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A Methodology for Measuring Engineering Knowledge Worker Productivity

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Abstract: In contrast with hourly manufacturing and service workers, the productivity of salaried knowledge workers such as engineers can be difficult to measure. In particular, hourly workers may practice physical absenteeism, while salaried engineers may practice mental absenteeism. An important aspect of this issue is what specifically causes engineers to mentally depart from their jobs before they physically leave. This phenomenon is labeled "cognitive turnover" (CT). The contribution of this article is to provide empirical data from engineers across multiple organizations to illustrate how CT can be identified and measured. This research demonstrates the first two phases in the development of a methodology that an engineering manager can use to identify the measures that provide evidence of eCT for engineering knowledge workers. The methodology seeks to identify personnel experiencing CT, categorize relevant causes, and provide pertinent solutions. This will allow organizations to evaluate their situation and explore solutions that can improve productivity for their engineers.

Keywords: Management Turnover, Burnout, Engineering Management, Maslach Burnout Inventory

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In our society today there is a dangerous mind-set, which engineering managers may be witnessing, that results in behavior harmful to the productivity of knowledge workers. The term "knowledge work" was first coined by Dr. Peter Drucker in the 1960s as any work that requires mental power rather than physical power (Fisher, 1998). It has been further defined as work that involves analyzing information and applying specialized expertise to solve problems, generate ideas, teach others, or create new products and services (Evans, 1993).

It is difficult to define knowledge work in more detail because knowledge work is primarily invisible. It is hidden in the head of the knowledge worker (Fisher, 1998). Because of the difficulty of measuring knowledge worker production, dissatisfied knowledge workers may take advantage of the situation. This dissatisfaction may produce behavior in which personnel seek more financial satisfaction by giving themselves a "stealth raise", i.e., cutting back the effective hours in which they perform knowledge work at the office. They may dedicate more mental effort to another activity that is not job-related that brings them more satisfaction (Barber, 1999). This contradicts Frederick Taylor's main philosophy of a fair day's work for a fair day's pay. Even though there should be no expectation of blind company loyalty as was expected in the past, companies should expect good work and some form of commitment to productivity from their knowledge workers while they are on the job.

Businesses lose $150 billion annually in health insurance and disability claims, lost productivity, and other expenses attributable to burnout, stress-related problems and mental illness (Bassman, 1992). Further quantification of the bottom-line impact of indirect cost is demonstrated by the high cost of absenteeism, which is estimated at approximately $40 billion per year in the U.S. (Gaudine, 2001). Previous studies on turnover and burnout categorize costs into three groups: direct costs, indirect costs, and opportunity costs. Direct costs include disability claims, worker's compensation claims, increased medical costs, and litigation costs (including wrongful discharge, hiring new personnel, training costs, advertisement for new personnel, and time spent interviewing new personnel). Indirect costs include those associated with poor quality, high turnover, absenteeism, poor customer relationships, or even sabotage. Opportunity costs include those associated with lowered employee commitment, lack of discretionary effort, commitments outside of the job, time spent talking about problems instead of working, and loss of creativity.

Cognitive turnover (CT) is a term developed in this research to describe a phenomenon that is created by a combination of turnover thoughts/cognitions brought about by burnout conditions. While everyone may manifest this mind-set periodically, excessive CT may be detrimental to the individual and the organization for which they work. Subtle acts such as absenteeism, poor quality, and lack of discretionary effort have been related to worker burnout and are common predecessors to quitting and becoming another turnover statistic. Non-commitment type behavior may stem from employee stress and burnout created by management or organizational abuse; hence eCT will lower productivity because of lack of commitment.

Engineering managers may be able to avoid the negative consequences to the organization and employee by identifying the non-productive knowledge workers experiencing eCT; however, it is probably more productive to seek aggregate or group information that will facilitate improvements in attitude, innovation, productivity of the organization, and may prevent ineffective events such as reduced employee productivity and sabotage.

This research demonstrates that an eCT condition occurs when a person is absorbed with the thoughts of turnover created by organizationally driven burnout and provides a methodology

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to identify personnel with eCT so that the organizations can take actions that may improve the companies' bottom-line.

Understanding Cognitive Turnover

'T is a combination of a turnover thought process and a burned ut mental condition. Turnover is defined as voluntary cessation of membership in an organization by an individual who receives monetary compensation for participating in that organization (Mobley, 1982). Turnover has cognitive indicators that predate eventual departure. During this pre-turnover stage, a worker generally has lower productivity. There may be an attempt, prior to quitting, to sabotage the workplace with negative sentiment or other more devious activities. This definition emphasizes voluntary behavior because prevailing turnover models primarily seek to explain what motivates employees to withdraw from the workplace.

Burnout is the mental dissonance from organizational pressure. Burnout, which has been viewed as fairly subjective, is a significant factor in the business world. Cherniss (1980) defines burnout as "a syndrome of inappropriate attitudes toward clients and toward self, often associated with uncomfortable physical and emotional symptoms." Maslach (1976) observed that burnout "appears to be a factor of job turnover, absenteeism, and low morale." He cites other various self-reported indices that indicate burnout may cause personal distress, including physical exhaustion, insomnia, increased use of alcohol and drugs, and marital and family problems. Other researchers present even longer lists of burnout symptoms (Cherniss, 1980).

Similar to pre-turnover thought processes, high degrees of burnout among major proportions of a group suggest low productivity. High burnout implies little slack in a person's ping capacities, and perhaps deficits in them. High measures of burnout are strong indicators of these phenomena, but the inverse, low burnout, does not necessarily indicate high productivity (Golembiewski, 1982). This research focused on the high measures of burnout in conjunction with pre-turnover indicators.

Study Scope and Objectives

The scope of this research was to develop and test a questionnaire to measure the components of CT in engineering knowledge workers and develop a mathematical model that can be used to measure CT. The researchers have developed a methodology that is being explored as a means to consistently measure knowledge worker CT. SECtCS, or Statistical Evaluation of Cognitive Turnover Control System, is a methodology that attempts to identify, measure, and document CT. The questionnaire developed in this study can be used by engineering managers and will be further described in the results and conclusions. The following are the six phases of the SECtCS Research Methodology for Knowledge Workers (note that this article focuses on the first two):

Phase 1 – Develop Test Instrument—(SECtCS Questionnaire)

Step 1: Develop a customized test instrument for the knowledge worker population
Step 2: Administer the questionnaire
Step 3: Collect and record scores
Step 4: Conduct reliability testing on the questionnaire

ıase 2—Develop Mathematical Model—(SECtCS Modeler)

Use the data collected to develop a regression model for a valid CT index score

Phase 3—*(not described here)*—Statistical Process Control Charts

Use data from the model developed in Phase 2 for the statistical measurement of individuals with respect to all respondents and identify at-risk CT index scores. (SECtCS Evaluator-i) Establish a tracking mechanism for "at risk" and "low risk" respondents. The respondents are required to retake the questionnaire every three months in order to complete the SPC charts.

Phase 4—*(not described here)*—Intervention

Educate, implement, and monitor the solution (SECtCS intervention)

Phase 5—*(not described here)*—Intervention Measurement

Remeasure the respondents after they have been subjected to the intervention and compare to the results of Phase 3 (SECtCS Evaluator-r)

Phase 6—*(not described here)*—Evaluate Intervention

Document the results and conclusions and add to solution database

Although the main objective of the overall research was to develop and test the SECtCS methodology, this article presents only the results of the first two phases of the SECtCS methodology. This involved the development of a questionnaire to measure CT in engineering knowledge workers and the creation of a mathematical model that measures and predicts the CT index levels. The long-term objective of this methodology is to provide a tool for engineering managers to use in assessing the level of CT in engineering knowledge workers. The CT index can then be used by organizations to identify possible low productivity knowledge worker personnel, departments, and groups prior to significant productivity loss. It has the potential to identify CT so that organizations can take appropriate actions and increase the retention and productivity of their knowledge workers.

Traditional models of burnout and aspects of pre-turnover have been constructed, for the most part, on personnel after the events have happened (i.e., the person has quit or has attacked management). The goal of this research was to identify this behavior in a more predictive mode and allow organizations to implement interventions prior to a negative event occurring. In this study, a questionnaire was developed that measures relevant facets of burnout and turnover related to cognitive turnover. The results were then used to develop a mathematical model that predicts the level of cognitive turnover. Lessons learned and future opportunities for using the proposed methodology are discussed.

Research Methodology

Phase 1: Develop Test Instrument (SECtCS Questionnaire)

The summated rated scale methodology was used to create the SECtCS questionnaire. Its invention is attributed to Rensis Likert (1932), who described this technique for the assessment of attitudes. These scales are widely used across the social sciences to measure attitudes and descriptions of people's lives. Summated rated scales have good psychometric properties and, if effectively developed, will demonstrate good reliability and validity. A well-devised scale is usually quick and easy for respondents to complete and typically does not induce complaints. The questionnaire was developed using questions that have been shown to measure

burnout constructs and turnover constructs. Multiple questions designed to measure responses are grouped into constructs, or measurable variables.

The questionnaire used in this study was developed from three widely used and accepted questionnaires—the Maslach Burnout Inventory (MBI) (Maslach and Jackson, 1981), the Minnesota Satisfaction Questionnaire (MSQ) (Lofquist and Dawis, 1967), and the Facet-Specific Job Satisfaction Questionnaire (FSJSQ) (Cook, Hepworth, Wall, and Warr, 1989). The MSQ is one of the most widely used measures of job satisfaction. The FSJSQ is commonly used in measuring specific jobs satisfaction items. The items, each measuring a "facet," as indicated in the scale's title, were previously used in a 1973 survey, and a similar measure was employed in 1969 (Cook et al., 1989). The reason both were used is that one measures general job satisfaction while the other measures constructs *related* to job satisfaction but not *specifically* job satisfaction. The reasoning for using both in this research is that low job satisfaction leads to turnover, or cognitive turnover.

Burnout is commonly assessed using the Maslach Burnout Inventory (MBI) (Maslach and Jackson, 1981). The MBI is a widely accepted questionnaire for numerous burnout studies that has been demonstrated as reliable and valid in case studies. It measures three constructs: depersonalization, personal achievement, and emotional exhaustion, which relate burnout to the respondents' physical well-being. See Exhibit 1 for a description of burnout constructs.

The eight constructs related to turnover are general job satisfaction, goals, comfort, challenge, financial rewards, relationships, resource adequacy, and promotions (Exhibit 1). Applicability to the knowledge worker was a primary criterion for question selection. The initial version of the questionnaire and rating scale was pilot tested and critiqued by other researchers. After feedback from other researchers, ambiguous or confusing items were identified and eliminated.

Respondents completed three questionnaires. The first was comprised of 109 questions concerning the job satisfaction constructs and burnout constructs. A second questionnaire asked for the respondents' more direct appraisal of their level of CT. Respondents were assured that their answers would remain anonymous. Respondents were given both a verbal and written description of CT and the levels of CT. A description of each range is shown in Exhibit 2. The respondent then self-scored their level of CT given the range (1 to 10). Respondents were asked to rate, on a scale of 1 (strongly agree) to 5 (strongly disagree),

Exhibit 1. General Definitions of Constructs

Cognitive Turnover Determinant	Construct	Construct Definitions
Burnout (B)	Depersonalization	Distancing oneself from others
Burnout	Personal Accomplishment	Performing well on things that matter
Burnout	Emotional Exhaustion	Ability to cope in high stress situations
Turnover (T)	Overall Job Satisfaction	Job satisfaction that determines turnover
Turnover	Goals	Feeling that goals are attainable and have meaning
Turnover	Comfort	The space and physical conditions of the job are adequate to perform at the job
Turnover	Challenge	Feeling that job is not boring and has reasonable challenges
Turnover	Financial Rewards	Financial Compensation is reasonable and fair
Turnover	Relationship with Co-workers	Ability and willingness to work with others
Turnover	Resource Adequacy	Organization provides adequate supplies and training to perform at job
Turnover	Promotions	Opportunity for fair chance at Promotions

Exhibit 2. CT Index 10-Point Scale Descriptions

Score	CT	Considering Leaving	Description
1-2	No	No	Not burned out
3-4	No	Occasionally	Light burnout
5-7	Yes	Open for other jobs	Medium to High
8-10	Yes	Strongly considering	High

Note: CT scores range from 1 to 10, with 1 representing low level of Cognitive Turnover and 10 representing high levels of the CT.

statements that indicated how they felt about their employer. An example is: "My employer is concerned about giving everyone a chance to get ahead." They were also asked to rate specific job satisfaction questions on a scale of 1 (very dissatisfied) to 5 (very ıtisfied). An example is: "On my present job, how do I feel about ıy pay and the amount of work I do?" The mean values were calculated for each construct.

The questionnaires were distributed to 108 engineering knowledge workers from over 20 companies in the Houston area. Fifty-one questionnaires were returned, representing a response rate of 47.2%. Four incomplete questionnaires were eliminated from the data set, reducing the sample to 47. The data were examined for skewness, kurtosis, and outliers and found to be within the parameters expected in normal distribution. Using SPSS, the data were analyzed to determine the main effects and interactions between the different constructs and CT classifications. An analysis of reliability for each construct was conducted to reduce the number of questions and provide a satisfactory internal consistency. After the elimination of confusing questions, an item factor analysis was performed on the returned questionnaires and the initial set of 109 questions was reduced to 59 questions.

A measurement instrument, if reliable, will give similar results when different people administer it or alternate forms are used. Coefficient alpha (Cronbach, 1951) is a measure of the internal consistency of a scale. The values of coefficient alpha are positive, taking values from 0 to 1.0, where larger values indicate higher levels of internal consistency. Nunnally (1978) and Spector (1992) provide a rule of thumb for acceptability that coefficient alpha should be at least .70 for a scale to demonstrate ıternal consistency.

Cronbach's alpha was determined for each construct. Questions were deleted in order to attain a desirable coefficient alpha for each of the eleven constructs. Items were successfully deleted from constructs from the original set in order to improve reliability. The final questionnaire was reduced from 109 questions to 59 questions. The results from reliability analysis are shown in Exhibit 3.

Exhibit 3. Coefficient Alphas for Each Questionnaire Construct

	Initial # of Questions	Revised # of Questions	Revised Cronbach's Alpha
Depersonalization (B)	9	5	0.85
Emotional Exhaustion (B)	9	4	0.90
Personal Achievement (B)	9	5	0.95
Job Satisfaction (T)	11	5	0.99
Challenge (T)	10	5	0.73
Comfort (T)	10	5	0.84
Financial (T)	10	4	0.72
Goals (T)	11	6	0.84
ʼromotions (T)	10	5	0.90
Relationships (T)	10	5	0.81
Resources (T)	10	10	0.91

The coefficient of determination, R square, is commonly used in research to measure the goodness of fit for regression models. It can also be used as the proportion of variation in the dependent variables "explained" by the model. If the R square is acceptable then model may be considered valid. Stepwise regression was used at an alpha level of 0.05 for our regression analysis. The final regression model was evaluated using R square for the models ability to determine future CT index scores from the questionnaire.

Phase 2: Develop Mathematical Model (SECtCS Modeler)

Multiple linear regressions were used to develop the SECtCS model. They were performed using the stepwise method for each of the different independent variables. The model was examined to ensure that no violations of assumptions occurred including multi-collinearity and heteroscedacity. The dependent variable in this study was respondents' cognitive turnover score. The turnover and burnout constructs measured on the questionnaire are the independent variables that were used to determine the dependent variable, or the CT index.

Cognitive Turnover Results

Exhibits 4 and 5 show results for demographic variables in this study. The ranges along these dimensions were small. The respondents' ages varied from 20 to 64 with a mean of 25 (see Exhibit 4). There were 15 females in the sample representing 29% of respondents as shown in Exhibit 5. The length of service ranged from 1 month to 480 months with a mean of 35 months as shown in Exhibit 6. The CT results, measured on a 10-point scale, are shown in Exhibit 6. There were 34 respondents who, while working, were looking for a better job (noted as LBJ in Exhibit 7), that represents 72% of the sample. There were only eight respondents working a secondary job or activity.

Exhibit 4. Age of Respondents

Category	Mean	Std Dev	Min	Max	Number of Participants
Age (Years)	25.60	7.50	20	64	51

Exhibit 5. Gender of Respondents

Category	Number	Percent to Total
Male	36	71%
Female	15	29%

Exhibit 6. CT Results and Lenghth of Service

Category	Mean	Std Dev	Min	Max	Number of Participants
CT Score	5.1489	2.1867	1	9	47
Current Length of Service	35.6410	79.1901	1	480	47

Exhibit 7. Results on Other Jobs

Category	Number	Percent to Total	Number of Participants
LBJ	34.00	72%	47
SSJ	8.00	17%	47

The mean value for each construct of turnover and burnout was determined. The mean scores from the questionnaire constructs were calculated from the values obtained from responses to the individual questions. The mean and standard deviations are listed in Exhibit 8.

Exhibit 8. Construct Means and Standard Deviations

Construct	Mean	Std Deviation
Depersonalization (B)	2.55	0.68
Emotional Exhaustion (B)	2.60	0.62
Personal Achievement (B)	3.68	0.57
Goals (T)	3.62	0.67
Comfort (T)	3.34	0.83
Challenges (T)	3.46	0.84
Finances (T)	3.23	0.66
Relationships (T)	3.73	1.11
Resources (T)	3.69	0.82
Promotions (T)	2.94	0.83
Satisfaction (T)	3.60	0.72

Note: These are measured on a 5-point Likert scale with 1 = not very satisfied and 5 = very satisfied and 1 = strongly disagree and 5 = strongly agree.

The result of the regression analysis is shown in Exhibits 9 and 10. The analysis of variance shows that only four variables had a significant effect on cognitive turnover. The p-values indicate that these variables (see Exhibit 10) have a significant effect on CT at an alpha level of 0.10.

The turnover variables Challenges and Promotions and the burnout variables Depersonalization and Personal Achievement were significant in predicting engineer's CT in this study. Most of the job satisfaction constructs were not shown to be significant (Goals, Comfort, Financial Rewards, Relationships with Co-workers, and Resource Adequacy) and only one of the burnout constructs was not significant in predicting CT the dependent variables (Emotional Exhaustion). These constructs had a weak impact on CT for this group.

Exhibit 9. Multiple Regression Results

Variable	DF	Sum of Squares	Mean of Squares	F-Value	Signif F
Regression	4	74.4758	18.6190	5.0037	0.0021
Residual	43	160.0036	3.7210		

Exhibit 10. Final Variables in the CT Index Equation

Variable	B	SE B	Beta	T	Sig T
CHALLENG (T)	1.1986	0.4254	0.4601	2.8170	0.0073
DEPERSON (B)	1.5749	0.5402	0.3766	2.9150	0.0056
PERACHV (B)	-1.7123	0.5884	-0.4099	-2.9100	0.0057
PROMOTIO (T)	-0.9351	0.3776	-0.3673	-2.4770	0.0173
(CONSTANT)	5.1224	2.3958		2.1380	0.0382

Based on these results, the mathematical model for predicting CT for engineers is given by the following equation:

$$F(x) = 1.199(\text{Challenges}) + 1.575(\text{Depersonalization}) - 1.712(\text{Personal achievement}) - 0.935\ (\text{Promotion}) + 5.122 \quad (1)$$

Exhibit 11 summarizes the four variables in the model that were determined to be significant predictors for CT and describes the impact of each on CT.

The function F(x) will be a number between 1 and 10. Scores in the 1-4 range represent low cognitions to leave and generally low burnout indications. Scores in the 5-8 range represent moderate burnout and leaving cognitions. Scores 9 and above represent eCT

Exhibit 11. Description of Relevant Variables

Construct	What It Measures	Type of Effect
Challenges	Feeling that the job is not boring and has reasonable challenges	Direct impact on CT. If you feel the job is too challenging, then you will have a higher CT index score.
Depersonalization	Distancing oneself from others	Has largest direct effect on CT. If you feel that you are not? involved as part of the team, you will have a higher CT index score.
Personal Achievement	Performing well on things that matter	Has largest OPPOSITE effect on CT. This means if you believe you perform well, your CT index score will be lower.
Promotion	Opportunity for fair chance of promotion	Has OPPOSITE effect on CT. If you believe you can be promoted, you will have a lower CT index score.

This may be true in certain instances but the discretionary effort that may be required to make a project or an initiative a true success may not come from outside influences but from internal motivators such as the feeling of importance in an organization. This study demonstrates an organized approach to evaluate and possibly improve these work motivations.

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