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ABSTRACT

This paper describes a computer model that was developed for use to predict the effects of operating the universities in the province of Ontario on a year round basis. The apparent advantage in going to year round operation of universities is the saving in capital costs of buildings and other facilities. This can be achieved because the student enrollment is spread more evenly over the twelve month year and therefore fewer students are in attendance at any one time. The disadvantage of year round operation is the increase in operational costs due to increased instruction costs associated with offering courses year round and also other costs associated with opening the university facilities all year. Whether any particular program of year round operation results in a net saving over the standard two term program depends on many factors and is the purpose of this model. This study was undertaken on behalf of the Ontario Commission on Post Secondary Education. The paper describes how key variables were identified, the method of analysis and the important conclusions derived from the results of the model. Particular attention is given to the problems encountered in obtaining data and how these problems were overcome by using a parametric approach. This allowed a sensitivity analysis to be performed whereby key variables were assigned different values and the sensitivity of the costs to these changes was observed. (Author)

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ABSTRACT

This paper describes a computer model which was developed for use to predict the effects of operating the Universities in the province of Ontario on a year round basis (i.e. switching from the common two-term plan to a Trimester or Quarterly plan). The apparent advantage in going to year round operation of universities is the saving in capital costs of buildings and other facilities. This can be achieved because the student enrolment is spread more evenly over the twelve month year and therefore fewer students are in attendance at any one time. The disadvantage of year round operation is the increase in operational costs due to increased instruction costs associated with offering courses year round and also other costs associated with opening the university facilities all year. Whether any particular program of year round operation results in a net saving over the standard two term program depends on many factors and is the purpose of this model.

This study was undertaken on behalf of the Ontario Commission on Post Secondary Education. The paper describes how key variables were identified, the method of analysis and the important conclusions derived from the results of the model. Particular attention is given to the problems encountered in obtaining data and how these problems were overcome by using a parametric approach. This allowed a sensitivity analysis to be performed whereby key variables were assigned different values and the sensitivity of the costs to these changes was observed. It was then possible to identify the variables which had important economic impact because of year round operation and the implied policy decisions resulting therefrom.

BACKGROUND

There have been numerous public statements in the past several years by business, academic, and political leaders favouring the all-year operation of universities and colleges. In most cases, the suggestion to switch to year round operation is based on the argument that there is a need for a more complete and efficient utilization of educational facilities and that the biggest single factor contributing to the low overall university utilization is the summer shut-down of undergraduate instruction. Other arguments suggest that an all-year university operation would help students complete their education and become financially self-sufficient at an earlier age, while at the same time removing from the economy the need to provide a large number of jobs to students during the summer months.

Mr. A.C. Scrivener, President of Bell Telephone Company of Canada, recommended in June 1970 to the Canadian Chamber of Commerce that they give leadership to a review of university operations. In particular Mr. Scrivener proposed that universities operate two six-month terms each year and that work-study programs be expanded. In this way, he felt that better utilization of the university facilities would be achieved and that students could more easily earn their way through university by alternately working and studying in these six-month terms.

The Honourable William Davis, then Minister of Education for Ontario, spoke in Thunder Bay in February 1971 indicating that he looked favourably on proposals for lengthening the university year to permit honours students to get their degrees in three instead of four years.

The Globe and Mail, in their editorial of February 3, 1971, commented favourably on Mr. Davis's remarks. They continued by saying that Ontario's grants to universities for both operating and construction had increased to $495 million that year from $155 million in 1965-66 and that "we can't stand another five years of high budget increases."

The Globe and Mail continued their support for the "12-month university year" in a later editorial (written after Mr. Davis became Premier) pointing out that Prime Minister Trudeau and the Secretary of State, Gerard Pelletier, appeared to favour extension of the university year. Mr. Trudeau said "If we didn't have this type of school year we have now which is based on an agricultural society where people attended universities and schools during the winter months and in the summer they worked on the farm in order to pay for their winter it is certain we wouldn't have this bulge of young people looking for work in the summer, and to try to meet that we are trying to convince the provinces, that they should be more and more considering the full academic year, without this summer break."

Mr. F. Lazar, a doctoral candidate in economics at Harvard and regular commentator in the Globe and Mail on trends in the Canadian economy, wrote in the April 13, 1972 issue "It is generally accepted that the current structure of the post-secondary academic year does not fully utilize the existing facilities. Thus the average taxpayer may rightfully inquire whether a plan for a fundamental restructuring of the school year cannot be developed so that it not only will provide for a more efficient use of educational facilities (and perhaps moderate the costs) but also will improve employment prospects for students."

These quotations reflect the views we believe, of a large number of Canadians who feel that year round operation of universities is desireable and that one of the major benefits of such action is an improvement in efficiency and a corresponding reduction in total costs to society. Is this assumption of increased efficiency and reduced total costs in fact correct? Most of the people who make such statements assume it to be obviously so but seldom have done an in depth analysis of the economic consequences of year round operation.

In August 1971 the Commission on Post-Secondary Education in Ontario awarded a contract to Woods, Gordon & Co. to undertake a study on the "Organization of the Academic Year." The main objectives of that study were:

1. To describe the options in the organization of the academic year.
2. To examine the merit of these choices.
3. To estimate the effects of the various choices on operating and capital costs of post-secondary institutions.

An important feature of this study was to be the use of quantitive modelling to estimate those operating and capital cost effects.

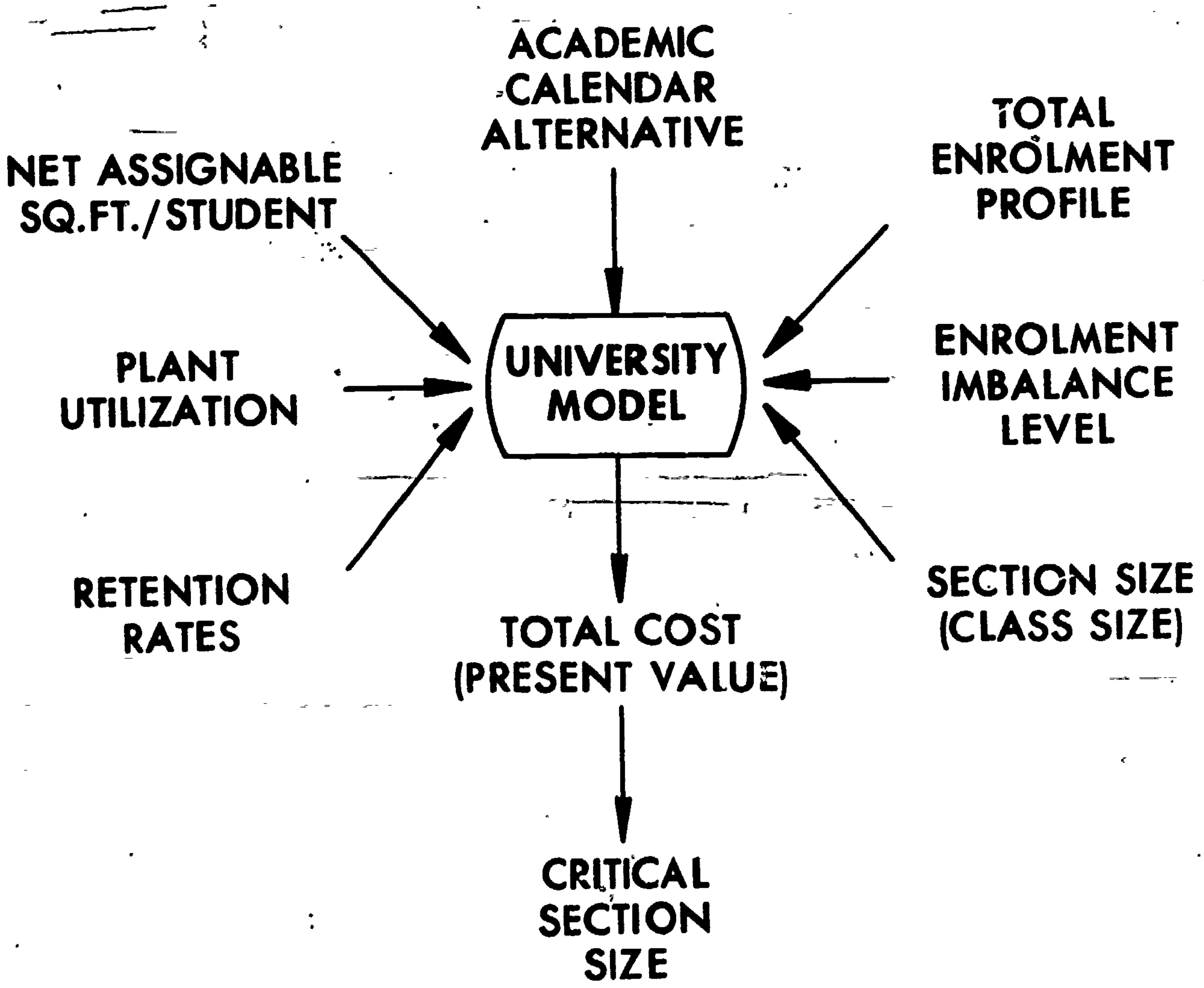
Our presentation today will ignore all of the many other advantages and disadvantages of year round operation and will deal with the one issue which is generally taken for granted - "Is year round operation more efficient and less costly to society?"

Model Formulation

It became quite clear at the outset of this project that detailed costs for a university, and in particular costs in a form which could be related to year round operation, were not readily available.

Exhibit I

YEAR ROUND OPERATION OF UNIVERSITIES — A PARAMETRIC ANALYSIS



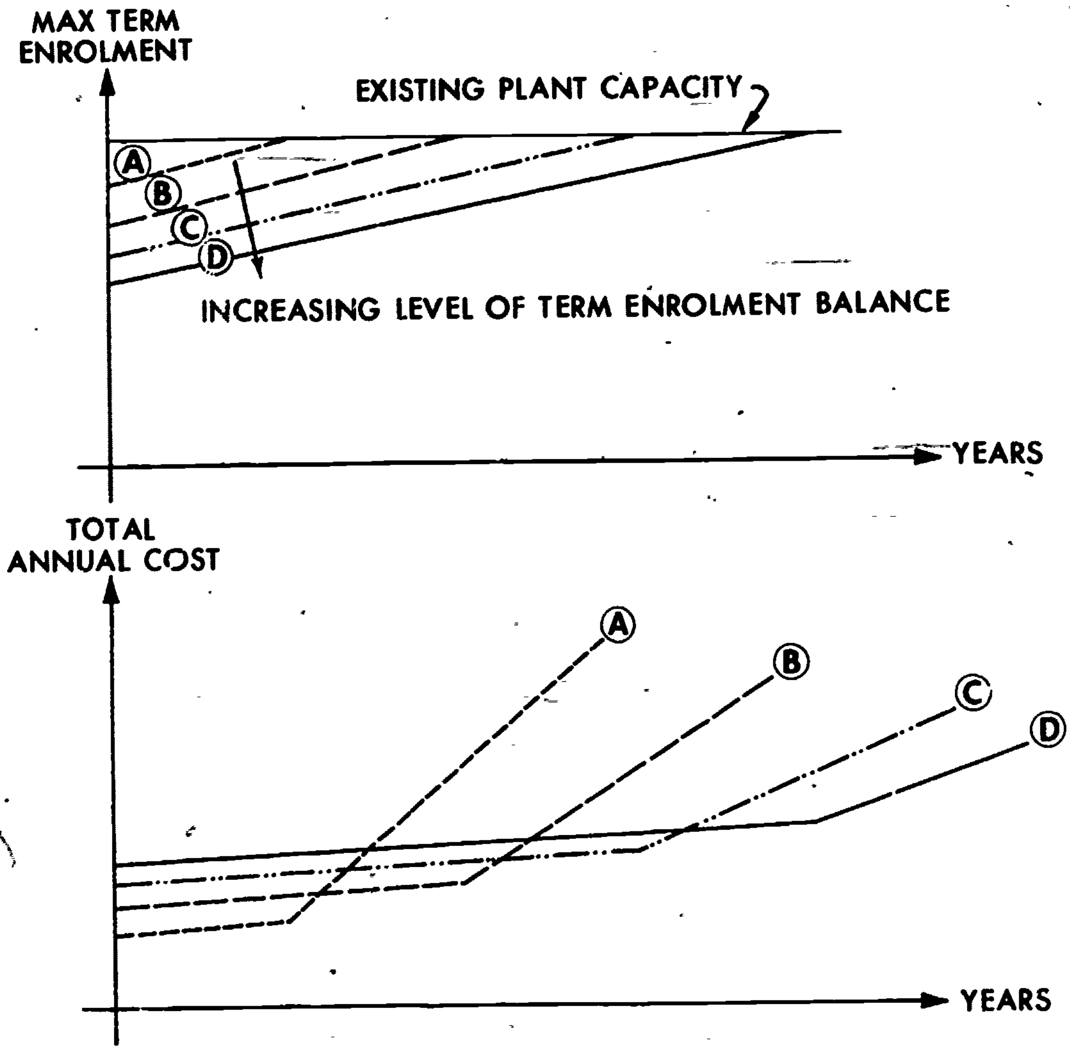
This ruled out the approach of attempting to correlate costs with some key variables and selecting the best fits as a basis for the model. The decision was made at this stage to base formulation of the model on aggregate cost figures (Statistics Canada, Department of Colleges and Universities of Ontario) and from data obtained at a Canadian University. The latter was chosen because of its experience with the trimester program and because detailed cost figures were readily available. Having formulated this model of a "typical" Ontario university a parametric analysis was undertaken whereby the important variables were independently assigned different values and the effect on total systems cost could be observed. Exhibit I shows the key variables that were assigned different values or a range of values in the analysis. Other variables are important in this analysis but only those which were allowed to vary are shown. These were chosen because they were the variables considered to have economic importance in going to year round operation.

The model uses total costs over a 20 year period (1971 - 1990) in comparing academic calendar year alternatives. The method used was to select a parameter set (specific values for total enrolment profile, section sizes, retention rates, plant utilization and net assignable square feet per student) and calculate total costs for a number of year round alternatives at changing levels of term enrolment balance for each year (percent of total enrolment attending each term) of the time span considered. The present value of these costs are calculated and compared against that for the standard two-term program.

This approach is illustrated in Exhibit II by showing a comparison of the standard two-term program (curve A) against a trimester plan with three levels of term enrolment balances (curves B, C and D).

Exhibit II

COMPARISON OF ALTERNATIVE ACADEMIC PLANS USING THE PRESENT VALUE OF TOTAL SYSTEMS COSTS



Ⓐ STANDARD TWO TERM PROGRAM

ⒷⒸⒹ TRIMESTER PROGRAM WITH VARYING LEVELS OF TERM ENROLMENT BALANCES

The upper graph shows maximum term enrolments for each of these four conditions ranging from the standard program with no summer enrolment and a high maximum term enrolment to the trimester plan with three equal term enrolments and hence a lower value of maximum term enrolment. The lower graph in this exhibit is a plot of the total annual costs over the span considered for the four conditions. These costs include operating and amortized capital costs. The capital costs are only incurred when it is required to purchase additional plant and this occurs when the curves as shown in the upper graph reach the existing plant capacity. Hence the points on the lower graph where the cost curves increase in slope coincide with those points on the upper graph where the maximum term enrolment exceeds the existing plant capacity and additional outlay is required for plant expansion. This point would occur earlier for the standard program as shown and later for the trimester program indicating that capital outlays are delayed as the balanced term enrolment condition is approached. In addition the slope of curves decrease as the balanced term enrolment condition is approached indicating that the capital outlays are reduced as the total enrolment is spread more equally across three terms. It must be remembered here that these are not actual results obtained but rather a basis upon which the model was formulated.

The initial slopes on the curves in the lower graph indicate a base of annual operating costs which increase in accordance with the increase in the level of total enrolment over the time span. These annual operating costs initially assume that each course is taught in at least three classes and there is therefore no increase in instruction costs in going to extended year operation with a trimester program. There is however an increase in the level of the operating costs from curve A to D and this is accounted for by the increases in operating costs other than instructional costs which are proportional to the increase in the academic year length and the extent to which the trimester program achieves a balanced term enrolment condition. Exactly how this is accounted for in the model is explained later in this paper.

The model calculates the present value of the total costs of B, C and D and relates this to the present value of the total cost of A. Assuming that the present value of either B, C or D is less than A then the indication is that the trimester program at some level of term enrolment balance is economically attractive and should be considered as a feasible alternative. However the analysis does not stop here but must go further to convert the results into operating decision rules. Recall that the assumption was made that each course in the standard program was taught in at least three sections and also that the increase in base operating cost in the trimester plan did not include instructional cost increases. This assumption is now relaxed and the model allows the section sizes to reduce in the trimester program with a corresponding increase in instructional costs such that the present values of the two systems are made equal.

This indicates what section sizes must be achieved in the alternative program to at least make it economically equal to the standard program. The critical value in this analysis is therefore section size (class size).

Academic Policy Implications of Model Results

Experience at universities has indicated that the success of trimester or quarter operation depends on balancing off the increase in operating costs by the savings in capital costs with these plans. The high operating cost results primarily from the decision to maintain a full course offering in the face of lower term enrolments, particularly in the summer term. If a university operating a standard program has the majority of its courses offered in multiple sections, this increase in operating costs will not be great. However, if the majority of a university's course offerings are given in one section only, many new sections will have to be opened and, with the same general level of overall enrolment, the section sizes will be reduced in switching to a quarter or trimester plan. It then becomes of interest to determine what mean value of section size will make the discounted cost of the standard program and the alternative under consideration equal. These section size values at the break-even point are referred to as the critical section sizes.

The critical section size values are directly dependent on the saving in capital costs minus the increase in operating costs for the year round alternative under consideration. This is because the difference is converted into a section size reduction to the critical value if the result is positive and an increase in section size if the result is negative.

If the difference is exactly zero, then the critical section sizes are the section sizes present in the standard program and the indication is that there is a fair trade-off between the savings in capital costs and increase in operating costs. Hence, nothing is to be gained economically in switching to year round operation.

The policy implications of this analysis are that the university must regulate its course offerings for the trimester or quarter plan so that the resulting mean section sizes are equal to, or greater than, the critical values. Course offerings the year round alternative which result in section sizes less than the critical values indicate uneconomical operation.

In predicting whether an institution could maintain mean section sizes at the critical values if it switched to a year round alternative, the academic policy-makers would have to determine the number of repeated sections for each course offering under its present system. It could then be possible to determine the extent of adjustments in course offerings necessary to maintain the critical section sizes under the new p .. For example, if an institution were operating under a standard two-term plan and each course were offered three times (in three sections) then switching to a trimester plan would not result in a decrease in section sizes and no increase in instruction costs would be incurred.

If each course in the standard program were offered in a single section and it was decided to switch to trimester operation, then instruction costs would triple with a complementary reduction in mean section sizes to one-third their original level. If these section size values were below the critical values calculated in the model, the only choice left would be to drop courses to increase section sizes to at least the critical values.

Exhibit III

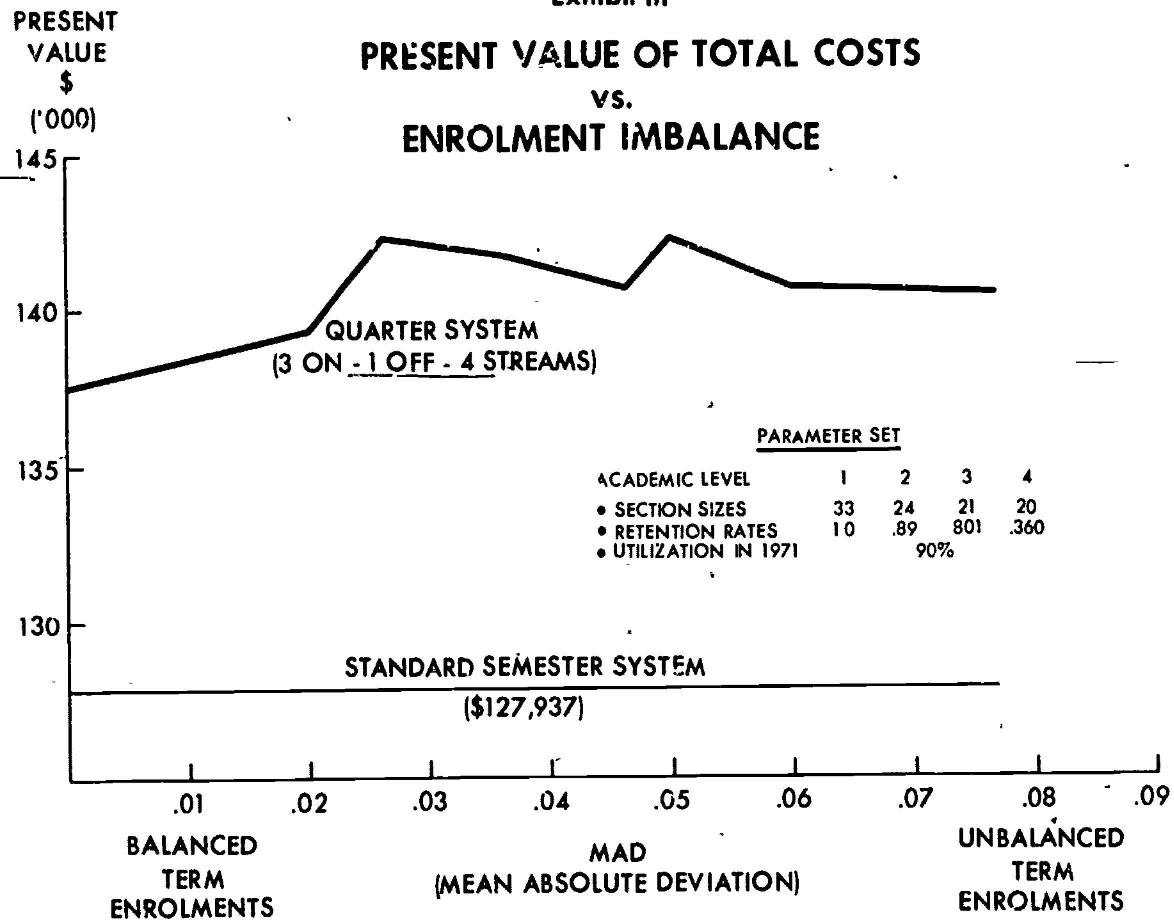
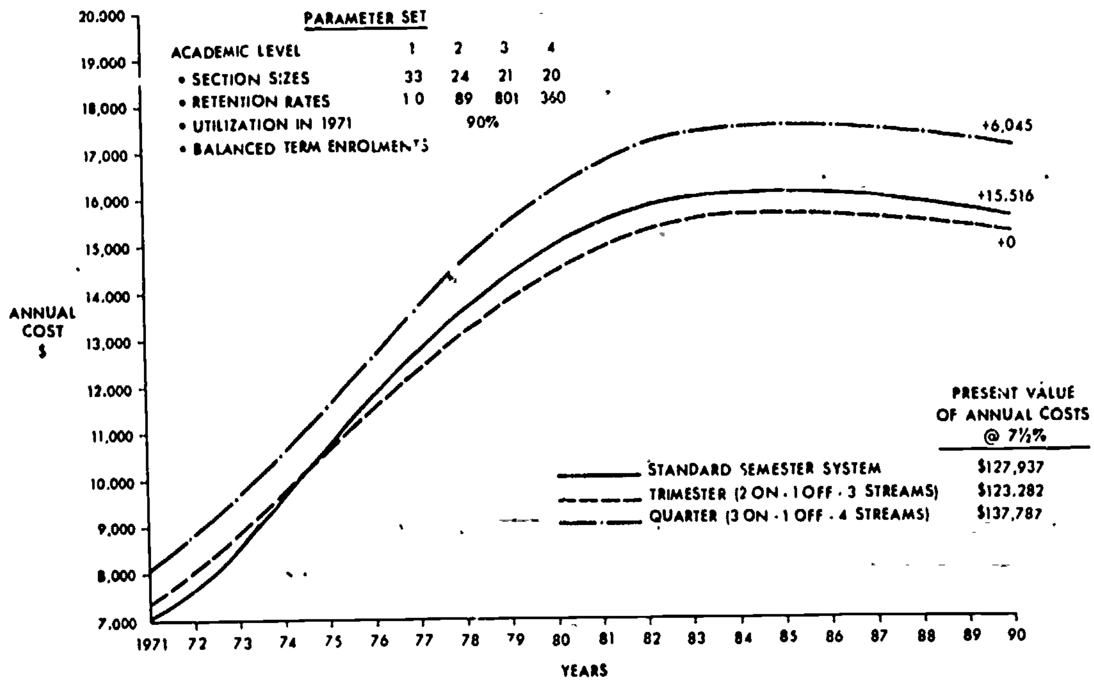


Exhibit IV

TOTAL ANNUAL COST*
vs.
YEARS



* NORMALIZED ANNUAL COSTS PER NUMBER OF FRESHMEN STARTING IN 1971

Summary of Model Results

Many computer runs of the model were made to show the effects on costs and critical section sizes of changes in the key input variables. The approach was to change the value of one particular variable such as section sizes and compare the results of the run for the year round alternative to the results of the run used as a benchmark. (i.e. the standard semester system). As mentioned earlier changes were made in total enrolment, term enrolment balance, section sizes, retention rates, plant utilization and net assignable sq. ft. per student. These changes were made one variable at a time so that the effect on total costs and critical section sizes to a change in this variable could be isolated.

The following important conclusions are based on the model results.

a) The quarter system with the same freshmen enrolment pattern as all other programs is economically unattractive under all operating conditions that were examined in the model, and should be ruled out as a feasible alternative. Exhibit III shows that the present value of total costs for the quarter system is greater than the present value of total costs for the standard semester system for all values of term enrolment imbalance levels. This was found to be true for all parameter sets examined in the model. To see how this looks on an annual cost basis Exhibit IV shows a plot of total annual cost for the years from 1971 to 1990 for the balanced term enrolment condition. The total annual cost curve for the

Exhibit V

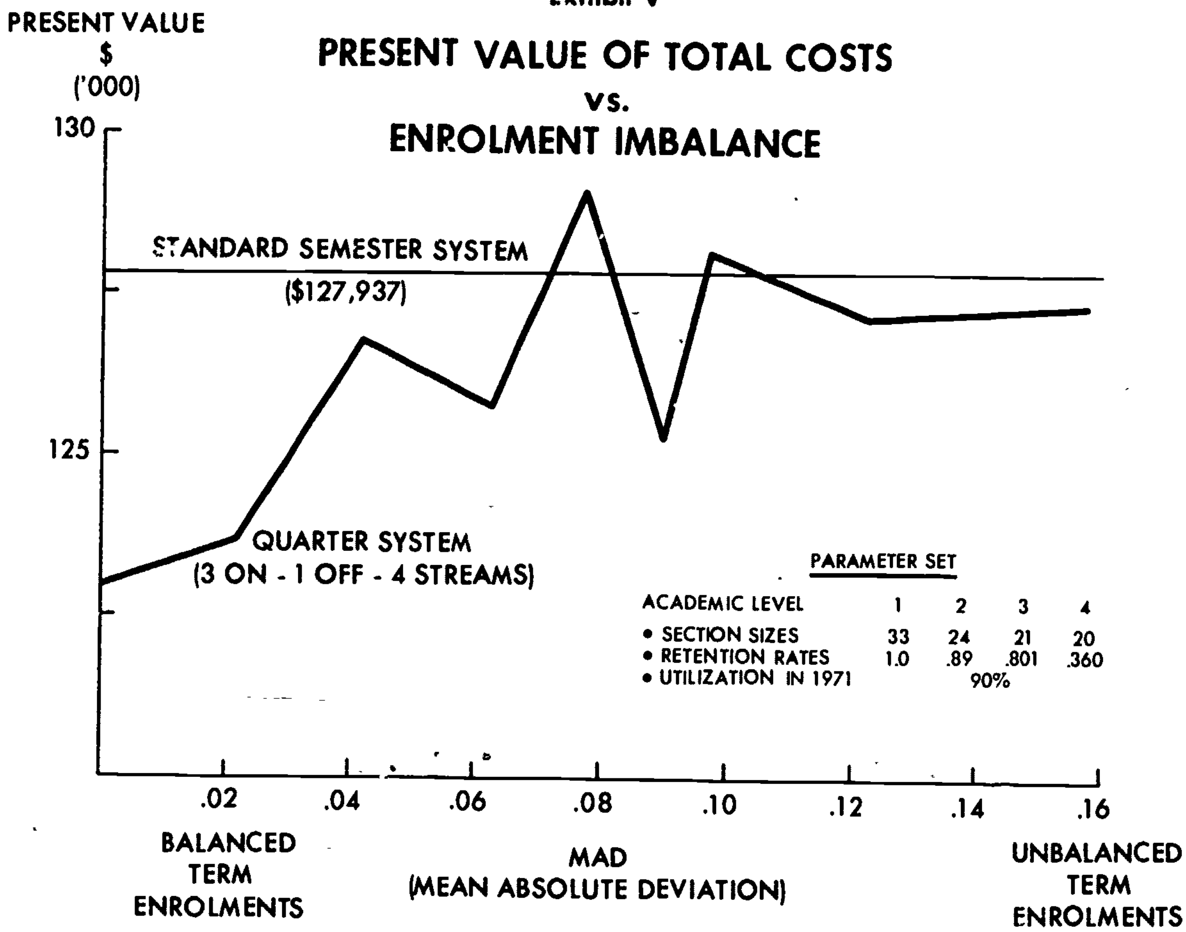
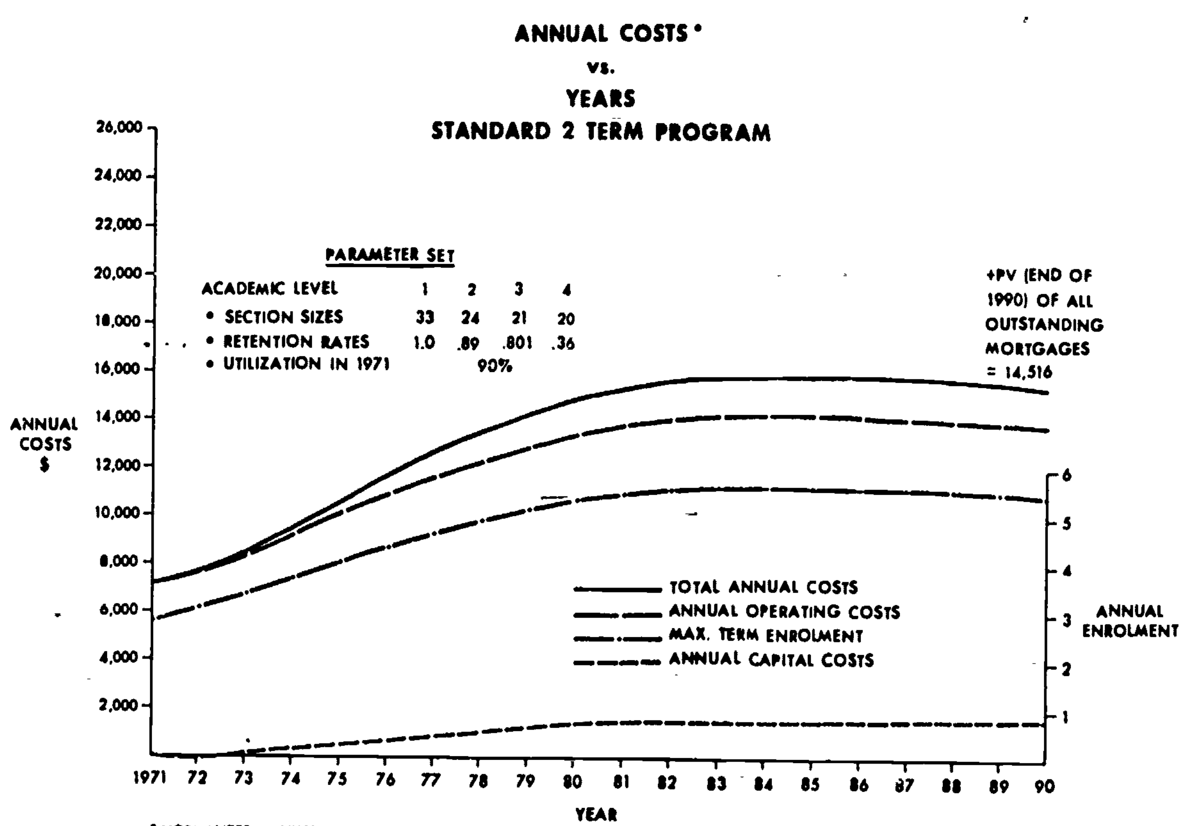


Exhibit VI



* NORMALIZED ANNUAL COSTS PER NUMBER OF FRESHMEN STARTING IN 1971.

Quarter program never crosses the cost curve for the standard semester program over the years considered.

b) The model results indicate that there may be some economic advantage to be gained in switching to a trimester program. As Exhibit V indicates the present value of the trimester program is less than that for the standard 2 term program particularly at the balanced term enrolment condition ($123,282 vs. $127,937). This allows a maximum reduction in average year round section sizes of 6.1% for the trimester program at which point the net present values of the two systems are equal. Exhibit IV shows that the total annual cost curve for the trimester program crosses over the cost curve for the standard program in 1975 and remains at a lower value for the remainder of the time span considered.

c) Amortized capital costs make up a small portion of total annual costs in the university system as determined in the model. This is caused by a levelling off of student enrolments over the twenty years simulated and this factor has an important effect on the economics of year round operation. Exhibit VI shows capital cost and total cost plotted against years for the standard two term program for a 1971 utilization factor of 90%. Also plotted on this graph are annual operating costs and maximum term enrolments. As explained previously, capital costs are a function of the 1971 utilization factor and the maximum term enrolments and for this case account for

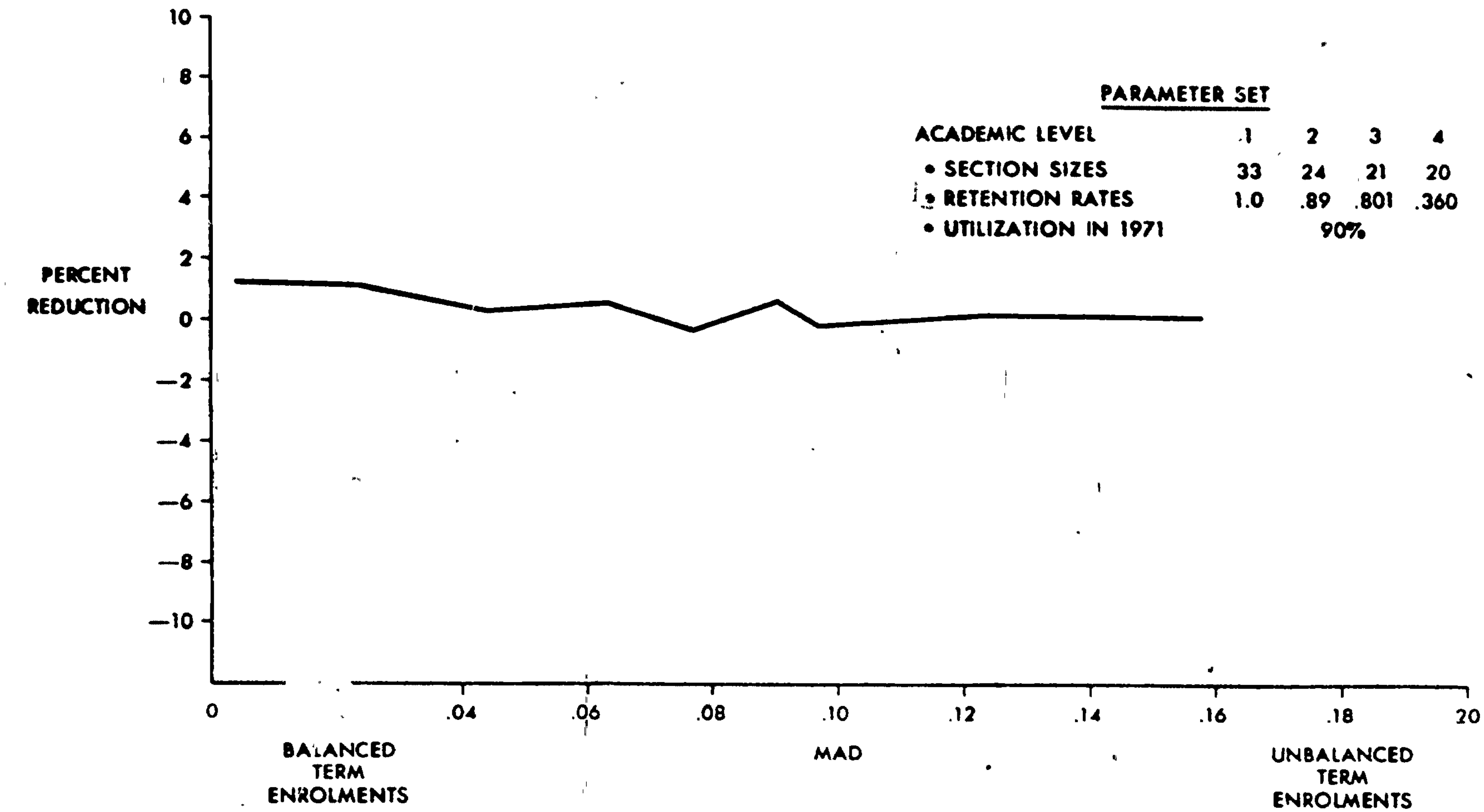
Exhibit VII

YEAR ROUND SECTION SIZE REDUCTIONS

vs.

LEVEL OF IMBALANCE (MAD)

TRIMESTER PROGRAM 2 ON - 1 OFF - 3 STREAMS



PARAMETER SET

ACADEMIC LEVEL	1	2	3	4
• SECTION SIZES	33	24	21	20
• RETENTION RATES	1.0	.89	.801	.360
• UTILIZATION IN 1971		90%		

approximately 12% of the total annual costs of the system at their highest level. As the 1971 utilization rate is reduced, it is reasonable to expect that capital costs are reduced and therefore 12% is the maximum percentage of total costs that is reached.

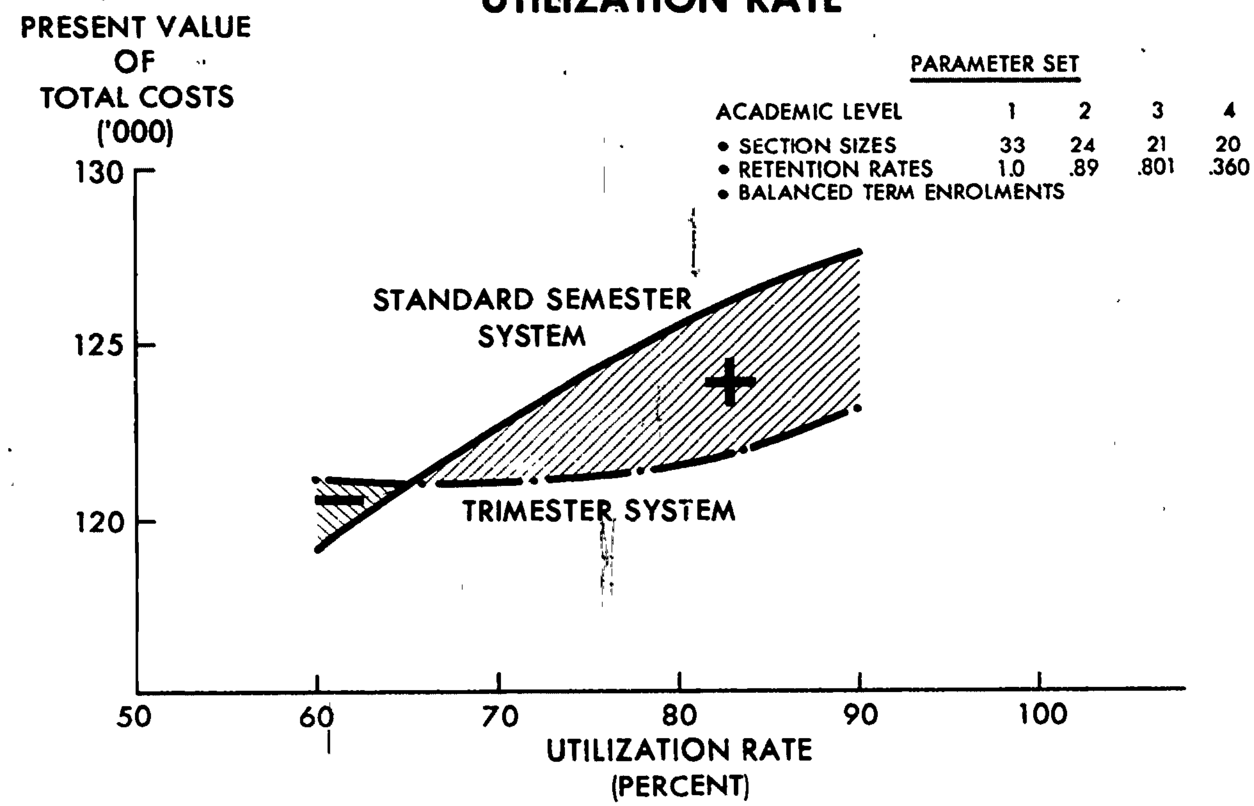
Since the economic advantage in switching to year round operation is based on some saving in capital costs over an increase in operating costs, the absolute value of capital costs is an important factor. With the projected stabilization in university enrolments, capital expansion is no longer required after a certain time (approximately 1981 in the model) and therefore the economic advantage of year round operation would be decreased.

d) There is a fair trade-off between savings in capital costs and increases in operating costs as the enrolment imbalance levels in the year round programs are varied. Consequently, the level of imbalance of term enrolments for the year round alternatives considered has little effect on the present value of total costs and critical section sizes.

Exhibit VII shows that year round critical section sizes are a flat function of MAD (mean absolute deviation) or term enrolment level of imbalance. This points to the fact that as the term enrolments approach the balanced condition, the increased saving in capital costs in changing to a year round program is offset by a corresponding increase in operating costs.

Exhibit VIII

PRESENT VALUE OF TOTAL COSTS vs. UTILIZATION RATE



e) There appears to be less economic incentive, if any, to switch to year round operation with low values of the 1971 utilization factor. Exhibit VIII shows the effect of assuming various values of utilization rate on the present value of total costs. Total costs for the standard semester program and the trimester program were compared for the balanced term enrolment condition for three utilization rates (60%, 75%, 90%). The difference in the present value of total costs for the trimester alternative minus that for the standard program becomes smaller and in fact becomes negative as the utilization rate drops from 90% to 60%. This is caused by fewer amounts of capital outlay as the utilization rate decrease. In other words, with a 1971 utilization rate of 60%, the increases in students enrolments through 1990 are serviced by smaller capital expansion costs than for a starting utilization rate of 90%, which reaches its plant capacity at any earlier date. With reduced plant expansion required at the lower utilization values, the reduced savings in capital costs are offset to a larger extent by the same increase in operating costs of the year round system. Hence the allowable reductions in critical section size values are less for each imbalance level.

f) An increase in the ratio of instruction costs to amortized capital costs, with a reduction in average section sizes, indicates that there is less economic incentive to switch to year round operation. When the absolute values of the average section sizes for the programs considered were reduced, the

Exhibit IX

YEAR ROUND SECTION SIZE REDUCTIONS
vs.
LEVEL OF IMBALANCE (MAD)
FOR THREE LEVELS OF SECTION SIZE VALUES
TRIMESTER PROGRAM 2 ON - 1 OFF - 3 STREAMS

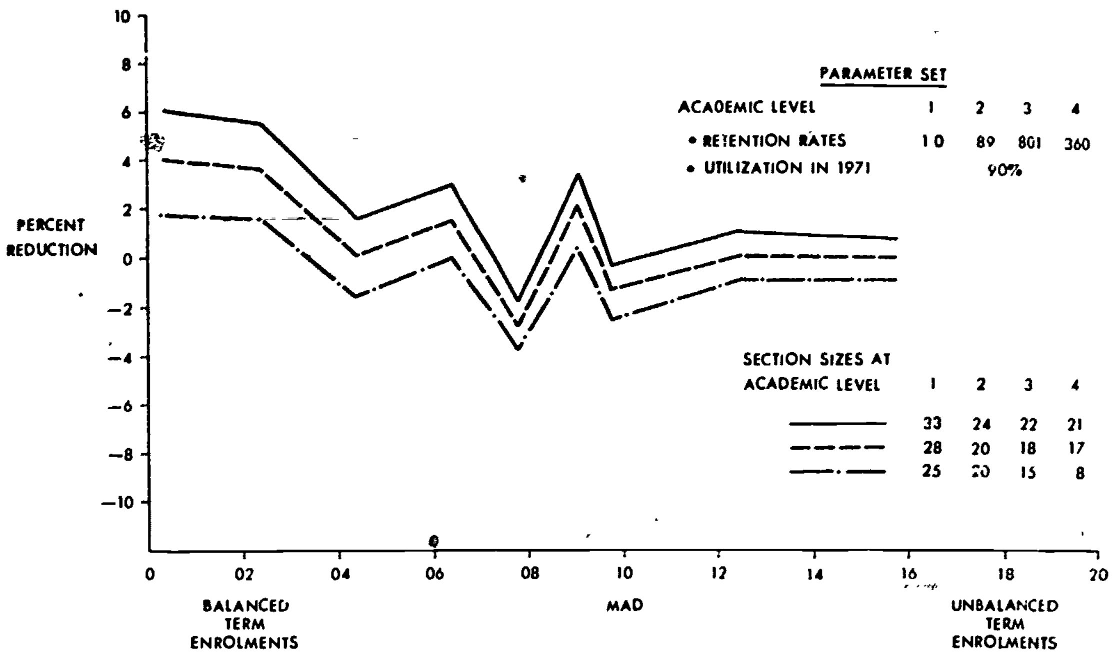
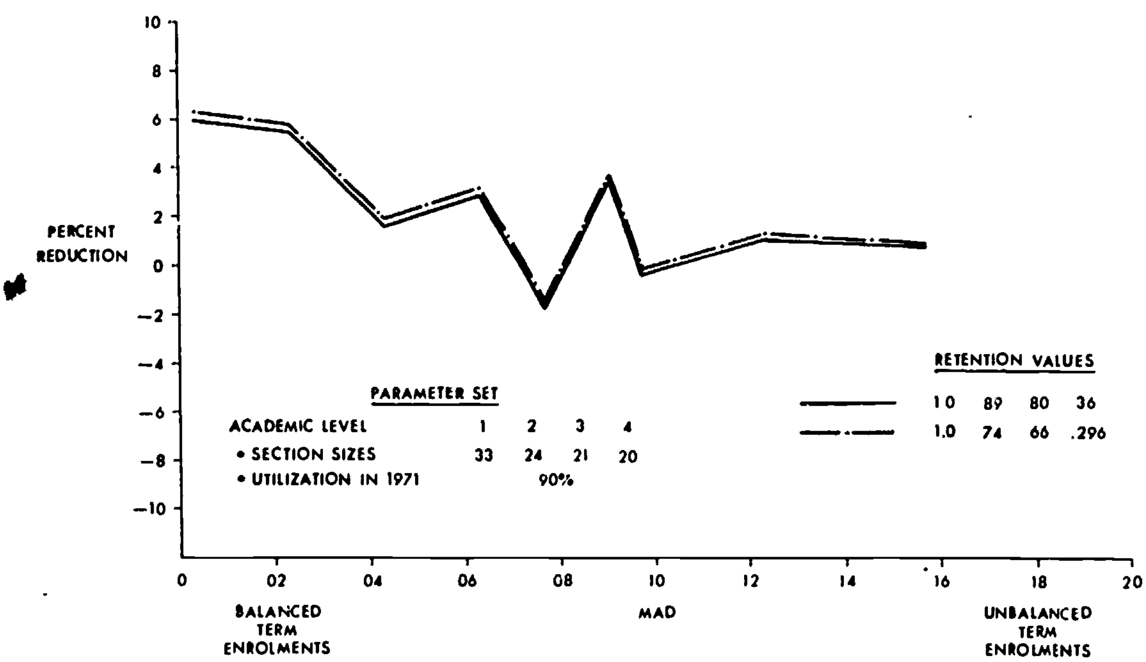


Exhibit X

YEAR ROUND SECTION SIZE REDUCTIONS
vs.
LEVEL OF IMBALANCE (MAD)
FOR TWO SETS OF RETENTION RATES
TRIMESTER PROGRAM 2 ON - 1 OFF - 3 STREAMS



present value of total costs rose, as did the average value of the critical section sizes.

When the absolute value of the average section sizes was reduced by approximately 15%, there was a corresponding increase in the present value of total costs. Exhibit IX shows a plot of percent reduction in section sizes versus level of imbalance for three absolute values of average section sizes. The percent allowable reduction in section sizes falls as the absolute values of section size decline.

This occurs because as the absolute value of section sizes decreases, instruction costs and therefore operating costs increase. Capital costs remain constant and are a smaller portion of total costs.

g) A reduction in student retention rates caused a slightly less than proportionate reduction in present value of total costs and had a negligible effect on the critical section size values.

The retention rates were reduced by approximately 17% and another computer run was made to observe the effect on output variables. While the present value of total costs was reduced by approximately 12%, there appeared to be no change in the values of section size reductions. This effect is shown in Exhibit X.

h) A reduction in projected student enrolments caused a proportionate reduction in the present value of total costs for all programs, and did not significantly affect the ranking of the alternatives by cost.

The projected freshman enrolments in years 1972 through 1990 were

Exhibit XI

YEAR ROUND SECTION SIZE REDUCTIONS
vs.
LEVEL OF IMBALANCE (MAD)
FOR 2 SETS OF FRESHMAN ENROLMENT PROJECTIONS
TRIMESTER PROGRAM 2 ON - 1 OFF - 3 STREAMS

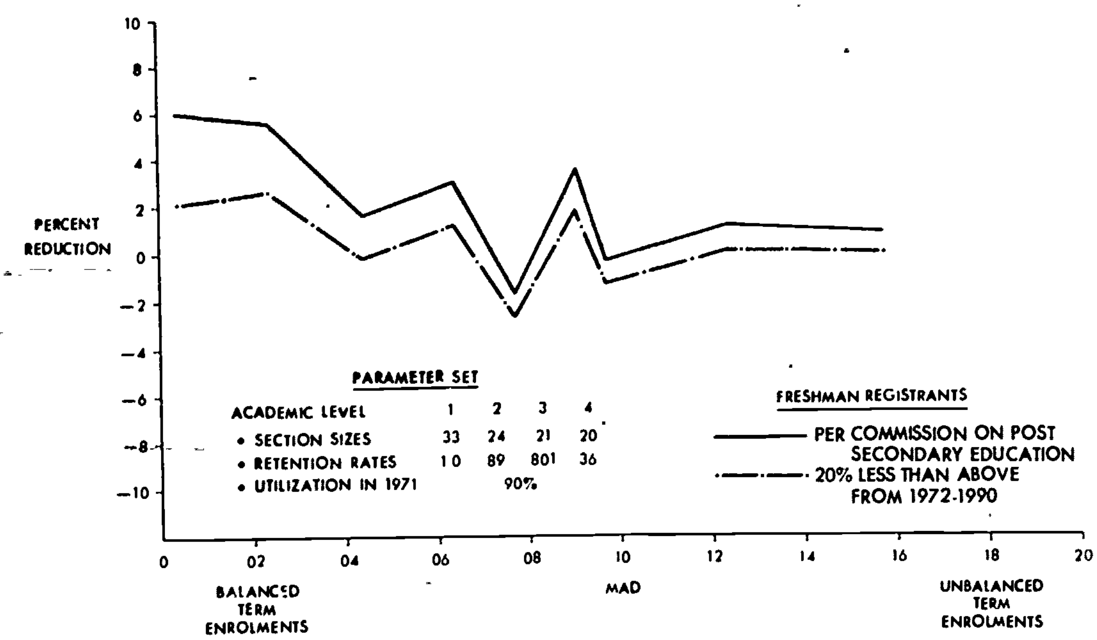
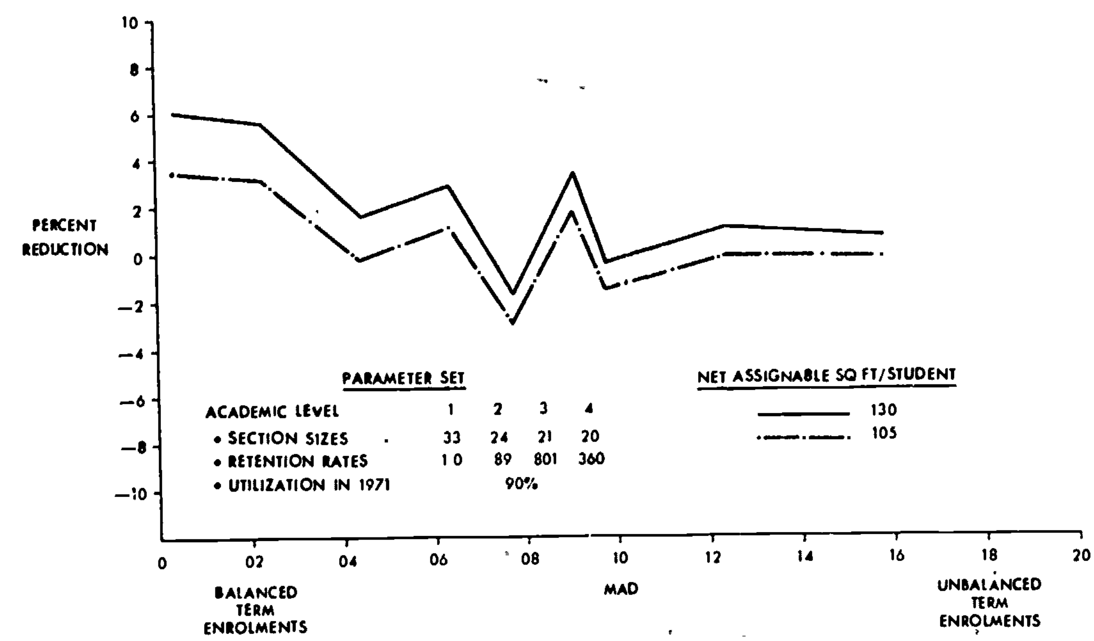


Exhibit XII

YEAR ROUND SECTION SIZE REDUCTIONS
vs.
LEVEL OF IMBALANCE (MAD)
FOR 2 VALUES OF NET ASSIGNABLE SQ.FT PER STUDENT
TRIMESTER PROGRAM 2 ON - 1 OFF - 3 STREAMS



reduced by 20% to see what the effect would be on the output variables. The enrolment in 1971 was left the same so that comparisons might be made with the present values of total costs derived from the previous runs. The present value of total costs was reduced by approximately 20% for each of the programs and the reduction was slightly lower for the year round operation alternatives than for the standard semester system. This made year round operation slightly less attractive economically than it had appeared with the higher enrolment projections. The smaller reductions in the present value of total costs for the year round alternatives caused the allowable reductions in critical section size values to be less for each imbalance level. This effect is shown in Exhibit XI.

i) A reduction in the net assignable square feet per student caused a much less than proportionate reduction in the present value of total costs and slightly reduced the economic incentive of year round operation.

When the value of net assignable square feet per student was reduced from 130 to 105 (19%), there was a slight reduction in the present value of total costs for all alternatives (1%-2%). The reduction was slightly less for the year round operation alternatives than for the standard semester system because the savings in capital expenditures achieved by year round operation were reduced while the increase in operating expenses remained the same. The effect was to reduce allowable reductions in critical section size values for each imbalance level. This effect is shown in Exhibit XII.

In summary our model shows that the quarter system is an uneconomical alternative to the standard semester system, that only modest savings can be achieved in switching to a trimester system and that for these savings to be realized certain optimum conditions must exist. These include:

(i) The average section sizes for all classes must be at least at the same level as in the standard two term system. This may be difficult if not impossible to attain without a major alteration of course offerings.

(ii) The physical plant must be presently coping with 75% or more of its potential student capacity under the standard two term plan without a major capital project.

(iii) The total student enrolment must be evenly balanced across the three terms.

Future Applications of the Computer Model

The computer model developed in this analysis could be used to forecast the economics of year round operation for specific universities and colleges. To do this, a detailed cost analysis for the institution under consideration would have to be made. This would include breaking down costs into defined categories as used in the model, or other categories particular to that institution. Enrolment forecasts would have to be made if none existed, and the effect on these forecasts predicted should the school under study switch to year round operation. Retention rates would have to be determined, not only across academic levels but across departments, to determine if there would be significant changes by department. The model developed for this study used average retention rates for the province which differed only by academic level. Some measure of instructional space utilization would have to be made for the institution under consideration and this could involve a study of class-room use if data were not available. Finally, an analysis would have to be made of course offerings and section sizes. The total number of courses offered as well as the number of multiple sections for each course would have to be determined. Average section sizes by academic level would have to be determined for each department within the school.

Generally speaking, to fix some of the parameters that were considered variables in this study would require detailed preparation and analysis of the data for a specific institution.

APPENDIX

METHODOLOGY

1. Calculation of Student Enrolments

The first step in the computer modelling of each alternative for year round operation of post-secondary educational facilities was to develop a projection of the number of students enrolled in each academic level in each term of every year from 1971 to 1990 inclusive. The numerical values of the student enrolments by level, term, and year were used as the basis for all subsequent calculations of operational and capital costs.

The number of students in each level, term and year depends upon the following factors:

a) The Retention Rates from the Freshman Level

By retention rate is meant the effective proportion of freshmen who eventually advance to each of the higher academic levels. There is one retention factor corresponding to each level. For example, if 88% of a freshman class advances to the second academic level, 80% to the third level and 36% to the fourth, the retention rates would be as follows:

TABLE 1

Level	Retention Rate
1	1.00
2	.88
3	.80
4	.36

If an operating schedule is such that students spend more than one term in each academic level, then there are retention rate values that apply to the terms within each level. For example:

TABLE 2

Level	Retention Rate Term 1	Retention Rate Term 2
1	1.00	.90
2	.88	.84
3	.80	.78
4	.36	.35

b) The Schedule of Attendance

Each of the alternative operating programs has a unique schedule of attendance which defines the program and affects the values of student enrolments. For example, a trimester program in which students attend classes for two consecutive terms, then vacation for one term, results in different enrolments in each level, term, and year compared to a trimester program in which students attend for three consecutive terms before vacationing. The student enrolment in a specific level, term, and year is equal to the freshman enrolment of one of the previous years factored down by the appropriate retention rate. The schedule of attendance defines exactly which freshman enrolment value and which retention rate must be used.

c) The Number of Registrations Per Calendar Year

In a year round operating program there may be one or several registrations per year, the maximum practical number being one at the beginning of each term. There is a separate schedule of

EXHIBIT XIII - ATTENDANCE MATRIX

	Year	0	0	0	0	-1	-1	-1	-1	-2	-2	-2	-2	-3	-3	-3	-3	-4	-4	-4	-4
	Term	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Level	Stream																				
1	1		1.000	.900																	
1	2			1.000	.900																
1	3																				
1	4																				
2	1						.890	.841													
2	2							.890	.841												
2	3																				
2	4																				
3	1										.801	.776									
3	2											.801	.776								
3	3																				
3	4																				
4	1														.360	.354					
4	2															.360	.354				
4	3																				
4	4																				

attendance which begins with each registration session in the first academic level, and consequently there are several schedules of attendance or streams within the operating program each beginning at a registration session. The number of streams within an operating program is equal to the number of freshman registration sessions per year. The total student enrolment in any level, term and year is equal to the sum of the corresponding enrolment in each of the attendance streams. The number of students enrolled in each stream depends on the split or level of imbalance of the total enrolment between the multiple registrations.

The concept of attendance streams is shown in Exhibit XIII for a trimester system in which students are in attendance for two consecutive terms, then are off for one term, and in which there are two registration sessions per year. Attendance stream 1 begins in the upper left-hand corner of the table. It can be seen by moving to the right that for every 1.000 freshmen who register in term 1 for the first time there are .900 freshmen remaining in stream 1 in term 2. Similarly on the second line of the table (stream 2), it can be seen that for every 1.000 freshmen who register in term 2 for the first time there are 0.900 freshmen remaining in stream 2 in term 3. In order to arrive at the total freshman enrolment in any term one must add together the enrolments in each of the streams. For example, the total freshman enrolment in term 2 is equal to 0.900 of the freshmen who registered for the first time in term 1 plus 1.000 of the freshmen who registered for the first time in term 2. In a similar fashion, the sophomore enrolment in each stream is shown on the fifth and sixth lines of the table to the right of "Level 2" and under "Year-1" which denotes that these factors must be multiplied against the number of freshmen who registered for the first time in the year previous to the current year. Again, the total sophomore enrolment in any term is equal to the sum of the sophomore enrolments in each of the streams. For example, the total sophomore enrolment in term 2 is equal to .841 of the freshmen who registered for the first time in term 1 of the previous year plus .890 of the freshmen who registered for the first time in term 2 of the previous year. The enrolments in levels 3 and 4 are shown in similar fashion in the bottom half of the table under "Year-2" and "Year-3".

Once the above information is known, the alternate program for year round operation is completely specified and it is possible to model student enrolments from a projection of freshman registrations in each year of the study. For example, the student enrolment in each term of 1971 for the standard semester system with one registration and retention rates as specified in table 2 can be calculated as follows:

```
E(I, J) = enrolment in term I, level J for 1971
F(N)    = number of feshman registrants in year N
E(1, 1) = 1.00 * F(71)
E(1, 2) =  .88 * F(70)
E(1, 3) =  .80 * F(69)
E(1, 4) =  .36 * F(68)

  Total enrolment in term 1, 1971 = 1.00*F(71) + .88*F(70 +
                                     .80*F(69) + .36*F(68)

E(2, 1) =  .90 * F(71)
E(2, 2) =  .84 * F(70)
E(2, 3) =  .78 * F(69)
E(2, 4) =  .35 * F(68)

  Total enrolment in term 2, 1971 = .90*F(71) + .84*F(70) +
                                    .78*F(69) + .35*F(68)
```

A similar set of equations was constructed for each year of each alternative program. As a further example, the enrolment equations for 1971 have been included below for a trimester system with a two term on, one term off, repetitive pattern with three registrations each year. The equations depend upon the proportion of the total enrolment that enters at each registration. For this example, the split was assumed to be .80, .10, .10. It was necessary to develop a similar set of equations for every such level of imbalance in student registrations.

TABLE 3

ENROLMENT EQUATIONS FOR 1971 OF A TRIMESTER SYSTEM

- 2 terms on, 1 term off
- 3 registration/year
- registration imbalance .80, .10, .10
- retention rates as per table 2

E(1, 1) = .800 * F(71) + .090 * F(70)

E(1, 2) = .712 * F(70) + .084 * F(69)

E(1, 3) = .640 * F(69) + .078 * F(68)

E(1, 4) = .288 * F(68) + .035 * F(67)

E(2, 1) = .720 * F(71) + .100 * F(71)

E(2, 2) = .673 * F(70) + .089 * F(70)

E(2, 3) = .621 * F(69) + .080 * F(69)

E(2, 4) = .283 * F(68) + .036 * F(68)

E(3, 1) = .090 * F(71) + .100 * F(71)

E(3, 2) = .084 * F(70) + .089 * F(70)

E(3, 3) = .078 * F(69) + .080 * F(69)

E(3, 4) = .035 * F(68) + .036 * F(68)

In the actual computerized model that was developed, full use was made of matrix algebra in order to construct the large number of equations that had to be examined for every combination of retention rates, schedule of attendance, and imbalance level between multiple registrations.

The source of the projection of freshmen registrants by year from 1971 to 1990 is the report prepared for the commission on Post-Secondary Education in Ontario entitled Manpower Forecasting and Educational Policy. The projection of student enrolments, which was stated in terms of a forecast of total enrolment in all academic levels by year, was worked backwards through the standard semester system using retention rates that expressed the average experience in Ontario from 1969 to 1971 in order to derive a projection of freshman registrants by year from 1971 to 1990. Rather than deal with the absolute values of freshman registrants, which would result in very large values of enrolments and costs in each year of the study, it was decided to normalize the projection of freshman registrants by dividing the projection for each year by the value of freshman registrants in 1971. Consequently all subsequent enrolment projections and costs may be thought of as the values that would be generated by each freshman registrant in 1971. In order to convert any enrolment projection, teacher requirement or cost into absolute figures one must multiply by the absolute value of 1971 freshman registrants.

2. Calculation of Teacher Requirements

Once the student enrolment in each level, term and year had been projected for an operating program, it was possible to determine the required teaching staff according to the following equation:

$$\# \text{ teachers required} = \frac{(\text{student enrolment projection}) * (\text{student course load})}{(\text{section size}) * (\text{faculty teaching load})}$$

In the above relationship between teachers and student enrolments, provision was made for student course load and faculty teaching load to vary with the academic level. In the case of section size, provision was made for variation with both academic level and term.

The following table indicates the way in which the total teacher requirements were calculated for each term for each year from 1971 to 1990.

TABLE 4

NUMBER OF TEACHERS REQUIRED IN 1971 FOR THE STANDARD SEMESTER SYSTEM WITH ONE REGISTRATION AND RETENTION RATES AS IN TABLE 2

Term	Academic Level	Normalized Student Enrolment	Student Course Load	Section Size	Faculty Teaching Load	Required Number of Teachers
1	1	1.0000	5	33	3	.0505
1	2	.7932	5	24	3	.0551
1	3	.6592	5	22	3	.0499
1	4	.2526	5	21	3	.0200
Total number of teachers required in term 1					=	.1755
2	1	.9000	5	33	3	.0455
2	2	.7495	5	24	3	.0521
2	3	.6395	5	22	3	.0484
2	4	.2484	5	21	3	.0197
Total number of teachers required in term 2					=	.1657

3. Calculation of Capital Costs

The unit used to measure plant capacity and required plant additions in each year was the number of students that could be serviced by the plant under normal operating conditions. In order to arrive at a starting value of plant capacity, it was necessary to define a utilization factor equal to the proportion of the total plant capacity that the 1971 total student enrolment at all levels represents under normal operating conditions and time-tables. Utilization values of .60, .75, and .90 were used in the analysis to test the effects of this variable. The available plant capacity in 1971 was calculated to be the 1971 first term total enrolment under the standard semester system divided by the utilization factor.

In each year of study for each alternative program, the term and value of maximum term enrolment at all levels were identified. If the value of maximum term enrolment was greater than the available plant capacity in any year, a plant addition was made sufficient to bring the plant capacity into line with the maximum enrolment. The cost of capital additions in dollars was calculated by use of the equation below.

Cost of Capital Addition = (Addition in Student Capacity) * (Net Assignable Square Feet/Student) * Construction Cost/Square Foot.

The following were used as values of the parameters in the above equation:

Net assignable square feet/student = 105 and 130

Construction cost/square foot = $55

The above figures are based on the Interim Capital Formula for Ontario Grants and discussions with Government officals.

The cost of capital additions in any year was amortized over thirty equal annual payments at an effective annual interest rate of 8.0%. Any costs which were to be repaid after the end of the twenty year period were discounted back to the end of year 1990 at the discount rate used for all costs, which was 7.5%. After the simulation of all capital additions in the twenty year horizon of the model was completed for an alternative, the total value of capital costs in each year was calculated by adding the repayments of all previous plant additions which occurred in that year. The capital repayments of individual plant additions and the total capital cost in each year are displayed as a table in the output of the computer model. The payment displayed in 1990 represents the actual cost in 1990 plus the discounted value at the end of 1990 of all future capital repayment costs that occur after the end of the simulation horizon.

4. Calculation of Annual Operating Costs and Annual Total Costs

The operating costs in the model can be broken into two major categories. These are base operating costs and incremental operating costs. Base operating costs are those operating costs that would be incurred for a standard two term program, whereas incremental operating costs are the incremental costs incurred in all operating cost categories because of any extension in length of operation in the calendar year for the alternative being considered.

The base operating costs in the model are derived using Statistics Canada data (Canadian Universities, Income and Expenditure - Catalogue No. 81-212) for the Province of Ontario. Base operating cost ratios were determined using this data and from these ratios base operating costs are calculated by category in the model. The operating cost ratios used in the model are as follows:

Operating Cost Category	Ratio to Total Operating Costs Excluding Assisted Research
Instruction	.623
Library	.085
Administration	.074
Plant Maintenance	.120
Other	.098
	1.000

The cost categories are as defined in the aforementioned Statistics Canada catalogue. The model calculates the instructional cost based on the number of teachers required for the alternative. The total base operating cost per year as well as the remaining operating costs per category are calculated by using the above ratios. This total base operating cost per year is calculated for all academic year alternatives. To these costs the incremental operating costs are added, the amount depending on the academic alternative being considered, its increase in length or operation and the term enrolments.

These cost increments are calculated in each of the categories according to the following two formulae:

a) $$\begin{array}{l}\text{Increment in}\\ \quad\text{Library}\\ \quad\text{Plant Maintenance}\\ \quad\text{Other Costs}\end{array} = \begin{array}{l}\text{Base}\\ \text{Cost}\end{array} \times \begin{array}{l}\text{Percentage of}\\ \text{Base Cost that}\\ \text{is Affected by}\\ \text{Extended Year}\\ \text{Operation}\end{array} \times \frac{\begin{array}{l}\text{Increment in}\\ \text{Year Length}\end{array}}{\begin{array}{c}\text{Standard Year}\\ \text{Length}\end{array}}$$

$$\times \frac{\text{Summer Enrolment}}{\text{Balanced Term Enrolment}}$$

b) $$\begin{array}{l}\text{Increment in}\\ \quad\text{Administration}\\ \quad\text{Costs}\end{array} = \begin{array}{l}\text{Base}\\ \text{Cost}\end{array} \times \begin{array}{l}\text{Percentage of}\\ \text{Base Cost that}\\ \text{is Affected by}\\ \text{Extended Year}\\ \text{Operation}\end{array}$$

$$\times \frac{\text{Enrolment in the First Term with an Added Registration}}{\text{Balanced Term Enrolment}}$$

$$+ \frac{\text{Enrolment in the Second Term with an Added Registration}}{\text{Balanced Term Enrolment}}$$

$$+ \ \ldots$$

The percentage of the base operating costs that is affected by extended year operation was determined from the study of trimester calendar costs at a Canadian university. It was then hypothesized what variable(s) would most affect these costs. The percentages and the identified variables are shown in the following table:

Operating Cost Category	Percentage of Cost Category that is Affected by Year Round Operation	Primary Variable Cost Affecting Increment	Secondary Variable Affecting Cost Increment
Library	9.0	Increment in Year Length	$\frac{\text{Summer Enrolment}}{\text{Balanced Term Enrolment}}$
Administration	14.0	Increase in the Number of Student Registrations	$\frac{\text{Enrolments in Terms of Added Registrations}}{\text{Balanced Term Enrolment}}$
Plant	42.0	Increase in Year Length	$\frac{\text{Summer Enrolment}}{\text{Balanced Term Enrolment}}$
Other Costs	17.0	Increase in Year Length	$\frac{\text{Summer Enrolment}}{\text{Balanced Term Enrolment}}$

Note that the secondary variable introduces a scale effect on the incremental costs. Neglecting instruction costs, it would be relatively inexpensive to add a few students in the summer, but to add as many students as are enrolled in the fall or spring terms would require large increases in these costs, at least to the full extent allowed by the primary variable.

The annual operating cost is calculated for the twenty years of operation considered in the model. To this cost is added that portion of the capital debt that falls due in a given year, to give a total annual cost. The total annual cost for each year over the 20 year horizon is discounted and added to give a net present value for each alternati.e.

5. Calculation of Section Size Reductions

A percentage increase or decrease in both year round average section sizes and summer average section sizes is calculated so that the present value of the alternative is made equal to the present value of the standard program.