senior Design	EIN5108 The Environment of Technical Organizations	EIN5117 Management Information Systems
Outcome 9. Professional growth	0.725	0	-1	-2	0	1	0	-1	0	0	-1	-1	1	1	-2	-1	-1	0	-1
Outcome 1. &10 Math, IE tools	0.71	0	-1	-1	0	0	0	1	0	0	0	-1	0	0	0	0	0	0	0
Outcome 6. Work with varied background	0.648	0	-2	-1	-1	-2	-1	-1	0	0	-3	-3	-2	0	0	0	0	-1	0
Outcome 3. Collect, analyze, and interpret data	0.616	0	-3	0	0	-3	-1	-2	0	0	0	-3	-2	0	-2	0	0	-2	-2
Outcome 8. impact of global and societal issues	0.583	0	0	-2	0	0	0	0	0	0	0	-1	-1	0	2	-1	-1	-1	-2
Outcome 2. integrity and ethics	0.556	0	0	-1	0	0	0	0	0	0	0	-1	-1	1	-3	0	0	0	-1
Outcome 4. industrial engineering design and problem-solving skills in classroom and real world projects.	0.551	0	-1	-1	-1	0	0	-1	0	0	0	-1	0	0	-1	0	0	-1	-1
Outcome 5. Communicate orally and written	0.550	0	0	-1	1	0	0	0	0	0	0	0	0	0	-1	0	0	1	-1
Outcome 7. Contemporary issues	0.444	0	-3	-1	0	0	0	2	2	2	0	0	0	1	-1	0	0	1	-2
Number of Outcomes Currently Covered		10	3	1	8	8	8	6	10	10	8	2	6	10	4	8	8	6	3

Figure 5.15 HoQ#3 - curriculum revision - part 1

Educational System Architecture / Business Capabilities (Learning Outcomes)	From HoQ #2	Instructional Processes																	
		Performance Indicators of the Curriculum Revision Process Cont.																	
		EIN5140 Project Engineering	EIN5248 Ergonomics	EIN5255 Interactive Simulation	EIN5251 Usability Engineering	EIN5317 Training Systems Design	EIN5346 Engineering Logistics	EIN5356 Cost Engineering	EIN 5392 Manufatcturing Systems Engineering	ESI4628C IE Applications of Computers	ESI4221 Empirical Methods for IE	ESI4234 Quality Engineering	ESI4312 Operations Research	ESI4523C Systems Simulation	ESI5219 Engineering Statistics	ESI 5227 Total Quality Improvemen	ESI5236 Reliability Engineering	ESI5306 Operations Research	ESI5359 Risk Assessment and Management
Outcome 9. Professional growth	0.725	0	0	0	1	0	-1	-1	-2	1	0	-2	1	-1	-1	0	-1	-1	0
Outcome 1. &10 Math, IE tools	0.71	0	0	0	-2	0	0	0	0	-2	0	0	0	0	0	0	0	0	0
Outcome 6. Work with varied background	0.648	0	0	0	1	-1	-1	-1	-1	-3	0	0	-1	-2	-1	0	-2	-2	0
Outcome 3. Collect, analyze, and interpret data	0.616	-1	-3	0	0	-2	-2	1	-2	-2	0	-2	-1	0	0	-1	0	0	0
Outcome 8. impact of global and societal issues	0.583	0	0	0	-1	0	0	-1	0	-1	-1	-1	-1	0	0	-1	0	-2	-1
Outcome 2. integrity and ethics	0.556	0	0	0	0	0	-1	1	0	0	0	0	-2	0	0	0	-1	-2	-1
Outcome 4. industrial engineering design and problem-solving skills in classroom and real world projects.	0.551	-3	0	0	1	0	0	2	0	0	0	-1	-1	-1	0	0	0	0	0
Outcome 5. Communicate orally and written	0.550	0	0	0	0	-1	0	0	-1	0	1	-1	0	0	2	0	2	0	0
Outcome 7. Contemporary issues	0.444	1	0	0	0	0	0	0	0	-3	-2	0	0	-1	-1	0	1	-1	-2
Number of Outcomes Currently Covered		8	9	10	7	7	5	7	6	4	8	5	5	6	7	8	7	5	7

Figure 5.16 HoQ#3 - curriculum revising - part 2

Educational System Architecture / Business Capabilities (Learning Outcomes)	From HoQ #2	Performance Indicators of the Stakeholders Feedback					
		Exit suyrvey	Student Satisfaction Survey	Employer survey	Alumni Survey	Senior Design Industrial Mentors Survey	Faculty Suvey
Outcome 9. Professional growth	0.725	-3	1	-3	-1	-3	-3
Outcome 1. &10 Math, IE tools	0.71	0	-2	-1	0	-3	-2
Outcome 6. Work with varied background	0.648	0	-2	0	-2	1	-2
Outcome 3. Collect, analyze, and interpret data	0.616	0	0	-1	0	-1	0
Outcome 8. impact of global and societal issues	0.583	-2	-1	0	-2	0	0
Outcome 2. integrity and ethics	0.556	-2	-2	-2	-2	0	-2
Outcome 4. industrial engineering design and problem-solving skills in classroom and real world projects.	0.551	0	0	0	0	-3	0
Outcome 5. Communicate orally and written	0.550	0	-2	-1	-2	0	0
Outcome 7. Contemporary issues	0.444	-2	-2	0	-3	0	0
Number of Outcomes Currently Covered		**6**	**3**	**4**	**4**	**5**	**5**

Figure 5.17 HoQ#3 - curriculum revising - part 3

The negative values in HoQ#3 indicate that the current situation is not as intended to meet the prioritized learning outcomes. Consequently, more attention has to be paid to a certain course, or to the design for a certain survey.

New designed surveys are recommended in this dissertation and they are shown in the Appendices F through J.

The designed surveys specify which learning outcome or educational objective each question measures, this facilitates the grouping of the questions into variables for the factor analysis in HoQ#1 and HoQ#2. The exit, employer, alumni, faculty and the senior design mentors surveys are designed to measure the educational objectives, some of them may be used to prioritize the gathered customer requirements in HoQ#1, while the student satisfaction survey is a more detailed survey that measures the learning outcomes.

CHAPTER 6 CONCLUSIONS AND FUTURE WORK

6.1 Conclusions

Companies need a business strategy that is operational, evolving and periodically updated to reflect any changes in customer needs in the market place; this raised an opportunity for improvement. Business enterprises lack accurate measures and clear understanding for the enterprise holistically that can keep it aligned in all of its complex dimensions with customer requirements.

This research work proposed a new illustration of the relationships between business strategy, capabilities, processes and customer requirements as shown in the proposed business alignment clock (Figure 3.3). It was developed as a tool to facilitate understanding the dynamic elements of the business enterprise model and how they change over time.

To reach a well balanced level of alignment between business strategy and customer expectations, a unique framework was proposed that integrates the business architecture with the house of quality. A statistical tool, multivariate data analysis, is used to increase the robustness of the house of quality relationship matrix and to avoid ambiguity in the results of the house.

The proposed framework can increase the efficiency of quality assurance in business enterprises since the integration between QFD and business architecture leads to a more precise design of any business that has a high level of customer focus. Investment in the design of quality will pay off to the business enterprise on the short and long run.

The contributions of this research are:

- A novel business alignment clock to represent the alignment between enterprise strategic goals, capabilities & processes and customer requirements (Figure 3.3).
- A dynamic framework using quantitative houses of quality to provide enterprises with accurate guidance about the requirements needed to align their strategies with customer requirements (Figure 3.5).
- Incorporation of the business architecture basic conceptual model in the proposed framework. EBA definition is in Table 3.1, while the basic conceptual model is shown in Figure 3.4.

The value of the model was demonstrated using the Accreditation Board of Engineering and Technology (ABET) process at the Industrial Engineering and Management Systems department at the University of Central Florida. The alignment between the IEMS educational objectives, learning outcomes and the customer requirements has to be accurately measured and not biased toward the ABET committee members' desires and experiences.

This dissertation introduced a new framework for all executives and strategists who care about achieving a superior execution of their strategies. It helps them periodically investigate the effect of a change in customer requirements on their strategy and its deployment. The periodic check depends on how often the business enterprise measures the changes in its customer requirements. The threshold at which the business enterprises have to accommodate for the effects of the new customer requirements on their strategies (change in strategies' weights) is left for the management to decide on a per case basis.

6.2 Future Work

After validating the novel business alignment clock and its mechanism, the implementation of the enterprise business architecture (EBA) may begin. The business architecture represents the common repository of data, information, and knowledge about the enterprise; it allows for a decomposition of the enterprise into manageable and understandable units, thereby reducing complexity. Decomposition allows effectiveness, efficiency and adaptability to be designed, engineered and optimized by the enterprise.

Lacking an adequate and a documented architecture leads to high business and IT expenditures; that is the pieces of a system do not fit and satisfy the intended purpose (Whittle et al., 2005). However; the researcher has to take into consideration the cost of building the architecture which may include the resources to plan, build, implement and maintain the architecture.

A complete EBA construction is highly recommended to show the relationships between the processes, their events and environment along with the value streams to which each process is tied. A holistic overview of the enterprise enhances the results of the alignment checking process; the steps of EBA construction start from the top of the EBA as shown previously in the basic conceptual model (Figure 3.4), but as the implementation starts, they become very iterative and not only top-down but bottom-up and middle-out.

The future research plan is to further investigate other applications to which the proposed methodology can be applied, such as health care sectors, government agencies, and any other service or product providers. However; the researcher has to show a clear mapping of the terminologies used in the selected application along with the ones used in the proposed methodology.

Researchers may further investigate more structured ways to gather the data and increase its accuracy; in this dissertation we relied on designing new surveys that have more precise and specific questions to reduce the ambiguity of understanding them by the customers. However; different measurement tools such as the product specifications, number of defects in a product/service or complaints log at the enterprise may be used to gather the data required to implement the proposed framework.

Another attractive future research initiative would be to conduct confirmatory factor analysis rather than exploratory factor analysis to verify the relationships inside the body of each house. However; normality of the data is critical in such research work.

APPENDIX A. : CONTRIBUTIONS IN THE LITERATURE

Subjects / Authors	Quality Function Deployment (QFD) applications	Quantitative methods with QFD (conjoint analysis, AHP, factor analysis, multiple regression, fuzzy logic..etc)	Applying QFD in business alignment, modeling and strategic planning	Applying QFD with software engineering and information systems
1. Teck Khim et al. (2000)	√	√		
2. Chan el al (2005)	√	√		
3. Ramasamy et al. (2004)	√			
4. Martins et al. (2001)	√			
5. Camevalli et al. (2008)	√			
6. Dikmen et al. (2005)	√			
7. Jalham et al. (2006)	√			
8. Ramasamy et al. (2002)	√			
9. Yang et al. (2006)	√			
10. Booysen(2006	√			
11. González el al (2008)	√			
12. Bier et al. (2001)	√			

Subjects / Authors	Quality Function Deployment (QFD) applications	Quantitative methods with QFD (Conjoint analysis, AHP, factor analysis, multiple regression, fuzzy logic..etc)	Applying QFD in business alignment, modeling and strategic planning	Applying QFD with software engineering and information systems
13. Bolt et al. (1999)	√			
14. Buyukozhan et al., (2005)	√			
15. Liu et al. (2006)	√	√		
16. Milan et al. (2003)	√			
17. Jian et al. (2007)	√			
18. Gilb (2008)	√			
19. Chen et al. (2008)	√	√		
20. Patrovi, (2006)	√	√		
21. Wasserman (1993)	√	√		
22. Kwong et al. (2002)	√	√		
23. Khoo et al. (1996)	√	√		
24. Kazmar et al. (2001)	√	√		
25. Trappey et al. (1996)	√	√		√

Subjects / Authors	Quality Function Deployment (QFD) applications	Quantitative methods with QFD (conjoint analysis, AHP, factor analysis, multiple regression, fuzzy logic..etc)	Applying QFD in business alignment, modeling and strategic planning	Applying QFD with software engineering and information systems
26. Yan et al. (2005)	√	√		
27. Gonzalez et al. (2008)	√	√		
28. Parkin et al. (2002)	√	√		
29. Glen et al. (2005)	√	√		
30. Krieg et al. (2004)	√	√		
31. Pullman et al. (2002)	√	√		
32. Erder et al. (2003)	√		√	
33. Crowe et al. (1996)	√		√	
34. Clegg et al. (2007)	√		√	
35. Yu et al. (2003)	√		√	√
36. Zhao et al. (2007)	√		√	√
37. Jin et al. (2008)	√		√	
38. Whittle et al. (2005)			√	√

Subjects / Authors	Quality Function Deployment (QFD) applications	Quantitative methods with QFD (conjoint analysis, AHP, factor analysis, multiple regression, fuzzy logic..etc)	Applying QFD in business alignment, modeling and strategic planning	Applying QFD with software engineering and information systems
39. Dixon (2008)			√	
40. Booch et al. (1999)				√
41. Zhou et al. (2004)	√			√
42. Dorn et al. (2009)			√	√
43. Gammoh, D. (2009)	☆	(proposed and implemented in this research) ☆	(proposed and implemented in this research) ☆	(part of the proposed methodology but the implementation is proposed for future work) ☆

APPENDIX B. : OLD EXIT SURVEY

Note: Questions 2 to 14 were analyzed, the answers are based on a Likert Scale (Strongly Agree-Agree-Neutral-Disagree-Strongly Disagree)

1. In general, how would you rate your overall experience in the UCF Industrial Engineering and Management Systems (IEMS) program?
2. Do you agree or disagree that the program provided you with adequate knowledge and skills to succeed in your chosen profession?
3. Do you agree or disagree that the program developed your ability to think logically/solve analytic problems?
4. Do you agree or disagree that the program developed your ability to design a meaningful experiment?
5. Do you agree or disagree that the program developed your ability to analyze and interpret data?
6. Do you agree or disagree that the program developed your ability to design or improve a system or process?
7. Do you agree or disagree that the program enhanced your speaking ability?
8. Do you agree or disagree that the program developed your ability to speak effectively?
9. Do you agree or disagree that the program developed your ability to effectively listen to others?
10. Do you agree or disagree that the program developed your ability to effectively work on a team?
11. Do you agree or disagree that the program developed your ability to effectively lead a team?
12. Do you agree or disagree that the program developed your ability to build an effective working relationship with a client?
13. Do you agree or disagree that the program developed your understanding of the need for ethical practice and professionalism?
14. Do you agree or disagree that the program developed your understanding of how IE can be applied to global work environments

What are your plans after graduation?

____

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APPENDIX C. : OLD EMPLOYER SURVEY

Please rate the following skills, abilities and attributes relative to how you observed recent UCF IE graduates ability to perform in these areas.

Important to Business					Performance of Our Graduates					
Very Important	Important	May not be Required	Not Important	**Skills or abilities:**	Outstanding	Above Average	Satisfactory	Below Average	Unsatisfactory	Cannot Evaluate
☐	☐	☐	☐	**Initiative**: Works well with minimal supervision; seeks things to do; seeks more responsibility, has the ability to initiate tasks/projects.	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	**Adaptability:** Adapts quickly to new work environments; follows detailed instructions well; can switch jobs easily.	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	**Quality of Work:** Does accurate; neat; consistent and quality jobs.	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	**Timely:** Accomplishes acceptable amount of work in a reasonable amount of time.	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	**Job Challenge - -** Acquire knowledge and command of job skills; use skills and knowledge well in challenging situations	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	**Competence and Creativity - -** Has the ability to develop new or innovative ideas, be a self starter; and has the required skills to assume challenging assignments.	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	**Communication - -** Has professional oral and written communication skills.	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	**Interaction - -** Functions well on multi-disciplinary or cross-functional teams	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	**Critical and Analytical Thinking - -** Able to identify, formulate, and solve engineering problems.	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	**Ethics - -** Applies professional ethics in work and decision-making.	☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	**OVERALL RATING FOR UCF IE GRADUATES**	☐	☐	☐	☐	☐	☐

APPENDIX D. : LEARNING OUTCOMES SURVEY

Note: The answers are based on a Likert Scale
(1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5=Strongly Disagree)

This survey is designed to measure the learning outcomes of the IEMS department at UCF. We believe in your input as a feedback to our department and we would really appreciate it if you answer these questions to the best of your ability.

Please evaluate how the IE classes you're currently taking contribute to your learning ability in the following aspects:

<u>Learning Outcome 1:</u>

1. Ability to use math to solve engineering problems (calculus, algebra, matrix operations, statistics or analytic geometry)
2. Ability to utilize fundamental engineering techniques, skills and tools for engineering practice

<u>Learning Outcome 2:</u>

3. Ability to overcome conflicts of interest with a client or consultant
4. Ability to perform engineering tasks only in areas of your competence
5. Be aware of engineering codes of professional conduct
6. Ability to prioritize tasks to meet expectations and deadlines

<u>Learning Outcome 3:</u>

7. Ability to collect relevant data about a problem
8. Ability to analyze a problem
9. Ability to conclude results and develop recommendations

<u>Learning Outcome 4:</u>

10. Ability to identify and describe a problem
11. Ability to find the correct tool for a certain problem
12. Ability to assess the validity of the proposed solution

<u>Learning Outcome 5:</u>

13. Ability to write clear reports and presentations
14. Ability to give an oral formal presentation of a project
15. Ability to communicate with a client/classmates/instructor effectively

<u>Learning Outcome 6:</u>

16. Ability to leverage various team member experiences
17. Ability to facilitate and resolve conflicts among team members
18. Ability to communicate and share knowledge within a team

<u>Learning Outcome 7:</u>

19. Ability to become aware of recent developments in your field of specialization as well as related fields
20. Accessibility to recent references such as papers, websites or news sources
21. Ability to brainstorm with your class mates on recent events and development on topics related to your class.
22. Ability to brainstorm with your Instructor on recent events and development on topics related to your class.

Learning Outcome 8:

23. Ability to relate the impact of global issues on industrial engineering solutions
24. Ability to envision how recent developments may impact your career path, the engineering profession or the society as a whole
25. Ability to use your IE skills in modern practical problems

Learning Outcome 9:

26. The IE department provides me with information about graduate studies
27. The IE department introduces me to technical and professional conferences in related field
28. The IE department provides the opportunity of being enrolled in professional societies and organizations

Learning Outcome 10:

29. Ability to understand the needs of the society in engineering related fields

Ability to use IE tools to solve problems to meet the needs of the society

APPENDIX E. : DETAILED SURVEY VS. LEARNING OUTCOMES ANALYSIS

Learning Outcomes 1-8	**Outcome 1 & 10**	**Outcome 2**	**Outcome 3**	**Outcome 4**	**Outcome 5**	**Outcome 6**	**Outcome 7**	**Outcome 8**	**Outcome 9**
	Students will be able to apply mathematics, science and engineering fundamentals in classroom and real world projects. Students will **utilize tools and techniques of industrial engineering** to effectively and efficiently design systems, products and processes that meet the needs of the society.	Students will make responsible decisions and exhibit integrity and ethics in classroom and real world projects.	Students will be able to collect, analyze, and interpret data in classroom and project settings as well as drawing meaningful conclusions and developing sound recommendations.	Students will effectively utilize industrial engineering design and problem-solving skills in classroom and real world projects.	Students will communicate effectively, orally and in writing, to peers and superiors in classroom and real world projects.	Students will be able to work with persons of varied backgrounds in classroom and real world projects.	Students will incorporate contemporary issues into the practice of industrial engineering.	Students will be able to measure the impact of global and societal issues on industrial engineering solutions to modern practical problems.	Students will explore options for professional growth, including graduate study, conference attendance, and professional society participation.

Graduating Seniors Survey - IEMS Program Specific Questions	✓	✓	✓	✓	✓	✓	✓	✓	
Question 1. In general, how would you rate your overall experience in the UCF Industrial Engineering and Management Systems (IEMS) program?									
Question 2. Do you agree or disagree that the program provided you with adequate knowledge and skills to succeed in your chosen profession?	1		1	1					
Question 3. Do you agree or disagree that the program developed your ability to	1		1	1					

think logically/solve analytic problems?									
Question 4. Do you agree or disagree that the program developed your ability to design a meaningful experiment?	1		1	1					
Question 5. Do you agree or disagree that the program developed your ability to analyze and interpret data?	1		1	1					
Question 6. Do you agree or disagree that the program developed your ability to design or improve a system or process?	1		1	1					
Question 7. Do you agree or disagree that					1				

the program enhanced your speaking ability?									
Question 8. Do you agree or disagree that the program developed your ability to write effectively?					1				
Question 9. Do you agree or disagree that the program developed your ability to effectively listen to others?					1				
Question 10. Do you agree or disagree that the program developed your ability to effectively work on a team?						1			
Question 11. Do you agree or disagree						1			

that the program developed your ability to effectively lead a team?									
Question 12. Do you agree or disagree that the program developed your ability to build an effective working relationship with a client?					1	1			
Question 13. Do you agree or disagree that the program developed your understanding of the need for ethical practice and professionalism?		1							
Question 14. Do you agree or disagree that the program							1	1	

developed your understanding of how IE can be applied to global work environments?										
Question 15. What are your plans after graduation?										
Attend graduate/professional school - applying/waiting for acceptance										
Attend graduate/professional school - been accepted/considering offer(s)										
Attend graduate/professional school - accepted offer										
Work - applying/waiting for offer(s)										

Work - received offer(s)/considering offer(s)									
Work - accepted position									
Total (senior survey)	5	1	5	5	4	3	1	1	0
Alumni Survey	✓	✓	✓	✓	✓	✓		✓	✓
Q1. Employment Status									
Q2. My program prepared me well for professional practice									
Q3. In comparison with my peers/co-workers who graduated from other universities, I rate my education									

superior to theirs									
Q4. The overall quality of IE program at UCF was excellent									
Q5. I feel sufficiently prepared by my study to obtain an entry-level Job that I wanted	1		1	1	1	1			
Q6. I feel I am sufficiently prepared to pursue graduate degree									1
Q7. My employer is considered to be a multinational organization									
Q8. I am well-prepared to assume professional and ethical responsibilities		1							

as an engineer									
Q9. Rate your overall preparation at UCF to:									
9a. Be an engineer	1		1	1					
9b. Obtain your first job after graduation or pursue graduate degree									
9c. Compete professionally as an engineer	1		1	1					
9d. Contribute to society as an engineer								1	
Q10. Would you recommend UCF to a friend or a relative									
Q11. Have you enrolled in a degree									1

program since graduating from the department									
Q12. Overall, how satisfied are you with your undergraduate education									
Q13. If you are currently employed, how relative is your job title to your profession as an Industrial Engineer?									
Q14. Today, how connected do you feel with the Industrial Engineering department at UCF									
Q15. Do you think you are receiving sufficient communications from the Industrial									

Engineering department at UCF?									
Q16. In light of your professional experience, please list three most useful knowledge, skills or attributes that you had acquired during years of education at UCF.									
Q17. Please list three most useful skills that you think should be taught in the engineering program at UCF.									
Q18. In your opinion, what should be done to improve the engineering education at UCF (use additional sheets if									

necessary)?									
Q19. What could you list as strength for the department?									
Q20. What could you list as weaknesses for the department									
Total (alumni survey)	3	1	3	3	1	1	0	1	2
Employer Survey	✓	✓	✓	✓	✓	✓	✓	✓	
Q1. Department/ Division:									
Q2. Position:									
Q3. Years in position:									
Q4. Which ONE of the following best describes your organization as									

a whole? (Government, Private, Other)									
Q5. Please rate the following skills, abilities and attributes relative to how you have observed recent UCF IE graduates' ability to perform in these areas.									
An ability to:"									
Q5a. Learn new skills	1								
Q5b. Develop new or innovative ideas				1					
Q5c. Operate in international and multicultural context						1			
Q5d. Work autonomously									

Q5e. Design and conduct experiments, analyze and interpret data			1						
Q5e. Design a system, component to meet a desired need				1					
Q5f. Function on multi-disciplinary or cross-functional teams						1			
Q5g. Identify, formulate, and solve engineering problems	1		1	1					
Q5g. Communicate orally: informal and prepared talks					1				
Q5h. Communicate in writing: letters, technical					1				

reports, etc.									
Q5i. Stay current technically and professionally							1	1	
Q5j. Use state of the art techniques, and tools in engineering practice (Computer, Internet, etc)							1	1	
Q6. Please rate the following skills, abilities and attributes relative to how you have observed recent UCF IE graduates' ability to perform in these areas.									
An understanding of:"									
Q6a. Leadership Skills						1			

Q6b. Professional and Ethical Responsibility		1							
Q6c.Impact of engineering solutions on society and environment								1	
Q6d.Contemporary social, economic and cultural issues							1		
Q7. Are there other attributes your organization or unit finds important when employing graduates?									
Q8. Did you provide additional (on the job or off the job) training in the first year of recruitment to improve your newly appointed									

engineers?									
Q9. If yes, what training did you provide? Please be specific.									
Q10. How do UCF graduates compare with graduates from other universities? (Much better, Somewhat better, About the same, Not as good, Much worse)									
Q11. What particular strengths do our graduates possess?									
Q12. In what areas does the IEMS department need to improve its preparation of graduates for employment?									

Total (employer survey)	2	1	2	3	2	3	3	3	0
Student Satisfaction Survey	✓	✓	✓	✓	✓	✓	✓	✓	✓
apply knowledge of mathematics, science, and engineering	1		1	1					
design and conduct experiments as well as to analyze and interpret data			1	1					
design a system, component, or process to meet needs			1	1					
function on multi-disciplinary teams						1			
identify, formulate, and solve			1	1					

engineering problems.									
understand professional and ethical responsibility		1							
communicate effectively					1				
understand the impact of engineering solutions in a global, economic, environmental, and societal context.								1	
recognition of the need for, and an ability to engage in life-long learning									1
enhance knowledge of contemporary issues							1		
use the techniques, skills, and								1	

modern engineering tools necessary for engineering practice									
Total (student satisfaction survey)	1	1	4	4	1	1	1	2	1
Senior Design Industrial Mentor			✓		✓	✓			
Baseline Data Analysis- How well did the team describe and quantify the operation's current performance?			1						
Opportunities for Improvement- How well did the team identify the primary opportunities for improvement?									
Plan for Next semester- How well did the									

team describe their plan to complete the project?									
Organization- How well is the presentation organize (does it facilitate communicatio n)?					1				
Visuals- How effective are the visual aids?									
Speech- How well did the team communicate verbally?					1	1			
Overall- How effective was the presentation overall?					1				
Data Analysis			1						
Alternatives									
Alternatives									

Evaluation									
Total (senior design)	0	0	2	0	3	1	0	0	0
Faculty Survey	✓	✓	✓	✓	✓	✓	✓	✓	
Academic Rank									
Number of years as a faculty member:									
Number of years as a faculty member at UCF:									
A. In your opinion, what would be the three most useful skills, abilities or attributes that need more emphasis in the IEMS programs at UCF?									
B. Please rate the following									

skills, abilities and attributes (An ability to):									
design and conduct experiments	1		1	1					
analyze and interpret data from experiments			1						
design a system or a component to meet a desired need			1	1					
function on multi-disciplinary or cross-functional teams						1			
identify, formulate, and solve engineering problems			1	1					
recognize professional and ethical		1							

responsibility									
communicate orally in English					1				
communicate in writing in English					1				
stay current technically and professionally							1	1	
use state of the art techniques and tools in engineering practice							1	1	
use computing technology in communicatio n					1				
use computing technology in engineering analysis/design			1						
synthesize and integrate knowledge across							1	1	

disciplines									
B. Please rate the following skills, abilities and attributes (An understanding of:):									
environmental aspects of engineering practice							1	1	
the practice of engineering on a global scale							1	1	
the relation of engineering to societal and cultural issues	1						1	1	
Total (faculty survey)	1	1	5	3	3	1	6	6	0

APPENDIX F. : NEW EXIT SURVEY

After having successfully completed the IEMS program, on a scale from (1) to (5), please rate your satisfaction on how well the IEMS program has prepared or provided you with the following:
(1= Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly Disagree).

1. **Engineering Technical Skills**	
1.1 Apply math to solve engineering problems (calculus, algebra, matrix operations, statistics, or analytic geometry)	**1 2 3 4 5**
1.2 Collect, analyze and interpret data	**1 2 3 4 5**
1.3 Find the correct tool to solve an engineering problem	**1 2 3 4 5**
2. **Communication Skills**	
2.1 Write clear reports and presentations	**1 2 3 4 5**
2.2 Communicate with a client/classmates/instructor effectively	**1 2 3 4 5**
2.2 Give an oral formal presentation	**1 2 3 4 5**
3. **Team Skills**	
1.5 Leverage various team member experiences	**1 2 3 4 5**
1.6 Facilitate and resolve conflicts among team members	**1 2 3 4 5**
1.7 Communicate and share knowledge within a team	**1 2 3 4 5**
4. **Professional Growth**	
1.1 IE program provided me with information about graduate studies	**1 2 3 4 5**
1.2 IE program introduced me to technical and professional IE conferences	**1 2 3 4 5**
1.3 IE program provided me with the opportunity to get involved in professional societies and organizations	**1 2 3 4 5**
5. **Contemporary Issues**	
1.1 IE program developed my understanding for engineering codes of ethics	**1 2 3 4 5**
1.2 IE program raised my awareness of recent developments in my field of specialization as well as related fields	**1 2 3 4 5**
1.3 IE program provided me with accessibility to recent references such as papers, websites, or news sources	**1 2 3 4 5**
1.4 IE program developed my ability to relate the impact of global issues on industrial engineering solutions	**1 2 3 4 5**
1.5 IE program broadened my vision how recent developments may impact my career path, the engineering profession or the society as a whole.	**1 2 3 4 5**

What opportunities for improvements you think that department has to consider in its program?

____

____

Thank You!

APPENDIX G. : NEW STUDENT SATISFACTION SURVEY

Course: ______________________ Your Major: __________________________
Instructor: _________________________ Semester: ______________________

1. Assessment of Abilities, Skills and Attributes Acquired in the course:

Please rate each of the following skills, abilities or attributes in terms of how well **THIS COURSE** contributes to your learning ability in the following aspects!

Level of preparation	Skills or abilities:	Importance for their professional career 1=Extremely Important 2= Very Important 3= Important 4=Somewhat Important 5= Not Important
Learning Outcome 1: Apply math, science, engr. fundamentals		
Ability to use math to solve engineering problems (calculus, algebra, matrix operations, statistics or analytic geometry)		**1 2 3 4 5**
Ability to utilize fundamental engineering techniques, skills and tools for engineering practice		**1 2 3 4 5**
Learning Outcome 2: Ethics and responsible decisions		
Ability to overcome conflicts of interest with a client or consultant		**1 2 3 4 5**
Ability to perform engineering tasks only in areas of your competence		**1 2 3 4 5**
Be aware of engineering codes of professional conduct		**1 2 3 4 5**
Ability to prioritize tasks to meet expectations and deadlines		**1 2 3 4 5**
Learning Outcome 3: Collect, analyze and interpret data		
Ability to collect relevant data about a problem		**1 2 3 4 5**
Ability to analyze a problem		**1 2 3 4 5**
Ability to conclude results and develop recommendations		**1 2 3 4 5**
Learning Outcome 4: Design and problem solving skills		
Ability to identify and describe a problem		**1 2 3 4 5**
Ability to find the correct tool for a certain problem		**1 2 3 4 5**
Ability to assess the validity of the proposed solution		**1 2 3 4 5**
Learning Outcome 5: Communication Skills		
Ability to write clear reports and presentations		**1 2 3 4 5**

Ability to give an oral formal presentation of a project	**1 2 3 4 5**
Ability to communicate with a client/classmates/instructor effectively	**1 2 3 4 5**
Learning Outcome 6: Working in Teams	
Ability to leverage various team member experiences	**1 2 3 4 5**
Ability to facilitate and resolve conflicts among team members	**1 2 3 4 5**
Ability to communicate and share knowledge within a team	**1 2 3 4 5**
Learning Outcome 7: Aware of Contemporary Issues	
Ability to become aware of recent developments in your field of specialization as well as related fields	**1 2 3 4 5**
Accessibility to recent references such as papers, websites or news sources	**1 2 3 4 5**
Ability to brainstorm with your <u>class mates</u> on recent events and development on topics related to class subject	**1 2 3 4 5**
Ability to brainstorm with your <u>instructor</u> on recent events and development on topics related to your class subject	
Learning Outcome 8: Impact of Global and Societal Issues	
Ability to relate the impact of global issues on industrial engineering solutions	**1 2 3 4 5**
Ability to envision how recent developments may impact your career path, the engineering profession or the society as a whole	**1 2 3 4 5**
Ability to use your IE skills in modern practical problems	**1 2 3 4 5**
Learning Outcome 9: Professional Growth	
Students knowledge about the graduate studies	**1 2 3 4 5**
Students knowledge about technical and professional conferences in related field	**1 2 3 4 5**
Students involvement in professional societies and organizations	**1 2 3 4 5**
Learning Outcome 10: IE tools with the needs of the society	
Ability to understand the needs of the society in engineering related fields	**1 2 3 4 5**
Ability to use IE tools to solve problems to meet the needs of the society	**1 2 3 4 5**

2. Assessment of the Learning Environment - - Please indicate your satisfaction with each of the following aspects

	Level of satisfaction					
	Extremely satisfied	Very satisfied	Satisfied	Somewhat satisfied	Not satisfied	Can't evaluate
A. Quality of instruction and support for learning provided by the instructor	☐	☐	☐	☐	☐	☐
B. Quality of instruction and support for learning given by TA's	☐	☐	☐	☐	☐	☐
E. Quality of the facilities:						
- Classrooms	☐	☐	☐	☐	☐	☐
- Laboratories	☐	☐	☐	☐	☐	☐
- Computing facilities	☐	☐	☐	☐	☐	☐

3. General Assessment: Please answer the following questions:

A. Please list some very important skills that you think you had learned in this course.

____

____

B. Please list some very important or useful skills that you expect to learn in class.

____

____

C. Please write down any comments or suggestions that you think will improve the course.

____

____

APPENDIX H. : NEW EMPLOYER SURVEY

As a major stakeholder in our college, we are seeking your assessment on how we are serving your needs through the quality of our graduates. The information that you provide through this survey will be very helpful in the continuous improvement process of our undergraduate industrial engineering program. We appreciate your help in filling out this survey. Thank you for your cooperation and support.

Name: ____ (Optional)

Employer & Location: ____

Department/Division: ____________________ Position: ______________________

Which ONE of the following best describes your organization as a whole?

Government: ☐
Public Sector: ☐
Private Sector: ☐
Service/Consultin ☐
Other : ☐ ______________________________________
Write Description

Thank You for Your Time!

Please rate the following skills, abilities and attributes relative to how you have observed recent UCF IE graduates ability to perform in these areas.

Important to Business		***Performance of Our Graduates***
1 = Very Important 2 = Important 3 = Maybe required 4 = Not Important	**Skills or abilities:**	1= Outstanding 2= Above Average 3= Satisfactory 4= Below Average 5= Unsatisfactory
	Engineering Technical Skills	
1 2 3 4 5	Able to identify, formulate, and solve engineering problems.	**1 2 3 4 5**
1 2 3 4 5	Has the ability to develop new or innovative ideas, be a self starter; and has the required skills to assume challenging assignments.	**1 2 3 4 5**
1 2 3 4 5	Able to collect, analyze and interpret data	**1 2 3 4 5**
1 2 3 4 5	Does accurate, neat, consistent and quality jobs.	**1 2 3 4 5**
	Communication Skills	
1 2 3 4 5	Write clear reports and presentations	**1 2 3 4 5**
1 2 3 4 5	Communicate with a client/classmates/instructor effectively	**1 2 3 4 5**
1 2 3 4 5	Give an oral formal presentation	**1 2 3 4 5**
	Team Skills	
1 2 3 4 5	Functions well on multi-disciplinary or cross-functional teams	**1 2 3 4 5**
1 2 3 4 5	Communicate and share knowledge within a team	**1 2 3 4 5**
1 2 3 4 5	Facilitate and resolve conflicts among team members	**1 2 3 4 5**
	Contemporary Issues	
1 2 3 4 5	Accomplishes acceptable amount of work in a reasonable amount of time.	**1 2 3 4 5**
1 2 3 4 5	Applies professional ethics in work and decision-making.	**1 2 3 4 5**
1 2 3 4 5	Awareness of recent developments in my field of specialization as well as related fields	**1 2 3 4 5**

1. **Please check the three most desirable qualities you seek in an IE graduate.**
   - ☐ Communications ☐ Motivation ☐ Leadership
   - ☐ Engineering Fundamentals ☐ Co-op Employment ☐ Team Skills
2. **Please indicate the importance of knowledge of the following subjects in your decision to hire IE - - mark all that apply**
   - ☐ Manufacturing Methods ☐ Total Quality Management
   - ☐ Systems Analysis ☐ Statistical Methods
   - ☐ Human Factors/Ergonomics ☐ Engineering Economy
   - ☐ Simulation ☐ Operations Research
   - ☐ Others; please indicate: _______________
3. **How do UCF graduates compare with graduates from other universities?**
   - ☐ Much better
   - ☐ Somewhat better
   - ☐ About the same
   - ☐ Not as good
   - ☐ Much worse

4. **Are there other attributes your organization or unit finds important when employing graduates?**
   a. __________________________________ c.____
   b. ___________________________________ d.______________________________________
5. **What particular strengths do our graduates possess?**
   a. ____
   b. ____
   c. ____
6. In what areas does the IEMS department need to improve its preparation of graduates for **employment?**
   a. ____
   b. ____
   c. ____

Thanks again for completing this survey!
Your feedback will be used to improve the preparation of our graduates for employment

APPENDIX I. : NEW SENIOR DESIGN MENTOR EVALUATION

Team:
Date:
Evaluator:

Please rate the following skills, abilities and attributes relative to how you have observed recent UCF IE graduates ability to perform in these areas.

Important to Business		***Performance of the Team***
1 = Very Important 2 = Important 3 = Maybe required 4 = Not Important	**Skills or abilities:**	1= Outstanding 2= Above Average 3= Satisfactory 4= Below Average 5= Unsatisfactory
	Engineering Technical Skills	
1 2 3 4 5	Able to identify, formulate, and solve engineering problems.	**1 2 3 4 5**
1 2 3 4 5	Has the ability to develop new or innovative ideas, be a self starter; and has the required skills to assume challenging assignments.	**1 2 3 4 5**
1 2 3 4 5	Able to collect, analyze and interpret data	**1 2 3 4 5**
1 2 3 4 5	Does accurate, neat, consistent and quality jobs.	**1 2 3 4 5**
	Communication Skills	
1 2 3 4 5	Write clear reports and presentations	**1 2 3 4 5**
1 2 3 4 5	Communicate with a client/classmates/instructor effectively	**1 2 3 4 5**
1 2 3 4 5	Give an oral formal presentation	**1 2 3 4 5**

Other Comments:

(Please include your impression of participation and contribution of each team member)

____

____

Thanks again for completing this survey!
Your feedback will be used to improve the preparation of our graduates for employment

APPENDIX J. : NEW FACULTY SURVEY

As faculty members you are major stakeholders in decision-making and evaluation for the quality of programs and services in the college. The following survey has been designed to collect your opinions and perceptions about the quality of our graduates, the college in general, and about several important aspects of your work environment.

ALL ANSWERS WILL BE CONFIDENTIAL AND ANONYMOUS. *Thank you in advance for your cooperation.*

Academic rank: (Optional)

- ☐ Professor
- ☐ Associate Professor
- ☐ Assistant Professor

Number of years as a faculty member: _______________

Number of years as a faculty member at UCF: _______________

Please rate the following skills, abilities and attributes: First, based on your observation of students who are near graduation; Second, according to the importance for their careers.

Assessment of students		**Importance for their professional career**
1= Very Well Prepared 2= Well Prepared 3= Prepared 4= Somewhat prepares 5= Cannot evaluate	**Skills or abilities:**	1= Extremely Important 2= Very Important 3= Important 4= Somewhat Important 5= Not Important
	Engineering Technical Skills	
1 2 3 4 5	Able to identify, formulate, and solve engineering problems.	**1 2 3 4 5**
1 2 3 4 5	Has the ability to develop new or innovative ideas, be a self starter; and has the required skills to assume challenging assignments.	**1 2 3 4 5**
1 2 3 4 5	Able to collect, analyze and interpret data	**1 2 3 4 5**
1 2 3 4 5	Does accurate; neat; consistent and quality jobs.	**1 2 3 4 5**
	Communication Skills	
1 2 3 4 5	Write clear reports and presentations	**1 2 3 4 5**
1 2 3 4 5	Communicate with a client/classmates/instructor effectively	**1 2 3 4 5**
1 2 3 4 5	Give an oral formal presentation	**1 2 3 4 5**
	Team Skills	
1 2 3 4 5	Functions well on multi-disciplinary or cross-functional teams	**1 2 3 4 5**
1 2 3 4 5	Communicate and share knowledge within a team	**1 2 3 4 5**
1 2 3 4 5	Facilitate and resolve conflicts among team members	**1 2 3 4 5**
	Contemporary Issues	
1 2 3 4 5	Accomplishes acceptable amount of work in a reasonable amount of time.	**1 2 3 4 5**
1 2 3 4 5	Applies professional ethics in work and decision-making.	**1 2 3 4 5**
1 2 3 4 5	Awareness of recent developments in my field of specialization as well as related fields	**1 2 3 4 5**

APPENDIX K. : NEW ALUMNI SURVEY

Name:________________________________ Year of Graduation: _______

Employer: ____

Employer Classification:

Government:	☐	______________________________ (Write Name)
Public Sector:	☐	______________________________ (Write Name)
Private Sector:	☐	______________________________ (Write Name)
Service/Consulting:	☐	______________________________ (Write Name)
Other	☐	______________________________ (Write Name)

Job Title: ____

Job Description: ____

Did you receive any promotions? Yes ☐ No ☐

If yes, when?

- ☐ Few months after Employment.
- ☐ One year after Employment.
- ☐ Two or more years after Employment.

Mailing Address: ____
____

E-mail ______________________________ Tel: ________________ Fax: ____________

University Honors/Recognitions (if any): ____

Employment Honors/Recognitions (if any): ____

Membership in professional Societies (if any): ______________________________________

The information that you provide through this survey will be very helpful in the continuous improvement process of our undergraduate industrial engineering program. We appreciate your help in filling out this survey. Thank you for your cooperation and support.

In comparison with your peers/co-workers who graduated from other universities, please rate your satisfaction on how well the IEMS program has prepared or provided you with the following :(1= Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly Disagree).

1. Engineering Technical Skills	
1.1 Apply math to solve engineering problems (calculus, algebra, matrix operations, statistics, or analytic geometry)	1 2 3 4 5
1.2 Collect, analyze and interpret data	1 2 3 4 5
1.3 Find the correct tool to solve an engineering problem	1 2 3 4 5
2. Communication Skills	
2.1 Write clear reports and presentations	1 2 3 4 5
2.2 Communicate with a client/classmates/instructor effectively	1 2 3 4 5
2.2 Give an oral formal presentation	1 2 3 4 5
3. Team Skills	
3.1 Leverage various team member experiences	1 2 3 4 5
3.2 Facilitate and resolve conflicts among team members	1 2 3 4 5
3.3 Communicate and share knowledge within a team	1 2 3 4 5
4. Professional Growth	
4.1 IE program provided me with information about graduate studies	1 2 3 4 5
4.2 IE program introduced me to technical and professional IE conferences	1 2 3 4 5
4.3 IE program provided me with the opportunity to get involved in professional societies and organizations	1 2 3 4 5
5. Contemporary Issues	
5.1 IE program developed my understanding for engineering codes of ethics	1 2 3 4 5
5.2 IE program raised my awareness of recent developments in my field of specialization as well as related fields	1 2 3 4 5
5.3 IE program provided me with accessibility to recent references such as papers, websites, or news sources	1 2 3 4 5
5.4 IE program developed my ability to relate the impact of global issues on industrial engineering solutions	1 2 3 4 5
5.5 IE program broadened my vision how recent developments may impact my career path, the engineering profession or the society as a whole.	1 2 3 4 5
I feel that the UCF IE program sufficiently prepared me to:	
6.1 Be an engineer	1 2 3 4 5

6.2 Obtain your first job after graduation or pursue graduate degree	1 2 3 4 5
6.3 Compete professionally as an engineer	1 2 3 4 5
6.4 Contribute to society as an engineer	1 2 3 4 5

1. Would you recommend UCF to a friend or a relative?
- ☐ Strongly recommend
- ☐ Recommend
- ☐ Don't recommend

2. Have you enrolled in a degree program since graduating from the department?
- ☐ No
- ☐ Yes, please specify_______________

3. Overall, how satisfied are you with your undergraduate education?
- ☐ Very Satisfied
- ☐ Satisfied
- ☐ Neutral
- ☐ Dissatisfied
- ☐ Very Dissatisfied

4. If you are currently employed, how relative is your job title to your profession as an Industrial Engineer?
- ☐ Exactly relevant
- ☐ Somehow relevant
- ☐ Not relevant

5. Today, how connected do you feel with the Industrial Engineering department at UCF?
- ☐ Very connected
- ☐ Moderately connected
- ☐ Somewhat connected
- ☐ Not very connected

6. Do you think you are receiving sufficient communications from the Industrial Engineering department at UCF?
- ☐ I'm currently getting too much communications
- ☐ Yes, I'm getting sufficient communications
- ☐ No, I would like to receive more frequent or additional updates via:
  - ☐ Regular mail
  - ☐ Email
  - ☐ Both regular mail and email

7. In light of your professional experience, please list three most useful knowledge, skills or attributes that you had acquired during years of education at UCF.

1.____
2.____
3.____

8. Please list three most useful skills that you think should be taught in the engineering program at UCF.

1.____
2.____
3.____

9. In your opinion, what should be done to improve the engineering education at UCF (use additional sheets if necessary)?

____
____

10. What could you list as strength for the department?

____
____

11. What could you list as weaknesses for the department?

____
____

Thank You!

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