Development of a New Freshman Engineering Policy

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Abstract **- Historically, any student admitted to our university could declare an engineering major and enroll in lower division engineering courses. A 2.25 grade point average in lower division STEM courses attempted at our university was required for admission into upper division engineering courses. However, with a 110% increase in enrollment in freshman engineering courses from the 2001-2002 to the 2010-2011 academic year, we need an enrollment management policy that moves identification of at-risk students from the end of the 4th semester to the end of the 2nd semester. Initial multivariate regression analysis of data on students who attempted freshman engineering courses during this time failed to identify predictors of success from data available at the conclusion of the 2nd semester. Before spring 2011 semester began, a pilot risk-factor analysis, based upon empirical evidence, was performed on one section of the 2nd semester freshman engineering course. All students identified as at-risk ultimately failed the course despite multiple outreach attempts and twice-weekly tutoring sessions. Risk-factor analysis was applied to the 1,600 students who enrolled in freshman engineering courses between 2001-2002 through 2010-2011 to enable the crafting of a new engineering admission policy, which will be effective in the 2013-2014 academic year.**

Index Terms – Enrollment management, Retention, SAT/ACT scores, Success indicators.

INTRODUCTION

Enrollment in the freshman engineering courses at Baylor University increased by 110% from the 2001-2002 to the 2010-2011 academic years. The first-semester freshman engineering course is EGR1301 – Introduction to Engineering, and the second-semester course is EGR1302 – Introduction to Engineering Analysis. Historically, there have been no additional entrance requirements, beyond acceptance to the university, for declaring an engineering major and enrolling in lower division (*i.e.*, freshman- and sophomore-level) engineering courses. In order to enroll in upper division (*i.e.*, junior- and senior-level) engineering courses, students were granted upper division admission provided that they earned a minimum 2.25 grade point average in all required freshman- and sophomore-level STEM courses attempted at Baylor. As the size of our incoming classes grew, faculty recognized the need to identify at-risk students earlier in the curriculum so that these students could be encouraged to seek a major that was a better fit for their talents and interests and to achieve greater retention of these students to graduation from our university.

The purpose of this study was to identify indicators of success from data generated prior to enrollment (*e.g.*, SAT/ACT scores) and during the first 2 semesters as engineering students. Are SAT/ACT scores correlated with success as an engineering student? If so, what is an appropriate minimum SAT/ACT score for admission to our engineering programs? What courses taken in the first 2 semesters are indicators of success for an engineering student?

Literature Review

Devens and Walker studied the relationship between SAT and in-house math exams as an indicator of success in the first-semester engineering course [1]. Although composite SAT (*i.e.*, sum of critical reading and math) score was found to be a poor predictor of success, they also stated that students with a composite SAT > 1300 had a high probability and students with a composite SAT < 1000 had a low probability of passing their first-semester engineering course. Data was presented topographically with no regression analysis to support their claims. The authors stated that their university used a minimum composite SAT score of 1000 for entry into an engineering program but that SAT scores were "not a reliable predictor" of student grades in their first engineering course [1].

Abdel-Salam *et al* studied SAT and high school GPA as indicators of success in the freshman year [2]. The authors reported a minimum composite SAT score of 1100 for entry into the engineering programs, but no statistical analysis was provided to justify the choice of minimum SAT score. Regression analysis of composite SAT versus high school GPA was used to report "a weak linear relationship" between the two variables; however, no statistical analysis was performed to support the claim that either composite SAT or high school GPA correlated with freshman engineering course grades [2].

Padilla *et al* studied data from nine universities and found that composite SAT scores correlated with cumulative GPA more strongly for engineering graduates at urban and/or research universities than at suburban universities [3]; however, no comparison was made with students who attempted engineering but were unsuccessful.

There is considerable discussion in the literature regarding SAT scores as predictors of success in engineering programs with some researchers concluding that composite SAT scores [4-6] or math SAT scores [7-9] are significant predictors of success while others find that any positive correlation between SAT and success is weak at best [1-2, 10-12].

Previous Analyses

In 2010 multivariate regression analysis was performed on all students who had enrolled in EGR1301 and/or EGR1302 from the 2001-2002 to the 2010-2011 academic years. Variables included gender, race, first semester attending Baylor, an indicator that identified students as transfers or incoming freshmen, composite SAT/ACT scores, math SAT/ACT scores, high school ranking, last major, overall GPA, and degree earned (if the student had graduated). The results of this analysis failed to identify predictors of success from data that was available prior to enrollment or generated by all students during their first 2 semesters at Baylor. Although Calculus 1 grade was significantly and positively correlated with GPA, fewer than one-half of our engineering students enroll in Calculus 1 in their first semester. Thus the use of Calculus 1 grades alone could not be applied to all engineering students as a requirement for engineering program admission.

My experiences in teaching EGR1301 for five semesters and EGR1302 for three semesters provided me with an intuitive feel for what measures might be used to predict success in our engineering programs. Prior to the start of the spring 2011 semester, I performed a risk-factor analysis on the students who were enrolled in my section of EGR1302. A value of one was added to a risk-factor counter if any of the following were true: 1) the student's composite SAT score was less than 1100 or composite ACT was less than 24; 2) the student earned less than a B in EGR1301; and 3) the student earned less than a C in the first math course attempted at Baylor. Students with 2 or 3 risk factors were considered at risk of failing the course, and I targeted them with repeated outreach attempts and the offer of twice-weekly tutoring sessions. Despite my attempts to help these at-risk students succeed, all earned a failing grade in the course.

The objective of the current study was to analyze SAT/ACT scores, first-year math grades, and first-year engineering course grades in order to determine what combination of factors would be most appropriate to replace our upper division admission policy with a freshman engineering admission policy and an engineering program admission policy to be applied after the student's 2nd semester.

METHODS

All students who attempted EGR1301 and/or EGR1302 from the 2001-2002 through the 2010-2011 academic years were included in this analysis. Also included in this analysis were transfer students whose first engineering course was at a more advanced level. Data was provided by Institutional Research and Testing. A total of 1,600 students were identified and grouped into eight categories:

- **Engineering Graduates:** Students who graduated from our university with an engineering degree.
- **Engineering Current:** Students in good academic standing (*i.e.*, GPA $\geq$ 2.0) with engineering as their declared major.
- **Engineering Probation:** Students on academic probation (*i.e.*, GPA < 2.0) with engineering as their declared major.
- **Engineering Left:** Students with engineering as their declared major who left our university without completing their degree.
- **Other Graduates:** Students who took EGR1301 and/or EGR1302 but who graduated from our university with a degree other than engineering.
- **Other Current:** Students in good academic standing who took EGR1301 and/or EGR1302 but who have a current major other than engineering.
- **Other Probation:** Students on academic probation who took EGR1301 and/or EGR1302 but who have a current major other than engineering.
- **Other Left:** Students with a declared major other than engineering who took EGR1301 and/or EGR1302 and who left the university without completing a degree.

The eight categories were collapsed into two. Engineering Graduates and Engineering Current were placed into a Successful category, and all others were placed into an Unsuccessful category. The Successful term merely denotes those students who were retained in engineering majors and who either earned an engineering degree or who continue to pursue their engineering degree in good academic standing.

SAT/ACT Scores

For a number of years, there has been an ongoing discussion among our engineering faculty and the administration of the School of Engineering and Computer Science regarding whether or not to apply a minimum SAT/ACT score as a requirement for incoming students wishing to declare engineering as their major. Further, there was additional discussion regarding what the minimum score should be. Some advocated that the composite score be used, and some wanted to use just the math component of the scores. However, there had been no statistical analysis performed to identify the appropriate score to use for admission into the engineering programs. Further, the analysis performed in 2010 had not identified either the math SAT/ACT or the composite SAT/ACT as one of the variables that positively correlated with GPA, which was used as an indicator of success in the engineering curriculum. Additionally, although there are publications describing the use of a minimum SAT and/or ACT score for admission into an engineering program, none of these provide statistical analysis to support the choice of the minimum score [1-2, 13-14].

With a statistician consultant, analysis was performed using SAS (SAS Institute, Cary, NC) in order to identify the composite SAT score, critical reading SAT score, and math SAT score above which 90% of all successful engineering students scored. For simplicity of analysis, all ACT scores were converted to equivalent SAT scores using concordance tables [15-16]. Using the Capability procedure in SAS, one-sided tolerance intervals at the 95% confidence level were calculated using data only from successful engineering students for math, critical reading, and composite SAT scores. According to the NIST e-Handbook of Statistical Methods, one-sided tolerance intervals can be used to calculate a confidence interval that "guarantees that *p* percent of population measurements will not fall below a lower limit"[17].

Freshman Engineering Course Series

To visually verify that my preliminary risk-factor analysis could serve to identify successful engineering students within their first 2 semesters, histograms were generated by letter grade for EGR1301 and EGR1302.

Math Course Series

Incoming engineering students at our university do not take a common first-semester math course; thus, it is not possible to rely upon a student's grade in a single math course (*e.g.*, Calculus 1) to identify successful engineering students within their first 2 semesters. There are four math courses commonly taken in the 1st semester: Pre-Calculus, Calculus 1, Calculus 2, and Calculus 3. A histogram was generated to ascertain what percentage of incoming engineering students enrolled in each of these four math course in their first semester at our university. Histograms were then generated for each individual math course. Note that the histogram for each course covers only a fraction of the total 1,600 students.

Selection of Optimum Admission Criteria

From the results of the preliminary analysis, a set of candidate admission critieria were selected. We needed to select admissions criteria that would minimize the number of successful students who would be prevented from enrolling in the engineering programs and to maximize the number of unsuccessful students who would be screened out after their first 2 semesters. The candidate criteria that were tested included:

- **SAT/ACT scores:** 1) minimum math SAT of 600 or math ACT of 26; 2) minimum critical reading SAT of 500 or ACT reading of 22; and 3) composite SAT of 1100 or composite ACT of 24.
- **Freshman engineering course series:** 1) minimum EGR1301 letter grade of B; 2) minimum EGR1302 letter grade of B; and 3) minimum average of EGR1301 and EGR1302 letter grades of B.
- **Math course series:** 1) minimum first semester math letter grade of C; 2) minimum average of first two semester math grades of C.

With our statistician consultant, logistic regression with stepwise variable selection was performed to identify the optimum set of admission criteria.

RESULTS & DISCUSSION

The numbers of students in each category are presented in Table I.

TABLE I
NUMBERS OF STUDENTS BY CATEGORY

Category	Number of Students
Engineering Graduates	381
Engineering Current	399
Engineering Probation	33
Engineering Left BU	281
Other Graduates	198
Other Current	163
Other Probation	14
Other Left BU	131

The numbers of students in the Successful and Unsuccessful categories are presented in Figure 1. Successful students make up 48.8% of the population. Please note that this is not retention to graduation because slightly more than half of these students are currently enrolled.

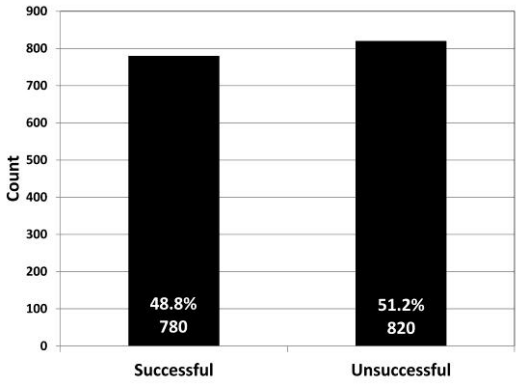

FIGURE 1
STUDENT POPULATION BY CATEGORY

SAT/ACT Scores

Results of the one-sided tolerance interval analysis are presented in Table II.

TABLE II
ONE-SIDED LOWER STATISTICAL INTERVALS ON SUCCESSFUL ENGINEERING STUDENTS, ASSUMING NORMALITY

Confidence Limit	p-value	Lower Limit		
		Math SAT	Critical Reading SAT	Composite SAT
95%	0.90	588.1	489.3	1105.6
	0.95	564.4	456.9	1057.3
	0.99	519.9	396.0	966.5

The 95% one-sided confidence level for the scores above which 90% (p-value = 0.90) of successful engineering students scored is 588.1 for the math SAT, 489.3 for the critical reading SAT, and 1105.6 for the composite SAT. For the sake of comparison, the scores above which 95% (p-value = 0.95) and 99% (p-value = 0.99) of successful

engineers scored are provided. Because one of our goals is to control growth in undergraduate enrollment, 90% values were chosen. For ease of administration, these values were rounded to the nearest 100, giving a math SAT of 600, critical reading SAT of 500, and a composite SAT score of 1100.

Freshman Engineering Course Series

The histogram for EGR1301 is presented in Figure 2. Of the 780 successful students, 675 (86.5%) earned a grade of B or better in EGR1301. Of the 820 unsuccessful students, 418 (51.0%) earned a grade of B or better. The designation of "N/A" for letter grade includes transfer students who did not take that course plus students who either dropped or withdrew from the course prior to completion.

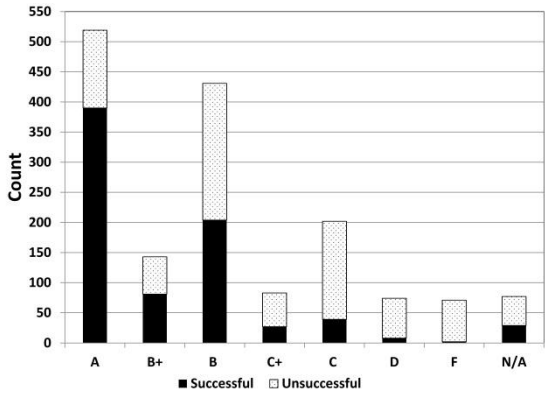

FIGURE 2
EGR1301 GRADES IN 2001-2002 THROUGH 2010-2011

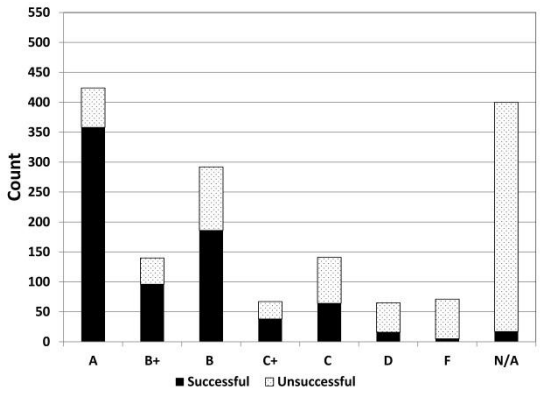

FIGURE 3
EGR1302 GRADES IN 2001-2002 THROUGH 2010-2011

The histogram for EGR1302 is presented in Figure 3. Of the 780 successful students, 640 (82.1%) earned a grade of B or better. Of the 820 unsuccessful students, 216 (26.3%) earned a grade of B or better, and this is a dramatic drop from the first to the second semester. The number of unsuccessful students in the N/A category increased dramatically from EGR1301 to EGR1302. This category includes students who changed their major or left the university after taking EGR1301.

Math Course Series

A histogram of incoming engineering students enrolled in each of the four math courses in their first semester at Baylor is presented in Figure 4.

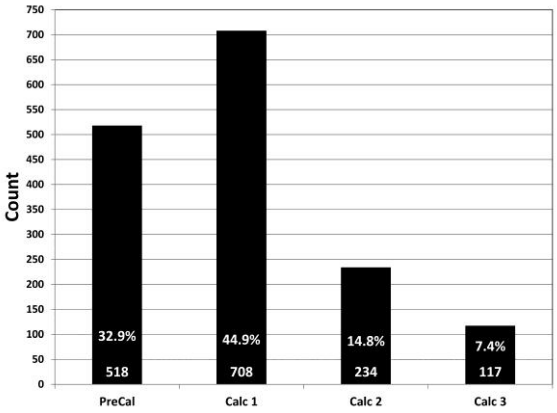

FIGURE 4
FIRST-SEMESTER MATH COURSES TAKEN BY INCOMING ENGINEERING STUDENTS IN 2001-2002 THROUGH 2010-2011

The most surprising finding was that fewer than half (44.9%) of first-semester engineering students enrolled in Calculus 1. Approximately one-third (32.9%) of incoming engineering students at Baylor enrolled in Pre-Calculus. The remaining 22.2% enrolled in either Calculus 2 or Calculus 3. A large number of our students arrive with either AP credit or dual credit for Calculus 1 and/or Calculus 2. Prior to this study, we had not analyzed how incoming engineering students performed in their first-semester math courses.

- **Pre-Calculus (Figure 5):** Of the 780 successful students, 152 (19.5%) earned a grade of C or better in Pre-Calculus. These 152 students make up 29.3% of the 518 engineering students who took Pre-Calculus as their first math class. Of the 820 unsuccessful students, 245 (29.9%) earned a grade of C or better. These 245 students make up 47.3% of the 518 engineering students who took Pre-Calculus as their first class. Most of the students who earn a B+ or better in Pre-Calculus are successful, and most of the students who earn a B or below are unsuccessful in the pursuit of an engineering degree. While the faculty would like to see freshmen engineering students ready for Calculus 1 when they begin their college careers, we are unwilling to prevent such a large number of potential engineers from pursuing this course of study. However, it is very clear from Figure 5 that most of the students who earn a B or below in Pre-Calculus are unsuccessful in their pursuit of an engineering degree. It might be helpful to include a requirement in the future that engineering students who enroll in Pre-Calculus must earn a B in order to enroll in EGR1302.
- **Calculus 1 (Figure 6):** Of the 780 successful students, 371 (47.6%) earned a grade of C or better in Pre-Calculus. These 371 students make up 52.4% of the

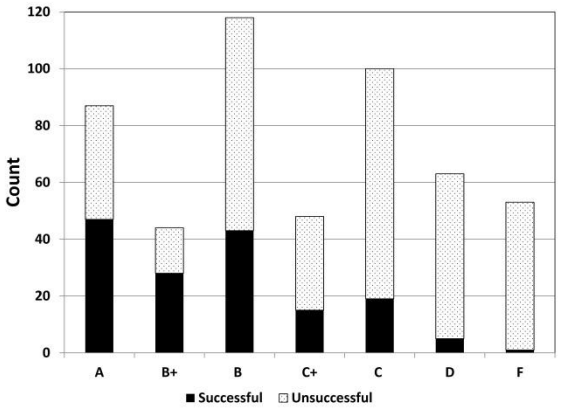

FIGURE 5
GRADES EARNED IN FIRST-SEMESTER MATH COURSE - PRE-CALCULUS
2001-2002 THROUGH 2010-2011

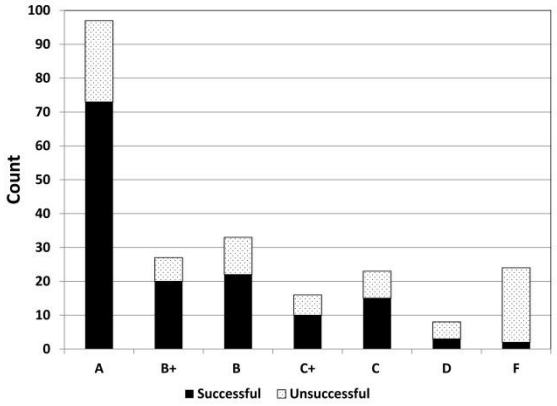

FIGURE 7
GRADES EARNED IN FIRST-SEMESTER MATH COURSE - CALCULUS 2
2001-2002 THROUGH 2010-2011

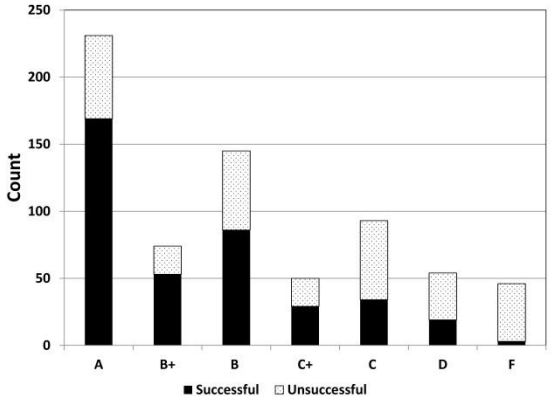

FIGURE 6
GRADES EARNED IN FIRST-SEMESTER MATH COURSE - CALCULUS 1
2001-2002 THROUGH 2010-2011

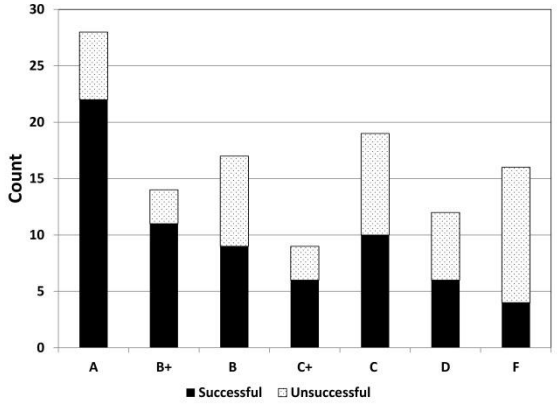

FIGURE 8
GRADES EARNED IN FIRST-SEMESTER MATH COURSE – CALCULUS 3
2001-2002 THROUGH 2010-2011

708 engineering students who took Calculus 1 as their first math class. Of the 820 unsuccessful students, 222 (27.1%) earned a grade of C or better. These 222 students make up 31.4% of the 708 engineering students who took Calculus 1 as their first class.

- **Calculus 2 (Figure 7):** Of the 780 successful students, 140 (17.9%) earned a grade of C or better in Calculus 2. These 140 students make up 59.8% of the 234 engineering students who took Calculus 2 as their first math class. Of the 820 unsuccessful students, 56 (6.8%) earned a grade of C or better. These 56 students make up 23.9% of the 234 engineering students who took Calculus 2 as their first math class. Incoming engineering students who enroll in Calculus 2 in their first semester at Baylor include the highest percentage of successful engineering students among the 4 math courses that engineering students commonly take in their first semester at Baylor. Students in this category include transfer students and incoming freshmen with AP credit for Calculus 1.
- **Calculus 3 (Figure 8):** Of the 780 successful students, 58 (7.4%) earned a grade of C or better in Calculus 3. These 58 students make up 24.8% of the 117 engineering students who took Calculus 3 as their first math class. Of the 820 unsuccessful students, 29 (3.5%) earned a grade of C or better. These 29 students make up 24.8% of the 117 engineering students who took Calculus 3 as their first class. Students in this category included transfer students, students with dual credit, and incoming freshmen with AP credit for both Calculus 1 and Calculus 2. Students with AP credit for Calculus may be viewed as individuals with a high level of motivation and preparation for pursuit of a college degree. An alarming number (23.9%) of these students earned a grade of D or F and were required to repeat Calculus 3 before proceeding on in the math course series. This was the most unexpected finding in this study. The majority of students who enrolled in Calculus 3 in their first semester at Baylor and who earned a D or F are ultimately unsuccessful in their pursuit of an engineering degree. In our desire to ensure that these student have the best opportunity to succeed, engineering faculty who serve as academic advisers during summer Freshman Orientation began in Summer 2011 to strongly recommend that students with AP

credit for both Calculus 1 and Calculus 2 forfeit their Calculus 2 credit and begin with Calculus 2 as their first math course rather than Calculus 3. We hope to provide an easier transition to college for these students and to increase the probability of retaining them as successful engineering students.

The Department of Mathematics has a long-standing policy that a student must earn a C or better in any math course before they are allowed to enroll in the following math course. From a visual assessment of Figures 5-8, it is clear that the C or better policy is an appropriate one.

Selection of Optimum Admission Criteria

From the logistic regression, the optimum set of admission criteria included the average of EGR1301 and EGR1302 letter grades ($p < 0.0001$), the average of the first two semester math course grades ($p < 0.0001$), and the composite SAT score ($p = 0.0282$). Of note is that the weakest correlations were with respect to SAT scores. Grades earned in the first two semesters in engineering and math courses are more strongly correlated with success in engineering.

Upon presentation of these results, the engineering faculty agreed to the following engineering admission policy, to be effective with the 2013-2014 catalog:

- Incoming students declare "First Year Engineering" as their major.
- Incoming freshmen must earn a composite SAT score ≥ 1100 or composite ACT ≥ 24 in order to enroll in EGR1301.
- Students may declare their chosen engineering major at the end of their first 2 semesters if they meet the following requirements:
  - Composite SAT ≥ 1100 or composite ACT ≥ 24.
  - Average grade of B or better for EGR1301 and EGR1302.
  - Average grade of C or better in first 2 math courses (i.e., PreCalculus, Calculus 1, Calculus 2, or Calculus 3) attempted at Baylor.

FUTURE WORK

A large number of engineering students in good academic standing chose to leave the university. We plan to develop a survey instrument designed to determine why these promising engineering students chose to leave Baylor.

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