Application of an Assessment Model to Engineering Economy for Mechanical Engineering Students

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I.   Abstract

A quantitative engineering program assessment model has been developed and validated at the University of Texas at El Paso (UTEP). The model uses an engineering assessment parameter, called the weighted Tarquin number, which is used to assess the impact of programmatic decisions. The Tarquin number is the average score across all subjects for a particular group of students minus that value from the individual score in the particular subject. The weighted Tarquin number in turn is an average of individual Tarquin numbers for each subject area weighted by the number of students taking the particular Fundamentals of Engineering (FE) Examination. In this research, the assessment methodology is used on a case study involving the performance of mechanical engineering students on the engineering economy section of the FE exam. Correlation analyses indicated that having a formal FE exam review course maybe the most important parameter in mechanical engineering students' performance in the subject of engineering economy on the FE exam.

II.   Introduction

The most significant obstacle facing universities will be developing quantitative measures for assessing engineering programs and tracking the effects of curricular changes.[2,4,5,7] Many of the difficulties result from a lack of available uniform, across institution performance measures. At this time, the only available performance measure taken by a large number of students from many institutions is the FE exam.[1,6,8] UTEP has embarked on an effort to utilize the FE exam for assessment and tracking of engineering programs. This effort has been supported by UTEP's National Science Foundation (NSF)-funded Model Institutions for Excellence (MIE) Program. The following presents the methodology developed for engineering program assessment.

III.   Methodology

A Fundamentals of Engineering Examination national database has been created in order to make meaningful comparisons. A strong argument in support of using the FE exam for assessment purposes is that many of the topics covered in the exam can be traced back to a course or a set of courses. Even though the FE exam may be biased toward mechanical and civil engineering disciplines, the model proposed in the following will have construct validity for programmatic assessment with respect to the subject areas tested in the FE exam, since engineering students from many disciplines are required to take many of the same courses tested

by the FE exam.[6,8] Despite this, to make meaningful comparisons, the model differentiates between students from different disciplines.[3]

Data from 57 universities in 12 states over several years have been input into a relational database from which the meaningful comparisons are made. Different levels of comparisons can be made depending on the information that is desired and how that information may suit the audience.

Performance comparisons can be made using individual subject scores by discipline relative to the discipline-specific national averages. The relative score (RS), based on the national average for each FE subject, is computed per exam for each institution according to the following equation:

$$RS_{ij} = APC_{ij} - NAPC_{ij} \qquad (1)$$

where,

RS = Relative Score

i = FE exam subject (*e.g.*, engineering economy, dynamics, *etc.*)

j = FE exam (*e.g.*, April 1995, October 1995, April 1996, *etc.*)

APC = Average % Correct

NAPC = National Average % Correct

The RS does not account for student population differences between universities. For example, some universities have very high admission standards while others have an open admission policy. Nevertheless, RS information can be used to assess how well the students within engineering departments are performing on the FE exam by individual subject versus the rest of the nation. For this particular study, only mechanical engineering data are used because this group of students represents the largest student population taking the exam.[6]

In order to remove the student population bias between institutions, a measure, called the Tarquin number, is developed to allow institutional subject-specific comparisons. The Tarquin number is computed as follows:

$$TARQUIN_{ij} = \left[\left(APC_{ij} - NAPC_{ij} \right) - \frac{\sum_{k=1}^{n} \left(APC_{kj} - NAPC_{kj} \right)}{n} \right] \qquad (2)$$

where,

n = total number of FE Examination subject areas used in the model and

k = subject area.

As indicated in Equation 2, the Tarquin number effectively removes the student population by calculating the average score across all subjects for a particular group of students and subtracting that value from the individual score in a particular subject. This measure, which is calculated for each institution, provides a basis for comparison of performance in individual subjects relative to the other subjects as measured by the FE exam. For example, a "high" or "low" Tarquin number in an individual subject area can be an indicator for "best" or "worst"

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practices in that subject area at a particular institution. An important assumption is that these Tarquin numbers, which measure performance on an examination for many subjects nationally, are normally distributed.

Since the number of students taking the FE exam during each exam event varies within and between institutions, a weighted Tarquin number is computed as follows:

$$\delta W\_TARQUIN_i = \frac{\sum_{\forall j}\left[\left(APC_{ij} - NAPC_{ij}\right) - \frac{\sum_{k=1}^{n}\left(APC_{kj} - NAPC_{kj}\right)}{n}\right] * NS_j}{\sum_{\forall j} NS_j} \tag{3}$$

and,

$$W\_TARQUIN_i = \delta W\_TARQUIN_i - \frac{\sum_{k=1}^{n} \delta W\_TARQUIN_k}{n} \tag{4}$$

where,

$\delta W\_TARQUIN_i$ = Delta Weighted Tarquin number for FE Examination i

NS = Number of Students

$W\_TARQUIN_i$ = Weighted Tarquin Number for FE Examination i

As can be seen from Equations 3 and 4, the Weighted Tarquin number is a single measure that is an average of individual Tarquin numbers over all exams weighted by the number of students taking a particular exam. Thus, a particularly high or low score with few students will only affect the measure proportional to the number of students taking that exam. The average (over all subjects) of the Delta Weighted Tarquin numbers is non-zero, because the number of students taking individual FE Examinations varies. Thus, the second term on the right-hand-side of Equation 4 subtracts this average, yielding the Weighted Tarquin number for a particular FE Examination ($W\_TARQUIN_i$). In the end, the Weighted Tarquin number has an average over all subjects of zero, which is desired for the model. The utility of the Weighted Tarquin number has been demonstrated by Wicker, Quintana, Tarquin, *et al*.[9]

IV. Results

Institutions identified for analysis in this study have a Weighted Tarquin number for engineering economy as their "best-in-class" performer. In addition, only data pertaining to mechanical engineering students were considered. "Best-in-class" performer is defined as an institution's largest Weighted Tarquin number out of the eight subject areas from the FE exam included in this study. At this time, seven institutions were available from the FE exam database that fit the above definition for "best-in-class" performer in the subject area of engineering economy. It is the intention of this study to identify a plausible explanation for the identified "best-in-class" performance in the subject of engineering economy for the identified institutions.

Upon identification as "best-in-class" performer for engineering economy, the institution's undergraduate mechanical engineering advisor was contacted by telephone and

asked several program-specific questions. While none of the institutions contacted require students to pass the FE exam to graduate, some institutions require students to take the FE exam before graduation. Formal FE exam review course requirements were also sought. Engineering economy is not a required course at many institutions but students are allowed to take the course as a technical elective while at other institutions the subject is covered in a "design" sequence over the course of the junior and senior years. Some engineering economy courses have a mandatory problem-solving laboratory once a week. The department that the course was taught out of as well as the status of the instructor (full or part time and length of time teaching the course) was collected. The instructor was contacted for textbook and syllabus information. The data collected is shown in Table 1. Note that the number one denotes "Yes", the number two denotes "No", "R" denotes required, and "TE" indicates technical elective. Timing describes the approximate time the course engineering economy is taken, with one being the first semester of the freshman year and eight being the second semester of the senior year.

It should be noted that the semester during which engineering economy was taken is not necessarily the same as when the degree plan mandates. The majority of the advisors contacted indicated that the students could have taken the course any time during their junior or senior year. The length of time a given instructor has been teaching the course also contains room for error. While some instructors teach engineering economy every semester, many teach the course sporadically. Consequently, results obtained using the parameters timing and length of time teaching must be studied more closely.

Table 1 - Programmatic Parameter Data Collected

Institution	Weighted Tarquin Number	Timing	Mandatory Problem-Solving Laboratory	Length of Time Teaching Engineering Economy	Required to Take FE Exam	Mandatory FE Exam Review	Engineering Economy Required or Taken as a Technical Elective
A	0.280859	6	2	2	2	2	TE
B	0.794565	6	1	1	2	1	R
C	0.756667	5	2	1	2	2	TE
D	0.550616	3	2	2	2	2	TE
E	0.534282	7	2	1	2	2	R
F	0.367381	8	2	1	1	2	R
G	0.950503	8	2	1	1	1	R

Correlation analyses were performed to determine the strength of association between the Weighted Tarquin number and the programmatic and course-specific information collected. The results of the analyses are shown in Figure 1.
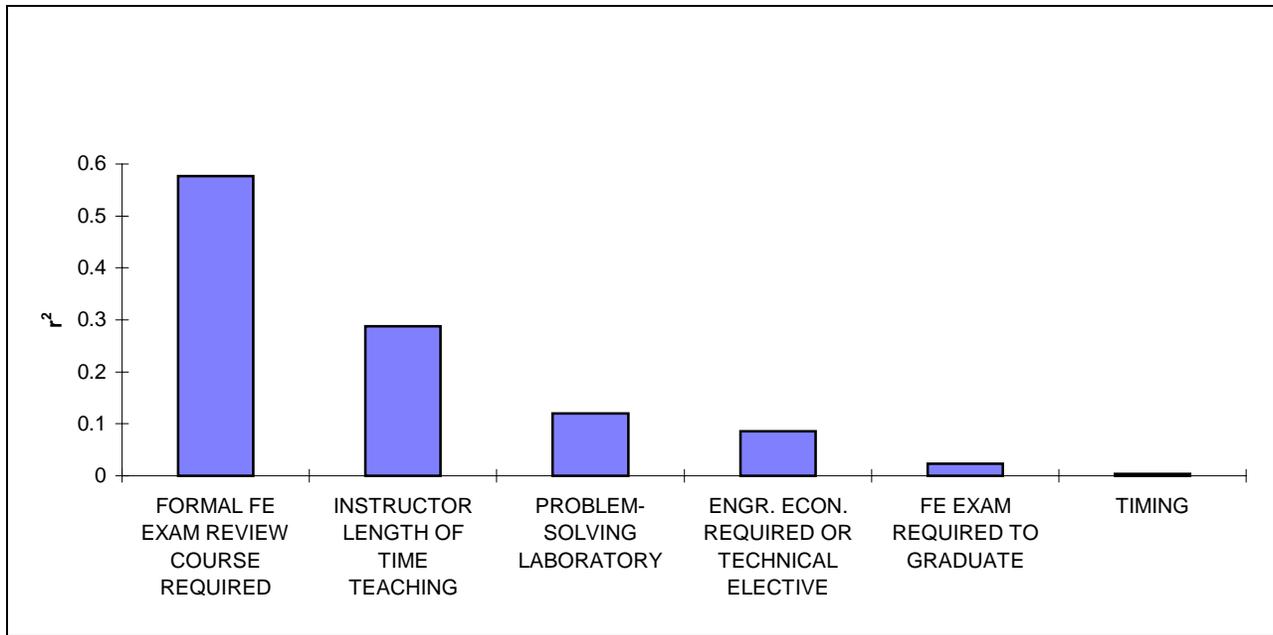
Figure 1 - Correlation Results for Weighted Tarquin Numbers and Programmatic Parameters

The r^2 coefficient is a ratio of the explained variability over the total variability. In this case, it is used to identify the relationship between the variables under study. The highest r^2 value was obtained using the formal FE exam review course parameter. The next highest value obtained was for the variable length of time teaching engineering economy (however, recall the uncertainty associated with this measurement which was discussed earlier.) The rest of the r^2 values indicate a low measure of association. The analyses point to a required FE exam review course as a plausible explanation for the "best-in-class" performance in the subject area of engineering economy of any one of the institutions included in this study.

V.   Conclusions

While many factors are considered to be important to performance on the FE exam in the subject area of engineering economy, the analyses indicate that a required FE exam review course may have the most influence(see discussion under Future Research.) An institution could make programmatic decisions using the results of analyses like the ones gained from this study. For instance, UTEP is considering dropping the one hour class "Senior Professional Orientation," a required FE exam review course, from its degree plan. This study indicates this may not be appropriate with respect to mechanical engineering students' success on the engineering economy portion of the FE exam.

VI.   FUTURE RESEARCH

Acknowledging the fact that only seven institutions were identified for analysis, on-going research is focused on collecting more programmatic and course-specific information (at least thirty institutions) and performing statistical analyses for all subjects and all disciplines. Moreover, a more rigorous study of factors that affect performance on the FE exam is also in progress.

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