A Methodological Approach to Developing Stakeholder Defined Demand-Pull Requirements for Graduate-Level Industrial Engineering Graduates

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Introduction

Manufacturing and service organizations generate outputs to satisfy the needs of the consumer whose perceptions and judgments are shaped by an environment of political, economic, social, and technological change. Products and service outputs result from processes supported by these companies' engineering employees, who may be also represented as an "output" from a diverse set of originating sources. Such "sources" can be the "general workforce," direct accession from high school, or graduates of higher education engineering programs.

As the source for granting degrees to industrial engineering undergraduate and graduate-level students, engineering higher education is motivated to adapt to the manufacturing and service consumer's changing requirements for an educated engineering employee. This motivation may be partially based on institutional and departmental-level accreditations, a critically important concern for stakeholders in institutions and the institutions' engineering departments. While an accreditation is alone significant and requires an institution/department to plan, collect, archive, and employ feedback data representing the explicit needs of the stakeholder in the output of academic programs, there also exists other significant "drivers" [motivators] acting upon an institution to better understand the consumer. These drivers may be generally provoked from an institutional appreciation for a singular body of knowledge; a recognition of an expanding market for "on demand," on-line education; and, finally, efforts to incorporate quality, technology, and a diversity of institutionally unique program outcomes demanded by the consumer into engineering programs.

Earlier scholarly research of engineering education revealed that the engineering discipline, and in particular industrial engineering, "…has problems, such as a theoretical approach to problem solving, insufficient understanding of real-life problems, and poor communication skills. [1] Further, engineering education research has not been discriminant in modeling the graduate and undergraduate consumer. A conclusion may be that an imprecise definition of the term "student" [graduate or undergraduate] could affect the process of educating the graduate-level industrial engineer such that their subsequent presentation as a candidate for the workforce community is not "aligned" with that community's needs. [2]

In attempting to satisfy institutional accreditation and the needs of various consuming stakeholders, previously mentioned, university-level academic departments develop "linkage processes" to effect collaboration and cooperation with stakeholders. [3], [4] However, evidence from interviews suggests that linkage processes, for example departmental advisory boards and self-reported surveys of a program's graduates result in technically biased expectations for reasons beyond the scope of this research. However, the same evidence also suggests that advisory boards and surveys tend to generalize expectations from non-technical factors such as a graduate's capabilities in communication, inter-personal relationships, management, and "…other duties as required." Indeed, there may be a universe of needs the stakeholders would seek in an engineering program's graduate-level graduate given the program had access to unlimited resources. However, a systematic process to explicitly define a hierarchy of needs with dependencies and priorities spanning the technical and non-technical components of an engineering program may not be well understood by a program's stakeholders.

Research is needed for a better understanding of and a methodological process for assessing the judgments of stakeholders in the interdependent system of educational institutions, students, and consumers of graduates, if a graduate-level industrial engineer is to possess a skills set closely aligned to the needs of the consumer upon their graduation.

Therefore, several questions are provoked: "What if the process of understanding alignment began at the manufacturing stakeholder level and proceeded to meet industrial engineering higher education at the level of the graduate student - a demand-pull context?"; or "What if industrial engineering higher education and its student populations were to make comparative judgments through the same skills hierarchy and prioritization instrument that was previously defined by the manufacturers?" An answer to these questions may be suggested by the following question: "If at a given point in time we knew the skills each stakeholder sought in graduate-level engineering graduates, would we witness an alignment or a lack of alignment in their skills expectations; and how similar are these stakeholders' needs sets? The goals for each stakeholder would appear to be synthesized in the following question and Figure 1:

> *"What characteristics are expected by employers in the ideal graduate-level industrial engineer following graduation?"*

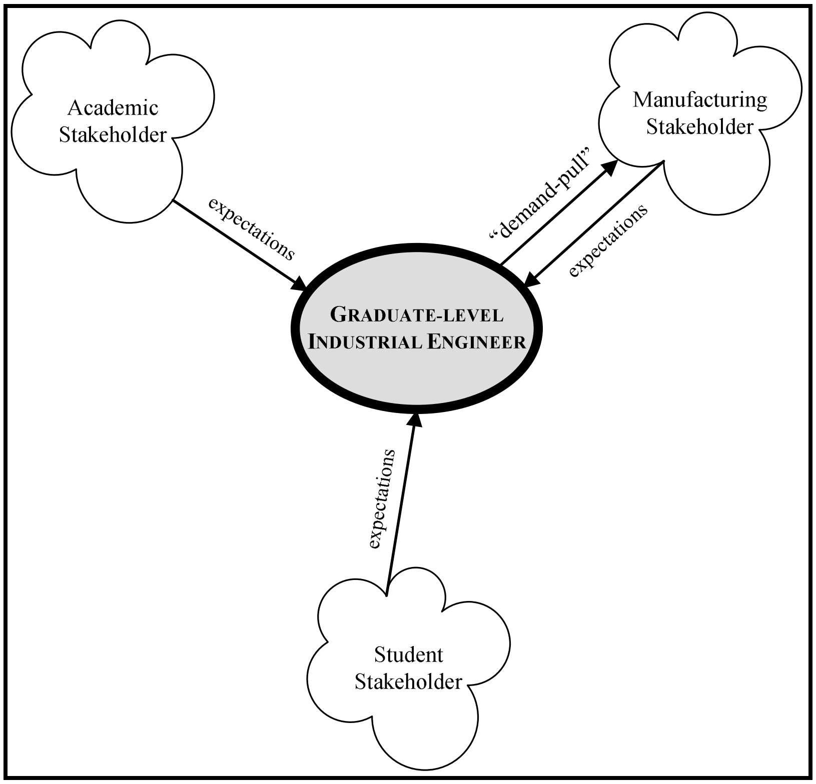

Figure 1. Triangular Perspectives of the "Stakeholder" Populations

In summary, the current research project seeks to answer those questions by presenting a methodological approach to define an expert manufacturing panel's set of graduate-level industrial engineering skills requirements. Next, the research employs the proposed methodological approach in empirical research designed to define a hierarchy of these requirements through a consensus process known as the Nominal Group Technique; and then to develop a set of comparative weights of the requirements. Next, the research addresses the needs of manufacturing stakeholders typical of industrial businesses hiring industrial engineers. The research also assesses the needs of an industrial engineering higher education stakeholders at the graduate level by collecting data from surveys of academicians, graduate students and senior students enrolled in a graduate-level industrial engineering course.

Statement of the Problem

Higher education's engineering programs and their stakeholders' requirements should be aligned to provide graduate-level engineers who possess the requirements of internal and external stakeholders. Previous research into a demand-pull methodology for assessing industrial engineering skills alignment at the graduate-level is unknown.

The Purpose of the Research

The objective of this research project is [to]

Model a methodology for developing the judgments of manufacturing companies for comparison to judgments made by academia and industrial engineering students at the graduate level in order to determine the significance of the alignment of graduate-level engineers' skills meeting the requirements of selected stakeholders.

Sub-objectives of the Research

To complete the research project, the objective was further stratified into the following sub-objectives:

Sub-objective 1

Develop a methodology to understand the needs of a stakeholder in the industrial engineering graduate student and to understand the process of obtaining a consensus of opinion about their needs.

Sub-objective 2

Determine the priorities for skills and knowledge required in selected manufacturing companies by applying selected consensus-gathering and comparative weighting schemes. A demand-pull process should clearly understand the skills and knowledge requirements, the hierarchical relationship among the requirements, and the weights [priorities] given these skills and knowledge.

Sub-objective 3

Determine the priorities for skills and knowledge required in selected industrial engineering departments in higher education by applying selected comparative weighting schemes. The demand-pull process should have the academicians understanding the manufacturers' skills and knowledge requirements, and then using a set of given definitions to develop a unique set of hierarchical relationships among the requirements, and the weights [priorities] given these skills and knowledge.

Sub-objective 4

Determine the priorities for skills and knowledge required in senior and graduate-level industrial engineering students by applying selected comparative weighting schemes. The demand-pull process should have the students understanding the manufacturers' skills and knowledge requirements, and then using a set of given definitions to develop a unique set of hierarchical relationship among the requirements, and the weights [priorities] given these skills and knowledge.

Sub-objective 5

Measure the significance of the alignment of the research stakeholders [academicians, manufacturers, and students (graduate and undergraduate/senior-level)] through an AHP analysis and a statistical comparison of their individual priorities.

Methodology of the Research Project

Table 1 maps the methodology proposed to answer the research objectives. It is based upon a synthesis of various approaches to qualitative observational research. [5], [6], [7] In addition, Table 1 includes a column, "Saaty step(s)", to map the research methodology steps to the Saaty algorithm. [8]

Table 1. Research Plan

Step	Description of the Step	Saaty step(s)*
1	Develop questions about the alignment of goals between the stakeholders.	1
2	Develop a survey research plan.	
3	Develop requirements for academia, employer, and student stakeholders.	
4	Develop an AHP hierarchy.	2
5	Develop a research instrument based upon the AHP hierarchy.	
6	Pretest the research instrument.	
7	Execute the survey research.	
8	Gather data from the survey instruments.	
9	Prepare the data for insertion into an Expert Choice© PC application.	3 & 4
10	Develop hypotheses about the alignment of goals between the stakeholders.	
11	Analyze each research instrument.	5, 6, & 7
12	Develop and execute statistical analyses.	
13	Draw and state conclusions	
*	(Refers to the steps in Saaty-based decision making. See Figure 3.2)	

Research Plan

The research plan is the overall scheme for this research. It details the course of action to accomplish the objective and sub-objectives. Table 2 works in concert with Table 1 to define the research algorithm (Table 3).

Table 2. Summary of Saaty's Analytical Hierarchy Process Defined for the Research Project [9]

Step #	Task
1	Define the problem and the desired solution.
2	Structure the hierarchy as an overall management perspective, starting from the top, through (the) intermediate level(s), to the bottom level at which intervention is possible. This is accomplished by broadly defining sets of criteria that influence the problem.
3	Construct a set of pairwise comparison matrices of the characteristics of the industrial engineering candidate for each of the lower levels for each element in the level immediately above (See Table 2.5). There are $n(n-1)/2$ pairwise comparisons, "judgments", required to develop each matrix.
4	Obtain all judgments required to develop the set of matrices called for in "step 3".
5	Following the collection of all pairwise comparisons, obtain the priorities and test for consistency.
6	Complete steps 3, 4, and 5 for all levels of the hierarchy.
7	Synthesize the hierarchy to weight the vectors of priorities by the weights of the criteria.

Methods for Evaluating and Measuring Stakeholder Judgments

Methods to model and analyze the "voice of the customer" include single attribute and multiple attribute analyses. Single attribute models include engineering economic analysis, "primitive" models, formal decision analysis, and utility theory. Multiple attribute analysis includes elementary models, quality function deployment, analytical hierarchy processes, principal components, and multicriteria models, such as multi-attribute utility theory, and multiple dimensional scaling.

The analytical hierarchy process is a more descriptive approach to multi-attribute decisions and appears to model the decision maker's ideal approach to structuring complex problems.

Analytical Hierarchy Process Modeling

Analytical hierarchy process (AHP) modeling has been used as a decision making approach in a large number of "hard" and "soft" engineering applications since the method was developed and published by Dr. Thomas L. Saaty. [10] For example, Drake (1998) discusses the use of AHP in the selection of a hydraulic pump meeting competing conditions ["Hard" application]. Tavana, Kennedy, and Joglekar (1996) report on the use of AHP in the selection of technical manager candidates ["Soft"]. [11] In his research, Saaty specifies the characteristics and advantages of AHP as a method for making choices from among competing alternative solutions, which relate to the present research. AHP models possess three principles particularly efficacious in this research: identity and decomposition; comparative judgments; and the synthesis of priorities. [12]

Beyond the assertion that the analytical hierarchy process is a more descriptive approach to multi-attribute decisions and appears to model the decision maker's ideal approach to structuring complex problems, two additional advantages of AHP over multi-attribute models are suggested. These advantages are, first, its ability to measure the consistency of decision makers' judgments; and, second, AHP can address group judgments in addition to individual judgments. These two advantages support the current research project, where it was determined necessary to compare the individual judgments of stakeholders, respondents. In the research, the respondents are synthesized into homogenous "group" judgments for analysis and comparison between the respondent groups.

Hierarchy of Academic Engineering Requirements

The literature is sparse that argues for the outcomes of a graduate engineering education drawn from the needs of manufacturing stakeholder in any hierarchical model. However, since the research anticipated use of a quantitative comparative weighting scheme with qualitative data and that the Saaty AHP model appeared to provide the necessary framework, an investigation of the Expert Choice homepage [http://www.expertchoice.com] reported approximately 1,450 studies using AHP.[13] However, the reported *engineering education* and the *engineering education assessment* literature are very limited in (un)published studies of the phenomena of <u>stakeholder preferences for the education of the engineering graduate</u>.[14] Bahurmoz reports that, "…only a few papers concern the application of AHP to decision making in education."[15] Previous research argued for an AHP model of undergraduate engineering characteristic. However, this earlier research was limited to the Thai manufacturing sector. [16]

Leepatanapan research modeled the pair-wise judgments within and between the factors comprising the *customer requirements* and *engineering characteristics;* the alternatives available to the manufacturing and professional service company decision maker. [17]

In summary, there is literature reported on the use of the AHP in quantitative and qualitative decision-making. In the literature of engineering education, however, no previous research is found that specifically evaluates the graduate-level academic expectations of stakeholders. Further, the environment of decision-makers in higher education is characterized by a complex set of internal and external forces stemming from stakeholders with an interest in the outcome of engineering programs. At the same time, researchers are arguing for a more collaborative engineering discipline, one more attuned to cross-disciplinary interaction. Students also have requirements, although research data are sparse. Alignment of their respective requirements appears relevant from the literature reporting research into the needs of the stakeholders. Further, it is also concluded that research into a demand pull from the engineering consumer does not address the graduate student. Further, earlier research is not in agreement upon a measure for the term *alignment*.

Figure 2 models the relationships to be analyzed by the research. Three populations are tested: student, school, and factory. The following key explains the figure's shapes and/or text:

- **Student** = Undergraduate and graduate industrial engineer enrolled in graduate-level courses.
- **Factory** = The manufacturer
- **School** = Higher education, industrial engineering academician
- **Expectations** = population of desired characteristics of the graduate-level industrial engineer.
-

1
2
3
4

  = The key characteristics of the graduate-level industrial engineer.

- Characteristics of the graduate engineer = A summary comparison

Three populations are used to study the goal. By triangularization, the author attempts to positively contribute to the validity and verification of the qualitative data through checking the consistency of the data using different sources. [18]

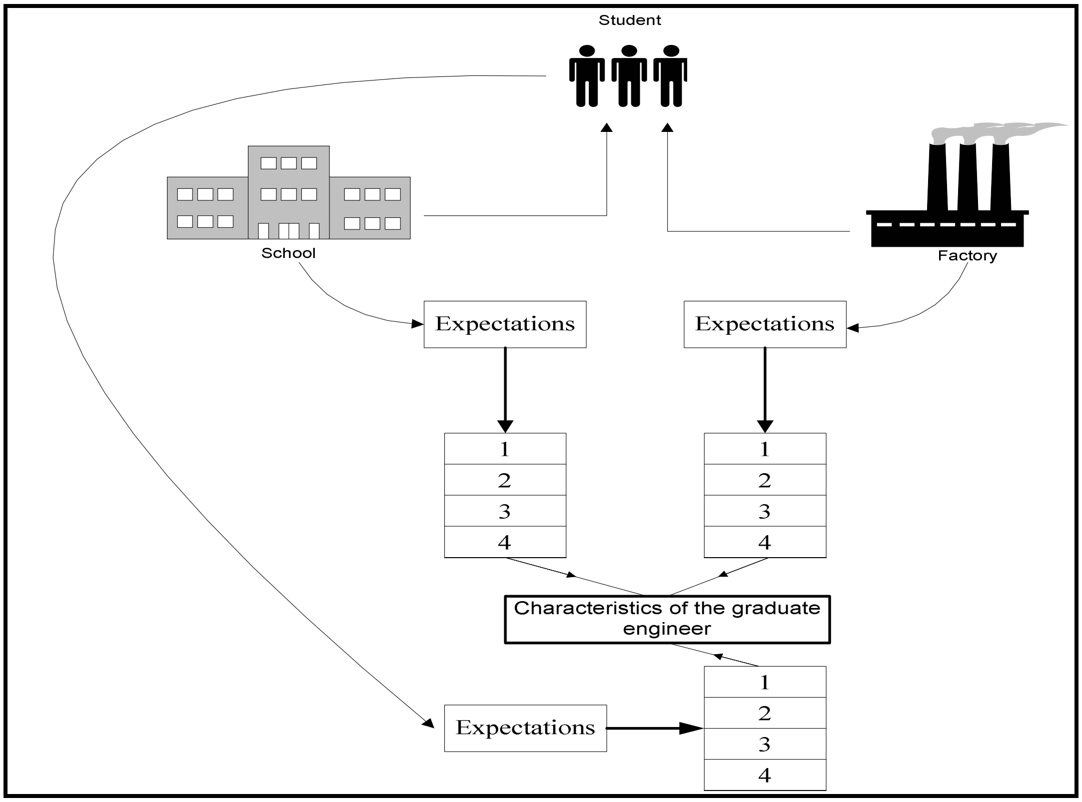

Figure 2. Model of Research Comparisons

Development of the Methodology

The purpose of the section is to develop the research methodology. Table 3 extends Table 1, "Research Plan," by including a column titled "Research Phase." The term "Research Phase" was given to: summarize; temporally sequence; classify the work accomplished in the research; and to report the interrelationship of the steps in the research plan. The "Sub-objectives" were previously stated. [19], [20], [21], [22], [23], [24]

Table 3. Research Plan: Development of the Methodology

Step	Description of the Step	Saaty Step	Research Phase	Sub-Objective
1	Develop questions about the alignment of goals between the stakeholders.	1	I	1
2	Develop a survey research plan.		I	
3	Develop requirements for academia, manufacturer, and student stakeholders.		I	1
4	Develop an AHP hierarchy.	2	I, II	

5	Develop a research instrument based upon the AHP hierarchy.		**I, II**	
6	Pretest the research instrument.		**I, II**	
7	Execute the survey research.		**III**	
8	Gather data from the survey instruments.		**III**	
9	Prepare the data for insertion into an Expert Choice© PC application.	**3, 4**	**III**	
10	Develop hypotheses about the alignment of goals between the stakeholders.		**III**	**2, 3, 4**
11	Analyze each research instrument.	**5, 6, 7**	**III**	**2, 3, 4**
12	Develop and execute statistical analyses.		**III**	**2, 3, 4**
13	Draw and state conclusions			**2, 3, 4, 5**

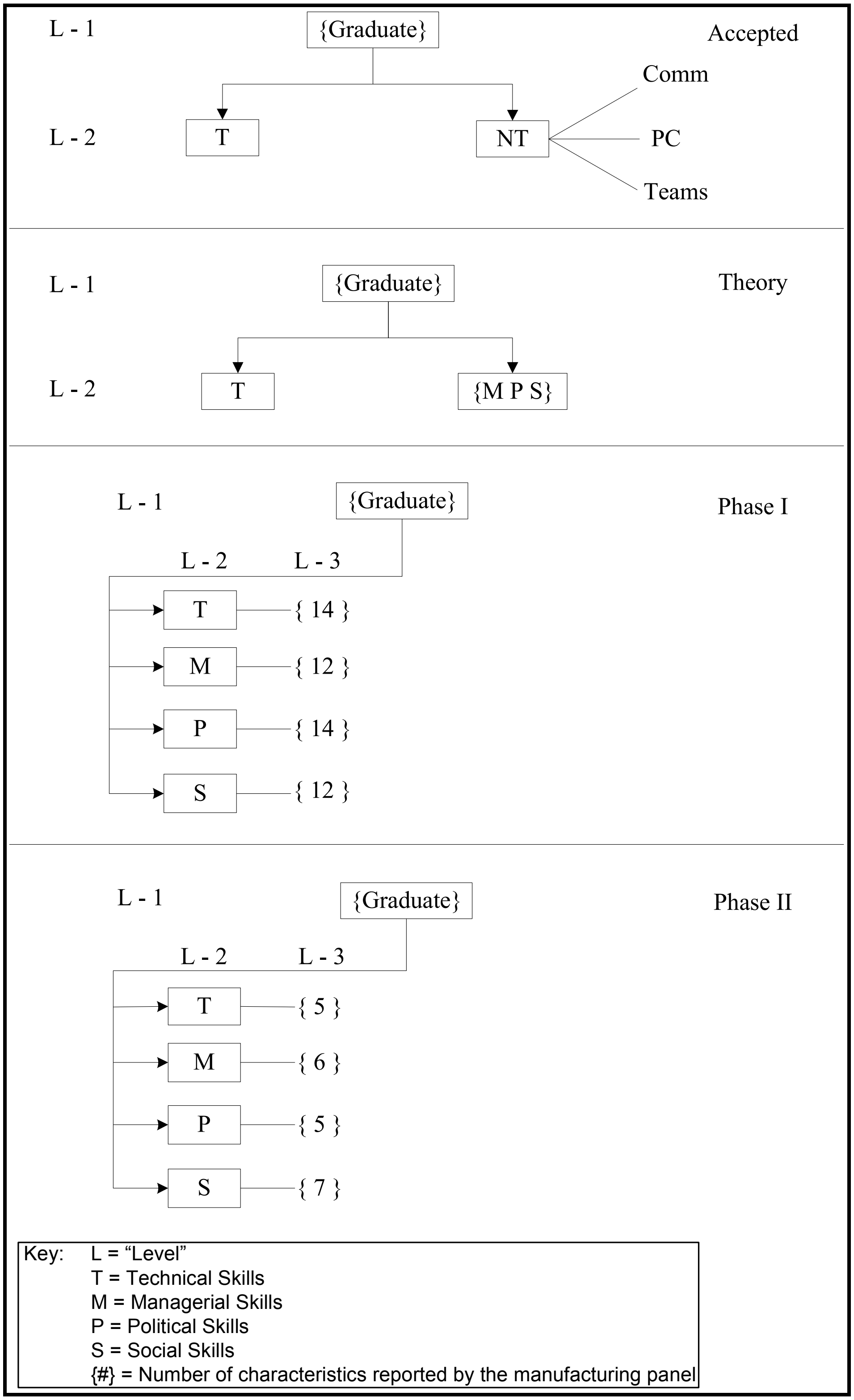

Figure 3. AHP Models: "Accepted", Theory, and Phases I and II

The Data

As previously stated, the primary data are the results of a mailed survey instrument distributed to a research frame of manufacturing respondents.

Statement of the Hypotheses

Figure 1 presented the triangular model for testing the agreement between the stakeholders on the goal *"What characteristics are expected by employers in the ideal graduate-level industrial engineer following graduation?"*

As initially stated, the NGT and Affinitization process was built to approach an answer to that goal. The surveys in Phase III tested the strength of the judgments between the respondents' samples on that goal. Figure 6 maps the sub-objectives to the triangular approach to the goal. Table 4 maps the hypotheses to the sub-objectives.

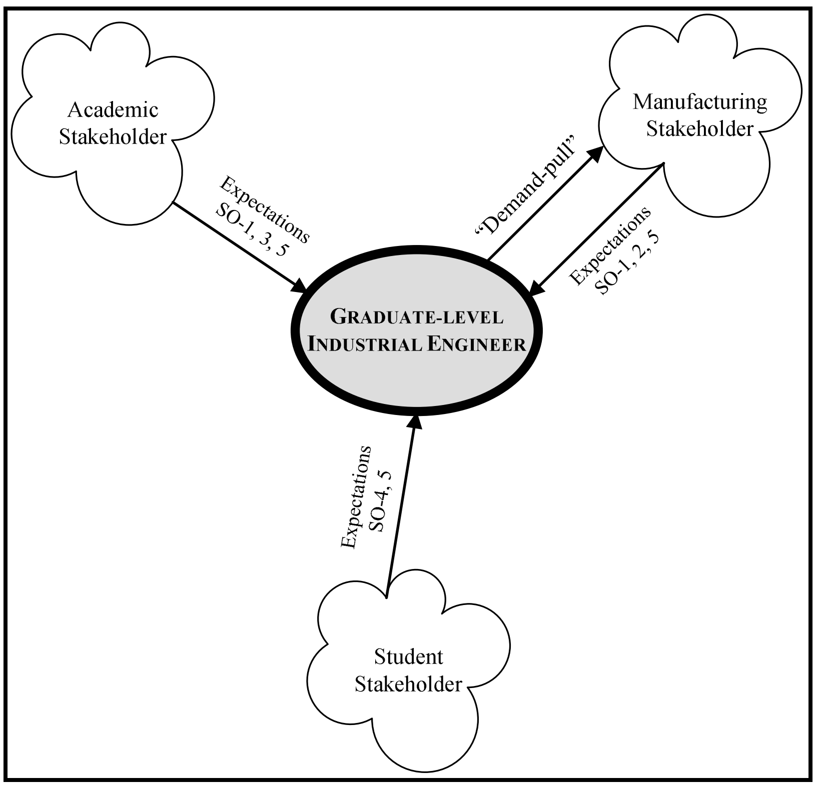

Figure 6. Triangular Perspectives of the "Stakeholder" Populations with Sub-objectives

As a result, the hypothesis is that,

There is alignment between the academia, student, and employer goals for the characteristics of the graduate-level industrial engineering candidate.

Table 4. Summary of Hypotheses

Hypothesis	Null Hypothesis	Alternative Hypothesis	Population & Characteristic tested	Sub-objectives Researched
1	H_0:	H_1:	Academic and Manufacturing judgments for characteristics -	2,3
1.1	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	T	
1.2	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	M	
1.3	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	S	
1.4	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	P	
2	H_0:	H_1:	Academic and Graduate Student judgments for characteristics -	2, 4
2.1	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	T	
2.2	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	M	
2.3	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	S	
2.4	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	P	
3	H_0	H_1:	Academic and Under Graduate Student judgments for characteristics -	2,4
3.1	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	T	
3.2	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	M	
3.3	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	S	
3.4	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	P	
4	H_0:	H_1:	Manufacturing and Graduate Student judgments for characteristics -	1,4
4.1	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	T	
4.2	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	M	
4.3	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	S	
4.4	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	P	
5	H_0:	H_1:	Manufacturing and Under Graduate Student judgments for characteristics -	1,4
5.1	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	T	
5.2	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	M	
5.3	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	S	
5.4	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	P	

6	H_0:	H_1:	Graduate Student and Under Graduate Student judgments for characteristics -	4
6.1	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	T	
6.2	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	M	
6.3	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	S	
6.4	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	P	

T = Technical; M = Managerial; S = Social; P = Political; H_0 & H_1: are the hypotheses; and μ = population mean.

Hypothesis 1.0

Null hypothesis: There is alignment between industrial engineering academic and employer goals for the characteristics of the graduate-level industrial engineering candidate

Versus

Alternate hypothesis: There is at least one misalignment between industrial engineering academic and employer goals for the characteristics of the graduate-level industrial engineering candidate.

Application Results and Analyses

The hypotheses require the analyses of the comparative judgments made by the participant populations on the following question *"[w]hat characteristics are expected by employers in the ideal graduate-level industrial engineer following graduation?"* This question motivated the responses given in Phases I and II of the research, which, in turn, structured the hierarchy of characteristics of the graduate-level industrial engineering student presenting themselves for employing stakeholder following graduation. In this research, the demand-pull characteristics were framed by a manufacturing stakeholder – the Oklahoma City Air Logistics Center and Boeing Integrated Defense Systems- St. Louis site.

Survey results

The data were extracted from completed surveys and entered into a Microsoft Excel XP© spreadsheet for insertion into the Expert Choice 2000© (EC2000) application.

Summary of the data. Table 5 reports a summary of data collected from the participant populations. They provide support for answering sub-objectives 2, 3, 4, and 5.

Table 5. Global Priorities for Respondents

	Technical	**Managerial**	**Social**	**Political**
Academic	0.450	0.170	0.150	0.090
Manufacturer	0.315	0.218	0.307	0.057
Student-G	0.241	0.221	0.187	0.087
Student-UG	0.146	0.282	0.200	0.127
Geometric Mean	**0.266**	**0.219**	**0.204**	**0.087**
Normalized G.M.	0.34	0.28	0.26	0.11

The priorities given to the goal *"[w]hat characteristics are expected by employers in the ideal graduate-level industrial engineer following graduation?"* That is, those skills meeting the requirements of selected stakeholders are shown bolded in the row marked "Geometric Mean". A normalized set of geometric means is illustrated in row following these means.

Conclusions

The survey of the sample populations presented data that departed from assumptions of normality and equal variance through statistical tests of the assumption of normality and equal variance. A familywise multiple comparisons test was selected that did not have an underlying assumption of equal variance between the sample populations. A test of the samples was then completed that revealed failure to reject the null hypotheses in two of the 24 comparisons: Academic and undergraduate student populations for the *technical* and *managerial* characteristics. Further, steps 10, 11, and 12 of the Research Plan [Tables 1, 2, 3] were completed. Finally, Phase III of the research project was completed.

Results, Conclusions and Recommendations

The methodology model (See Chapter 3) was employed. Twenty-four hypotheses were drawn (See Chapter 4) representing a family of paired comparisons between the four sample populations [academic, manufacturing, graduate student, and undergraduate student] and the four characteristics: the *technical, managerial, social,* and *political.* The hypotheses were tested using the Games-Howell methodology with reported data illustrated in Table 6, "Games-Howell Test Results," and Table 7, "Summary of Hypotheses." These tables summarize the statistical analyses previously detailed. [25]

The research could not find significant evidence to refute the hypotheses of no difference for the academic, manufacturing, and student populations between the *technical, managerial, social,* and *political* characteristics, except in two cases: the academic/*technical* and undergraduate student/*technical* and the academic/*managerial* and undergraduate student/*managerial.* It is unclear why there may be a difference in only two comparisons, given the lack of statistical significance for the other twenty-two comparisons, but this may be an area for future research.

It is, then, concluded that the manufacturing, academic and student sample populations are approximately coincident in their qualitative assessment of the needs for graduate-level industrial engineers.

The sub-objectives of the research are given in Tables 6.1, 6.2, 6.3 and 6.4. Table 6.3 uses the global weights to find a global geometric mean for all populations. Table 9 has the data in Table 8 normalized for a proportionate perspective.

Sub-objective 2. *Determine the priorities for skills and knowledge required in selected manufacturing companies by applying selected consensus-gathering and comparative weighting schemes.*

These priorities are given in Tables 8 and 9 in the row, "Manufacturer".

Sub-objective 3. *Determine the priorities for skills and knowledge required in selected industrial engineering departments in higher education by applying selected comparative weighting schemes.*

These priorities are given in Tables 8 and 9 in the rows, "Student-G" and "Student-UG" for graduate and undergraduate, respectively.

Sub-objective 4. *Determine the priorities for skills and knowledge required in senior and graduate-level industrial engineering students by applying selected comparative weighting schemes.*

These priorities are given in Tables 8 and 9 in the row, "Academic"

Sub-objective 5. *Measure the significance of the alignment of the research stakeholders [academicians, manufacturers, and students (graduate and undergraduate/senior-level)] through an AHP analysis and a statistical comparison of their individual priorities.*

This objective is answered below in Tables 6 and 7.

Generally, it can be said that this research found statistical similarity for the characteristics weighted by the participants and that the proportion of weight given to the characteristics of *technical, managerial, social,* and *political* in a graduate-level industrial engineer are as follows:

Normalized G.M.:	Technical = 0.340;	Managerial = 0.284;	Social = 0.264;	and Political = 0.112

Table 6. Games-Howell Test Results

	Error d.f.	t-Stat	Games-Howell $\lvert t_{jk} \rvert$		Alpha 0.05	Alpha 0.01		Significant	
At Mt	22	1.885211	2.666091		3.96	5.02			
At Gt	24	1.560074	2.206278		3.90	4.91			
At Ut	21	-3.825496	-5.410068		3.96	5.02		**	0.01
Mt Ut	21	2.212702	3.129234		3.96	5.02			
Mt Gt	29	0.036648	0.051827		3.90	4.91			
Gt Ut	26	-1.969894	-2.785850		3.90	4.91			
Am Mm	22	-2.240878	-3.169080		3.96	5.02			
Am Gm	25	-2.438823	-3.449017		3.90	4.91			
Am Um	14	2.994627	4.235042		4.11	5.32		*	0.05
Mm Um	17	-1.308252	-1.850148		4.02	5.14			
Mm Gm	28	-0.669800	-0.947240		3.90	4.91			
Gm Um	24	0.592683	0.838181		3.90	4.91			
As Ms	23	-1.579499	-2.233749		3.96	5.02			
As Gs	19	0.501912	0.709810		3.98	5.05			
As Us	20	0.423122	0.598384		3.96	5.02			
Ms Us	20	0.975968	1.380227		3.96	5.02			
Ms Gs	18	2.666130	3.770477		4.00	5.09			
Gs Us	15	0.917341	1.297316		4.08	5.25			
Ap Mp	18	1.324346	1.872908		4.00	5.09			
Ap Gp	27	-0.719691	-1.017797		3.90	4.91			
Ap Up	13	1.446708	2.045954		4.11	5.40			
Mp Up	11	-2.095353	-2.963276		4.26	5.62			
Mp Gp	22	-1.773750	-2.508462		3.96	5.02			

Gp Up	17	0.913700	1.292166		4.02	5.14			

Key:
Population: A=Academic; M=Manufacturer; G=Graduate Student; and U=Undergraduate Student

Characteristic t=technical; m=managerial; social; and p=political

Table 7. Summary of Hypotheses

Hypothesis	**Null Hypothesis**	**Alternative Hypothesis**	**Population & Characteristic tested**	**Significant**
1	H_0:	H_1:	Academic and Manufacturing judgments for characteristics -	
1.1	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	T	
1.2	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	M	
1.3	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	S	
1.4	$\mu_A = \mu_M$	$\mu_A \neq \mu_M$	P	
2	H_0:	H_1:	Academic and Graduate Student judgments for characteristics -	
2.1	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	T	
2.2	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	M	
2.3	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	S	
2.4	$\mu_A = \mu_G$	$\mu_A \neq \mu_G$	P	
3	H_0	H_1:	Academic and Under Graduate Student judgments for characteristics -	
3.1	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	T	** (0.01)
3.2	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	M	* (0.05)
3.3	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	S	
3.4	$\mu_A = \mu_{UG}$	$\mu_A \neq \mu_{UG}$	P	
4	H_0:	H_1:	Manufacturing and Graduate Student judgments for characteristics -	
4.1	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	T	

4.2	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	M	
4.3	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	S	
4.4	$\mu_M = \mu_G$	$\mu_M \neq \mu_G$	P	
5	H_0:	H_1:	Manufacturing and Under Graduate Student judgments for characteristics -	
5.1	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	T	
5.2	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	M	
5.3	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	S	
5.4	$\mu_M = \mu_{UG}$	$\mu_M \neq \mu_{UG}$	P	
6	H_0:	H_1:	Graduate Student and Under Graduate Student judgments for characteristics -	
6.1	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	T	
6.2	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	M	
6.3	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	S	
6.4	$\mu_G = \mu_{UG}$	$\mu_G \neq \mu_{UG}$	P	

T = Technical; M = Managerial; S = Social; P = Political; H_0 & H_1: are the hypotheses; and μ = population mean.

Table 8. Global Priorities for Respondents: Non-normalized

	Technical	Managerial	Social	Political
Academic	0.432	0.170	0.150	0.090
Manufacturer	0.315	0.218	0.307	0.057
Student-G	0.241	0.221	0.187	0.087
Student-UG	0.146	0.282	0.200	0.127
Geometric Mean	0.263	0.219	0.204	0.087
Normalized G.M.	0.340	0.284	0.264	0.112

Table 9. Global Priorities for Respondents: Normalized

	Technical	Manageri al	Social	Political	Σ
Academic	0.513	0.202	0.178	0.107	1.00
Manufacturer	0.351	0.243	0.342	0.064	1.00
Student-G	0.328	0.300	0.254	0.119	1.00
Student-UG	0.193	0.374	0.265	0.168	1.00
Geometric Mean	0.327	0.272	0.253	0.108	
Normalized G.M.	0.340	0.284	0.264	0.112	1.00

The absence of a larger set of rejected null hypotheses is a concern. Primarily, this concern is based upon papers published by Wulf (1998), Galvin (1996), and Smerdon (1996) and a speech delivered by Feisel (1999) that, collectively, call for stronger ties between engineering colleges and the consuming stakeholders for a wide range of issues resulting from several contributing factors: globalization; changing patterns of employment; restructuring of the practice of engineering; new engineering methods; and new kinds of employers. [26], [27], [28], [29] Feisel stated that these factors, at a minimum, "…have a direct impact on how engineering is structured and delivered." [30] While none of the contributing factors were explicitly surveyed as part of the data collected in the research instrument, it is the author's opinion from the project's literature research and the demographic analysis of the manufacturers that these contributing factors are evident in the manufacturing population surveyed. Therefore, differences between the sample populations would have been expected.

Several conclusions are possible. The results may be biased by the respondent's ability to read and comprehend the survey. Also, definitions for all terms were given in the survey. Further, one of the academic expert panel members involved in pre-testing the survey was foreign-born and had no comments regarding the readability of the instrument. Another conclusion is that there is, in fact, a no significant difference between the survey populations and that the null hypotheses cannot be rejected of no differences between the characteristics of *technical, managerial, social,* and *political* in a graduate-level industrial engineer. As previously stated, this is an area for additional research.

Recommendations

The implications for future research in this area are very intriguing. This research only begins to explore the demands of stakeholders for the characteristics of the graduate-level candidates they seek from the engineering schools of higher education.

The survey instrument can be reviewed and refined with additional expert engineering academic and manufacturing panels and the research model rerun in a variety of commercial and government-based product producing industries. Further, the process may be rerun in the service sector utilizing expert panels from that stakeholder community. Comparisons between the product and service producer, between the government and commercial product manufacturer and between engineering students from additional disciplines would be very interesting from the perspective of the proportion of weight given to the technical and non-technical components of the graduate-student's higher educational program.

Another area of research is to increase the number and type [product and service producing] of demand-pull stakeholders to the triangular model used (See Figures 1 and 6).

Further, the research has applicability in those areas of higher education more traditionally taught in the colleges of business. For example, the production and operations management and decision sciences disciplines have technical and non-technical components in graduate-level degree programs. It would appear that their graduates would have skills sets comprised of technical and non-technical requirements sought by their discipline's various stakeholders and that given accreditation issues with advisory board inputs would collectively suggest a need for a better understanding of their stakeholders needs as well.

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Biographical Information

David Hartmann received his doctorate in Industrial Engineering and Management from Oklahoma State University in 2004. Prior to joining the OU adjunct faculty, he was an adjunct faculty member at Hampton University and Rose State College. Currently, he is an assistant professor on the faculty of the University of Central Oklahoma. Dr. Hartmann received his Bachelor of Science degree in 1969 from the United States Air Force Academy. In 1976, he earned the Master of Science degree in Logistics Management at the Air Force Institute of Technology. He earned the Masters in Business Administration from The College of William and Mary in 1987. Dr. Hartmann served in the United States Air Force in a variety of operational and logistics assignments from 1969 until retirement in 1990 at the rank of Lieutenant Colonel. His operational assignments included service throughout Southeast Asia from 1971-73, Canada, Iceland, England, Japan, Germany, Egypt, and Saudi Arabia from 1979 to 1985. His logistics assignments included program management of airborne communications for command and control of strategic aircraft assets. Dr. Hartmann was also a foreign military sales officer for tactical command and control aircraft. Following a military career, in 1990, he joined the Gaylord Container Corporation as a Quality Process Manager. In 1996, he was selected as the first department chair at Saint Gregory's University, where he served on the self-study team that lead to the school receiving its first NCA accreditation as a bachelor's degree-granting institution. He is a USAF Command Pilot with over 3,000 flying hours in the T-41A/C, T-37, T-38, KC-135A, C-135E, EC-135, and the E-3A/B/C.