Title: Motivation of Engineers: Work Experience and its Effect on Motivational Factors

Course:
Year: 1992
Author(s): S. Blaine, K. Eden, D. Foote, J. Goulding, E. Kangas and A. Sandoval

Report No: P92038

Abstract: We studied the internal and external motivators affecting engineers. We did a ranking of the most important motivational factors and a comparison between groups of student engineers and experienced engineers. No statistically significant differences were found in how the two groups ranked the factors. Individuals, however, did differ dramatically in what motivated them. The importance of understanding these subtle differences - particularly for supervisors who motivate them -- is stressed.

Motivation of Engineers Work Experience and its Effect on Motivational Factors

Steve Blaine, Karen Eden, David Foote, John Goulding, Eric Kangas, Al Sandoval

EMP-P9238

Executive Summary

A study was made of the internal and external motivators affecting engineers. A ranking was found for the most important motivational factors and a comparison was made between a group of student engineers and a group of experienced engineers. No statistically significant differences were found in how the two groups ranked the factors. Individuals, however did differ dramatically in what motivated them. The importance of understanding these subtle differences -- particularly for supervisors who motivate them -- is thus stressed.

The intent of our study was to understand what makes engineers work effectively towards organizational missions, objectives, and goals. General motivational theories were reviewed along with more recent literature specifically addressing the motivation of technical personnel. Various theories identified generalized motivational factors; recent papers identified more specific factors. For the purposes of our study, the major factors were grouped into 11 inclusive categories, and a conceptual model was defined. A survey was developed and administered to compare and rank the relative importance of these factors for the two groups of student and experienced engineers. The pair wise comparison method was then used to compare these factors. The 11 factors and the pair-wise comparison results are tabulated below. Both groups chose the same top five factors. The Kendall's Tau test was performed; both groups rankings were similar. Therefore, no statistically significant changes appear to occur in motivational factors as experience grows for (groups of) engineers. Correlations were found between certain pairs of factors.

Experienced Engineers (motivational factors)	Factor Weighting	Student Engineers (motivational factors)	Factor Weighting
Growth	.113	Compensation	.112
Achievement	.108	Achievement	.112
Challenge	.101	Growth	.107
Job Security	.099	Challenge	.096
Compensation	.098	Job Security	.091
Management	.094	Recognition	.090
Recognition	.089	Environment	.085
Location	.085	Management	.081
Relations	.075	Location	.077
Authority	.074	Relations	.077
Environment	.065	Authority	.072

This survey or a similar assessment would be a very useful tool in evaluating motivational factors for the individual engineer and for effectively utilizing the engineering manager's ability to motivate the individual engineer. Knowledge of an individual's motivational factors to provide for a manager-to-engineer communications feedback is the first step in effectively (optimally) motivating an engineer. Performing such a survey is thus a clear recommendation towards understanding the motivational requirements of engineers.

Table of Contents

Motivation of Engineers:
Work Experience and its Effect on Motivational Factors

I. Introduction

Motivation is the internal or external drive that directs an individual's behavior towards satisfying some end goal. Motivation of engineers takes on a dual perspective: 1) what motivates the engineer as an individual, and 2) what can be done by management to motivate the engineer to perform in a manner that is most beneficial to the objectives of the organization? Clearly, a highly motivated engineer working on something that is of no value to the organization is of similar value as an engineer who is of marginal or limited ability.

The purpose of this project is to gain a better understanding of the motivational factors that engineers feel are most important. Based on a literature review, eleven motivational factors were identified and defined. These eleven factors were incorporated into a motivational survey. Student and professional groups of engineers made weighted preferences between the factors. A comparison was made between the two groups to determine if motivation changed with experience. Finally, recommendations for the motivation of engineers were established and the need for future work was proposed.

II. Review of Literature

Many studies have been done on the motivation of engineers and related technical people. Most of this research surveys engineers and technical people to rate which motivation factors are important [2], [3], [17], [21], [29], [49], rather than asking the respondents to discriminate between motivational factors. The factors in the literature vary, and in some cases the respondents were asked to list their own needs [29], [49]. Such rankings of motivational factors for various engineering groups have produced conflicting results. Probably, this difference is due to different methods of study, different populations, and different methods of analysis.

For engineers, the highest noted motivational factors are challenging work [2], [3], [29], [49] and achievement [17], [21]. Bogarty states that the psychological profiles and needs of engineers,

given the proper environment is present, embody self-motivation [8]. Notwithstanding, salary and monetary compensation is of key interest to motivating engineers. For technical people, the fairness of salary in relation to co-workers and merit-based raises are suggested to be more important issues than the monetary reward itself [8].

A. Motivation Theories

Motivation is intrinsically an emotional response or process. Significant effort to determine what drives or stimulates a person to action in the work place is recorded in the literature; consequently, there are numerous theories on human needs and motivation. For this motivation of engineers study, briefly reviewing some of these recognized theories will provide background and an appreciation for the complexity and diversity of human needs and their influence on motivation.

Social scientists and researchers have long attempted to define human needs and behavior characteristics in theories and models. Classically, theories have been grouped into three sets: 1) content theories, 2) process theories, and 3) behavior modification concepts. Content theories describe what elements or needs motivate human behavior. Process theories attempt to model motivation and behavior as a systemic process. Behavior modification is a learned response to external stimuli.

Content Theories. Maslow [33] developed a system for classifying human needs in a hierarchy by order of importance. In it, the needs of each underlying level must be considered fulfilled before the next level is a factor. Maslow makes an important distinction between the motivators (one class of determinants) and other biological, cultural and situational determinants of human behavior. McClelland [35] and his colleagues have identified three drives that influence an individual's behavior: 1) the need for achievement or pride in accomplishment, 2) the need for affiliation or belonging, and 3) the need for power or influence. Nash [39] draws upon McClelland's work to state that the need for achievement is the pre-eminent motivator. The achievement motivator is said to produce more goods and services for society as a whole than any other motive. McGregor [37] identifies certain assumptions managers make about workers in Theory Y and Theory X. Theory Y states that people like to work, are interested in their work, and accept responsibility.

Theory X, states that people are basically lazy and require a great deal of control and supervision to work. The two-factor or motivation-hygiene theory introduced by Herzberg et. al. [22] suggests two separate sets of factors that influence the attitudes and behaviors of workers. Factors that lead to high levels of job satisfaction and goal-oriented behavior and give the employee intrinsic satisfaction are identified as motivators. These motivators include achievement, recognition, work itself, responsibility and advancement. Factors that prevent job dissatisfaction and relate to the situation in which the worker performs the job are identified as hygiene factors. These hygiene factors include supervision, salary, interpersonal relations, working conditions, and company policies. Hygiene factors are generated externally and must be replenished; so, they affect the short term behavior of the employee. Long-term behavioral changes are internal to the worker and thus require the use of motivators.

Process Theories. Festinger [15] provides the theory of cognitive dissonance. An individual experiences cognitive dissonance when he or she learns or knows something about the organization that is in conflict with his or her value system. People will avoid situations that increase dissonance and thus take positive actions to reduce dissonance. Such employee attitudes and values can have significant impacts on the way they work. A theory of social inequity was developed by Adams [1]. Adams theorizes that inequity exists when one individual is not rewarded the same as another for the same perceived level of contribution. Employees will then attempt to balance the ratio of rewards to contributions by either requesting more appropriate rewards or reducing the amount of work and contributions. Expectancy theory was introduced by Vroom [50], who theorizes that individuals define their own behaviors or courses of action based on the expected outcome or results of their actions within their environment. Locke [31] proposed that most employee behavior is consciously goal oriented. This goal-achievement model states that people work to achieve goals they recognize as desirable and important. Highly motivated individuals perform best when goal-difficulty increases and when goals are specific and accepted by the worker.

Behavior Modification Concepts. Luthans and Kreitner [32] take a learning approach to modifying employee work place behavior. Their work is based on the operant behavior theory of B. F. Skinner. In this theory, behavior is dependent on consequences and on the environment which

changes and constrains behavioral-actions. In operant behavior, environmental limits, desired specific employee behaviors, and consequences of those behaviors are identified and a determination is made as to which consequences reinforce the desired behavior. Four reinforcement approaches are used to encourage and achieve desired behavior: 1) positive reinforcement, 2) punishment, 3) negative reinforcement, and 4) extinction.

B. Motivation Factors

It is apparent from the literature that the majority of motivational theories utilize "motivational factors" as causes of worker actions. From the literature study, 25 prominent factors emerged. The team-based affinity diagram method, also called KJ diagrams, was used to organize these motivational factors into eleven groups. Figure 1 illustrates the affinity process. These eleven groups thus constitute the engineering motivation paradigm. To better develop a paradigm which reflects today's worker, it is necessary to survey the worker often. Such a survey reflects the theories presented in the literature, and it acts as a rating device to re-define the importance of motivational components. Once grouped, the results of the survey reflect today's understanding of motivation as viewed under the classical theories.

C. Problem Statement

The affinity diagram (Figure 1) was again utilized to clarify the nature of this study. By studying the relationship between the motivational factor groups, expectations of survey results, available participants, and analysis techniques. The following problem statement was developed:

> We intend to review motivational theories presented in the literature and develop a survey questionnaire to probe the differences in motivation factors between junior and experienced engineers. The survey will use statistics and the Pair-wise Comparison Method (PCM) of analysis to rank various major motivational factors. Pertinent ideas generated form the literature will be critically evaluated against the survey results, and a summary of recommendations will be written. Our project should provide guidelines useful to practicing engineering managers.

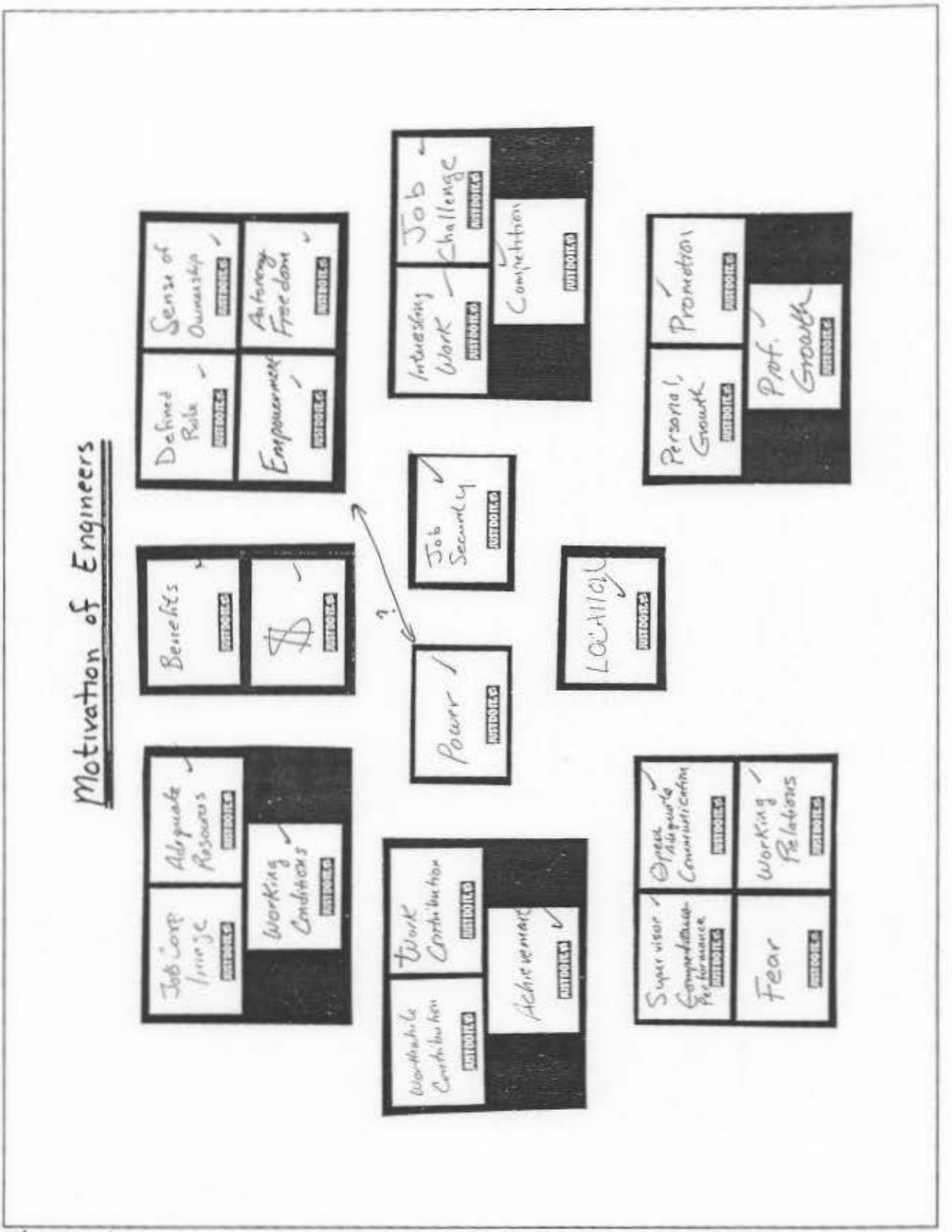

Motivation of Engineers
Defined Role
Sense of Ownership
Empowerment
Autonomy Freedom
Benefits
$
Job Security
Power
Location
Interesting Work
Job Challenge
Competition
Personal Growth
Promotion
Prof. Growth
Job Comp Issue
Adequate Resources
Working Conditions
Work Contribution
Worthwhile Contribution
Achievement
Super visor Competence Performance
Open Adequate Communication
Working Relations
Fear

Figure 1

III. Survey Methodology

One accepted method of gathering information on the relative weight of various engineering motivational factors from individuals is the pair-wise comparison survey. This pair-wise method requires a questionnaire in which respondents weight the relative importance of motivational factors by comparing them two at a time, hence the name pair-wise. A copy of the "Work Motivational Survey" used in this study is presented in Appendix A, for reference.

Three steps were needed to develop the "Work Motivational Survey." First, the overall problem statement was developed to define the objectives, to plan the survey actions, and to determine the participants of the survey. The literature was discussed and a conceptual model was defined for the questionnaire. Finally, the survey was administered.

A. Conceptual Model

The cause & effect diagram of Figure 2 was developed from the affinity diagram (Figure 1) using the group process. In it, the eleven groups, representing the 25 motivational factors, define the primary external inputs, or causes, that influence the worker. These primary motivational factors consciously and subconsciously form the basis of (or internally map the inputs to) a motivation-state or effect. Note that the eleven factors were intentionally small in number because the number of questions increases geometrically as the number of pair-wise comparisons increases, i.e., the user's time is recognized.

The cause & effect diagram thus represents a "black-box model" of a worker, and is illustrated in Figure 3 wherein the eleven factors form the input to the worker and the state is the output. A feedback loop is also illustrated; feedback is the externally applied dynamic response to modify the input to achieve the desired motivational state. The goal of the survey is to understand the worker's conscious and subconscious internal mapping of motivation so the correct feedback may be identified and applied. Using the survey method, workers will rate the motivational factors using the pair-wise comparison method. The motivational factors are:

Motivational Factor #1: Achievement. Achievement is pride and sense of accomplishment in one's work. Communication is an essential component of achievement [13]. "Desire for achievement"

Figure 2

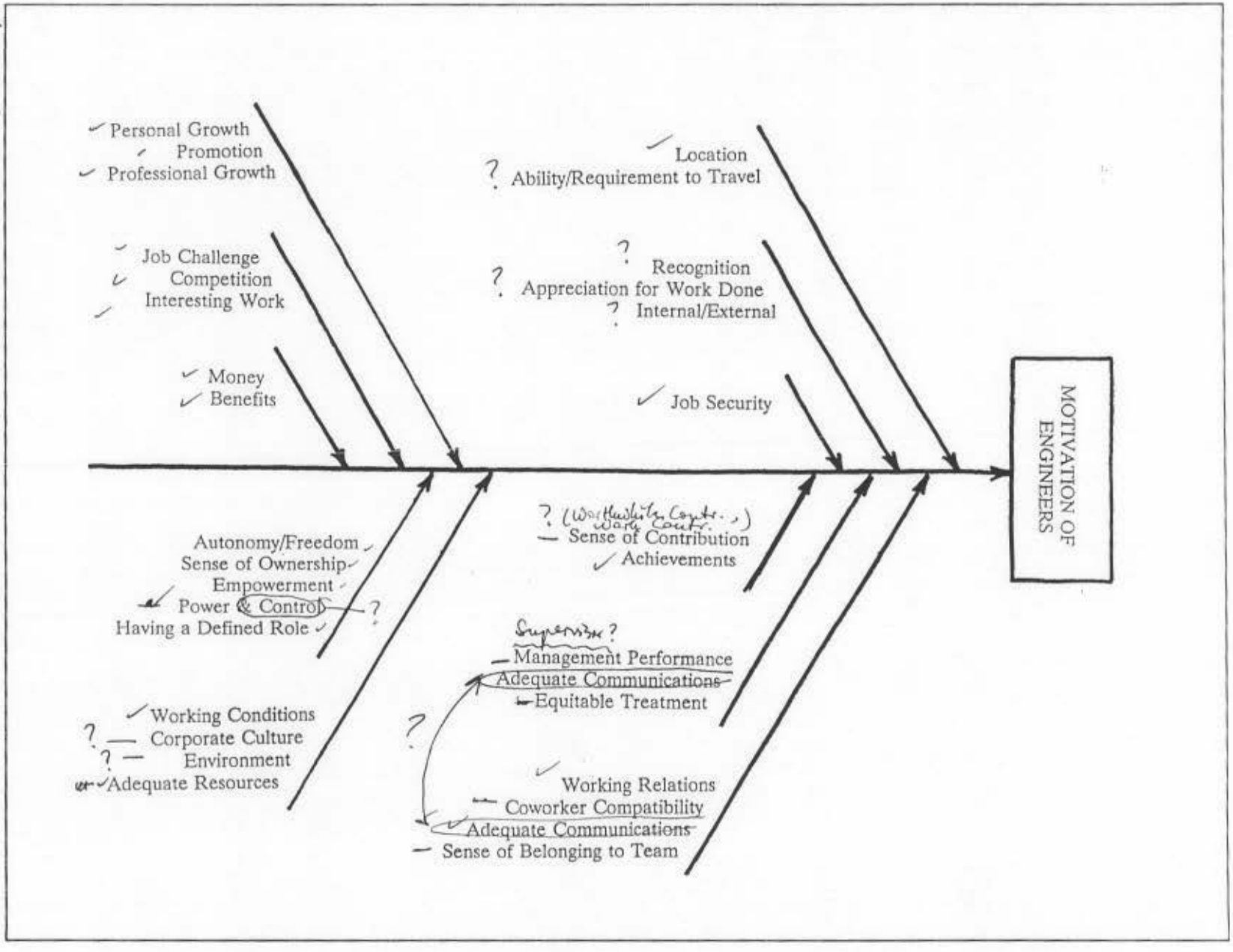
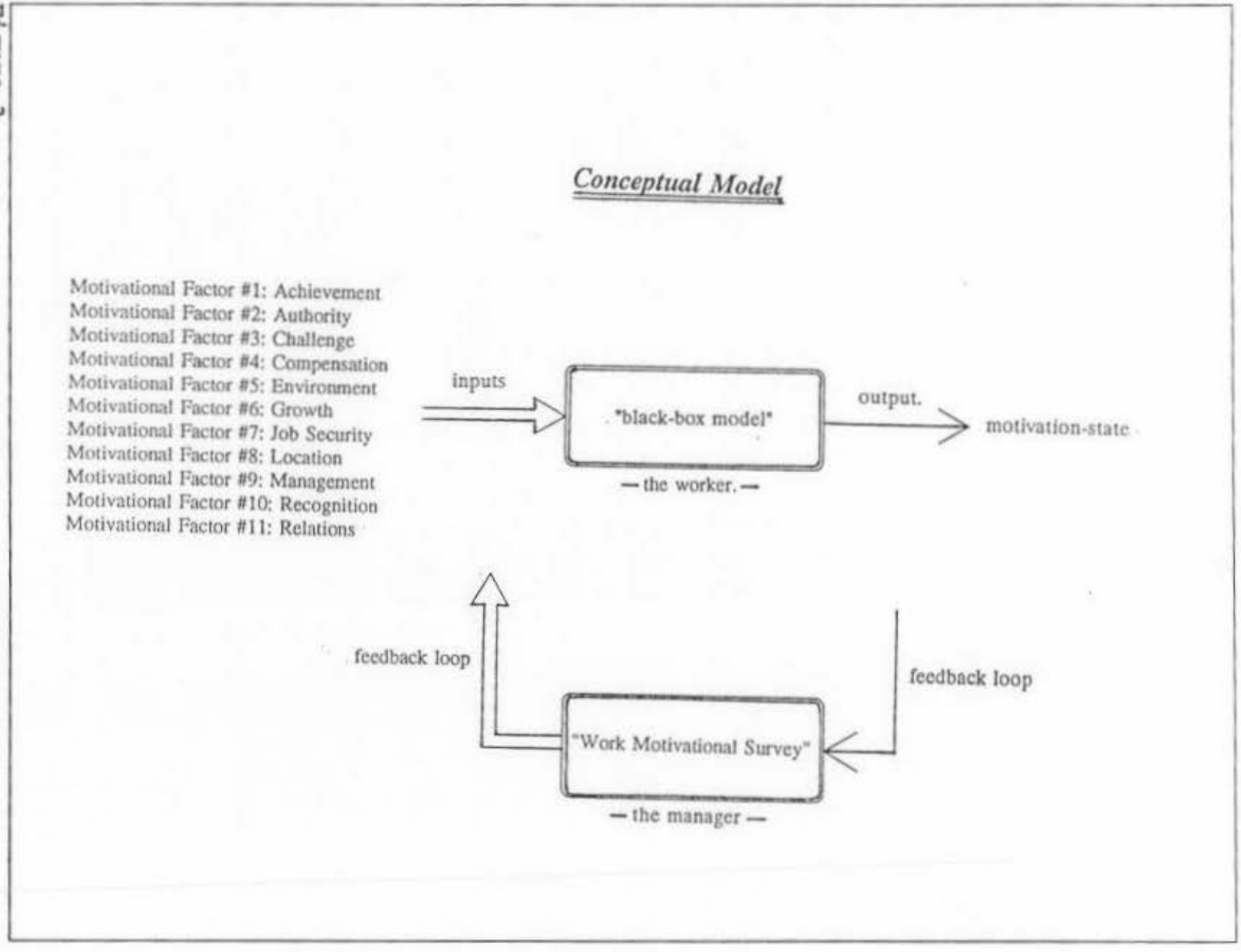

Personal Growth
Promotion
Professional Growth
Job Challenge
Competition
Interesting Work
Money
Benefits
Location
Ability/Requirement to Travel
Recognition
Appreciation for Work Done
Internal/External
Job Security
MOTIVATION OF ENGINEERS
Autonomy/Freedom
Sense of Ownership
Empowerment
Power & Control
Having a Defined Role
Working Conditions
Corporate Culture
Environment
Adequate Resources
Sense of Contribution
Achievements
Management Performance
Adequate Communications
Equitable Treatment
Working Relations
Coworker Compatibility
Adequate Communications
Sense of Belonging to Team

Figure 3


Conceptual Model
Motivational Factor #1: Achievement
Motivational Factor #2: Authority
Motivational Factor #3: Challenge
Motivational Factor #4: Compensation
Motivational Factor #5: Environment
Motivational Factor #6: Growth
Motivational Factor #7: Job Security
Motivational Factor #8: Location
Motivational Factor #9: Management
Motivational Factor #10: Recognition
Motivational Factor #11: Relations
inputs
"black-box model"
output.
motivation-state
— the worker. —
feedback loop
feedback loop
"Work Motivational Survey"
— the manager —

is ranked near the top in nearly all studies of technical personnel's motivational factors. As Maslow stated in his theory of self-actualization: "what I can be, I must be." Consequently, the need for understanding this factor is important not only in motivating people to do good work, but to work at a high level of output. Achievement can only follow after competence is gained and curiosity and persistence achieve worthwhile pursuits. McClelland argues that this need is learned early in childhood [35]. Andrew Grove argues for keeping the need for achievement constantly unmet by setting objectives and goals that are just out of reach [18].

Motivational Factor #2: Authority. Authority is the extent of power, influence, control, and freedom an employee has in his or her work and with others in the work place. The scope of influence and control can include the range from an individual's specific task to operation of an entire organization. Empowerment is the act of delegating specific authority to employees and allowing them to have control over the task within defined roles and boundaries. The employee in turn accepts responsibility for the task results.

Motivational Factor #3: Challenge. Challenge is described as the act of performing stimulating and meaningful work under "creative tension" or intensive work efforts [30]. Work challenge early in an engineer's career positively affects future job performance [25]. Challenging work is often linked to a high performance supervisor who gives employees stimulating and meaningful projects to complete [25]. These projects typically involve innovation to solve problems, creative thought, intelligence, and technical knowledge [30].

Motivational Factor #4: Compensation. Compensation is pay and benefits earned through work. Monetary compensation includes salary, increases, and bonuses. Benefits include direct value employee advantages such as personal insurance, paid time off, and retirement plans.

Motivational Factor #5: Environment. Environment is the climate, culture, and physical make-up of the work-place. Resource sharing, adequately meeting the needs of two or more groups, is common in today's lean and aggressive organizational environment [51]. In fact, resources have long been recognized as sources of power [19]; note the old saying, "he who has the gold makes the rules." All too often, resources are used coercively, and the formal rules and regulations, centralization, and

the rigid hierarchy which dominate many companies corporate culture stifles the innovative engineer who seeks the more open organic organization [10]. In the extreme, external adaptation to and internal expectations and integrations of Taylorism -- Frederick W. Taylor's scientific management theory -- bound the creative engineer within the framework of past actions, biases, and habits; thus, limiting resources to those of past experience [52], e.g., resistance to automation.

Motivational Factor #6: Growth. Growth is the opportunity to advance to personal and professional potentials. By Maslow's theories, workers constantly seek to fulfill ego and self-fulfillment needs [46]. Most technical people seek growth in either external advancement or internal project-oriented work [2]; such success might include presentation and publication of innovative research papers within the community. Furthermore, engineers are often motivated by corporate benchmarks. Promotion to a management position or the opportunity to plan, organize, and control projects meet such benchmarks [2].

Motivational Factor #7: Job Security. Job security relates to one's stability of employment. Job insecurity is associated with declines in commitment and trust. In Herzberg's 2-Factor Theory of Motivation, job security is considered a de-motivator. New insights through recent studies indicate not only the loss of a specific activity and income, but also of identity which is the threat of loss of self-worth [28]. Even perceived lack of predictability and control may induce perceptions of job security [4]. Such threats may have deleterious effects on health [28].

Motivational Factor #8: Location. Location is the physical and geographical location of the work place. It is estimated that engineers will change jobs every five years and change locations every eight years [8].

Motivational Factor #9: Management. Management is the outward performance and treatment of workers. Accurate management feedback is regarded as critical to effective performance [6]. A lack of response by management can indicate a negation of personal worth [53]. The level of openness in supervisor-subordinate communications is positively related to worker satisfaction with the company, job, and the performance appraisal [40]. Lack of productivity feedback can increase role ambiguity as well as worker motivation and job satisfaction; simple extrinsic feedback to exchange

information is an effective form of work place feedback and may achieve marginal increases in productivity [42]. Formal reviews influence important organizational outcomes such as performance and satisfaction.

Motivational Factor #10: Recognition. Recognition is the act of realizing and rewarding by peers, managers, or outside competitors through acts such as awards and bonuses, or through means such as praise and congratulations. Recognition may be either earned or unearned [46]. Unearned recognition, which should not be thought of as a substitute for earned recognition, plays an essential role as a motivational maintenance factor. This type of recognition takes the form of friendliness, reassurance, small talk, and personal interest, and satisfies security, status, and social needs. Badaway states that engineers are particularly sensitive to what they regard as unfairness and they resent rewards based on any other basis but recognizable professional achievement [5]. Ingram feels recognition must be equal and fair, and all staff must know and understand the criteria for special recognition [24]. As a general rule, the organizational climate needs to recognize and reward those who perform well regarding their personal development [47]. Recognition of achievement is a crucial part to keeping any organization motivated and working towards a common goal.

Motivational Factor #11: Relations. Relations is teamwork, compatibility, and interpersonal interactions with co-workers. Job feelings are crucial to our job experience, and the people with whom we work with are key contributors [27]. We recognize the error of Max Weber's bureaucratic rational of *dehumanization* for efficiency, and embrace sensitivity training and democratic leaders [52]. Indeed, the 1930's structured "personnel counseling" -- in Roethlisberger and Dickson's *Management and the Worker* interpretation of the Hawthorn experiments -- has shifted to coworker compatibility in the empowered age of the 1990's [45]. To this end, the increased use of teams and the awareness of group dynamics is being factored in as a major contributor to job satisfaction [44]. One can only expect the increased use of concurrent engineering and "corporate right-sizing" to increase the friction amongst incompatible workers. In the extreme, machiavellianism and political behavior can work against even the most empathetic non-partisan engineer; so, quitting ones job becomes welcomed [12].

B. Data Gathering

Appendix B contains the "Work Motivational Survey." This survey was distributed to two groups of workers. The first group of engineers was composed of 37 senior mechanical engineering students and 6 graduate engineering students at Portland State University. Of the 37 surveys handed out to the seniors, only 19 were returned. The second group of professional engineers and scientists was composed of 38 engineering management students at Portland State University and 8 other persons from Nike Corporation and Precision Castparts Corporation. The demographics of the engineers reveal an average of 10.5 years of experience and represented auto, footwear, electronics, public utilities, power generation, heavy manufacturing, and semiconductor industries.

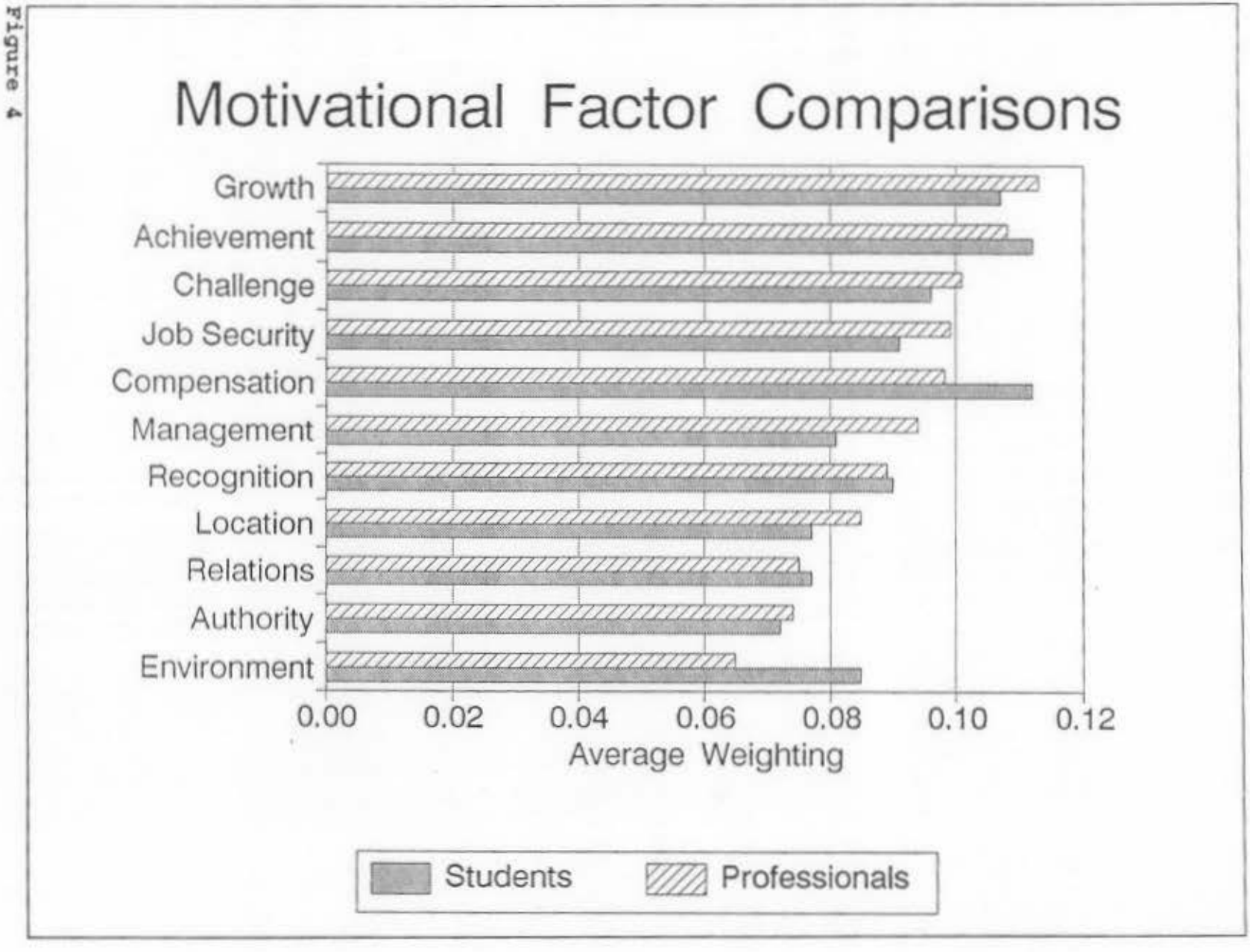
IV. Data Analysis

Individual responses from the motivational survey were evaluated using the pair-wise comparison method (PCM) of analysis. To further reduce the respondent's answer time, the factors were divided into two groups; each group of questions were then factored together using *compensation* as the common weighting factor. Figure 4 graphically details the results of the pair-wise comparison study. Kendall's Tau method was used to evaluate the statistical significance of the rankings for the two groups. This analysis shows that there was an association in professional and student rankings, i.e., the two groups statistically ranked the factors similarly.

A. Pair-wise Comparison

Each respondent performed thirty pair-wise comparisons of the eleven motivational factors. Each pair of factors was given a total of 100 points, which the respondent split between the two factors according to relative importance. For example, if compensation, factor 1, was three times as important (to you) as location, factor 2, then (you would) give compensation a 75 and location a 25. For example, one respondent weighted achievement as 60 and authority as 40. A sample of the "Work Motivational Survey" is found in Appendix A. The factors were divided into two groups for comparison basis. A common factor, compensation, was placed in each group so that all eleven factors could be simultaneously weighted and ranked 1 (most important) through 11 (least important).

Figure 4


Motivational Factor Comparisons
Growth
Achievement
Challenge
Job Security
Compensation
Management
Recognition
Location
Relations
Authority
Environment
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Average Weighting
Students
Professionals

The eleven weighted scores for each group sum to 1.0. The scaled scores and corresponding rankings are depicted in Table 1.

Table 1 -- Pair-Wise Comparison Results

Motivational Factor	Students		Professionals	
	Score	Rank	Score	Rank
Compensation	.112	1	.098	5
Achievement	.112	1	.108	2
Growth	.107	3	.113	1
Challenge	.096	4	.101	3
Job Security	.091	5	.099	4
Recognition	.090	6	.089	7
Environment	.085	7	.065	11
Management	.081	8	.094	6
Location	.077	9	.085	8
Relations	.077	9	.075	9
Authority	.072	11	.074	10
Sum:	1.000		1.000	

With any series of pair-wise comparisons, one consideration is consistency of individual responses. The average inconsistency rating was 0.045 and 0.032 for the student and professional groups respectively; 22 of the 24 students and 35 of 46 professionals showed significant inconsistency (>.016). Removing the professional individuals with high inconsistencies (>.039) did not have significant effect on the ranked results. Allowing the respondents time to go through the questionnaire twice might reduce the inconsistency.

Correlations between motivational factors were calculated for each group. Individual test critical values were increased to account for the multiple t-test using the Bonferroni t-table [38];

ordinary t-tests were applied to the correlation results. The null alternative hypothesis were:

H_o: The two factors are independent, rho = 0.

H_A: The two factors are related, rho $\neq$ 0.

Where rho is the correlation coefficient. The individual test alpha levels were decreased to give an overall alpha level of $p<.05$. The boxed correlations in Tables 2 and 3 depict the related factors. For the professional engineers, challenge correlated with achievement ($r = .53$) and with growth ($r = .49$). The only significant correlation for the student engineers was management with relations ($r = .76$). These correlations were most likely due to how each group perceived the factors based on the definition given in the survey. Overall, the lack of significant correlation among the factors indicates overall independence.

B. Kendall's Tau Test

The rankings of the two groups were examined statistically for differences using a Kendall's Tau test. In cases where two factors were tied, each factor received a ranking equal to the mean of the ranking and the next lowest ranking. In the student results, the rating for compensation and achievement was tied at 1. Thus, each was given a ranking of 1.5 (the mean of 1 and 2). The student rankings are listed in ascending order along side the corresponding professional rankings. For comparison of these two groups the null hypothesis was:

H_o: The rankings of the two groups are not associated.

This hypothesis suggests that the two groups rank the factors independently. The alternative hypothesis is that there is an association among student and professional rankings.

The Kendall's Tau test of independence was applied to these data [41]. The number of pair-wise concordances (order agreements) were compared to the number of pair-wise discordances (order disagreements). Accommodation was made for ties among the two groups. The computation results of the Kendall's Tau test is in Table 4. In this study there were 46 concordances, 5 discordances, and 4 ties. The null hypothesis was rejected at $p<.05$. Acceptance of the alternative hypothesis suggests that the two groups ranked the factors similarly. Although the exact order was juggled, both groups

Table 2

Motivational Factor Correlations for Engineering Students

Factor	Achievement	Authority	Challenge	Compensatio	Environment	Growth	Job Security	Location	Management	Recognition	Relations
Achievement	---	-0.378	0.425	-0.368	-0.109	0.568	-0.232	-0.303	-0.240	0.141	-0.243
Authority	---	---	-0.242	-0.282	0.065	0.150	-0.056	-0.291	0.172	-0.147	0.017
Challenge	---	---	---	0.017	-0.147	0.486	-0.345	-0.526	-0.556	0.169	-0.398
Compensatio	---	---	---	---	-0.259	-0.517	-0.040	-0.038	-0.082	-0.118	-0.259
Environment	---	---	---	---	---	-0.004	0.021	-0.047	-0.253	-0.224	-0.087
Growth	---	---	---	---	---	---	-0.427	-0.494	-0.242	-0.137	-0.077
Job Security	---	---	---	---	---	---	---	0.444	-0.181	-0.202	-0.325
Location	---	---	---	---	---	---	---	---	0.132	-0.041	0.266
Management	---	---	---	---	---	---	---	---	---	-0.096	0.758
Recognition	---	---	---	---	---	---	---	---	---	---	0.033
Relations	---	---	---	---	---	---	---	---	---	---	---

Statistical Significance P < .05

Table 3

Motivational Factor Correlations For Professionals

Factor	Achievement	Authority	Challenge	Compensation	Environment	Growth	Job Security	Location	Management	Recognition	Relations
Achievement	—	-0.064	0.530	-0.239	0.218	0.318	0.201	-0.078	0.018	0.205	-0.264
Authority	—	—	-0.071	-0.140	-0.037	0.106	-0.147	-0.131	-0.049	-0.106	0.058
Challenge	—	—	—	-0.134	-0.073	0.489	-0.180	-0.192	-0.014	0.164	-0.141
Compensation	—	—	—	—	0.064	-0.054	0.444	0.332	-0.121	-0.092	0.012
Environment	—	—	—	—	—	-0.241	0.092	-0.002	0.003	-0.003	0.419
Growth	—	—	—	—	—	—	-0.075	-0.009	-0.016	0.118	-0.073
Job Security	—	—	—	—	—	—	—	0.180	-0.275	0.120	-0.163
Location	—	—	—	—	—	—	—	—	-0.272	-0.009	0.053
Management	—	—	—	—	—	—	—	—	—	0.373	0.370
Recognition	—	—	—	—	—	—	—	—	—	—	0.289
Relations	—	—	—	—	—	—	—	—	—	—	—

Statistical Significance P < .05

ranked compensation, growth, achievement, challenge, and job security as the top five motivational factors.

Table 4 -- Kendall's Tau Results

Motivational Factors	Students	Professionals
Compensation	1.5	5
Achievement	1.5	2
Growth	3	1
Challenge	4	3
Job Security	5	4
Recognition	6	7
Environment	7	11
Management	8	6
Location	9.5	8
Relations	9.5	9
Authority	11	10

V. Discussion

The results of this study show that both student engineers and professional engineers have similar rankings of motivational factors. The top seven motivational factors compare well with previous research on motivation of engineers with the exception of job security which was not rated in other studies. One premise of the conceptual model is change over career growth. This premise implies that the conscious and sub-conscious map between the various input motivational factors and the worker's motivational state is dynamic. This study shows that the two groups of engineers surveyed did not show significant statistical change in the ranking of motivational factors; the top five and bottom six motivational factors do not change with experience. However, factors that motivate the individual engineer do change over time; subtle (no statistical significance) changes in the top five and bottom six motivational factors occur with experience. While this study did not evaluate changes in individuals over time, the surveys show large differences among individual weightings for all

motivational factors, e.g., challenge for professional engineers had a low of .037 to a high of .225. One of the keys to effectively motivating engineers is to recognize the individual's unique motivational factors, i.e., motivating the individual is a one-on-one process which must be understood for each person to be optimally effective. Additionally, it is recognized that engineers may be subject to other subconscious factors not considered in the "Work Motivational Survey."

Job security was rated in the top five motivational factors for both the students and professional engineers, but it was not rated as an important motivational factor in previous research. The importance of job security now compared to earlier studies is most likely due to today's corporate "right-sizing" and aggressive cost cutting coupled with relatively slow economic conditions.

Salary often is discussed in the context of a motivator. Many technical people see in their financial reward a yardstick of corporate appreciation for their contributions as well as recognition of their achievements [14]. Landis [29] notes that once a basic security need such as salary is generally met, only those at the very top or the very bottom of the satisfaction scale will still consider them issues. Engineers often recognize that there are budgetary constraints on salary increases; so, motivation based on the expectation of a limited salary increase is not usually a large factor, and in some cases an acceptable surrogate such as growth potential or added authority is accepted [50]. From the survey, this shift is found as compensation moves from first for students to fourth for (experienced) professional engineers.

Gomersall [17] breaks work place needs into two rigid categories, maintenance needs and motivational needs, very similar to the hygiene and motivator factors of Herzberg [22]. Maintenance needs of the individual must be satisfied before motivational needs can be fully applied. One would have to seriously question whether this theory holds true for salaried engineers, particularly when Gomersall lists friendliness, seniority, lunch facilities, and restrooms as maintenance needs. These may have a large impact on hourly workers, but this work indicates that engineers have less concern over these types of maintenance needs and are more interested in and driven by motivational needs such as growth, achievement, challenge, and job security. Gomersall does make the point that certain

motivational needs can have a high backlash effect creating de-motivational factors in each motivational area, however.

While some research and theories attempt to differentiate between motivators and maintenance needs (or satisfiers), they are basically differentiating motivational factors into two groups; motivational factors which are positive or perceived as positive in nature, such as recognition and achievement, and those that are perceived as restrictive or negative in nature, such as scheduled compensation, organizational policies, and the work environment. Clearly, as there is a strong degree of individual perception (or mapping) to these. So, what may be negative to engineer one may be perceived as a positive to another engineer. As such, this study approached all factors from the standpoint of positively motivating the group. Bogarty [8] notes that one of the problems with much of the published material lies in the effort to generalize from a narrow or undefined population. This is important to consider in that results obtained from this survey can not be broadly applied. Additionally, individual differences account for significant variances in output.

VI. Conclusions & Recommendations

This study shows subtle changes (of no statistical significance) between motivational factors for engineers surveyed with respect to work experience. For student engineers who have not had work experience, the top five motivators are compensation, achievement, growth, challenge, and job security. For professional engineers having 1 to 25 years of experience with an average of 10.5 years, the top five motivators are growth, achievement, challenge, job security, and compensation. Statistically, both group's top five weightings (and consequently bottom six: recognition, environment, management, location, relations, and authority) are the same.

From the perspective of the engineering manger and project manager, the most important aspect of motivation is to have engineers who are highly motivated to perform in a manner that is most beneficial to meeting the objectives and goals of the organization or project. Motivation is often strongly associated with employee productivity, especially in the case where tasks and responsibilities are clearly defined; the work output must be properly directed by the manager to meet the goals and

objectives of the organization. This study shows that, as a group, engineers have motivational needs that are different from the general worker. As such, the rankings from this study are beneficial in that they can be uniquely applied to create an organization that provides for the engineering professional.

This study also shows that motivational needs vary from individual to individual. As such, it is also very important for the engineering manager to account for individual differences in motivating engineers. This survey or a similar assessment would be a very useful tool in evaluating motivational factors for the individual engineer and for effectively utilizing the engineering manager's ability to motivate the individual engineer. Knowledge of an individual's motivational factors to provide for a manager-to-engineer communications feedback is the first step in effectively (optimally) motivating an engineer. Performing such a survey is thus a clear recommendation towards understanding the motivational requirements of engineers.

Future work should address the inconsistencies found in the survey respondent's rankings. The surveys should either be returned to the engineers for review or the survey format revised and re-administered.

Acknowledgements

Special thanks is given to Dr. D. Kocaoglu for his assistance and helpful suggestions in developing the survey questionnaire.

References

[1] J. S. Adams, "Toward an Understanding of Inequity", *Journal of Abnormal and Social Psychology*, pp. 422-436, Oct. 1963.

[2] T. J. Allen and R. Katz, "Age, Education, and The Technical Ladder," *IEEE Transactions on Engineering Management*, vol. 39(3), 1992.

[3] T. J. Allen and R. Katz, "The dual ladder: motivational solution or managerial delusion?", *R&D Management*, vol. 16, pp. 185-197, 1986.

[4] S. J. Ashford, C. Lee, and P. Bobko, "Content, Causes, and Consequences of Job Insecurity: A Theory-Based Measure and Substantive Test," *Academy of Management Journal*, 1989, vol. 34(2), 803-29.

[5] M. K. Badaway, "One More Time: How To Motivate Your Engineers," *IEEE Transaction on Engineering Management*, Vol. EM-25, N. 2, May 1978, 37-42.

[6] T. E. Becker and R. J. Klimoski, "A Field Study of The Relationship Between The Organizational Feedback Environment and Performance," *Personnel Psychology*, 1989, 42(2), 343-58.

[7] R. R. Blake and J. S. Mouton, *Productivity The Human Side*, 1981.

[8] H. Bogarty, "Employees of Technical Organizations Can Be Motivated.", *Research Management*, vol. 11, pp. 5-24, Jan. 1969.

[9] R. N. Bolles, What Color Is Your Parachute? Berkeley, CA: Ten Speed Press, 1980.

[10] T. Burns and G. M. Stalker, The Management of Innovation. London: Social Science Paperbacks, 1961.

[11] W. C. Byham, *Zapp The Lightning of Empowerment*, 1988.

[12] R. Christie and F. L. Geis, Studies in Machiavellianism. New York: Academic Press, 1970.

[13] D. I. Cleland and D. F. Kocaoglu, Engineering Management. New York: McGraw-Hill, 1980.

[14] J. H. Dessauer, "How a Large Corporation Motivates Its Research People", *Research Management*, vol. 13, pp. 51-55, May 1971.

[15] L. A. Festinger, *A Cognitive Theory of Dissonance*, Evanston, IL: Row-Peterson, 1957.

[16] G. R. Gemmill and H. J. Thamhain, "Influence styles of project managers: Some project performance correlates", *Acad. of Manag. J.*, vol. 17, no.2, pp.216-224, June 1974.

[17] E. R. Gomersall, "Current and Future Factors Affecting the Motivation of Scientists, Engineers and Technicians", *Research Management*, vol. 13, pp. 43-51, May 1971.

[18] A. S. Grove, High Output Management. New York: Random House, 1983.

[19] D. Hellrigel, J. W. Slocum, and Richard W. Woodman, Organizational Behavior, 6th ed. St. Paul: West, 1992.

[20] R. I. Henderson, *Compensation Management Rewarding Performance Third Edition*, Reston, VA: Reston Publishing Co. Inc., 1982.

[21] F. Herzberg, "One More Time: How Do You Motivate Employees?", *Harvard Business Review*, vol.46 , pp.53, Jan.-Feb. 1968.

[22] F. Herzberg, B. Mausner, and B. Snyderman, *The Motivation to Work*, New York, NY: Wiley, 1959.

[23] L. V. Imundo, *The Effective Supervisors Handbook*, New York, NY: AMACON, 1991.

[24] S. L. Ingram and C.B. Thompson, "For The Long Haul," *Association Management*, November 1990, 65-67.

[25] R. Katz and M. Tushman, "A Longitudinal Study of the Effects of Boundry Spanning Supervision on Turnover and Promotion in Research and Development," *Academy of Management Journal*, Vol. 26, pp. 437-456, 1983.

[26] H. G. Kautman, "Relationship of Early Work Challenge to Job Performance, Professional Contribution, and Competence of Engineers," *Journal of Applied Psychology*, vol. 59(3), pp. 377-379, 1974.

[27] A. Kronhauser, "Satisfaction: Its Determinants and Effects," Management and Motivation, V. H. Vroom and E. L. Deci Ed. Harmondsworth: Penguin, 1970.

[28] K. W. Kuhnert and D.R. Palmer, "Job Security, Health, and The Intrinsic and Extrinsic Characteristics of Work," *Group and Organizational Studies*, vol. 16(2), 1991, 178-92.

[29] F. Landis, "What Makes Technical Men Happy and Productive?" *Research Management*, vol. 13, pp. 24-42, May 1971.

[30] D. M. S. Lee, "Job Challenge, Work Effort, and Job Performance of Young Engineers: A Causal Analysis," *IEEE Transactions on Engineering Management*, vol. 39(3), pp. 214-225, 1992.

[31] E. A. Locke, "Toward a Theory of Task Motivation and Incentives", *Organization Behavior and Human Performance*, vol. 3, pp. 157-189, 1968.

[32] F. Luthans and R. Kreitner, *Organizational Behavior Modification*, Glenview, IL: Scott, Foresman, 1975.

[33] A. H. Maslow, "A Theory of Human Motivation", *Psychological Review*, vol. 50, pp. 370-396, 1943.

[34] A. H. Maslow, Motivation and Personality. New York: Harper & Row, 1954.

[35] D. C. McClelland, "Achievement motivation Can Be Developed", *Harvard Business Review*, vol. 43, pp.6-24,178, 1965.

[36] D. C. McClelleand, The Achieving Society. New York: Van Nostrand, 1961.

[37] D. McGregor, *The Human Side of Enterprise*, New York, NY: McGraw-Hill, 1960.

[38] J. L. Meyers, Fundamentals of Experimental Design, 3rd. ed. Boston: Allyn & Bacon, 1979. 549-550.

[39] M. Nash, *Making People Productive*, San Francisco, CA: Jossey-Bass Inc., 1985.

[40] B. R. Nathan, A. M. Mohrman, and J. Milliman, "Interpersonal Relations as a Context for The Effects of Appraisal Interviews on Performance and Satisfaction: A Longitudinal Study," *Academy Of Management Journal*, 1991, 34(2), 252-69.

[41] G. E. Noether, Introduction to Statistics, The Nonparametric Way. New York: Springer-Verlag, 1992.

[42] C. A. Pearson, "An Assessment of Intrinsic Feedback on Participation, Role Perspectives, Motivation, and Job Satisfaction In A Self-Managed System For Monitoring Group Achievement," *Human Relations*, 44(5), 517-37.

[43] B. C. Pelz and F. M. Andrews, Scientists in Organizations. Ann Arbor, MI: Institute for Social Research, 1976.

[44] P. Ramsden, Top Team Planning: A Study of the Power of Individual Motivation in Management. New York: Wiley, 1973.

[45] F. J. Roethlisberger and William J. Dickson, Management and the Worker. Cambridge: Harvard University Press, 1939.

[46] R. E. Shannon, Engineering Management. New York: Wiley, 1980.

[47] S. L. Sokolik, The Personnel Process. New York: Intext, 1970.

[48] C. R. Stoner, "Developing a Dynamic Motivational Environment", *SAE*, paper 900914, Bradley University, 1990.

[49] H. J. Thamhain, "Managing Engineers Effectively.", *IEEE Trans. Eng. Mgmt.*, vol. EM-30, pp. 231-237, Nov. 1983.

[50] V. H. Vroom, *Work and Motivation*, New York, NY: Wiley, 1964.

[51] G. Walker and L. Poppo, "Profit Centers, Single Source Suppliers, and Transaction Costs," *Administrative Science Quarterly*, No. 36, 1991.

[52] S. P. Waring, Taylorism Transformed: Scientific Management Theory Since 1945. Chapel Hill: University of North Carolina Press, 1991.

[53] H. Weisinger, "How Tough Critics May Be Mentors In Disguise," *Working Woman*, 14(6), 102-5.

Appendix A -- Survey

Appendix A contains the "Work Motivational Survey." This survey was distributed to two groups of workers. The first group of junior engineers was composed of 37 senior mechanical engineering students and 6 graduate engineering students at Portland State University. Of the 37 surveys handed out to the seniors, only 19 were returned. The second group of professional engineers and scientists was composed of 38 engineering management students at Portland State University and 8 other persons from Nike Corporation and Precision Castparts Corporation.

WORK MOTIVATIONAL SURVEY

NAME:(optional)_____DATE:_____

JOB TITLE:_____

BUSINESS/INDUSTRY:_____

YEARS PROFESSIONAL EXPERIENCE:_____

EDUCATION (DEGREE/MAJOR):_____

SEND RESULTS? _____YES _____NO

This survey is part of an Engineering Management class project that evaluates the importance of various motivational factors in the work of engineering and technical employees. Your support and cooperation in filling out this survey would be appreciated. If you are interested in the results, please indicate and we will be glad to share them with you.

This survey uses a pair-wise comparison analysis model that asks you to rate the relative importance of motivational factors by comparing them two at a time, hence the name pair-wise. Each factor should be evaluated as to the importance in motivating you to work. Each pair of factors is given a total of 100 points, which are split between the two factors according to relative importance.

Ratio A:B	Weight A	Weight B
1:1	50	50
1.5:1	60	40
2:1	67	33
3:1	75	25
4:1	80	20
5:1	83	17
10:1	91	9
99:1 (max)	99	1

A list of the motivational factor definitions is attached.

WORK MOTIVATIONAL FACTORS

Achievement
Pride and sense of accomplishment.

Authority
The extent of power, influence, control and freedom an employee has in their work and with others in the workplace.

Challenge
Stimulating and meaningful work often requiring intensive effort.

Compensation
Salary and benefits - including insurance, paid time off, investment and retirement plans.

Environment
The climate, culture and physical amenities of the workplace.

Growth
Opportunity to achieve personal and professional goals.

Job Security
Stability and continuity of employment.

Location
Physical and geographic location of workplace.

Management
Superiors' performance and their treatment of employees.

Recognition
Appreciation and respect for the value of an individual or group contribution - both internal and external.

Relations
Interpersonal interactions, compatibility and teamwork among co-workers.

WORK MOTIVATIONAL SURVEY

Example: Compare your preference for:
Cars 75 vs. Pick-ups 25

The respondent preferred cars 3 to 1 over pick-ups.

Motivational Factor Comparisons. Please answer with consistency.

1) Environment _____ vs. Challenge _____

2) Achievement _____ vs. Authority _____

3) Compensation _____ vs. Authority _____

4) Achievement _____ vs. Environment _____

5) Environment _____ vs. Compensation _____

6) Challenge _____ vs. Authority _____

7) Growth _____ vs. Compensation _____

8) Compensation _____ vs. Challenge _____

9) Growth _____ vs. Challenge _____

10) Growth _____ vs. Environment _____

11) Growth _____ vs. Authority _____

12) Compensation _____ vs. Achievement _____

13) Achievement _____ vs. Challenge _____

14) Authority _____ vs. Environment _____

15) Growth _____ vs. Achievement _____

WORK MOTIVATIONAL SURVEY

Motivational Factor Comparison (cont.)

16) Job Security _____ vs. Relations _____

17) Recognition _____ vs. Job Security _____

18) Job Security _____ vs. Compensation _____

19) Management _____ vs. Location _____

20) Management _____ vs. Job Security _____

21) Management _____ vs. Compensation _____

22) Recognition _____ vs. Relations _____

23) Management _____ vs. Relations _____

24) Location _____ vs. Recognition _____

25) Relations _____ vs. Compensation _____

26) Locations _____ vs. Compensation _____

27) Management _____ vs. Recognition _____

28) Relations _____ vs. Location _____

29) Recognition _____ vs. Compensation _____

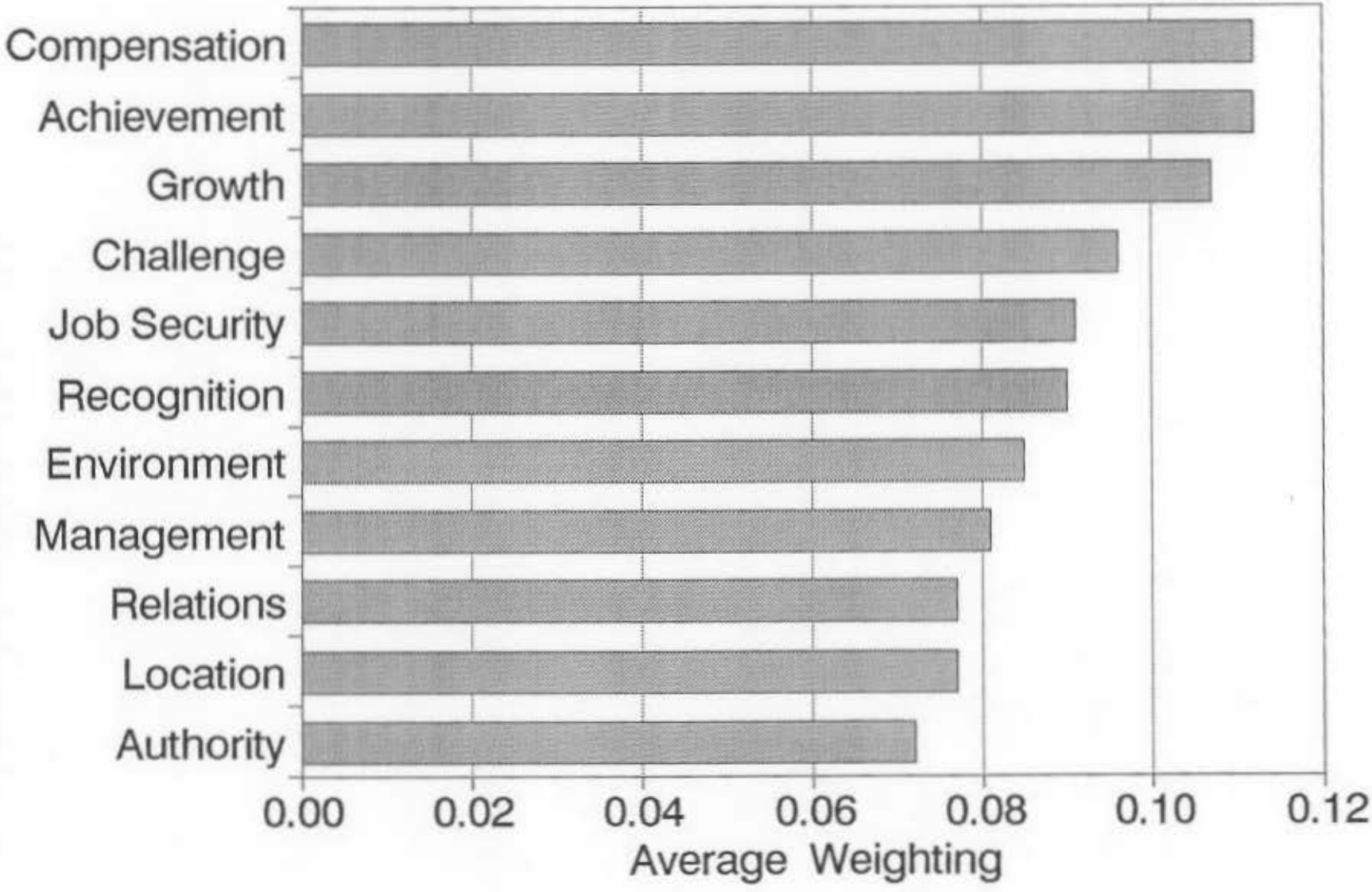
30) Location _____ vs. Job Security _____

Appendix B -- Analysis and Results

Appendix B contains the analysis records and results of the "Work Motivational Survey" as normalized values, intercorrelations, pair-wise ranking, percentage ranking, and Kendall's Tau analysis.

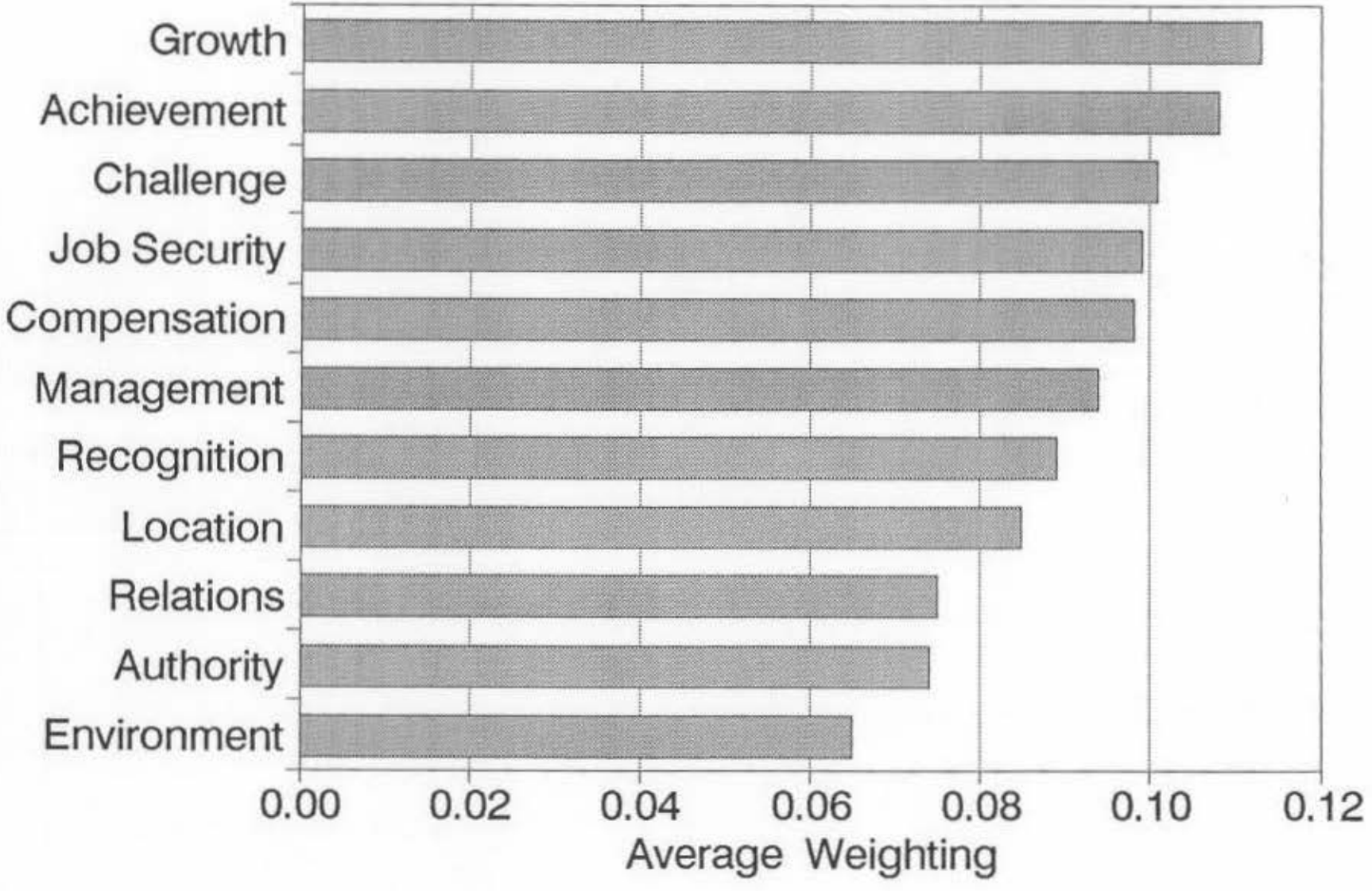
Motivational Factor Ranking

Engineering Students



Motivational Factor Ranking

Professional Engineers



Motivational Factor Weightings (Professionals)

Person	Achievement	Authority	Challenge	Compensation	Environment	Growth	Job Security	Location	Management	Recognition	Relations
1	0.079	0.055	0.075	0.134	0.035	0.124	0.089	0.198	0.057	0.070	0.083
2	0.090	0.096	0.119	0.113	0.048	0.137	0.098	0.026	0.113	0.088	0.072
3	0.118	0.043	0.123	0.102	0.016	0.134	0.136	0.119	0.034	0.147	0.028
4	0.162	0.058	0.098	0.069	0.087	0.104	0.045	0.104	0.099	0.104	0.069
5	0.133	0.061	0.083	0.072	0.122	0.083	0.119	0.052	0.103	0.057	0.114
6	0.094	0.089	0.114	0.044	0.035	0.114	0.039	0.033	0.278	0.094	0.067
7	0.094	0.059	0.136	0.124	0.100	0.077	0.119	0.038	0.086	0.065	0.102
8	0.085	0.035	0.085	0.174	0.085	0.035	0.141	0.154	0.040	0.094	0.074
9	0.058	0.085	0.069	0.132	0.101	0.079	0.132	0.102	0.084	0.054	0.102
10	0.125	0.042	0.092	0.074	0.042	0.083	0.105	0.037	0.173	0.142	0.086
11	0.084	0.074	0.064	0.119	0.049	0.084	0.094	0.069	0.125	0.125	0.094
12	0.083	0.125	0.037	0.099	0.068	0.104	0.064	0.047	0.117	0.117	0.140
13	0.086	0.065	0.097	0.108	0.049	0.135	0.102	0.091	0.119	0.068	0.080
14	0.096	0.048	0.067	0.106	0.077	0.087	0.119	0.162	0.062	0.081	0.094
15	0.153	0.057	0.073	0.107	0.045	0.130	0.097	0.075	0.145	0.064	0.054
16	0.074	0.079	0.059	0.084	0.049	0.143	0.167	0.078	0.107	0.078	0.084
17	0.067	0.055	0.178	0.067	0.086	0.165	0.018	0.054	0.058	0.121	0.130
18	0.126	0.070	0.225	0.091	0.049	0.133	0.044	0.044	0.107	0.079	0.032
19	0.065	0.060	0.085	0.095	0.100	0.095	0.071	0.178	0.089	0.083	0.077
20	0.097	0.069	0.109	0.069	0.029	0.200	0.044	0.142	0.079	0.079	0.083
21	0.132	0.078	0.108	0.066	0.090	0.120	0.085	0.113	0.075	0.057	0.075
22	0.097	0.120	0.112	0.127	0.067	0.217	0.085	0.046	0.042	0.054	0.031
23	0.085	0.085	0.056	0.107	0.107	0.130	0.086	0.021	0.145	0.118	0.059
24	0.104	0.054	0.050	0.079	0.067	0.067	0.072	0.132	0.178	0.119	0.079
25	0.067	0.149	0.057	0.108	0.077	0.051	0.120	0.132	0.090	0.078	0.072
26	0.125	0.025	0.119	0.176	0.019	0.163	0.159	0.060	0.077	0.049	0.027
27	0.110	0.115	0.121	0.049	0.022	0.132	0.054	0.099	0.079	0.114	0.104
28	0.129	0.070	0.097	0.075	0.048	0.118	0.086	0.113	0.086	0.097	0.081
29	0.105	0.073	0.099	0.078	0.078	0.084	0.073	0.107	0.112	0.084	0.107
30	0.098	0.156	0.098	0.091	0.059	0.156	0.069	0.082	0.048	0.061	0.082
31	0.099	0.093	0.088	0.146	0.053	0.105	0.124	0.118	0.051	0.073	0.051
32	0.128	0.047	0.093	0.140	0.058	0.116	0.106	0.145	0.073	0.039	0.056
33	0.150	0.086	0.109	0.046	0.063	0.127	0.115	0.041	0.097	0.097	0.069
34	0.179	0.124	0.151	0.076	0.041	0.110	0.088	0.084	0.068	0.044	0.036
35	0.114	0.078	0.114	0.090	0.072	0.126	0.090	0.075	0.070	0.105	0.065
36	0.084	0.105	0.090	0.132	0.053	0.069	0.090	0.084	0.096	0.108	0.090
37	0.075	0.064	0.087	0.156	0.127	0.064	0.092	0.075	0.098	0.052	0.110
38	0.061	0.071	0.099	0.118	0.038	0.085	0.118	0.033	0.137	0.118	0.124
39	0.093	0.058	0.139	0.064	0.104	0.122	0.059	0.088	0.103	0.098	0.073
40	0.130	0.027	0.097	0.114	0.049	0.130	0.114	0.114	0.068	0.142	0.017
41	0.130	0.117	0.111	0.111	0.052	0.130	0.060	0.037	0.083	0.083	0.087
42	0.059	0.099	0.064	0.178	0.020	0.079	0.206	0.096	0.069	0.089	0.041
43	0.186	0.035	0.041	0.076	0.163	0.076	0.166	0.040	0.050	0.101	0.066
44	0.104	0.088	0.088	0.036	0.052	0.145	0.073	0.062	0.140	0.104	0.109
45	0.180	0.076	0.221	0.062	0.069	0.083	0.059	0.022	0.092	0.095	0.040
46	0.152	0.010	0.142	0.020	0.056	0.132	0.244	0.086	0.015	0.096	0.046
MEAN	0.108	0.074	0.101	0.098	0.065	0.113	0.099	0.085	0.094	0.089	0.075
MIN	0.058	0.010	0.037	0.020	0.016	0.035	0.018	0.021	0.015	0.039	0.017
MAX	0.186	0.156	0.225	0.178	0.163	0.217	0.244	0.198	0.278	0.147	0.140
STD DEV	0.033	0.031	0.038	0.036	0.031	0.036	0.043	0.043	0.044	0.027	0.028

Motivational Factor Weightings (Engineering Students)

Person	Achievement	Authority	Challenge	Compensatio	Environment	Growth	Job Security	Location	Management	Recognition	Relations
1	0.127	0.064	0.102	0.089	0.083	0.178	0.076	0.062	0.080	0.076	0.062
2	0.086	0.086	0.091	0.123	0.064	0.086	0.100	0.076	0.106	0.088	0.094
3	0.136	0.149	0.054	0.088	0.068	0.177	0.046	0.017	0.097	0.084	0.084
4	0.070	0.090	0.065	0.110	0.095	0.065	0.117	0.110	0.098	0.092	0.086
5	0.072	0.249	0.098	0.052	0.059	0.118	0.097	0.032	0.097	0.077	0.048
6	0.225	0.019	0.097	0.077	0.077	0.148	0.129	0.112	0.034	0.039	0.043
7	0.050	0.050	0.039	0.252	0.101	0.073	0.068	0.109	0.129	0.034	0.095
8	0.098	0.077	0.098	0.077	0.259	0.084	0.100	0.042	0.031	0.088	0.046
9	0.086	0.036	0.121	0.413	0.036	0.021	0.049	0.035	0.056	0.105	0.042
10	0.129	0.050	0.089	0.069	0.069	0.089	0.064	0.098	0.133	0.093	0.116
11	0.140	0.059	0.091	0.075	0.070	0.108	0.032	0.118	0.059	0.177	0.070
12	0.093	0.056	0.060	0.074	0.093	0.088	0.160	0.086	0.105	0.093	0.093
13	0.047	0.084	0.042	0.141	0.089	0.061	0.234	0.161	0.040	0.047	0.054
14	0.092	0.081	0.081	0.107	0.076	0.076	0.071	0.113	0.077	0.119	0.107
15	0.094	0.065	0.188	0.138	0.051	0.188	0.042	0.046	0.050	0.058	0.079
16	0.133	0.038	0.091	0.119	0.043	0.062	0.125	0.069	0.144	0.081	0.094
17	0.170	0.069	0.094	0.050	0.088	0.164	0.029	0.017	0.126	0.096	0.096
18	0.101	0.088	0.076	0.101	0.145	0.114	0.106	0.067	0.063	0.072	0.067
19	0.080	0.085	0.080	0.064	0.117	0.106	0.048	0.112	0.101	0.080	0.128
20	0.101	0.059	0.082	0.073	0.046	0.096	0.116	0.085	0.085	0.146	0.110
21	0.106	0.035	0.075	0.106	0.062	0.062	0.112	0.145	0.119	0.106	0.073
22	0.153	0.025	0.166	0.134	0.051	0.115	0.159	0.040	0.010	0.134	0.015
23	0.145	0.086	0.132	0.073	0.112	0.119	0.073	0.052	0.064	0.068	0.077
24	0.160	0.029	0.189	0.073	0.094	0.182	0.031	0.048	0.031	0.100	0.062
MEAN	0.112	0.072	0.096	0.112	0.085	0.107	0.091	0.077	0.081	0.090	0.077
MIN	0.047	0.019	0.039	0.050	0.036	0.021	0.029	0.017	0.010	0.034	0.015
MAX	0.225	0.249	0.189	0.413	0.259	0.188	0.234	0.161	0.144	0.177	0.128
STD DEV	0.040	0.046	0.039	0.075	0.044	0.044	0.048	0.039	0.036	0.032	0.026

Professional Engineers Inconsistencies

Person	Inconsistency(2)	Inconsistency(1)
1	0.036	0.02
2	0.042	0.018
3	0.079	0.049
4	0	0.003
5	0.008	0.026
6	0.033	0.016
7	0.035	0.018
8	0.031	0.024
9	0.007	0.011
10	0.016	0.02
11	0.004	0.006
12	0.038	0.025
13	0.015	0.016
14	0.043	0.021
15	0.023	0.059
16	0.011	0.011
17	0.028	0.033
18	0.088	0.044
19	0.018	0.004
20	0.012	0.012
21	0.025	0.03
22	0.052	0.04
23	0.036	0.018
24	0.11	0.182
25	0.003	0.005
26	0.069	0.048
27	0.036	0.035
28	0.052	0.011
29	0.01	0.017
30	0.011	0.038
31	0.011	0.005
32	0.011	0.005
33	0.057	0.044
34	0.039	0.009
35	0.014	0.007
36	0.004	0.012
37	0.039	0.058
38	0.012	0.022
39	0.009	0.021
40	0.039	0.047
41	0.018	0.004
42	0.008	0.062
43	0.027	0.022
44	0.023	0.045
45	0.038	0.026
46	0.151	0.161
MEAN	0.032	0.031
MIN	0.000	0.003
MAX	0.151	0.182
STD DEV	0.029	0.034

Engineering Student Inconsistencies

Person	Inconsistency	inconsistency
1	0.022	0.018
2	0.002	0.003
3	0.091	0.021
4	0.003	0.001
5	0.025	0.029
6	0.048	0.073
7	0.128	0.038
8	0.032	0.012
9	0.044	0.139
10	0.014	0.086
11	0.041	0.046
12	0.029	0.02
13	0.045	0.031
14	0.179	0.194
15	0.148	0.003
16	0.037	0.018
17	0.077	0.015
18	0.025	0.004
19	0.019	0.009
20	0.023	0.037
21	0.014	0.054
22	0.051	0.082
23	0.011	0.041
24	0.032	0.034
MEAN	0.048	0.042
MIN	0.002	0.001
MAX	0.179	0.194
STD DEV	0.044	0.045

Professional Engineers Demographics

Person	YRS EXP	INDUSTRY	EDUCATION
1	20	ELECTRONICS	BSEE
2	11	FOOTWEAR	ME
3	9	PROJENG;BAKERY	BSIE/CS
4	2	FOOTWEAR	BS EX SCI
5	17	CASTING	BSMET
6	5	CASTING	BSE
7	16	CASTING	BS MFG
8	16	CASTING	NONE
9	11	CASTING	BSIE
10	11	CASTING	BS MET
11	5	FOOTWEAR	BS MATH
12	1	CITY OF PTLD	BSME
13	3	FOOD PROD	BS AG E
14	25	COMPUTER	BS/MS MATH
15	4	STEEL	BSEE
16	2	ARMY CORP	BSCE
17	3	R&D	BSME
18	8	ENV	BS/MSCE
19	7	CONSULT	BSME
20	7	SEMICONDUCTOR	BSMS
21	18	COMPUTER	MSCS
22	2	CONSULT	BSME
23	10	TOOLS	BSME
24	1	BUSINESS	ENGR
25	9	ARMY CORP	BSCE
26	5	PUBLIC UTILITY	BSCE
27	9	SEMICONDUCTOR	BS/MS CHEM ENG
28	12	PUBLIC TRANSIT	BSCE
29	12	COMPUTERS	BSEE
30	16	NUCLEAR POWER	BSEE
31	8	CASTINGS	BSME
32	10	CASTINGS	BSEE
33	10	N/A	N/A
34	16	PUBLIC UTILITY	BS/MSME
35	23	IC's	MS MAT SCI
36	20	CASTINGS	BSME
37	5	ENGR	BSEE
38	3	COMPUTER	BSCE
39	5	ELECTRONIC	BSEE
40	20	ELECT POWER	BSMS
41	15	DATA PROC	M
42	10	COMPUTER	BSEE
43	13	HI-TECH	BSEE
44	10	GOVT	BSCE
45	25	DATA PROC	MA
46	11	EDUCATION	BS MFG E T

MEAN	10.46
MIN	1
MAX	25
STD DEV	6.43