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The Prediction of Academic Success in the University of New Mexico College of Engineering from Data Available During the Students' First Semester of Enrollment

John J. Wittich

WITTICH

ACADEMIC SUCCESS IN THE UNIVERSITY OF NEW MEXICO COLLEGE OF ENGINEERING

THE PREDICTION OF ACADEMIC SUCCESS IN THE UNIVERSITY OF NEW MEXICO COLLEGE OF ENGINEERING FROM DATA AVAILABLE DURING THE STUDENTS' FIRST SEMESTER OF ENROLLMENT

By

John J. Wittich

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Thesis committee

B. M. Crawford
CHAIRMAN

E. H. Tilley

L. P. Manninga

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CHAPTER I

THE PROBLEM

In the past, when virtually all schools at the secondary level were college preparatory in purpose, there were few serious problems arising because of a lack of objective criteria to use in determining which students should enroll in institutions of higher learning. Today, however, secondary schools attempt to diversify their curricula in order to fit the student for various fields of life work while at the same time retaining as one of their purposes that of preparing for higher education. This expansion of curricula and goals for secondary education accentuates the problem of predicting the degree to which pupils leaving the high school will do successful work at the college level. The making of final recommendations for the acceptance or the rejection of high-school graduates for admission to college is primarily the responsibility of the high-school principal. The solution of the problem that confronts these administrators depends upon the derivation of valid measures or criteria by which success in college can be forecast.

Statement of the problem. The purpose of this investigation is to determine with what degree of certainty

CHAPTER I

THE PROBLEM

In the past, when virtually all secondary or the secondary level were college preparatory in purpose, there were few serious problems arising because of a lack of objective criteria to use in determining which students should enroll in institutions of higher learning. Today, however, secondary schools attempt to diversify their curricula in order to fit the student for various fields of life work while at the same time retaining as one of their purposes that of preparing for higher education. This expansion of curricula and goals for secondary education accentuates the problem of predicting the degree to which pupils leaving the high school will do successful work at the college level. The making of final recommendations for the acceptance or the rejection of high-school graduates for admission to college is primarily the responsibility of the high-school principal. The solution of the problem that confronts these administrators depends upon the derivation of valid measures or criteria by which success in college can be forecast.

Statement of the problem. The purpose of this investigation is to determine with what degree of certainty

the achievement of freshmen in the College of Engineering at the University of New Mexico can be predicted from an analysis of data available during their first semester of enrollment in college. These data are (1) high-school achievement as indicated by teachers' marks over a four-year period; (2) scores made on a battery of psychological and achievement tests administered at the time of enrollment in the university; and (3) college success attained in the first semester as indicated by semester marks.

Importance of the study. It has been implied that the high-school principal should desire to have access to all possible information which will assist him to render more valid educational guidance to the college-preparatory student. For the purpose of making recommendations to colleges, facts concerning the relative value of high-school marks in contrast to even rough guesses of probable success should be of concern; however, information obtained at the time of college entrance or orientation week may be found to be much more pertinent and reliable. If the additional data obtained by the university test battery materially improves the basis for college recommendations, the implication for high-school principals is obvious. The college test battery should first be administered to prospective engineering students in the high schools.

Although numerous prognosis studies concerning

college success have been made in the past, there have been no recent investigations of this nature at the University of New Mexico. This status of past research is especially true as it pertains to engineering freshmen. Furthermore, since the particular test battery utilized in this study has not been thoroughly examined, it is important that an investigation of its value be made for measuring success to be attained in college.

Limitations of the study. The prognosis of college success is such a broad problem that achievement in any one of several colleges or departments would be of sufficient scope to warrant a separate study. The College of Engineering was chosen for investigation by the writer because a more extensive test battery is administered by the university Bureau of Counseling and Testing to freshman engineering students than to freshmen in other colleges. Thus, the availability of sufficient data needed for careful analysis necessarily limited this study to prediction for this particular college.

Organization of the remainder of the thesis. The remainder of the thesis is divided into four chapters, the Bibliography, and the Appendix. Chapter II is concerned with the review of the related literature; Chapter III with the method of conducting the investigation;

Chapter IV with an analysis of the data; Chapter V with conclusions and recommendations; the Bibliography with the articles, books, and monographs studied, and the Appendix with the computation of a multiple coefficient of correlation and the development of a six-variable regression equation.

CHAPTER II

REVIEW OF RELATED LITERATURE

Because of the considerable volume of published and unpublished investigations concerning the prognostic value of such factors as high-school marks and intelligence and achievement tests, the writer will present only the findings which he considers to be the most pertinent. Conclusions derived from earlier investigations that are summarized in more recent literature will not be presented. The persistency with which the prediction of college success has been investigated is evidence that the problem is an important one.

Literature on the reliability of high-school marks and the American Council on Education Psychological Tests. Easley[1] states that the reliability coefficient of the American Council on Education Psychological Tests (1930 edition), as determined by Thurstone, is .95 and consequently the low predictive efficiency which it manifests cannot be due in any large measure to lack of reliability. After deriving a coefficient of correlation of .510 between high-school marks and intelligence, Easley maintains that

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[1] Howard Easley, "On the Limits of Predicting Scholastic Success," Journal of Experimental Education, 1:272-76, March, 1933.

the low correlation between the two variables is primarily due to a fundamental lack of relationship, rather than to the unreliability of school marks. This was true not only when marks for a single semester were used but to an even greater degree for marks attained over a two-year period. He further states that such results indicate that simply increasing the reliability of school marks will have practically no effect upon their correlation with intelligence test scores. Easley concludes:

> While increasing the reliability would be expected to increase the correlation with test scores, in this case other factors were inevitably introduced which tend to lower the correlation, and the net result is that it remains approximately constant. This relation obviously could not hold for extremely low reliabilities, but teachers' marks would not have to have a reliability of above .30 to make possible a correlation with test scores as high as is usually found.[2]

Heston,[3] on the other hand, presents a divergent and popular, but undocumented, view of the reliability of marks when he states:

> When the guesses of different instructors are combined to derive an average (hour-point ratio, grade-point average, etc.) we have much the same result as though we added apples and pears, multiplied the sum by doorknobs, and divided by peanuts. The result is

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[2] Ibid., p. 274.

[3] Joseph C. Heston, "The Graduate Record Examination vs. Other Measures of Aptitude and Achievement," Educational and Psychological Measurement, 7:618-30, No. 3, Autumn, 1947.

the low correlation between the two variables is primarily due to a fundamental lack of relationship, rather than to the unreliability of point marks. This was true not only when marks for a single semester were used, but to an even greater degree for marks averaged over a two-year period. He further states that such results indicate that by increasing the reliability of second marks, it is practically no effort upon their correlation with intelligence test scores. Mainly complicated.

> While increasing the reliability could be expected to increase the correlation with test scores, in this case other factors were temporarily neutralized which tend to lower the correlation, and the net result is that it remains approximately constant. This relation obviously could not hold for extremely low reliabilities, but teachers' marks would seem to have a reliability of above .80 to make measurable a correlation with test scores as high as is usually found.[2]

Eaton,[3] on the other hand, presents a strong and popular, but undocumented, view of the reliability of marks when he states:

> When the results of different instructors are combined to derive an average (hour-point ratio, grade-point average, etc.), we have much the same result as though we added angles and lengths, multiplied the sum by doorknobs, and divided by pennants. The result is

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[2] Ibid., p. 27.

[3] Joseph C. Eaton, "The Graduate Record Examination vs. Other Measures of Aptitude and Achievement," Educational and Psychological Measurement (7:379-387) No. 3, Autumn, 1947.

arithmetical truth but psychological nonsense.[4]

In 1933 Watts[5] attempted to reweight the various subtests of the American Council on Education Psychological Test (1927 edition) to determine whether they could be made to predict accurately scholastic success for three different college groups, namely, agricultural, engineering and general. After determining the reliability coefficient of .904 for the test, and after studying the results obtained from intercorrelations of the scores made on the subtests (completion, artificial language, analogies, arithmetic, and opposites) by 401 first-year students at the Alabama Polytechnic Institute, Watts concluded:

> There is not a sufficient difference in the weight of a given subtest for the different groups, Agricultural, Engineering and General, to warrant differential prediction of scholastic success in college on the basis of the psychological examination of the ACE.[6]

Literature on the relation of high-school marks and college success. In 1930 Stoddard[7] made the general statement

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[4] Ibid., p. 620.

[5] J. V. Watts, "The Differential Predictive Value of the Psychological Examination of the American Council on Education," Journal of Experimental Education, 1:264-71, 1933.

[6] Ibid., p. 271.

[7] George D. Stoddard, "Quantitative Measurement in Inducting the Student into the Institution of Higher Learning and Predicting His Academic Success," Eighteenth Yearbook of the National Society of College Teachers of Education, Chapter IV, 1930, pp. 80-120.

that correlations between high-school and first-semester college marks will tend to center about .40, "although it appears likely that improvements in examination methods may raise this figure somewhat."[8] Stoddard's broad statement does not seem to be accurate even as a generalization, as the following summaries may illustrate.

Pettit,[9] one of the earliest investigators to make a study in this field, computed a correlation coefficient of .63 between averages of high-school and freshman marks at Columbia University.

In the same year Smith[10] derived a correlation coefficient of .53 between high-school and college marks at the University of Iowa.

Using data concerning students graduating from New York State College for Teachers in 1921, 1922, and 1923, Gilkey[11] obtained a coefficient of correlation of .498 between the averages of marks made in high school and marks received in college. This coefficient was greater than any

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[8] Ibid., p. 102.

[9] Walter W. Pettit, "A Comparative Study of New York High Schools and Columbia College Grades," (unpublished Master's thesis, Teachers College, Columbia University, 1912).

[10] F. O. Smith, A National Basis for Determining Fitness for College Entrance (Studies in Education, No. 31. Iowa City: University of Iowa, 1912), p. 58.

[11] Royal Gilkey, "Relation of Success in Certain Subjects in High School to Success in the Same Subjects in College," School Review, 37:576-588, October, 1929.

that correlations between high-school and first-semester college marks will tend to weaker areas. Although it appears likely that improvements in admission methods may raise this figure somewhat,[8] Stoddard's broad statement does not seem to be accurate even as a generalization as the following summaries may indicate.

Pettit,[9] one of the earliest investigators to make a study in this field, computed a correlation coefficient of .63 between averages of high-school and freshman marks at Columbia University.

In the same year Smith[10] derived a correlation coefficient of .33 between high-school and college marks at the University of Iowa.

Using data concerning students graduating from New York State College for Teachers in 1921, 1922, and 1923, Olney[11] obtained a coefficient of correlation of .49 between the averages of marks made in high school and marks received in college. This coefficient was greater than his

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[8] Ibid., p. 192.

[9] Walter W. Pettit, "A Comparative Study of One Year High School and Collegiate Courses," Unpublished Master's thesis, Teachers College, Columbia University, 1921.

[10] W. G. Smith, A National Basis for Determining Fitness for College Entrance (Studies in Sciences, No. 3; Iowa City: University of Iowa, 1923), p. 34.

[11] Royal Olney, "Relation of Success in Subjects in High School to Success in the Same Subjects in College," School Review, XXIX:583, October, 1921.

computed between marks attained in specific subjects taken in both high school and college. The correlation coefficient between high-school English marks and college marks was only slightly lower at .481. He concluded that a student's performance in high-school English is a reliable indication of his intelligence as well as being a good subject upon which to rely for prediction of college success.

Pierson[12] attempted to discover the pattern of subjects taken and the marks attained in both high school and the first year of college that would provide the most efficient index for prediction of scholastic success in the engineering curricula. Studying 463 pre-war graduates of the School of Engineering at the University of Utah for the period 1932-1941, he found that the combined grade-point ratio attained in all high-school subjects was more closely related to general scholarship in engineering than the marks assigned in any high-school subject matter area. Furthermore, he found that general scholarship in engineering could be predicted as efficiently from the total high-school grade-point ratio as from marks earned in English, mathematics, physics, and chemistry combined in a multiple regression equation. The zero-order coefficient of

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12 G. A. Pierson, "School Marks and Success in Engineering," Educational and Psychological Measurement, 7:612-17, No. 3, Autumn, 1947.

correlation between marks made in all high-school subjects and marks made in college engineering proved to be .58. The coefficient of multiple correlation (between high-school marks in English, mathematics, physics, and chemistry in combination) and marks made in college engineering was found to be only .52. The marks earned in high-school English were discovered to be as closely related to general achievement in engineering as marks earned in mathematics or science. High-school marks in both mechanical drawing and mechanical arts were found to have little or no relationship to the engineering grade-point ratio. Pierson concluded "that students should be guided in terms of their general scholastic achievement rather than in terms of marks earned in any particular high-school or college subject."[13]

Literature on the relation of combinations of high-school marks and test results to college success. Johnson[14] converted the rank which 1,088 high-school seniors attained in their classes to percentile ranks. Psychological test scores were also converted to percentile ranks and the two were averaged to form combined ratings for each senior. These combined ratings were labeled "CR" ratings. The

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[13] Ibid., p. 617.

[14] J. B. Johnson, "Predicting College Success for the High-School Senior," The Vocational Guidance Magazine, 6:289-94, April, 1928.

correlation between marks made in all high-school subjects and marks made in college engineering proved to be .55.[13] The coefficient of multiple correlation (between high-school marks in English, mathematics, physics, and chemistry and combination) and marks made in college math weighing the four found to be only .72. The marks earned in high-school English were discovered to be so slightly related to general achievement in engineering as marks earned in another field or science. High-school marks in pure mathematics, drawing and mechanical arts were found to have little or no relationship to the engineering grade-point ratio. Therefore, concluded "that students should be guided in terms of their general scholastic achievement rather than in terms of marks earned in any particular high-school or college subject."[14]

Literature on the relation of non-academic high-school marks and best results in college appears. Johnson converted the rank within 1,000 high-school graduates attained in their classes in personality rank. Freshmen intelligence scores were also converted to percentile ranks. These ranks were averaged to form a combined ranking for each student. These combined rankings were labeled "new ranks." The

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[13] Ibid., p. 612.

[14] L. E. Johnson, "Predicting College Success for the High-School Senior," The Vocational Guidance Magazine, 6:239-34, April, 1928.

investigator predicted that girls whose CR was twenty-five or less, and boys whose CR was thirty-five or less, would not secure the required satisfactory standing of "C" in their college studies. As a result, a certain 208 students were predicted to fall below a "C" average. Of these 208 only three secured the "C" standing. Johnson maintained:

> This method identifies in advance more than one-half of those who are unable to do college work. These are equal to about twenty per cent of the class and comprise three hundred to four hundred students in a large state university. Of the forty per cent who stand lowest in the combined ratings, only one-tenth make satisfactory records in college.[15]

In 1932 Crawford and Burnham[16] found after studying four freshman classes at Yale University (3,277 students in all) that secondary school marks correlated .57 with first year university marks while scores made on the College Board Examinations correlated only .47 with the same criterion.

Garrett[17] made a study involving the records of two hundred students who graduated from the same high school and who subsequently attended fifty-two colleges. He found that scores made on the Ohio State Psychological Examination

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[15] Ibid., p. 293.

[16] A. B. Crawford and P. S. Burnham, "Entrance Examinations and College Achievement," School and Society, 36:344-52, September 10, 1932.

[17] Wiley S. Garrett, "The Ohio State Psychological Examinations," Occupations, 22:489-95, May, 1944.

and college marks attained correlated .608 with each other. The correlation coefficient between college and high-school marks attained was .665. Since the coefficient of correlation derived between the psychological test scores and the high-school grade-point average was .709, Garrett concluded that the Ohio State Psychological Examination is a reliable guide for predicting college marks, but the high-school grade-point average, representing four years of study, is better.

Cohen[18] prepared his data by subtracting high-school averages from the certification grades of the various high schools. He stated:

> Analysis showed that the average of the high-school mathematics and science (chemistry and/or physics) marks minus the corrected certification grade correlated .51 with first semester Tech marks and .57 with the final aptitude test battery which, as noted above, consisted of mathematics and science achievement tests and a spatial relations test. This low correlation might indicate that math and science high-school grades, at least as corrected by this study, are determined by factors other than ability and achievement, and the rather large correlation with college marks might indicate that those intangible factors of personality, studiousness, etc. necessary for success in college are measured by these corrected high-school marks.[19]

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[18] Leonard L. Cohen, "Predicting Academic Success in Engineering College and Suggestions for an Objective Evaluation of High-School Marks," Journal of Educational Psychology, 37:381-384, September, 1946.

[19] Ibid., p. 383.

CHAPTER III

METHOD OF CONDUCTING THE INVESTIGATION

For the purpose of greater clarity this chapter is divided into two sections, of which one describes the sources and method of collecting the data and the other is devoted to a definition of the terms used.

I. SOURCES OF THE DATA

The raw data upon which this study is based were recorded from three university sources: (1) the office of the College of Engineering, (2) the office of the Registrar, and (3) The Bureau of Counseling and Testing.

The names of 120 first-semester freshmen in the College of Engineering in the fall of 1947 were selected at random from the class rolls of the required beginning course, "Introduction to Engineering."

High-school records were obtained for these 120 students from the high-school transcripts on file in the Registrar's office. Both subjects pursued and marks attained were recorded.

The scores made by the group on the intelligence and achievement tests were recorded from the files of the Bureau of Counseling and Testing.

The final first-semester marks attained by these

selected students were recorded from the files in the general office of the College of Engineering at the conclusion of the semester.

In order that the reader may better understand the raw data composed of school marks and test scores, a brief enumeration and description is presented.

High-school marks. In passing, the writer wishes to emphasize his cognizance of the many criticisms directed toward the unreliability of teachers' marks. The view of Heston[1] that marks are "psychological nonsense" is popular and may sometimes be well-founded. It is true that the variability and the subjectivity of marks cannot be ignored, yet it must be remembered that, inefficient and unfair as some marks may be, they are virtually the only means which are used to evaluate success in the American system of formal education. Crawford states, in this regard:

> Nevertheless, marks are still used very extensively as "yardsticks" both within and outside the modern educational structure. As achievement measures, to a large degree, they determine whether pupils are admitted to college, fail or pass their courses, receive aspired Ph.D.'s, play on athletic teams, are invited to or rejected by social and honorary societies, secure or lose prospective positions when other factors are equal. Many other examples

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[1] Heston, op. cit., p. 619.

such as these point undeniably to the fact that marks are used as achievement criteria, if for no other reason than that none better are available.[2]

In this study high-school marks in English, mathematics, the physical sciences, and the biological sciences were recorded.

College marks. The marks used in this study were attained in subjects of the required program for engineering college freshmen. These courses and the number of credit hours per semester for each are:

College Algebra, three credit hours.

Solid Geometry, three credit hours.

Engineering and Descriptive Geometry, three credit hours.

Chemistry, four credit hours.

Introduction to Engineering, one credit hour.

The battery of tests used to evaluate engineering freshmen included (1) the 1946 edition of the American Council on Education Psychological Examination for College Students; (2) the Cooperative English Test; (3) the Engineering and Physical Science Aptitude Test; and (4) the

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[2] B. M. Crawford, "Guidance Implications Obtained from the Use of Four Types of Interest Measurements," (unpublished Doctor's dissertation, The University of Michigan, Ann Arbor, 1945), p. 69.

University of New Mexico Mathematics Test.

The psychological test. The American Council on Education Psychological Examination for College Students (ACE) is divided into two sections, the L section and the Q section. The L section is a measure of verbal aptitudes such as are involved in social science or language courses. It is subdivided into three parts: (1) same-opposites, (2) verbal analogies, and (3) vocabulary. There is a total raw score of 120 points on this section. The Q section is a measure of quantitative aptitudes involved in such courses as mathematics, physical science, and accounting. The Q section is subdivided into three parts: (1) mathematics, (2) figure analogies, and (3) number series. A total of eighty points is possible on this section.

The English test. The score of the Cooperative English Test (which is published by the Cooperative Test Service) is based on usage, grammar, punctuation, spelling, and basic English skills. The scores made on this test are used to classify students in the freshman English classes.

The engineering aptitude test. The Engineering and Physical Science Aptitude Test includes (1) tests of mathematical abilities, (2) ability to understand and remember scientific terms and concepts, and (3) ability to analyze

and understand basic principles used in physics. This test is published by the Psychological Corporation.

The mathematics test. The University of New Mexico Mathematics Test samples basic algebraic procedures. This test was devised by H. P. Rogers of the university mathematics department.

II. DEFINITION OF TERMS USED

College grade-point average. All of the first-semester college marks of the students included in this investigation were given a numerical point value; an "A" was assigned a value of four, a "B" was assigned a value of three, a "C" was assigned a value of two, a "D" was assigned a value of one, and an "F," indicative of failing work, was assigned a value of zero. These values were multiplied by the number of course hours in which the marks were obtained and the products added. The sum was then divided by the total number of course hours taken to determine the grade-point average. For example, a student who had earned three semester hours of "A," three hours of "B," three hours of "C," three hours of "D," and three hours of "F" would have a total of thirty grade-points. This total divided by fifteen, the number of course hours, has a quotient of a grade-point average of 2.0, a straight "C" average.

High-school achievement. The degree of high-school achievement as used in this study was determined by assigning to high-school marks numerical values identical with those for computing college grade-point averages. If, for example, a student had a record of four "A's" and four "B's" for eight semesters of English work, he had accumulated twenty-eight points which, when divided by eight, produces an average score of 3.5, midway between a straight "A" and a straight "B" average. The high-school average was computed by following this procedure for all of the high-school subjects for which data were available.

High-school subjects and. The degree of high-school achievement as used in this study was determined by adding to high-school marks numerical values indicated for those for completing college preparatory courses. For example, a student had a record of four "A's" and four "B's" for eight semesters of English work. He had accumulated twenty-eight points which when divided by eight, produces an average score of 3.5, midway between a straight "A" and a straight "B" average. The high-school average was computed by following this procedure for all of the high school subjects for which data were available.

CHAPTER IV

ANALYSIS OF THE DATA

In order to facilitate clear understanding, this study will employ the following arbitrarily determined descriptive and quantitative values to interpret coefficients as recommended by Darley:[1]

.80 and up equals very high correlation
.50 to .80 equals substantial correlation
.30 to .50 equals some correlation
.20 to .30 equals slight correlation
.00 to .20 equals practically no correlation

The initial treatment of the data consisted of determining the coefficients of correlation (r) between twenty-eight different combinations of variables and the probable errors ($P.E._r$) or these coefficients. These computations were made for two reasons: (1) to determine the extent of relationship which exists between such variables of the data as intelligence, aptitudes, and marks attained in high school and college, and (2) to select the variables to use for later computation of coefficients of multiple correlation (R) and to develop regression equations for predicting the degree of success to be attained in the engineering college by a prospective student. The coefficients of

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[1] John G. Darley, Testing and Counseling in the High-School Guidance Program (Chicago: Science Research Associates, 1943), p. 71.

correlation between the average marks attained in all high-school subjects, average marks received in certain high-school subject matter areas, and scores made on various tests are presented in Table I.

I. RELATIONSHIP BETWEEN VARIABLES OF THE DATA

The reader will notice the lack of substantial correlation between the high-school average marks and the Q, L, and T scores of the American Council on Education Psychological Test (ACE). This seems to indicate that the relationship between marks attained in high school and later achievement on an intelligence test administered in college is so low as to be almost nonexistent. Since the coefficients obtained are less or only slightly greater than three times the product of their respective probable errors, the three coefficients are statistically unreliable. On the assumption that the ACE results are a valid measure of pupil ability, one may imply that other factors than ability determine marks assigned in high school.

It is interesting to note that even the Q score of the ACE and averages of high-school marks attained in such quantitative subjects as mathematics and the physical sciences does not manifest a coefficient greater than .170. One may thus conclude that the relationship between marks attained in high school and intelligence as measured by

TABLE I

COEFFICIENTS OF CORRELATION BETWEEN AVERAGES OF HIGH-SCHOOL AND COLLEGE ACHIEVEMENT AND SCORES MADE ON CERTAIN TESTS BY COLLEGE OF ENGINEERING FRESHMEN

Measures correlated	Number of cases	r	$P.E._r$
HIGH-SCHOOL ACHIEVEMENT			
High-School Average with			
Q Score of the ACE	104	.047	.066
L Score of the ACE	104	.213	.063
T Score of the ACE	104	.222	.062
HIGH-SCHOOL SUBJECT MATTER AREAS			
Q Score of the ACE with			
High-School Biological Science	83	.085	.073
High-School Mathematics	107	.170	.063
High-School Physical Science	92	.130	.069
HIGH-SCHOOL SUBJECT MATTER AREAS AND RELATED COLLEGE AVERAGES			
High-School Biological Science and College Chemistry	79	.233	.022
High-School Physical Science and College Chemistry	88	.524	.016
High-School Mathematics and College Mathematics	88	.437	.018
High-School English and College English	89	.404	.059
COLLEGE ACHIEVEMENT			
College Average with			
Q Score of the ACE	111	.379	.069
L Score of the ACE	111	.400	.053
T Score of the ACE	111	.466	.050

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College Average with			
Q Score of the ACE	111	.379	.069
L Score of the ACE	111	.400	.053
T Score of the ACE	111	.466	.050

the ACE is negligible. It would certainly be hazardous to predict a pupil's degree of performance on the ACE when only his high-school record is known. It may be important to add, however, that the relationships between marks attained in high-school subjects such as physical science, mathematics, and English and marks attained in respectively related subjects in college are considerably greater. The coefficients for the relationships are .524, .437, and .404 respectively. Furthermore, an analysis of Table I reveals that, although the relationships are not great, the coefficients between the Q, L, and T scores of the ACE and average marks attained in the first semester of engineering college are considerably greater. In summary, one may conclude: (1) that some relationship exists between scores made on the ACE and average college marks; (2) that almost no relationship is manifest between scores made on the ACE and marks received in high school; (3) that there is a tendency for marks attained in respectively related areas of high-school and college subject matter to be related.

Table II indicates that the relationship between marks attained in high school and those received in the first semester of engineering college is greater than between marks attained in high school and scores made on the ACE.

In this regard the coefficient of .569 computed

between marks received in high school and those attained in college surpasses the coefficient of .222 between marks received in high school and subsequent scores made on the ACE. Thus, since this coefficient is higher than any

TABLE II

COEFFICIENTS OF CORRELATION BETWEEN THE COLLEGE GRADE-POINT AVERAGES AND VARIOUS FACTORS

Correlated with the college grade-point averages	Number of cases	r	$P.E._r$
High-School Average	103	.569	.044
High-School English Average	107	.461	.051
Engineering and Physical Science Aptitude Test	107	.616	.040
Cooperative English Test	103	.472	.051
UNM Math Test	104	.495	.049

computed between marks received in the first semester of engineering college and scores made on the ACE, it would appear that average high-school marks are a more reliable indicator of success in engineering college than performance on the ACE. In fact, all the coefficients presented in Table II are greater than any coefficients derived between Q, L, and T scores of the ACE and marks attained in the first semester of the College of Engineering as previously discussed. As a cautionary measure, the writer wishes to suggest that even the greatest coefficient of .616 derived

between marks received in high school and those attained in college surpasses the coefficient of .22 between marks received in high school and subsequent scores made on the ACE. Thus, since this coefficient is higher than any

TABLE II

COEFFICIENTS OF CORRELATION BETWEEN THE COLLEGE GRADE-POINT AVERAGE AND VARIOUS FACTORS

Correlated with the college grade-point average	Number of cases	r	P.E.r
High-School Average	103	.[illegible]	.[illegible]
High-School English average	103	.[illegible]	.[illegible]
Engineering and Physical Science Aptitude Test	103	.[illegible]	.[illegible]
Cooperative English Test	103	.[illegible]	.[illegible]
UNM Math Test	103	.[illegible]	.[illegible]

computed between marks received in the first semester of engineering college and scores made on the ACE, it would appear that average high-school marks are a more reliable indicator of success in engineering college than performance on the ACE. In fact, all the coefficients presented in Table II are greater than any coefficient derived between G, L, and T scores of the ACE and marks attained in the first semester of the College of Engineering as presently discussed. As a cautionary measure, the writer wishes to suggest that even the greater coefficient of .[illegible] derived

between scores made on the Engineering and Physical Science Aptitude Test and average college marks received indicates only a relatively strong tendency for relationship, but is, at the same time, extremely unreliable for individual prediction.

The substantial relationship between the college grade-point averages and scores made on the EPSA ($r = .616$), shows this test to be the best single indicator of college success, although the coefficient of .569 computed between average marks received in high school and average marks made in college is only slightly less. This latter coefficient of correlation closely approximates the findings of Crawford and Burnham, who found that high-school marks correlated .57 with first-year averages.[2] This relationship is also in accord with the conclusions of Pierson, who maintained that students should be guided according to their scholastic achievement and not by marks earned in any particular or individual high-school or college subject.[3]

In Table III it will be noted that the UNM Math Test correlates with the T, the Q, and the L scores of the ACE and the Cooperative English Test (CET) respectively in an order of decreasing significance. Although none of the

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[2] Crawford and Burnham, op. cit., p. 350.

[3] Pierson, op. cit., p. 617.

TABLE III

COEFFICIENTS OF CORRELATION BETWEEN SCORES MADE BY ENGINEERING FRESHMEN ON THE UNM MATH TEST, THE AMERICAN COUNCIL ON EDUCATION PSYCHOLOGICAL TEST, AND THE COOPERATIVE ENGLISH TEST

Correlated with UNM Math Test	Number of cases	r	$P.E._r$
Q Score of the ACE	106	.412	.054
L Score of the ACE	106	.365	.056
T Score of the ACE	106	.419	.054
Cooperative English Test	106	.299	.059

coefficients is indicative of a high relationship, an interesting observation should be made. It appears that the variables which require greater ability to think quantitatively correlate higher with scores made on the UNM Math Test (T score, r = .419 and Q score, r = .412) than do variables which are concerned for the most part with the remembrance of learned rules and vocabulary. Thus, the scores made on the UNM Math Test correlate only .365 and .299 respectively with scores attained on the L section of the ACE and the Cooperative English Test.

The Engineering and Physical Science Aptitude Test (EPSA) has been extensively used by colleges of engineering for prediction of success to be attained by prospective

students. The substantial correlations presented in Table IV emphasize a relationship that the reader may have noted previously. Evidence of the importance of one

TABLE IV

THE COEFFICIENTS OF CORRELATION BETWEEN SCORES ON THE ENGINEERING AND PHYSICAL SCIENCE APTITUDE TEST AND THE SCORES ON THE ACE AND UNM MATHEMATICS TEST

Correlated with the Engineering and Physical Science Aptitude Test	Number of cases	r	$P.E._r$
Q Score of the ACE	109	.491	.049
L Score of the ACE	109	.665	.036
T Score of the ACE	109	.696	.033
UNM Math Test	106	.556	.040

of the functional concomitants of English, the ability to read with understanding, is apparent. The L scores of the ACE correlate substantially with scores made on the EPSA (r = .665). This result is in agreement with Pierson,[4] who found a marked relationship between success attained in a college of engineering and high-school English. The Q score of the ACE has a less significant relationship with

[4] Pierson, op. cit., p. 617.

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Correlated with the Engineering and Physical Science Aptitude Test	Number of cases	r	P.E.
Q Score of the ACE	109	.491	.044
L Score of the ACE	109	.665	.030
T Score of the ACE	109	.693	.023
UNM Math Test	109	.395	.040

of the functional concomitants of English, the ability to read with understanding, is apparent. The T scores of the ACE correlate substantially with scores made on the EPSA (r = .665). This result is in agreement with Pierson,[4] who found a marked relationship between success attained in a college of engineering and high-school English. The Q score of the ACE has a less significant relationship with

[4] Pierson, op. cit., p. 612.

the EPSA, as indicated by the coefficient of .491. Since the scores on the EPSA correlate substantially with the T scores of the ACE (r = .693), it would appear that the EPSA is also a measure of general ability. The coefficient of correlation of .556 between scores on this latter measure and the scores on the UNM Math test may reflect the influence of common elements, for example basic algebra, which is a substantial part of the engineering test. However, in passing, the reader will recall that the scores made on the L section of the ACE, a measure of language ability, correlate almost as highly (.655) with scores made on the EPSA.

II. THE PROGNOSTIC VALUE OF THE VARIABLES IN COMBINATION

Since the greatest coefficient of correlation manifesting relation to college engineering success was found to be between college grade-point averages and scores made on the EPSA (r = .616), the writer desires to make the following comment. Even though a coefficient of .616 may be considered as substantial according to the arbitrary classification system used in this study, all that a coefficient of such magnitude really implies is that for another sampling of cases similarly selected a substantial relationship would also result. In terms of providing a basis for predicting the success to be attained by a prospective

engineering student in relation to the data so far presented, a coefficient of correlation of only .616 is extremely unreliable and little better than a rough guess. Consequently, in order to ascertain to what degree, if any, the reliability of prognosis can be increased, the investigator combined variables used in this study in order to compute multiple coefficients of correlation and to develop regression equations for the purpose of facilitating individual prediction.

Two criteria used for selection of the variables to combine for the development of the regression equations may be stated in the form of two questions: (1) Which variables manifest the greatest correlation with college grade-point averages or achievement? and (2) Which variables appear to have the most unique value for this investigation in contrast with studies made elsewhere in the country?

Since the Engineering and Physical Science Aptitude Test (EPSA), high-school average marks, the UNM Math test, the Cooperative English Test (CET), and the T score of the ACE provided data which correlated highest with college grade-point averages, the above with one exception were chosen. Because the T score of the ACE includes the L score, a measure of verbal aptitudes, the closely related CET was eliminated from further statistical treatment.

In order to compute the multiple coefficients of

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In order to compute the multiple coefficients of

correlation and develop regression equations, it was necessary to select a constant number of cases for which complete data were available. Ninety-five cases were subsequently discovered to satisfy this criterion. Table V presents the coefficient of correlation computed for both the constand sampling of ninety-five cases and the original sampling.

TABLE V

COMPARISON OF COEFFICIENTS OF CORRELATION BETWEEN THE SAME VARIABLES FOR A TOTAL AND SMALLER SAMPLES

Correlation between college grade-point average and	Coefficient of correlation for all cases			Coefficients of correlation for ninety-five cases		
	N	r	$P.E._r$	N	r	$P.E._r$
T of the ACE	111	.466	.050	95	.504	.051
High-School English Average	107	.461	.051	95	.462	.054
High-School Average	103	.569	.044	95	.597	.044
UNM Math Test	104	.495	.049	95	.555	.048
Engineering and Physical Science Aptitude Test	107	.616	.040	95	.619	.042

The reader will note that the coefficients remain relatively stable even though the number of cases in the constant sampling was reduced. The greatest difference is

an increase of .060 between college grade-point averages and scores on the UNM Math Test in favor of the constant sampling.

Since the computation of multiple coefficients of correlation (R's) necessitates the determination of all the possible intercorrelations between the variables to be later combined, the coefficients computed are presented in Table VI. Three of these coefficients of correlation merit comment. The previously noted relation between the T scores of the ACE and the EPSA results, which produced a coefficient of correlation of .693, is increased to .766 when computed using the ninety-five cases for which all data were available. This increase serves to emphasize further the view that the EPSA measures general ability to a large extent. The very high relationship between the high-school English averages and the total high-school averages (r = .846) is probably influenced by the factor of common elements, namely, English courses which comprise one quarter of the entire high-school curriculum. The relation between ability in English and general ability has been previously commented upon. The lack of relationship manifested by the coefficient of correlation of .024 between the high-school English averages and scores on the UNM Math Test is in accord with the opinion stated earlier that there is no relationship between these abilities.

an increase of .060 between college grade-point averages and scores on the UNM Math Test in favor of the constant sampling.

Since the computation of multiple coefficients of correlation (R's) necessitates the determination of all the possible intercorrelations between the variables to be later combined, the coefficients computed are presented in Table XI. Three of these coefficients of correlation merit comment. The previously noted relation between the T scores of the ACE and the EPSA results, which produced a coefficient of correlation of .693, is increased to .706 when computed using the ninety-five cases for which all data were available. This increase serves to emphasize further the view that the EPSA measures general ability to a large extent. The very high relationship between the high-school English averages and the total high-school averages (r = .849) is probably influenced by the factor of common elements, namely, English courses which comprise one quarter of the entire high-school curriculum. The relation between ability in English and general ability has been previously commented upon. The lack of relationship manifested by the coefficient of correlation of .024 between the high-school English averages and scores on the UNM Math Test is in accord with the opinion stated earlier that there is no relationship between these abilities.

TABLE VI

INTERCORRELATIONS OF THE COLLEGE GRADE-POINT AVERAGES AND FIVE VARIABLES FOR NINETY-FIVE STUDENTS

	Total High-School Averages	High-School English Averages	UNM Math Test	Engineering and Physical Science Aptitude Test	T Score of the ACE
College Grade-Point Averages	.597	.462	.555	.619	.504
T Score of the ACE	.241	.296	.452	.766	
Engineering and Physical Science Aptitude Test	.322	.279	.559		
UNM Math Test	.112	.024			
High-School English Averages	.846				

Although the partial correlations of this study were computed primarily for use in the development of regression equations,[5] the former are also of interest because a partial r denotes a relationship of two variables when the influence of other factors (variables) is held constant. An example of the effect of this technique upon a coefficient of correlation may be illustrated by considering the relationship between the college grade-point averages and the T Scores of the ACE (r - .504). When the influence of the Engineering and Physical Science Aptitude Test is held constant, the first-order coefficient decreases to .059. Since stabilizing the remaining variables does not result in a significant increase in correlation, one may conclude that the relationship between college grade-point averages and the T scores of the ACE is dependent upon a number of factors which are an integral part of some of the other variables, especially the Engineering and Physical Science Aptitude Test.

In contrast to the decrease of relationship by partial correlation in the preceding paragraph, the correlation between college grade-point averages and high-school English averages when T scores of the ACE, scores on the Engineering

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[5] The summary of derived measures, including partial coefficients of correlation and their computation, may be found in the Appendix.

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In contrast to the decrease of relationship by partial correlation in the preceding paragraph, the correlation between college grade-point averages and high-school English averages when T scores of the ACE, scores on the Engineering

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[5] The summary of derived measures, including partial coefficients of correlation and their computation, may be found in the Appendix.

and Physical Science Aptitude Test, and scores on the UNM Math Test are held constant, is fairly significant ($r_{15,234} = .466$). Thus, the relationship between the correlated variables is a result of the lack of factors held in common with the variables held constant.

The basic data for the development of a six-variable regression equation using the results obtained on the score of the ACE, the Engineering and Physical Science Aptitude Test, the UNM Math Test, the high-school English averages and the total high-school averages in combination follows:

X_1= College Grade-Point Averages

X_2= T Score of the ACE

X_3= Engineering and Physical Science Aptitude Test

X_4= University of New Mexico Mathematics Test

X_5= High-School English Average

X_6= High-School Average

$M_1 = 1.932$	$M_2 = 109.02$	$M_3 = 89.95$
$\sigma_1 = \pm .980$	$\sigma_2 = \pm 20.04$	$\sigma_3 = \pm 20.07$
$M_4 = 21.02$	$M_5 = 2.44$	$M_6 = 2.48$
$\sigma_4 = 5.56$	$\sigma_5 = \pm .78$	$\sigma_6 = .525$

Zero Order Coefficients of Correlation:

$r_{12} = .504$	$r_{16} = .597$	$r_{26} = .241$
$r_{13} = .619$	$r_{23} = .766$	$r_{34} = .559$
$r_{14} = .555$	$r_{24} = .452$	$r_{35} = .279$
$r_{15} = .462$	$r_{25} = .296$	$r_{36} = .322$
$r_{45} = .024$	$r_{46} = .112$	$r_{56} = .846$

Regression Equation: (score form for six-variable equation)

$$X_1 = b_{12.3456}X_2 + b_{13.2456}X_3 + b_{14.2356}X_4 + b_{15.2346}X_5 + b_{16,2345}X_6 + K$$

The following equations show the improvement obtained in the size of multiple R by using successively two, three, four, five, and six variables.

Regression Equations:

$$\bar{X}_1 = .024X_2 - .68$$

$$\bar{X}_1 = .003X_2 + .028X_3 - .91$$

$$\bar{X}_1 = .002X_2 + .020X_3 + .052X_4 - 1.198$$

$$\bar{X}_1 = .007X_2 + .024X_3 + .065X_4 + .479X_5 - 3.51$$

$$\bar{X}_1 = .014X_2 + .016X_3 + .031X_4 - .162X_5 + 1.145X_6 - 4.117$$

Standard Error of Estimate:	Coefficient of Correlation:
$\sigma_{X_1} = .849$	$r_{12} = .504$
$\sigma_{X_1} = .769$	$R_{1(23)} = .620$
$\sigma_{X_1} = .732$	$R_{1(234)} = .664$
$\sigma_{X_1} = .650$	$R_{1(2345)} = .748$
$\sigma_{X_1} = .614$	$R_{1(23456)} = .773$

It is evident that the final equation is not significantly better for predicting the grade-point average that a student will obtain in the engineering college than the preceding one consisting of five variables. The standard error of estimate for the final equation is slightly less (.036) and the multiple R is greater by only .025. The two increases of multiple R that are of any consequence result when the third variable EPSA, and the fifth variable, high-school English averages, are added to the equations. The latter addition results in a multiple R of .748, a much more significant coefficient than the initial zero order of .504 for predicting the probable success of a group. However, the final R of .773 indicates that the entire combination of six variables has only a 38 per cent forecasting efficiency for predicting the grade-point average an individual student will obtain in the College of Engineering of the University of New Mexico. Since the coefficient must be greater than .87 for the forecasting efficiency to be better than 50 per cent, the degree of dependability found in this study does not warrant the use of the regression equations for the prediction of success to be attained by an individual.

III. VALIDITY IMPLICATIONS OF THE UNM MATH TEST

Because the UNM Math Test is a non-standardized test with a substantial relationship to the college grade-point averages (r= .555), it was further analyzed for indications of validity. The criterion used to measure validity was the capacity of the test to discriminate between known groups. Of the ninety-five students for whom all data were available, the means of the college grade-point averages of the twenty students who made highest scores and the twenty students who made lowest scores on the UNM Math Test were compared. Table VII summarizes these findings. A critical

TABLE VII

MEANS, STANDARD DEVIATIONS, PROBABLE ERRORS OF THE MEANS, AND CRITICAL RATIO OF THE COLLEGE GRADE-POINT AVERAGES OF TWO GROUPS ON THE UNM MATH TEST*

Known groups	Mean	S.D.	$P.E._M$
High	2.67	.72	.109
Low	1.36	.76	.115
Difference	1.31	$P.E._d$=	.158
Critical Ratio = 8.23			

$$* \text{ Critical Ratio} = \frac{\text{Difference of the Means}}{\text{Probable Error of the Difference of the Means}}$$

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

I. CONCLUSIONS

1. The Engineering and Physical Science Aptitude Test is the best single indicator of success in first-semester engineering, and the high-school average is the next most reliable.

2. Although the coefficients of correlation are so low as to be valueless for prediction of success to be attained by an individual, the college marks correlate higher with the American Council on Education Psychological Test than do high-school marks.

3. The University of New Mexico Mathematics Test and the Cooperative English Test are better indicators of success in the first semester in the College of Engineering than the American Council on Education Psychological Test or the high-school English average.

4. The high-school English average is a good indicator of general ability.

5. In summary of the foregoing, the predictive efficiency of the American Council on Education Psychological Test, a widely used instrument for student classification and prognosis, ranks behind the Engineering and Physical

Science Aptitude Test, the high-school averages, and the Cooperative English Test when organized in a decreasing scale of relationship to the college grade-point averages.

6. High-school marks have no value for predicting the degree of success to be attained on the American Council on Education Psychological Test administered at the time of enrollment in engineering college.

7. Respectively related areas of high-school and college subject matter manifest some correlation (approximately .45).

8. In general, ability in mathematics is no indication of ability in English and vice versa.

9. The combining of variables for computation of a multiple coefficient of correlation and development of regression equations for six variables does not yield a "forecasting efficiency" for individual prediction that is great enough to warrant the effort expended. As an indicator of the tendency for success to be attained by a group, the final derived coefficient of .773 is worthy of merit.

10. Although the University of New Mexico Mathematics Test is non-standardized, the capacity with which it discriminates between known groups implies considerable validity. The test should be retained in the battery.

II. RECOMMENDATIONS

1. The Engineering and Physical Science Aptitude Test should be included in the high-school test files for evaluation of prospective engineering students.

2. The high-school English average as well as the total high-school average made by a prospective engineering student should be carefully evaluated since each is a good indicator of general ability. Both are also good indicators of success to be attained in engineering college.

3. The University of New Mexico Mathematics Test should be included in the test files of New Mexico high schools for evaluation of prospective engineering students.

4. The results made on all the measures considered in this study are unreliable for predicting success to be attained by an individual. However, if the data are consistently high, the high school principal should recommend the student for college since these measures have a 38 per cent forecasting efficiency.

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APPENDIX

APPENDIX

EXHIBIT A

FORMULAS AND COMPUTATIONS FOR THE DETERMINATION OF A MULTIPLE COEFFICIENT OF CORRELATION (R) AND DERIVATION OF THE ACCOMPANYING REGRESSION EQUATION INVOLVING SIX VARIABLES

1. Regression Equation

$$\bar{X}_1 = b_{12.3456}X_2 + b_{13.2456}X_3 + b_{14.2356}X_4 + b_{15.2346}X_5 + b_{16.2345}X_6 + K$$

$$\bar{X}_1 = .014X_2 + .016X_3 + .031X_4 - .162X_5 + 1.145X_6 - 4.117$$

2. Regression Coefficients

$$b_{12.3456} = r_{12.3456} \frac{\sigma_{1.23456}}{\sigma_{2.13456}}$$

$$= .179 \frac{.614}{8.11} = .014$$

$$b_{13.2456} = r_{13.2456} \frac{\sigma_{1.23456}}{\sigma_{3.12456}}$$

$$= .275 \frac{.614}{10.3} = .016$$

$$b_{14.2356} = r_{14.2356} \frac{\sigma_{1.23456}}{\sigma_{4.12356}}$$

$$= .190 \frac{.614}{3.73} = .031$$

$$b_{15.2346} = r_{15.2346} \frac{\sigma_{1.23456}}{\sigma_{5.12346}}$$

$$= -.071 \frac{.614}{.268} = -.162$$

$$b_{16.2345} = r_{16.2345} \frac{\sigma_{1.23456}}{\sigma_{6.12345}}$$

$$= .334 \frac{.614}{.177} = 1.145$$

3. Partial r's

(a) r's of the fourth order

$$r_{12.3456} = \frac{r_{12.345} - r_{16.345} r_{26.345}}{\sqrt{1-r^2_{16.345}} \sqrt{1-r^2_{26.345}}}$$

$$= \frac{-.131 - .331\ (-.741)}{.9440 \times .6726} = .179$$

$$r_{13.2456} = \frac{r_{13.456} - r_{12.456} r_{23.456}}{\sqrt{1-r^2_{12.456}} \sqrt{1-r^2_{23.456}}}$$

$$= \frac{.336 - .207\ (.721)}{.9777 \times .6940} = .275$$

$$r_{14.2356} = \frac{r_{14.235} - r_{16.235} r_{46.235}}{\sqrt{1-r^2_{16.235}} \sqrt{1-r^2_{46.235}}}$$

$$= \frac{.416 - .509\ (.549)}{.8617 \times .8352} = .190$$

$$r_{15.2346} = \frac{r_{15.234} - r_{16.234}r_{56.234}}{\sqrt{1-r^2_{16.234}}\ \sqrt{1-r^2_{56.234}}}$$

$$= \frac{.461 - .539\ (.934)}{.8417 \times .3676} = -.071$$

$$r_{16.2345} = \frac{r_{16.234} - r_{15.234}r_{56.234}}{\sqrt{1-r^2_{15.234}}\ \sqrt{1-r^2_{56.234}}}$$

$$= \frac{.539 - .461\ (.934)}{.8879 \times .3676} = .334$$

(b) r's of the third order

$$r_{12.345} = \frac{r_{12.45} - r_{13.45}r_{23.45}}{\sqrt{1-r^2_{13.45}}\ \sqrt{1-r^2_{23.45}}}$$

$$= \frac{.209 - .424\ (.696)}{.9075 \times .7141} = -.131$$

$$r_{16.345} = \frac{r_{16.34} - r_{15.34}r_{56.34}}{\sqrt{1-r^2_{15.34}}\ \sqrt{1-r^2_{56.34}}}$$

$$= \frac{.593 - (.523)(.850)}{.8542 \times .5268} = .331$$

$$r_{26.345} = \frac{r_{26.34} - r_{25.34}r_{56.34}}{\sqrt{1-r^2_{25.34}}\ \sqrt{1-r^2_{56.34}}}$$

$$= \frac{-.135 - .283(.850)}{.9600 \times .5268} = -.741$$

$$r_{13.456} = \frac{r_{13.45} - r_{16.45}r_{36.45}}{\sqrt{1-r^2_{16.45}}\ \sqrt{1-r^2_{36.45}}}$$

$$= \frac{.425 - .422(.326)}{.9075 \times .9440} = .336$$

$$r_{12.456} = \frac{r_{12.45} - r_{16.45}r_{26.45}}{\sqrt{1-r^2_{16.45}}\ \sqrt{1-r^2_{26.45}}}$$

$$= \frac{.209 - .422(.050)}{.9075 \times .9987} = .207$$

$$r_{23.456} = \frac{r_{23.45} - r_{26.45}r_{36.45}}{\sqrt{1-r^2_{26.45}}\ \sqrt{1-r^2_{36.45}}}$$

$$= \frac{.696 - .050(.326)}{.9987 \times .9440} = .721$$

$$r_{14.235} = \frac{r_{14.23} - r_{15.23}r_{45.23}}{\sqrt{1-r^2_{15.23}}\ \sqrt{1-r^2_{45.23}}}$$

$$= \frac{.314 - .378)-.173)}{.9250 \times .9854} = .416$$

$$r_{16.235} = \frac{r_{16.23} - r_{15.23}r_{56.23}}{\sqrt{1-r^2_{15.23}}\ \sqrt{1-r^2_{56.23}}}$$

$$= \frac{.546 - .378(.903)}{.9250 \times .4359} = .509$$

$$r_{46.235} = \frac{r_{46.23} - r_{45.23} r_{56.23}}{\sqrt{1-r^2_{45.23}} \quad \sqrt{1-r^2_{56.23}}}$$

$$= \frac{.08 - (-.173)(.903)}{.9854 \times .4359} = .549$$

$$r_{15.234} = \frac{r_{15.23} - r_{14.23} r_{45.23}}{\sqrt{1-r^2_{14.23}} \quad \sqrt{1-r^2_{45.23}}}$$

$$= \frac{.378 - .314(.-173)}{.9507 \times .9854} = .461$$

$$r_{16.234} = \frac{r_{16.23} - r_{14.23} r_{46.23}}{\sqrt{1-r^2_{14.23}} \quad \sqrt{1-r^2_{46.23}}}$$

$$= \frac{.546 - .314(.08)}{.9507 \times .9968} = .539$$

$$r_{56.234} = \frac{r_{56.23} - r_{45.23} r_{46.23}}{\sqrt{1-r^2_{45.23}} \quad \sqrt{1-r^2_{46.23}}}$$

$$= \frac{.903 - (-.173)(.08)}{.9854 \times .9968} = .934$$

(c) r's of the second order

$$r_{12.34} = \frac{r_{12.3} - r_{14.3} r_{24.3}}{\sqrt{1-r^2_{14.3}} \quad \sqrt{1-r^2_{24.3}}}$$

$$= \frac{.059 - .323(.057)}{.9479 \times 9982} = .043$$

$$r_{15.34} = \frac{r_{15.4} - r_{13.4}r_{35.4}}{\sqrt{1-r^2_{13.4}}\ \sqrt{1-r^2_{35.4}}}$$

$$= \frac{.538 - .446(.175)}{.8930 \times .9854} = .523$$

$$r_{25.34} = \frac{r_{25.4} - r_{23.4}r_{35.4}}{\sqrt{1-r^2_{23.4}}\ \sqrt{1-r^2_{35.4}}}$$

$$= \frac{.319 - .706(.175)}{.7042 \times .9854} = .283$$

$$r_{16.34} = \frac{r_{16.4} - r_{13.4} - r_{36.4}}{\sqrt{1-r^2_{13.4}}\ \sqrt{1-r^2_{36.4}}}$$

$$= \frac{.644 - .446(.318)}{.8930 \times .9474} = .593$$

$$r_{56.34} = \frac{r_{56.4} - r_{35.4}r_{36.4}}{\sqrt{1-r^2_{35.4}}\ \sqrt{1-r^2_{36.4}}}$$

$$= \frac{.850 - .175(.318)}{.9854 \times .9474} = .850$$

$$r_{26.34} = \frac{r_{26.4} - r_{23.4}r_{36.4}}{\sqrt{1-r^2_{23.4}}\ \sqrt{1-r^2_{36.4}}}$$

$$= \frac{.215 - .706(.318)}{.7042 \times .9474} = -.135$$

$$r_{13.45} = \frac{r_{13.4} - r_{15.4}r_{35.4}}{\sqrt{1-r^2_{15.4}}\ \sqrt{1-r^2_{35.4}}}$$

$$= \frac{.446 - .538(.175)}{.8417 \times .9854} = .425$$

$$r_{16.45} = \frac{r_{16.4} - r_{15.4}r_{56.4}}{\sqrt{1-r^2_{15.4}}\ \sqrt{1-r^2_{56.4}}}$$

$$= \frac{.644 - .538(.850)}{.8417 \times .5268} = .422$$

$$r_{36.45} = \frac{r_{36.4} - r_{35.4}r_{56.4}}{\sqrt{1-r^2_{35.4}}\ \sqrt{1-r^2_{56.4}}}$$

$$= \frac{.318 - .175(.850)}{.9854 \times .5268} = .326$$

$$r_{12.45} = \frac{r_{12.4} - r_{15.4}r_{25.4}}{\sqrt{1-r^2_{15.4}}\ \sqrt{1-r^2_{25.4}}}$$

$$= \frac{.339 - .538(.319)}{.8417 \times .9474} = .209$$

$$r_{26.45} = \frac{r_{26.4} - r_{25.4}r_{56.4}}{\sqrt{1-r^2_{25.4}}\ \sqrt{1-r^2_{56.4}}}$$

$$= \frac{.215 - .319(.850)}{.9474 \times .5268} = .050$$

$$r_{23.45} = \frac{r_{23.4} - r_{25.4}r_{35.4}}{\sqrt{1-r^2_{25.4}}\ \sqrt{1-r^2_{35.4}}}$$

$$= \frac{.706 - .319(.175)}{.9474 \times .9854} = .696$$

$$r_{14.23} = \frac{r_{14.2} - r_{13.2}r_{34.2}}{\sqrt{1-r^2_{13.2}}\ \sqrt{1-r^2_{34.2}}}$$

$$= \frac{.423 - .422(.374)}{.9075 \times .9290} = .314$$

$$r_{15.23} = \frac{r_{15.2} - r_{13.2}r_{35.2}}{\sqrt{1-r^2_{13.2}}\ \sqrt{1-r^2_{35.2}}}$$

$$= \frac{.378 - .422(.085)}{.9075 \times .9968} = .378$$

$$r_{45.23} = \frac{r_{45.2} - r_{34.2}r_{35.2}}{\sqrt{1-r^2_{34.2}}\ \sqrt{1-r^2_{35.2}}}$$

$$= \frac{(-.129) - .374(.085)}{.9290 \times .9968} = -.173$$

$$r_{16.23} = \frac{r_{16.2} - r_{13.2}r_{36.2}}{\sqrt{1-r^2_{13.2}}\ \sqrt{1-r^2_{36.2}}}$$

$$= \frac{.566 - .422(.221)}{.9075 \times .9755} = .546$$

$$r_{56.23} = \frac{r_{56.2} - r_{35.2}r_{36.2}}{\sqrt{1-r^2_{35.2}}\ \sqrt{1-r^2_{36.2}}}$$

$$= \frac{.837 - .085(.221)}{.9968 \times .9755} = .903$$

$$r_{46.23} = \frac{r_{46.2} - r_{34.2}r_{36.2}}{\sqrt{1-r^2_{34.2}}\ \sqrt{1-r^2_{36.2}}}$$

$$= \frac{.003 - .374(.221)}{.9290 \times .9755} = -.088$$

(d) r's of the first order

$$r_{12.3} = \frac{r_{12} - r_{13}r_{23}}{\sqrt{1-r^2_{13}}\ \sqrt{1-r^2_{23}}}$$

$$= \frac{.504 - .619(.766)}{.7846 \times .6380} = .059$$

$$r_{12.4} = \frac{r_{12} - r_{14}r_{24}}{\sqrt{1-r^2_{14}}\ \sqrt{1-r^2_{24}}}$$

$$= \frac{.504 - .555(.452)}{.8352 \times .8930} = .339$$

$$r_{13.4} = \frac{r_{13} - r_{14}r_{34}}{\sqrt{1-r^2_{14}}\ \sqrt{1-r^2_{34}}}$$

$$= \frac{.619 - .555(.559)}{.8352 \times .8285} = .446$$

$$r_{23.4} = \frac{r_{23} - r_{24}r_{34}}{\sqrt{1-r^2_{24}}\ \sqrt{1-r^2_{34}}}$$

$$= \frac{.766 - .452(.559)}{.8930 \times .8285} = .706$$

$$r_{15.4} = \frac{r_{15} - r_{14}r_{45}}{\sqrt{1-r^2_{14}}\ \sqrt{1-r^2_{45}}}$$

$$= \frac{.462 - .555(.024)}{.8352 \times .9998} = .538$$

$$r_{35.4} = \frac{r_{35} - r_{34}r_{45}}{\sqrt{1-r^2_{34}}\ \sqrt{1-r^2_{45}}}$$

$$= \frac{.279 - .559(.024)}{.8285 \times .9998} = .175$$

$$r_{25.4} = \frac{r_{25} - r_{24}r_{45}}{\sqrt{1-r^2_{24}}\ \sqrt{1-r^2_{45}}}$$

$$= \frac{.296 - .452(.024)}{.8930 \times .9998} = .319$$

$$r_{16.4} = \frac{r_{16} - r_{14}r_{46}}{\sqrt{1-r^2_{14}}\ \sqrt{1-r^2_{46}}}$$

$$= \frac{.597 - .555(.112)}{.8352 \times .9939} = .644$$

$$r_{36.4} = \frac{r_{36} - r_{34}r_{46}}{\sqrt{1-r^2_{34}}\ \sqrt{1-r^2_{46}}}$$

$$= \frac{.322 - .559(.112)}{.8235 \times .9939} = .318$$

$$r_{56.4} = \frac{r_{56} - r_{45}r_{46}}{\sqrt{1-r^2_{45}}\ \sqrt{1-r^2_{46}}}$$

$$= \frac{.846 - .024(112)}{.9998 \times .9939} = .850$$

$$r_{26.4} = \frac{r_{26} - r_{24}r_{46}}{\sqrt{1-r^2_{24}}\ \sqrt{1-r^2_{46}}}$$

$$= \frac{.241 - .452(.112)}{.8930 \times .9939} = .215$$

$$r_{15.2} = \frac{r_{15} - r_{12}r_{25}}{\sqrt{1-r^2_{12}}\ \sqrt{1-r^2_{25}}}$$

$$= \frac{.462 - .504(.296)}{.8660 \times .9539} = .378$$

$$r_{13.2} = \frac{r_{13} - r_{12}r_{23}}{\sqrt{1-r^2_{12}}\ \sqrt{1-r^2_{23}}}$$

$$= \frac{.619 - .504(.766)}{.8660 \times .6380} = .422$$

$$r_{14.2} = \frac{r_{14} - r_{12}r_{24}}{\sqrt{1-r^2_{12}}\ \sqrt{1-r^2_{24}}}$$

$$= \frac{.555 - .504(.452)}{.8660 \times .8930} = .423$$

$$r_{34.2} = \frac{r_{34} - r_{23}r_{24}}{\sqrt{1-r^2_{23}}\ \sqrt{1-r^2_{24}}}$$

$$= \frac{.559 - .766(.452)}{.6380 \times .8930} = .374$$

$$r_{45.2} = \frac{r_{45} - r_{24}r_{25}}{\sqrt{1-r^2_{24}}\ \sqrt{1-r^2_{25}}}$$

$$= \frac{.024 - .452(.296)}{.8930 \times .9539} = -.129$$

$$r_{35.2} = \frac{r_{35} - r_{23}r_{25}}{\sqrt{1-r^2_{23}}\ \sqrt{1-r^2_{25}}}$$

$$= \frac{.279 - .766(.296)}{.6380 \times .9539} = .085$$

$$r_{16.2} = \frac{r_{16} - r_{12}r_{26}}{\sqrt{1-r^2_{12}}\ \sqrt{1-r^2_{26}}}$$

$$= \frac{.597 - .504(.241)}{.8660 \times .9708} = .566$$

$$r_{36.2} = \frac{r_{36} - r_{23}r_{26}}{\sqrt{1-r^2_{23}}\ \sqrt{1-r^2_{26}}}$$

$$= \frac{.322 - .766(.241)}{.6380 \times .9708} = .221$$

$$r_{46.2} = \frac{r_{46} - r_{24}r_{26}}{\sqrt{1-r^2_{24}}\ \sqrt{1-r^2_{26}}}$$

$$= \frac{.112 - .452(.241)}{.8930 \times 9708} = .003$$

$$r_{56.2} = \frac{r_{56} - r_{25}r_{26}}{\sqrt{1-r^2_{25}}\ \sqrt{1-r^2_{26}}}$$

$$= \frac{.846 - .296(.241)}{.9539 \times .9708} = .837$$

(e) Zero-order r's

These coefficients are found on page 34.

4. Standard Deviations

$$\sigma_{1.23456} = \sigma_1 \sqrt{1-r^2_{12}}\ \sqrt{1-r^2_{13.2}}\ \sqrt{1-r^2_{14.23}}$$

$$\sqrt{1-r^2_{15.234}}\ \sqrt{1-r^2_{16.2345}}$$

$$= .98 \times .8660 \times .9075 \times .9507 \times .8879 \times .9440$$

$$= .614$$

$$\sigma_{2.13456} = \sigma_2 \sqrt{1-r^2_{23}}\ \sqrt{1-r^2_{24.3}}\ \sqrt{1-r^2_{25.34}}$$

$$\sqrt{1-r^2_{26.345}}\ \sqrt{1-r^2_{12.3456}}$$

$$= 20.04 \times .6380 \times .9982 \times .9600 \times .6726 \times .9837$$

$$= 8.11$$

$$\sigma_{3.45621} = \sigma_3 \sqrt{1-r^2_{34}}\ \sqrt{1-r^2_{35.4}}\ \sqrt{1-r^2_{36.45}}$$

$$\sqrt{1-r^2_{23.456}}\ \sqrt{1-r^2_{13.2456}}$$

$$= 20.07 \times .8285 \times .9854 \times .9440 \times .6940 \times .9629$$

$$= 10.3$$

$$\sigma_{4.12356} = \sigma_4 \sqrt{1-r^2_{24}}\ \sqrt{1-r^2_{34.2}}\ \sqrt{1-r^2_{45.23}}$$

$$\sqrt{1-r^2_{46.235}}\ \sqrt{1-r^2_{14.2356}}$$

$$= 5.56 \times .8930 \times .9290 \times .9854 \times .8352 \times .9818$$

$$= 3.727$$

$$\sigma_{5.12346} = \sigma_5 \sqrt{1-r^2_{25}}\ \sqrt{1-r^2_{35.2}}\ \sqrt{1-r^2_{45.23}}$$

$$\sqrt{1-r^2_{56.234}}\ \sqrt{1-r^2_{15.2346}}$$

$$= .78 \times .9539 \times .9968 \times .9854 \times .3676 \times .9975$$

$$= .268$$

$$\sigma_{6.12345} = \sigma_6 \sqrt{1-r^2_{26}}\ \sqrt{1-r^2_{36.2}}\ \sqrt{1-r^2_{46.23}}$$

$$\sqrt{1-r^2_{56.234}}\ \sqrt{1-r^2_{16.2345}}$$

$$= .525 \times .9708 \times .9755 \times .9968 \times .3676 \times .9440$$

$$= .176$$

5. Standard Error of Estimate

$$\sigma_{(\text{est. } X_1)} = .614$$

6. Coefficient of Multiple Correlation, R.

$$R_{1(23456)} = \sqrt{1 - \frac{{}^2{}_{1.23456}}{\sigma_1^2}}$$

$$\sqrt{1 - \frac{.3769}{.9604}} = .773$$