SUPPLY AND DEMAND FOR ENGINEERING MANPOWER RELATED TO THE UNIVERSITY SYSTEM IN ONTARIO

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> All we can ever predict is continuity that extends yesterday's trends into tomorrow. What has already happened is the only thing we can project and the only thing that can be quantified. But these continuing trends, however important, are only one dimension of the future, only one aspect of reality.
>
> The most accurate quantitative projection never predicts the truly important: the meaning of the facts and figures in the context of a different tomorrow.
>
> Peter F. Drucker,
> The Age of Discontinuity
> (New York: Harper and Row, 1968).

Ontario is a province of more than 7,500,000 people with fourteen universities operating under a provincial mandate (there are also several church-supported institutions and one funded by the federal government). Nine of these provincially-assisted institutions grant degrees in engineering while two of the others offer the first two years of engineering and both have indicated a desire to add the remaining two years in order to be able to award engineering degrees. The remaining three do not provide any instruction in engineering.

At the request of the Committee of Presidents of Universities of Ontario (now the Council of Ontario Universities - COU), the Committee of Ontario Deans of Engineering (CODE) developed a proposal to conduct a study of engineering education

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1 The views expressed in this paper are those of the authors and do not necessarily represent those of the Council of Ontario Universities.

in Ontario. It was to cover both the undergraduate and graduate fields and examine student flows, curricula, research, staff, facilities and costs. The objective was to create a master plan which might be used as a guide for rational growth of engineering education during this decade.

The study commenced in October of 1969 under a full-time director and was completed in January, 1971 with the presentation of the report "Ring of Iron"[2], and three auxiliary documents containing the source material, to the Council of Ontario Universities.

In this paper we will cover only one portion of the original study: the supply and demand of engineering manpower in Ontario. Though this was but a small segment of the total study it was considered to be vital. Two of the three source documents dealt specifically with supply and demand. The topic is important if considered solely from a monetary point of view. The universities spend approximately $8,000 to produce a baccalaureate engineer, $16,000 to produce an engineer with a master's degree and $40,000 to $60,000 to produce an engineering doctorate. We cannot afford to produce a great excess at these prices.

In the following discussion we shall treat the topics of supply and demand as mutually exclusive subjects. Thus we shall make no attempt to identify the relationships and balances between the projected supply of qualified engineers and the future market demand. Instead we shall explore first the projected supply of engineers, given that certain conditions within the education system prevail; and then we shall study the possible demand that might exist during the next decade.

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2 "Ring of Iron" - A Study of Engineering Education in Ontario", Council of Ontario Universities (formerly Committee of Presidents of Universities of Ontario), December 1970.

Also, Ontario was considered a closed system in the study since 85 percent of the freshmen intake comes from the province and the majority of graduates find employment there.

SUPPLY:

Two topics will be covered under this heading: (1) a review of the methodology used to project the supply of engineering manpower in Ontario during the coming decade and (2) the possible application of the new theoretical models to such a study. The methodology used in projecting the supply is covered in a source document to the main report entitled "Undergraduate Engineering Enrolment Projections for Ontario, 1970-1980"[3]. The report concludes that if entrance requirements are altered, by 1981 the Ontario universities will be producing, on average, about 1,700 to 1,800 engineering baccalaureates per annum.

We shall be concerned here only with the supply of baccalaureates since it has been recommended that the supply of graduate degrees be held to quotas identified in the report Ring of Iron. Though the actual study of supply involved projections of several stocks, we shall focus our attention on only two methods in this presentation.

Table 1 gives the full-time undergraduate enrolments from 1941-42 to 1969-70. The purpose of this section is to study the projection of these stocks to 1980-81. Since approximately 95 percent of undergraduate students in Ontario are from that province it appeared reasonable to utilize Ontario statistics and high school data. In 1969-70 students

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3 Philip A. Lapp, "Undergraduate Engineering Enrolment Projections for Ontario, 1970-1980", Council of Ontario Universities (formerly Committee of Presidents of Universities of Ontario), November 1970.

TABLE 1

FULL-TIME UNDERGRADUATE ENGINEERING ENROLMENTS 1941-69

ONTARIO UNIVERSITIES

Academic Year	First-Year Engineering Enrolment	Total Engineering Enrolment	
1941-42	670	1,719	Sources: Data from 1941 to 1959, from Engineering Institute of Canada, Engineering Journal, generally reflect early Fall registrations.
1942-43	818	2,008	
1943-44	563	1,739	
1944-45	596	1,711	
1945-46	742	2,435	
1946-47	2,367	5,642	
1947-48	1,477	5,610	
1948-49	836	5,110	
1949-50	679	3,908	
1950-51	664	2,917	
1951-52	723	2,346	
1952-53	923	2,410	
1953-54	894	2,591	
1954-55	1,058	2,938	
1955-56	1,046	3,132	
1956-57	1,187	3,416	
1957-58	1,431	3,860	
1958-59	1,372	4,123	
1959-60	1,247	4,220	
1960-61	1,213	3,791	Data from 1960 to 1969, from submissions received from Ontario Universities, reflect engineering enrolments as of December 1 each year.
1961-62	1,284	3,823	
1962-63	1,470	3,922	
1963-64	1,706	4,401	
1964-65	1,870	4,894	
1965-66	2,233	5,685	
1966-67	2,581	6,415	
1967-68	2,735	7,218	
1968-69	2,789	8,002	
1969-70	2,676	8,502	

entering engineering were required to have successfully completed two mathematics subjects (mathematics A and mathematics B), physics and chemistry. Therefore it was concluded that an analysis of these grade 13 subjects would provide some insight into the academic preferences of young people preparing for university. Furthermore, any trends in the number of high school students taking these subjects would permit speculation on future prospects for enrolment.

Of great interest was the percentage of passes over the years in each grade 13 subject. These are shown in Figures 1, 2 and 3. Figure 1 illustrates the percentage of grade 13 students passing in mathematics. Up to 1965-66, mathematics consisted of algebra, geometry and trigonometry, but in 1966 these subjects were replaced by mathematics A (introduction to analysis) and mathematics B (algebra). Figure 1 reveals a remarkably uniform consistency over the past forty years, with all subjects falling within a 45-65% band and algebra being the least popular subject.

Figure 2 shows the percentage of grade 13 students who passed in physics and chemistry. These curves reveal a very significant trend. Since 1955 there has been a declining interest in both of these subjects. Since the achievement of a pass in physics (credit or better), together with minimum over-all averages, is adequate to enter engineering the pass curves of Figure 2 were used as a basis for one projection. There has also been reasonable consistency between the number of students who enter engineering and those who pass physics and chemistry. First-year engineering enrolments plotted as a percentage of successful passes in grade 13 physics and chemistry the previous year are shown in Figure 3.

FIGURE 1 - MATHEMATICS - GRADE 13 DEPARTMENTAL EXAMINATIONS
PERCENTAGE OF GRADE 13 STUDENTS ACHIEVING PASS - 50% OR BETTER

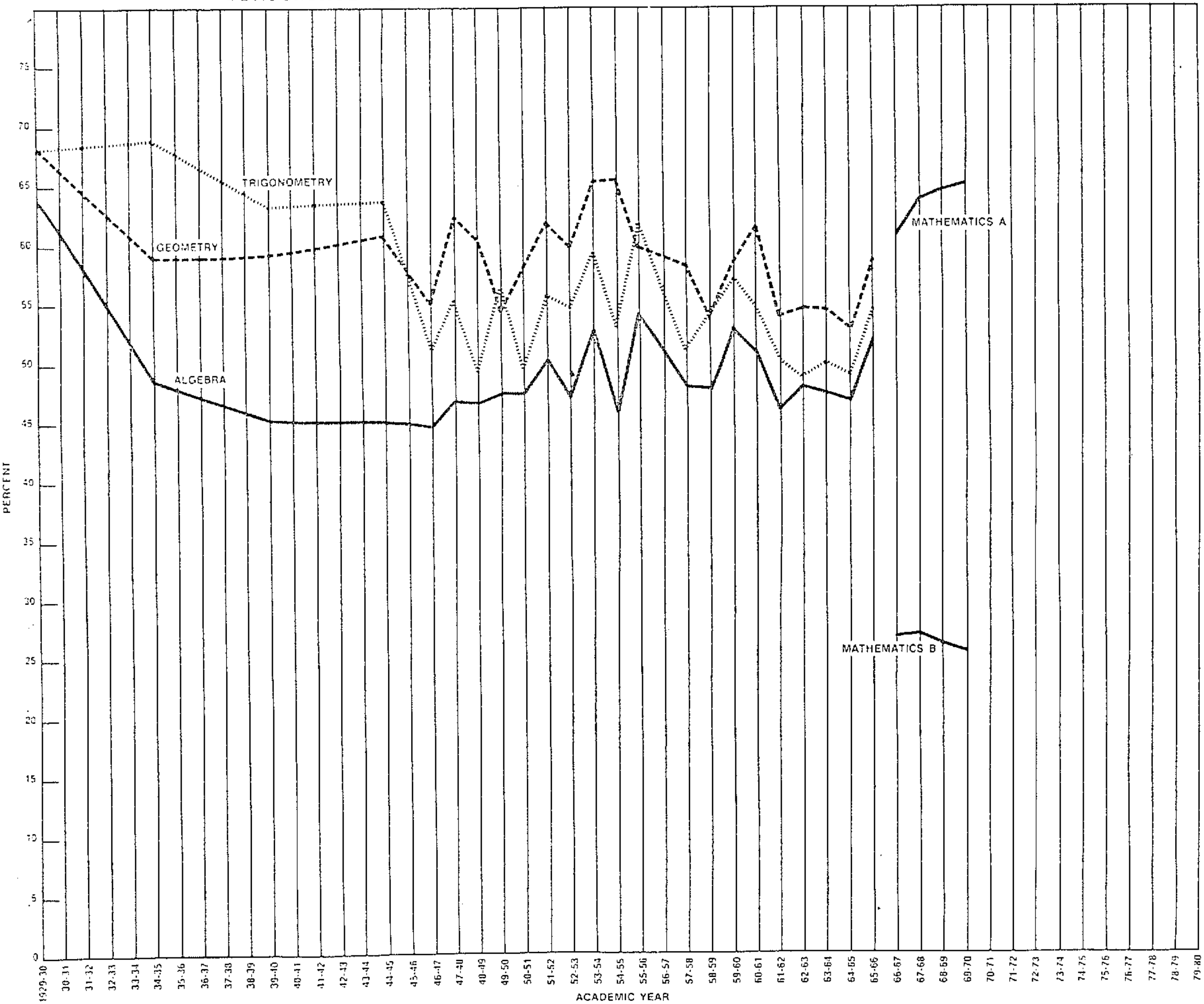


FIGURE 2 - PHYSICS AND CHEMISTRY - GRADE 13 DEPARTMENTAL EXAMINATIONS
PERCENTAGE OF GRADE 13 STUDENTS ACHIEVING PASS - 50% OR BETTER

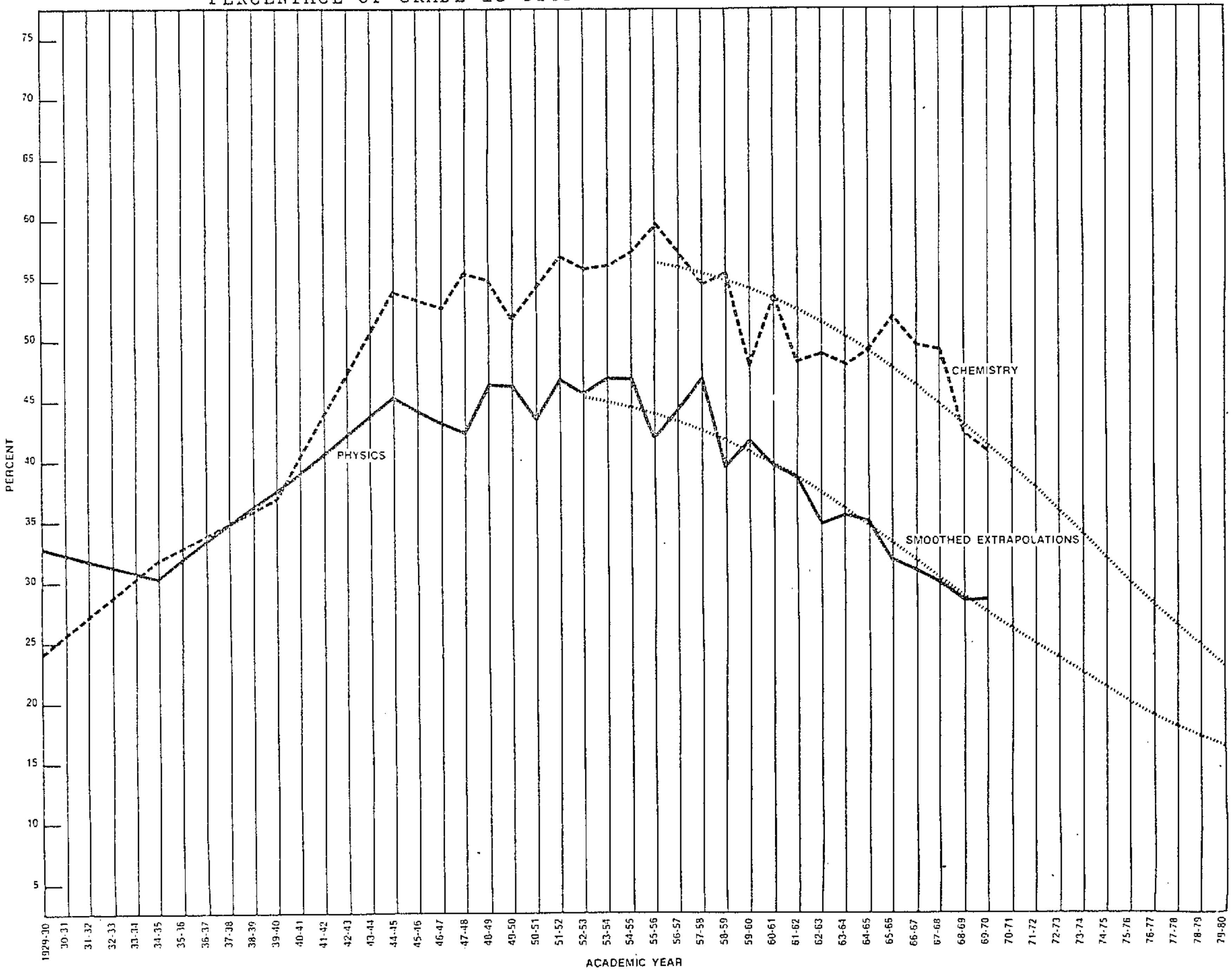
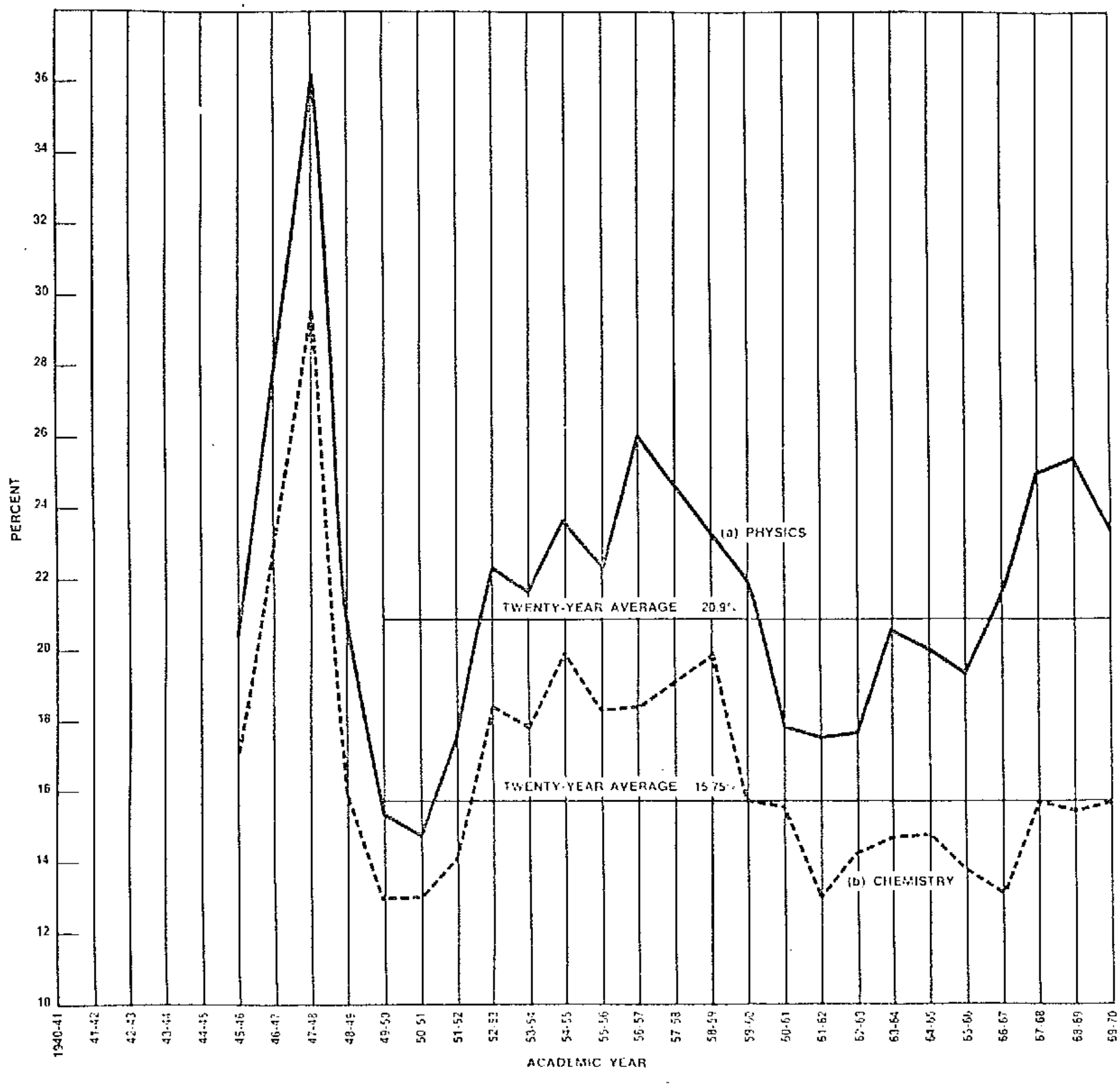


FIGURE 3 - FIRST-YEAR ENGINEERING FALL ENROLMENT AS A PERCENTAGE OF STUDENTS ACHIEVING PASS - 50% OR BETTER - IN PHYSICS AND CHEMISTRY IN THE PREVIOUS SPRING DEPARTMENTAL EXAMINATIONS



The physics and chemistry curves in Figure 2 were smoothed and extended to 1980. Next, the freshman engineering percentages of passes in physics and chemistry data were averaged over the past twenty years. A projection of first-year engineering enrolment in 1980-81 of 2,460 using physics data, and 2,750 using chemistry data, was derived from a projection of grade 13 enrolments supplied by the Ontario Institute for Studies in Education[4] and the averages derived from Figures 2 and 3.

In deriving enrolment projections for the engineering programs, it was necessary to have the capacity to derive either total enrolment from a projection of first-year enrolments, or freshmen enrolment from projections of total enrolment. Because data was available only on the stock of engineering students at each level in any academic year, it was necessary to construct an approximation to the general transition matrix A(i,j) where element a(i,j) refers to the percentage of students moving from state i at time t to state j at time t+1.

$$A = \begin{bmatrix} .15 & .70 & 0 & 0 \\ 0 & .05 & .80 & 0 \\ 0 & 0 & 0.01 & .90 \\ 0 & 0 & 0 & .01 \end{bmatrix}$$

The approximation consisted of positive elements only on the super diagonal. (Example-matrix C) Thus it was assumed that no student remained in a given year for longer than one time period but either graduated to the next level or was lost to the system.

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4 Cicely Watson, Saeed Quazi and Aubert Kleist, "Ontario Secondary School Enrolment Projections to 1981-82", OISE Enrolment Projections No. 5, 1969.

$$C = \begin{bmatrix} 0 & 0.75 & 0 & 0 \\ 0 & 0 & 0.85 & 0 \\ 0 & 0 & 0 & 0.92 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Submissions from the Ontario engineering schools contained data on enrolments in each year of each program over the period 1960-61 to 1969-70. Examination of the data revealed that the super diagonal transition proportions developed for a matrix such as C did not remain constant from one year to the next but appeared to change with the rate of enrolment growth. Therefore, it was assumed that the enrolment in any one session t (eg. 1969-70) is linearly related to the enrolment in the previous session t-1 and to the absolute rate of change of enrolment from session t-2 to t-1.

$$E(t) = A + F(t) + PE(t-1) + C\left|E(t-1) - E(t-2)\right| \quad \ldots\ldots\ (1)$$

$$\begin{bmatrix} e_1(t) \\ \vdots \\ e_4(t) \end{bmatrix} = \begin{bmatrix} a_1 \\ \vdots \\ a_4 \end{bmatrix} + \begin{bmatrix} f_1(t) \\ \vdots \\ f_4(t) \end{bmatrix} + \begin{bmatrix} P_{11} & \cdot & P_{14} \\ \vdots & & \vdots \\ P_{41} & \cdot & P_{44} \end{bmatrix} \begin{bmatrix} e_1(t-1) \\ \vdots \\ e_4(t-1) \end{bmatrix} +$$

$$\begin{bmatrix} C_{11} & \cdot & C_{14} \\ \vdots & & \vdots \\ C_{41} & \cdot & C_{44} \end{bmatrix} \left| \begin{bmatrix} e_1(t-1) \\ \vdots \\ e_4(t-1) \end{bmatrix} - \begin{bmatrix} e_1(t-2) \\ \vdots \\ e_4(t-2) \end{bmatrix} \right|$$

$$E_T(t) = \sum_{i=1}^{4} e_i(t)$$

$e_i(t)$ = enrolment in year i at time t

$f_i(t)$ = net inflow of students into year i from outside the system at time t; $f_i(t) = 0$ for all $i \doteq 1$

P_{ij} = proportion of students moving from year i to year j; $P_{ij} = 0$ for $j \neq i + 1$

A = matrix of constant terms

C = matrix of elements c_{ij} where $C_{ij} = 0$ for all $j \neq i + 1$

$E_T(t)$ = total engineering enrolment at time t

For this model all elements of matrices A, P and C were determined by applying a step-wise linear regression to the historical enrolment structure. Freshmen enrolments for six previous years are required to develop all the terms to yield the following parameters:

i	a_i	$P_{i,i+1}$	$C_{i,i+1}$	Correlation Coefficient
1	0.0	0.0	0.0	-
2	-352.6	1.042	-0.502	0.998
3	187.4	0.686	-0.370	.988
4	- 12.3	0.949	-0.067	.997

Finally, a simple model for estimating bachelor degree output was constructed by using a simple linear regression relating the degrees awarded in session t, d(t), to fourth-year enrolment, $e_4(t)$:

$$d(t) = 36.33 + 0.976e_4(t)$$

Because of the absolute term in equation (1) it was found easier to develop first-year enrolments from total enrolments by an iterative process (the determination of a set of first-year enrolment figures which translated through the model, matches the given set of total enrolment figures). The model was applied to the projection of first-year enrolments to derive a projection of total enrolments and these are shown as the lower branches in Figure 4. The upper branches are projections of first-year and total engineering enrolments assuming that entrance requirements are altered and mathematics, plus a minimum over-all standing become the only prerequisites.

In Figure 5, parts a, b and c, the ratios of science and engineering to total undergraduate enrolments are plotted separately and combined. The combined ratio shows reasonably smooth and steady growth and the growth in science percentages coincides with the acceleration in the decline of engineering percentages. Figure 6 contains plots of total university ratios on an expanded logarithmic scale for projection purposes. The ratio of engineering to total university enrolments has been plotted for a period of sixteen years from 1953-54 to 1969-70 (Figure 6a). The ratio of engineering to total university male enrolments (over 99% of all engineering students are male) has also been plotted in Figure 6 (a third plot is shown on the graph of total engineering enrolment as a percentage of the Ontario 18-24 male age population but is not used in this paper).

Because the popularity of science and mathematics subjects in grade 13 shows a general decline we have assumed that total science enrolment will saturate at about 26% of total university enrolment. Also because there is no indication that there will be any major trend changes between pure science and engineering we assumed that the proportion of engineering students to total university enrolments would not undergo any major trend changes. This proportion was

FIGURE 4 - ENGINEERING UNDERGRADUATE ENROLMENTS

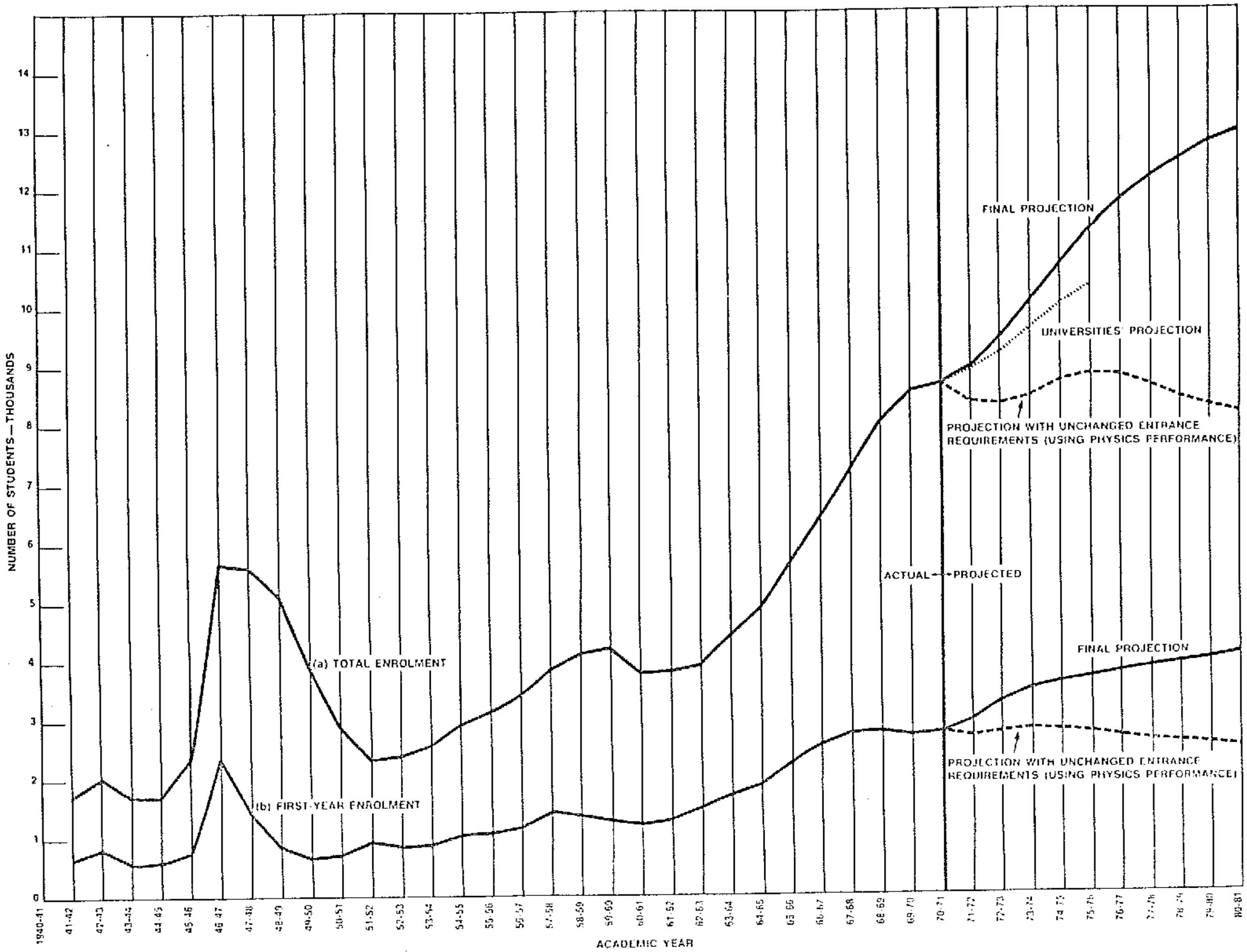


FIGURE 5 - TOTAL ENROLMENT RATIOS - ENGINEERING AND SCIENCE

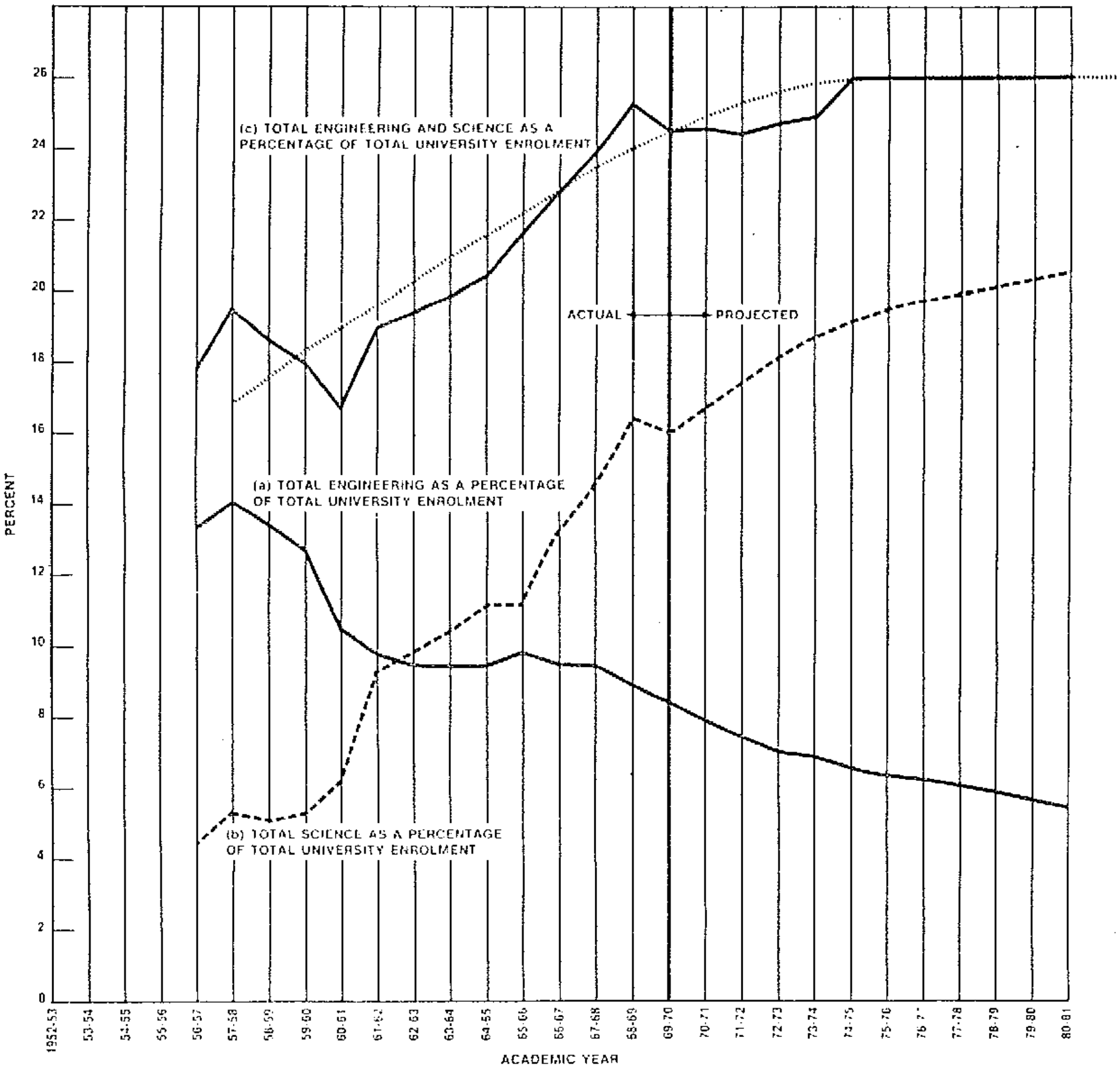
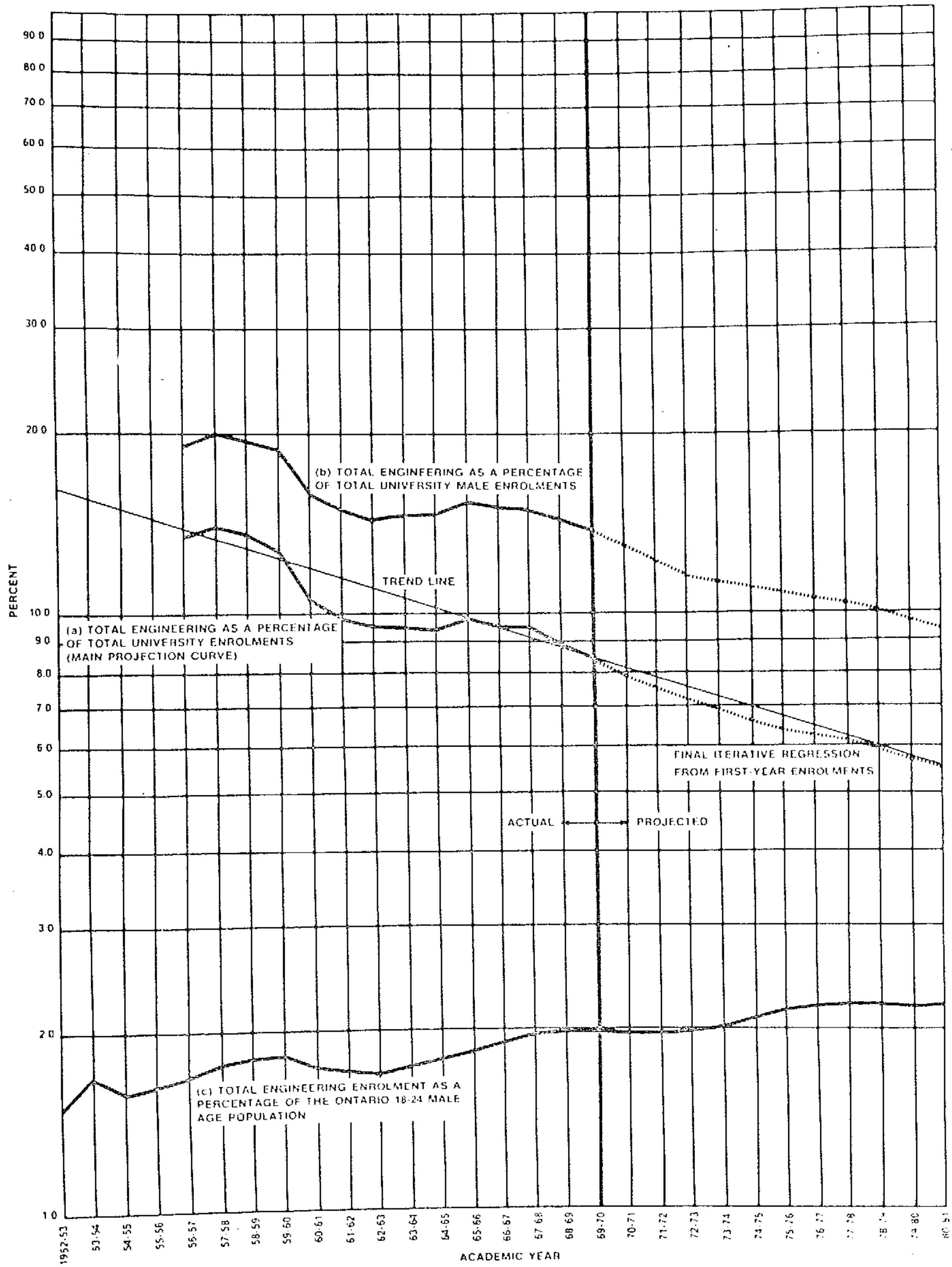


FIGURE 6 - TOTAL ENGINEERING ENROLMENT RATIOS



extrapolated (Figure 5a) and plotted on Figure 6a). From this an initial table of total engineering enrolments was developed from projections of total university enrolment and an iterative procedure used with the attrition model to develop a first-year enrolment curve. (Table 2)

These first-year enrolment projections were tested for consistency by applying them to grade 13 and grade 12 stock projections and extending the curves in Figure 7. Both these curves show remarkable consistency with the broad trend lines extending back almost twenty years.

Several other stocks and trends were also considered in the complete analysis but for varying reasons were rejected in the final determination. They are covered, together with a more complete dissertation on the methods discussed in this paper, in the original document[5].

The remaining part of this section on supply is devoted to a discussion of the application of Markov probability models to such a study. The closest we came to developing transition matrices was in the application of the attrition model which was, in fact, an approximation since the transition proportions were estimated solely from aggregate time series data on stocks.

How far are we away from being able to derive and study true transition matrices? In Ontario, except for special studies where individual students were actually traced, we are definitely several years away from having the necessary data bases. There are generally three problems to be faced: unique identification, protection of the individual, and the cost and collection of the data.

Many of the universities record a considerable amount of data about each student, some records totalling as much as 120 separate items, ranging from the name and address to the day, month, year and reason for withdrawal. The high schools also

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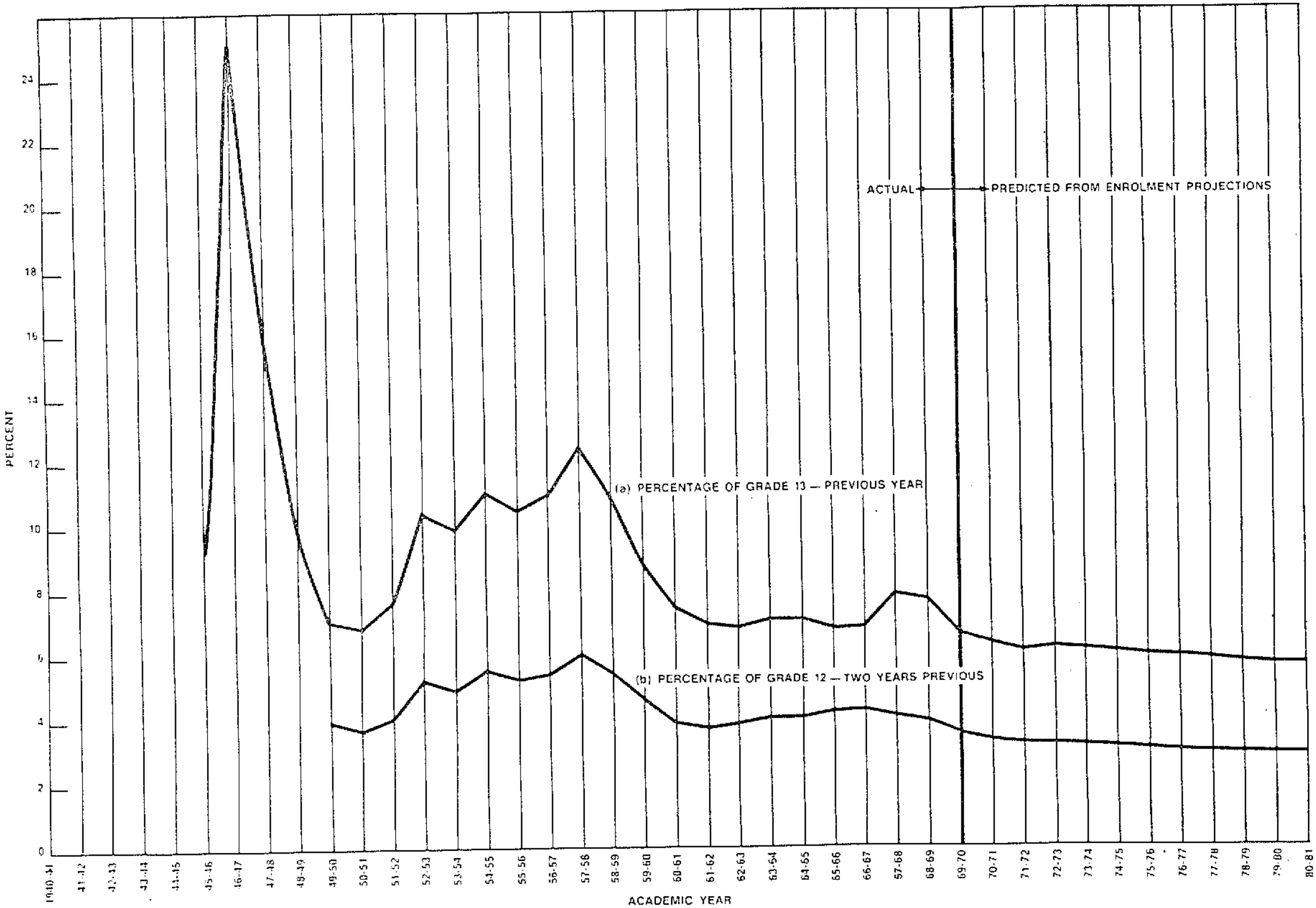
5 Ibid, page 3.

TABLE 2 - ENGINEERING UNDERGRADUATE ENROLMENTS

Academic Year	Total Enrolment - Final Projection	Total Enrolment - Universities' Projection	Total Enrolment - Projection with Unchanged Entrance Requirements (Using Physics Performance)	First Year Enrolment Final Projection	First Year Enrolment - Projection with Unchanged Entrance Requirements (Using Physics Performance)
1969-70	For actual enrolments to 1970, see Table 1.				
70-71	8,620	8,540	8,620	2,750	2,750
71-72	8,448	8,899	8,326	2,970	2,660
72-73	9,401	9,167	8,300	3,290	2,740
73-74	10,061	9,563	8,452	3,500	2,800
74-75	10,672	9,957	8,738	3,610	2,780
75-76	11,247	10,272	8,855	3,695	2,730
76-77	11,763		8,790	3,780	2,640
77-78	12,166		8,603	3,855	2,610
78-79	12,466		8,408	3,915	2,580
79-80	12,712		8,276	3,970	2,530
80-81	12,950		8,154	4,040	2,460

FIGURE 7 - FIRST-YEAR ENGINEERING ENROLMENTS AS A PERCENTAGE OF STUDENTS ENROLLED IN GRADE 13 IN THE PREVIOUS ACADEMIC YEAR, AND IN GRADE 12 TWO YEARS PREVIOUS



maintain extensive records together with the Ontario Department of Education where the results of all grade 13 examinations are maintained. Yet there is no single element that ties all of these records together. A student moves from high school to one of the universities or transfers from one university to another and the record is broken. Within Canada there is in existence a unique identification system, the issuing of a social insurance number to every person who has been employed. However it is not mandatory for persons who have not been employed, high school students for example, to apply for a social insurance number. To date neither has it been mandatory for students to list a social insurance number when applying to a university nor in fact do the high schools record them.

There are discussions under way between the several levels of education to overcome these problems but actually little headway has been made. Until all students are required to have a social insurance number there is little hope that students can be tracked through the system except by studying a special sample.

Perhaps a more significant problem is that of confidentiality. At the present time legislation is being prepared at both the federal and provincial level to strictly control the retaining of any data which can be traced to an individual. This development may eventually cause serious problems to the development of Markov probability models for the projection of student numbers.

Fourteen provincially-assisted universities and at least five central agencies would be involved in any collection of student data. All are interested parties. Some universities maintain the information on card and tape while the smaller institutions maintain only paper files. Therefore it is anticipated that problems of collection and co-ordination between central agencies will have to be overcome.

An idea of the cost of building a Markov model can be discerned from another project currently being undertaken by the Council of Ontario Universities. This project involves tracing university professors from one year to the next to study both the characteristics of incoming staff and to build a model to aid in a study of the demand for academic staff. The processing costs of matching 6,000 records from 1968-69 to 7,000 records from 1969-70 and constructing the resulting Markov probability model was several thousand dollars (the matching was not done through a unique identifier but through a series of dates on each record). Added to this is the cost of collecting the data, checking and coding. Certainly the question will be raised - is the increased accuracy (and will there be increased accuracy?) worth the additional cost?

Taking all these factors into account we can only conclude that we are still several years away from having the data available, on a regular basis, to generate the required transition matrices. Thus for some time to come we shall be faced with having to infer student flows from stock data. The theoretician has better models but the practitioner has no data. Perhaps, soon, instead of looking too far into the future all interested parties can come together and make better use of what is available.

DEMAND:

In Canada, the profession of engineering is regulated by acts of the provincial legislatures, administered by provincial associations. Although the acts differ in detail, the entrance qualifications are generally similar across the country, and an engineer is defined as one qualified to be registered as a professional engineer. At present, approximately 85% of all such engineers are registered in one or more of the provincial associations.

It is necessary to distinguish between two separate concepts when assessing manpower requirements. One is need: the necessary mixture and flow of manpower required to meet objectives and goals; the other is demand: the aggregate of individual employment opportunities available within the economy. We have adopted the economist's approach to the problem of estimating demand - for him, supply must equal demand. The way in which they are equalized is by effecting adjustments to both sides of the equation. Supply is increased by attracting people from other fields, by higher salaries and benefits, by immigration, by retraining and upgrading employees, by working overtime, or delaying retirement. Demand is reduced by such means as re-defining jobs to require less skill, by shifting priorities of projects, and by automation. In effect, employers "make do" with existing personnel.

For the Ontario engineering study, demand was precasted for the ten-year period 1970-1980. The basic method was to project the growth of the stock of engineers in Canada from a base year of 1961 (the last census year in Canada) over a twenty year period at the same rate as the Gross National Product (GNP). The annual attrition rate was assumed to be maintained at the level experienced with the 1961 stock (1.94%)

because no data was available on attrition of those engineers who entered the labour force after 1961. These assumptions generated a required inflow of 68,300 engineers during the period 1961-1981. The known net inflow of new graduates and immigrants between 1961 and 1968 resulted in an annual average required inflow of 3,300 engineers per year for the period 1968-1981.

The objective of the demand study[6] was to estimate the requirements for engineering graduates from the Ontario universities. The study revealed that Ontario should produce between 35% and 46% of the number of engineering graduates required for Canada up to 1981, less what it receives from immigration. Immigration will be offset by those engineering graduates who do not enter the engineering labour force (those that go to graduate school ultimately do enter or re-enter the labour force). Immigration has averaged about half as much as the annual number of bachelor's degrees, and it is doubtful that the loss of new graduates from the profession is that large. The study also analyzed three previous projections and drew comparisons to arrive at the conclusion that the number of new graduates per year required from the Ontario universities is not likely to exceed 1,500, with 2,300 as an extreme upper limit.

The validity of this approach to demand projection is subject to many criticisms. Extrapolation of past trends does not take into account major structural changes in society that create discontinuity between present and future -

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6 M. L. Skolnik and W. F. McMullen, An Analysis of Projections of the Demand for Engineers in Canada and Ontario and An Inquiry into Substitution Between Engineers and Technologists, CPUO Report No. 70-2, November 1970.

particularly when many of the variables are influenced by technology. Furthermore, the scant data available on technical manpower in Canada coupled with a need to extrapolate from stock information nearly ten years old (the next Canadian census takes place in 1971) makes it difficult to place confidence in using the results of such a study for educational planning.

A study was also conducted on the influence of a growing stock of technologists in Canada on the demand for engineers. Sixteen companies were examined in depth, which collectively employed 250,000 people including 7,500 engineers, 1,500 physical scientists and 3,500 technologists and technicians. Approximately one-tenth of all engineers in Canada were covered in this study. It was discovered that technologists are still not regarded as career substitutes for engineers and that there are distinct barriers to the upward mobility of technologists. Substitution does take place in work functions, where there is a functional organization of the engineer's activity. When it becomes routine, often geared to a computer, this work is usually passed on to a technologist.

The relative supplies of engineers and technologists appeared to have little influence on manpower demands, but the absolute supplies of both engineers and technologists were of importance. When the number of engineers decreased substantially (e.g. mining and geology), technologists were substituted to meet the demand. The number of available technologists influences the speed of adjustment to changes in technology. A more rapid response was possible when trained technologists were readily available as an alternative to in-plant training. It was concluded that increasing numbers of technologists will not have a significant effect on the demand for engineers. In future, this picture could change as industry learns how to use the technologist more effectively.

The selection of GNP as a basis for projecting demand growth was based on the fact that this economic variable is perhaps more predictable over the long haul (as evidenced from past performance in Canada) than other variables that could be more pertinent to the engineer's activity. An examination of past trends revealed that capital expenditure would have been a superior variable, but this is far less predictable because of its short-term dependence on the cost of money - a completely unpredictable quantity dependent upon government monetary policies and the world economy.

The U.S. Engineering Manpower Commission conducts periodic industrial surveys to uncover short-term hiring plans, and uses these to predict demand and reveal current trends in meeting hiring objectives. Until recently, demand has exceeded supply and there has been a shortfall in meeting corporate hiring objectives. Even such short-term projections cannot take into account sudden changes in government policies and unexpected turns in the economy.

An attempt was made to predict the demand for engineers with advanced degrees. For the master's degree, there was little evidence that industry placed a premium on such graduates (except for research and development activities) and the demand for them was included in the annual figure for bachelor's degrees. For the doctorate, the demand was analyzed in detail because of the over-supply of such graduates developing in Canada. Most engineering doctorates pursue careers in teaching or research and so an analysis was conducted on the demand for university professors, together with industrial and government research workers for the 1970-1980 decade. It was concluded that there would be a maximum demand of 100 per year, plus emigration of 25 per year, for a total of 125 doctoral graduates per year from the Ontario universities.

It would have been desirable to disaggregate the demand for engineers by branch, especially at the graduate level. Too little was known of existing stocks to attempt this, and long-term technological trends could result in shifts that are not clearly visible at the time of forecasting. For example, the 1961 census revealed that the dominant branch of engineering was civil at that time whereas the largest branch is now electrical. Industrial engineering was virtually non-existent in Canada a decade ago, but is now the fastest growing branch in terms of demand.

CONCLUSIONS:

In Canada, as in most other countries, the indigenous supply of engineers is the result of social choice and not subject to direct planning or control at the undergraduate level. The influence of demand upon supply is difficult to detect because of the four-year delay period which makes the market feedback influence so inefficient. The main effects on the supply of engineers appears to have been the swing to pure science after Sputnik in 1957, the swing to sociology (related to the ecology movement and anti-technology doctrines) developed during the late 1960's, and possibly now the temporary surplus of engineers caused by recent anti-inflation measures and government cut-backs. Traditionally, Canada has faced a shortage of engineers and met its demands by immigration. Unless extreme surpluses can be foreseen, it is questionable as to whether demand studies for baccalaureate engineers should play a prominent role in educational planning.

On the other hand, the high cost of graduate studies has led us to conclude that demand studies are extremely relevant and indeed should govern the number of graduate student places provided in the Ontario system. This is particularly true for the doctorate, where the traditional careers in teaching or research are limited in number and relatively easy to forecast.

It is easy to conclude that our ability to project both supply and demand is severely limited by the availability of accurate and timely data. To collect information is costly, and so the real problem yet to be solved is to select only a minimum number of measurable variables such that adequate planning models can be constructed so as to provide just sufficient visibility for enlightened policy formulation.

May 28, 1971.