COMPUTER MODEL FOR ESTIMATION OF TEACHING FACULTY REQUIREMENT

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CHAPTER I

INTRODUCTION

Personnel planning is part of any administrative set up in an organization. An administrator is required to forecast his personnel requirement and his estimate is based on his knowledge of the trend and behavioral pattern in the past, and a set of decision parameters. These decision parameters can be both qualitative and quantitative. The qualitative parameters are assigned certain reasonable weights or values before a decision is made.

In this report an attempt is made to build a computer model for estimation of teaching faculty requirement for the Engineering School of Kansas State University.

A faculty member is required to perform either one or a combination of the following duties:

1. Teaching
2. Research
3. Administration

The weight given to each of these functions vary with each faculty member. Each of these functions impart a certain workload on the faculty member. Hence the faculty requirement can be conceived as being constituted of the requirements for each of these functions. This functional catagorization of faculty requirement also aids the administrator in his assignment of duties to individual faculty members. This model deals with the faculty requirement for only one such function namely teaching. Though the model is built for the Engineering School in particular, care is taken to see that the procedure could be adapted to any school.

The following decision parameters were considered in the model.

1. Desired section size - Desired number of students in a section.
2. Minimum section size - Minimum number of students in a section.
3. Number of students in each curriculum at various levels - Freshmen, Sophomore, Junior and Senior.
4. Weight factors to quantify the proportion of the load imparted by the student count in a course, level of the course and the mode of instruction; the level being an indication of the difficulty associated with the course and the mode of instruction representing the way the course is taught, namely lecture, recitation, laboratory and individual instruction (called problems).
5. Full time equivalent credit hours for each faculty member.
6. Full time equivalent credit hours for the individual instructions.

The model also includes a decision rule to determine the number of sections resulting from the projected enrollment in a given course.

CHAPTER II

ANALYSIS OF THE PROBLEM

The first step in the analysis is to identify the objective of the study and the factors affecting it. In this problem the objective can be stated as:

1. Aiding the administrator in planning the faculty requirement.
2. Identification of the factors leading to wasteful utilization.
3. Sensitivity analysis of the factors affecting the model.

In most instances, the administrator would have developed a feel for the problem based on his past experience and built on approximate regression model for the faculty requirement, identifying certain common sense factors. He will be validating any new model in this perspective. Hence it is desirable to incorporate those features in the model which will aid him in the comparative study.

Teaching faculty requirement is comprised of the requirement for each individual course offered in each of the departments in the school. The work load induced by each course may be conceived of as being a function of the following course parameters.

1. Student count in the given course
2. Level of the course
3. Mode of instructions and the associated hours
4. Section size - Numbers of students in a given section
5. Speciality and importance of the course in relation with the other courses

Having agreed upon these course parameters it is a question of the subjective argument as to which of these factors is a major contributor to the work load of a teaching faculty. The following methods may be considered reasonable for calculating the full time equivalent teaching faculty for a given course.

1. A method based on the student count in a course, level of the course and the mode of instruction in conjunction with the associated hours.
2. A method which discards the mode of instruction and considers the work load as a function of the level of the course, and the student credit hours which is the product of the number of students and the credit hour associated with the course.
3. A method which considers the section size limitations and the work load as being constituted of two components. A constant work load which is dependent on the number of sections irrespective of the number of students in the section and a varying load induced by the student count in a particular section. Each of these componends may be considered as varying with the level of the course and the mode of instruction, and may have to be weighted to denote the proportionate work load.

All these methods do not consider the speciality requirement of the course, since the speciality requirement will have erratic behavior at different times, and can usually be hand picked. A computer model which considers all of these features or capable of giving all relevent parameters for a comparative study seems to be most desirable. In these methods we had conceived of the possibility of varying the induced course load with different levels and modes of instruction. The weight given to these factors are qualitative in nature depending on the judgement of the administrator and have to be quantified in the model. Since the judgement may vary with each administrator it is desirable to feed this as input variables to the model.

Since the method 2 does not take into consideration the mode of instruction, which is considered as a relevant factor in deciding the work load, it was not included in the present model, though student credit hours generated, are given for comparative purposes. The first method which is based upon only the number of students in a given course is formulated by D. P. Hoyt and has been widely used (2). The input parameters in the model for calculating the full time equivalant teaching faculty requirement by the last method were chosen to approximate the Hoyt model. The model also identifies the courses which do not fulfil the minimum course count requirements and calculates the deleted teaching faculty requirement for different classifications seperately.

2.1 GENERAL METHODOLOGY

The general procedure employed in the model can best be described by the following flow chart, shown in Figure 2-1. The full time equivalant teaching faculty requirement is calculated by two methods. The input parameters under the jurisdiction of the administrator are marked with an asterik.

2.1.1 Method 1 (Hoyt's method)

$$FTE_{school} = \sum_{i=1}^{N_o} \sum_{j=1}^{N_{ci}} \sum_{k=1}^{4} \frac{K_j \times \omega_{jk} \times H_{jk}}{A}$$

2.1.2 Method 2

$$FTE_{school} = \sum_{i=1}^{N_o} \sum_{j=1}^{N_{ci}} \sum_{k=1}^{3} S_j \times P_{jk} \times F_1 + \frac{K_j}{B_c} \times \omega_{jk} \times F_2 \times \frac{H_{jk}}{B}$$

+ problem load calculated by Method 1.

where

FTE_{school} = Full time equivalant teaching faculty requirement for the school.

N_o = Number of curricula comprising the school

N_{ci} = Number of courses in the i^{th} curriculum

k = Index representing the mode of instruction

k=1 represents lecture, k=2 represents recitation

k=3 represents labaratory, k=4 represents problems

**ω_{jk} = Weighting factor for j^{th} course k^{th} mode, for calcuation of teaching load due to student count.

H_{jk} = Number of contact hours for j^{th} course, k^{th} mode.

**A = Base student credit hours constituting 1-FTE teaching load attributed to student count.

S_j = Number of sections for j^{th} course

**P_{jk} = Constant load factor depending on number of sections for j^{th} course, with k^{th} mode instruction.

**F_1 = Weighting factor representing the administrator's judgement of the proportion of load attributed to the number of sections irrespective of the section size.

**F_2 = Weighting factor representing the administrator judgement of the proportion of load attributed to the student count in a given course($F_1 + F_2 = 1.$)

K_j = Student count in j^{th} course

$**B_c$ = Base student count (non weighted) to represent full load attributed to course count.

**B = Base student credit hour to represent 1-FTE teaching faculty member.

The first method of FTE computation is a special case of the second method where

$F_1 = 0 \quad F_2 = 1 \quad B_c \times B = A.$

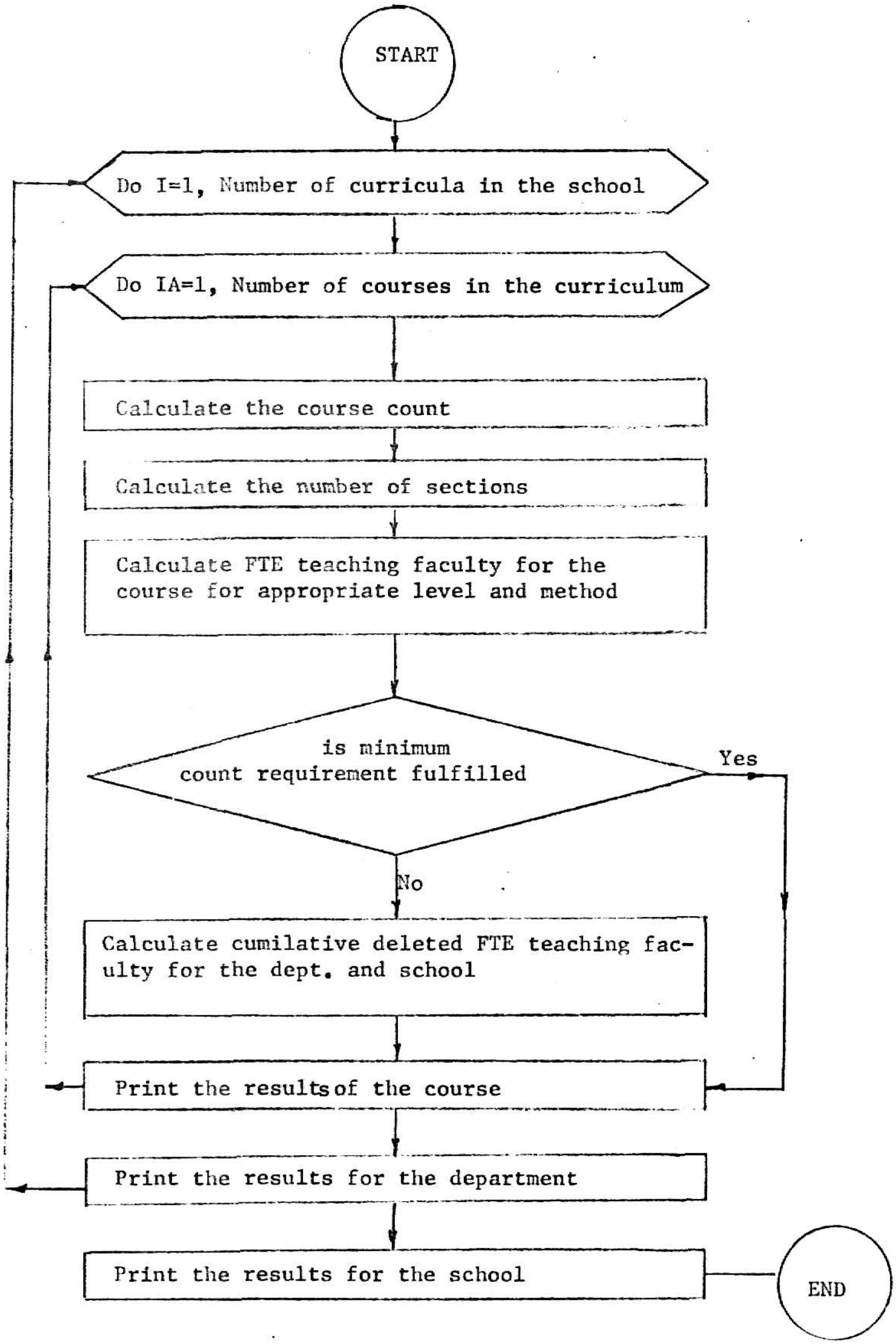

Figure 2.1 General flow chart

CHAPTER III

ESTIMATION OF COURSE PARAMETER

The four relevant course parameters used in the model were

1. Student count - Number of students enrolled in a given course.
2. Desired section size - Desired number of students to constitute one section.
3. Minimum section size - Minimum number of students required to constitute a section.
4. Number of sections

Of these parameters, the desired and minimum section size are under the jurisdiction of the administrative heads and are the input parameters in the model. The student count and the number of sections are calculated in the model.

3.1 ESTIMATION OF STUDENT COUNT

The student count is a function of the following factors

1. Curriculum specification.
2. The number of students enrolled in different curricula at different levels.
3. The relevance of the course content to other subjects, curricula, and schools.
4. Personal factors viz. compatibility of the teaching faculty, the work content etc.

The last two factors are qualitative and difficult to quantify in a regular regression model. Hence a model which includes factors based on observation that reflect these qualitative tendencies, seems to be a reasonable answer.

A certain fraction of students from different curricula or schools constitute the student count in a particular course. We should identify the interrelationship between these fractions and the factors affecting the student count and specify these fractions so that they reflect these factors. This could be done by one or a combination of the following methods:

1. Estimation from curriculum specification.
2. Judgement of departmental heads and concerned faculty.
3. Historical data.

The first of these methods reflect the effect of curriculum specification and the other methods reflect the qualitative aspects of the problem and the electives.

This model attempts to find a method of logical estimation of these fractions, from here onwards specified as "Course curriculum fractions", based on curriculum specification and historical data. Judgement of department heads was not sought, since it was thought that historical data available will give the same information more accurately, though many times, especially when a new course is introduced, the departmental heads' judgement will be the only way. The historical data was available for the 1970 Fall and 1971 Spring semesters as part of the work in a related field, namely estimation of classroom requirement, by Mr. Tom Compton (1). At this stage it was uneconomical to get more data. A sample of these data is given in Appendix A.

The students enrolling in a particular course were considered as belonging to the following classifications:

1. Curriculum Specifying The Course As Requirement

2. Curriculum Specifiying The Course As Elective

3. A School Comprising Group Of Curriculums, Subdivided Into The Following Classification

   3 i Engineering school

   3 ii Other schools

In the computer program the student count is calculated by summation of the product of course curriculum fraction and the corresponding enrollment figure in the curriculum. This required easy identification of curriculum enrollment. This was done by a two dimensional variable NC, the first index representing the curriculum number, the second index representing the course curriculum fraction level, and the value of the variable representing the enrollment figure. For this purpose the schools have to be classified in the same manner as curriculum for identification purposes. Hence the schools were given artificial identification numbers from 1000 onward since a 3 digit number specifies the regular curriculum numbers. They were

1000 - School of Agriculture

1001 - School of Architecture

1002 - School of Arts and Science

1003 - School of Business

1004 - College of Education

1005 - Engineering School

1006 - College of Home Economics

1007 - College of Veterinary Science

1008 - Portion of graduate school representing students enrolled for master program.

1009 - Portion of graduate school representing students enrolled for PhD program.

1010 - Portion of graduate school representing students enrolled for masters program in the Engineering curriculum.

1011 - Portion of graduate school representing students enrolled for Phd program in the Engineering curriculum.

Course curriculum fractions, except for the courses specified as curriculum requirement, was based on historical data. For the courses offered in both the semesters, the average of the fall and spring data was taken. The undergraduate students were divided into eight levels, each subsequent pair representing Freshmen, Sophomore, Junior and Senior level, the odd numbers representing the Fall semester and the even number representing the Spring semester. The graduate students were divided into two levels, the level 1 representing the Fall semester and the level 2 representing the Spring semester.

3.2 ESTIMATION OF COURSE CURRICULUM FRACTIONS FROM CURRICULUM SPECIFICATION

If the students were considered regular, adhering to the curriculum strictly, then a fraction equal to 1.0, assigned to the corresponding level would be most appropriate. But rarely does this regularity assumption hold true, and the deviation from this regularity is likely to be more marked in those cases where the course is offered in both the semesters. Examples to the effect are given in Appendix B. However it would be desirable to explore the feasibility of a method to represent the degree of irregularity. This could be represented by a fractional factor with which the result obtained by the regularity assumption has to be multiplied. This fractional factor could be specified for individual courses, for individual curricula, or for the whole school. Specifying the fraction for individual courses would have to be based on historical data, which would result in discarding the curriculum specification. The amount of data available did not justify the fractional factor being specified for individual departments. Moreover this would mean that sensitivity analysis due to change in curriculum specification would be more elaborate. Hence this was done for the whole school. Any uniform pattern applied to the whole school is likely to create a certain amount of distortion in the estimate. Hence the following performance criteria were formulated:

1. To minimize absolute deviation from the mean.
2. To prefer overestimation to underestimation.
3. To determine the fraction to the accuracy of one decimal place.

Since the irregularity pattern is likely to be related to the number of times the course is taught in a given period, the courses were divided into the following three categories.

1. Category 1. Courses are offered in one semester only.
2. Category 2. The courses are offered in both the semesters and the curriculum specifies it as a requirement only in one semester.
3. Category 3. Courses are offered in both the semesters and the curriculum specifies it as requirement in both semesters. This category of courses are usually lecture courses viz. engineering assembly.

Appendix 'C' gives the estimated student count and the deviation from the actual student count for individual courses. The summarized results are given in Tables 1, 2 and 3. Based on the performance criteria a fraction of 0.5 was chosen for Category 1 courses and 0.8 for Category 2 courses.

Table 1

Summary of Deviation of Estimated Student Count From Actual Student Count

For Category 1 Courses

Fraction	Fall Semester		Spring Semester		Both semesters	
	Mean Deviation	Mean abs. Deviation	Mean Deviation	Mean abs. Deviation	Mean Deviation	Mean Deviation
0.7	0.2857	3.7571	0.7222	4.2778	+.2813	4.0938
0.8	-2.2143	4.2143	-1.333	4.3333	-1.7188	4.2813
0.9	-4.3572	5.2143	-3.3889	5.0556	-3.8125	5.1250

Table 2

Summary of Deviation of Estimated Student Count From Actual Student Count

For Category 2 Courses

0.4	4.625	9.7917	3.3125	8.6250	3.8750	9.125
0.5	-6.5417	12.8750	-1.8475	8.4063	-3.8714	10.3214
0.6	-13.500	17.1667	-7.0625	10.6250	-9.8214	13.4286

Table 3

Summary of Deviation of Estimated Student Count From Actual Student Count

For Category 3 Courses

0.7	15.0000	15.0000	18.6667	18.6667	16.8333	16.8333
0.8	5.8333	5.8333	7.5000	7.5000	6.6667	6.6667
0.9	-3.6667	5.3333	-3.8333	4.0000	-3.7500	9.3333

Category 3 courses are usually held in one section irrespective of the student count and hence FTE faculty requirements are not affected appreciably due to the sectioning rule. Hoyt's method correlates the student count and FTE teaching faculty requirement linearly and to partially offset the effect due to overestimation a fraction of 0.8 was chosen, though 0.9 was more appropriate from the point of view of the chosen performance criteria.

3.3 DECISION RULE FOR SECTION SIZE

Ideally, the number of students in a class is bound by two limits, the upper limit and the lower limit. The lower limit is the minimum student count in a section, representing the tolerance limit to wasteful utilization. The upper limit is limited by any of the following factors:

1. Teaching effectiveness
2. Classroom size
3. Speciality requirement of the course
4. Course demand and faculty availability
5. Equipment available in the case of labaratory classes.

The department head usually uses his judgement in deciding the section size depending on personnel resources, conceived importance of the course, course demand and load balancing of faculty. Hence there are likely to be some exceptions to the uniform sectioning rule, whatever the logical rules for decision may be. But the uniform sectioning rule aids the administrator in overall policy decision and acts as a base criterion to examine the exceptional cases.

These exceptions are not likely to affect the final estimate of faculty requirements appreciably, as long as they remain as exceptions and not a rule.

The following decision rules may be considered logical:

3.3.1 Divide the number of students by the maximum section size and if there is a remainder increase the number of sections by 1.

3.3.2 Divide the student count by desired section size and examine the remainder if any, with a percentage of desired section size to decide whether any additional section should be created or whether the students should be redistributed in the existing number of sections.

3.3.3 Divide the student count by the desired section size and examine the remainder, if any, to find the number of students who will be redistributed into the existing section. If this number is greater than a specified level, then increase the number of sections by 1.

Though no method can be considered as overwhelmingly superior to others and any one method may be considered reasonable depending on the view of the administrator, it may be desirable to examine the various methods. The method 3.3.1 is rigid in the sense that it bases the decision on maximum section size and irrespective of the remaining number of students increases the section size by 1. This basically leads to the assumption that the factors influencing the decision of maximum section size are not flexible. The method 3.3.2 and 3.3.3 are similar to each other except for the specified level of students with which the remaining students are examined. In method 3.3.3 it is specified as a fixed percentage of desired section size.

The method 3.3.3 allows a certain amount of flexibility to the administrator in deciding these parameters, based on the practical situation. However it should be pointed out this method in practice will coincide with the method 3.3.1 when the maximum section size is specified as the sum of the desired section size and the specified level with which the remainder is examined. The advantage of method 3.3.3 is in the philosophy of deciding these section sizes. If method 3.3.3 is chosen then the question arises as to what the specified comparison level should be. Again there is no one answer to such questions, but minimum section size may be considered as reasonable from the following view points:

1. Most of the decision arises as to whether the number of sections should be 1 or 2. In such cases it would not be wise to create a section less than the minimum section size.
2. This could be easily conceived by the administrator and is no longer an arbitary level.

Hence the method 3.3.3 with minimum section size as the specified level was chosen.

CHAPTER IV

COMPUTATIONAL ALGORITHM

4.1 PROGRAM COMPONENTS

The model is comprised of

a. One main program

b. Five control subroutines - CALCUL, LECTUR, RECIT, LAB, AND PROB

c. Seven functional subroutines - COUKNT, COUDET, TEADET, MINSIZ, FINRES, and INIATL

The control subroutines classify the courses according to different course levels and mode of instruction, and route them to appropriate functional subroutines for calculation. The detailed functions of these subroutines are given in Appendix D.

4.2 INPUT PARAMETERS

The main input variables that reflect the administrators judgement are:

1. Desired section size for various levels and modes of instruction.
2. Minimum section size for various levels and modes of instruction.
3. Constant and varying load weighing factors for different course levels and mode of instruction.
4. Curriculum enrollment figures.
5. Course curriculum details.

The administrator can study the effect due to changes in any of these parameters. Besides these variables there are other input variables for the identification of the semester, method of calculation and initiating the program. The details of all the parameters are given in Appendix E-1. The data and types are given in E-4.

4.3 OUTPUT VARIABLES

The main output variables are FTE teaching faculty requirements of each course, different curricula and the school, classified both by the mode of instruction and the course level. In addition to this, deleted FTE teaching faculty requirement due to minimum section size requirements, as well as generated credit hours are given for various classifications. The details are given in Appendix E-2.

4.4 GENERAL COMPUTATION PROCEDURE

The first step in the computation is to estimate the student count from enrollment figures and course curriculum fractions. The courses are then grouped as to their mode of instruction and level. The projected number of sections for each course is calculated from this estimated student count and the desired and minimum section sizes. The full time equivalent teaching faculty requirement is calculated by either method using the appropriate weighting factors. The estimated student count is compared with minimum section size for the subject modes of instruction. If this requirement is not met for at least for one mode of instruction, then the full time equivalent teaching faculty requirement for that course is not included for curricula and the school, but is cumulated separately. The courses which do not satisfy the minimum section size requirements are also identified with asteriks, in the output. This procedure is repeated for different courses in the curriculum and for all the curricula comprising the school. A general flow chart is given in Appendix F.

4.5 USE OF THE COMPUTER PROGRAM

As stated earlier the model should aid the administrator in planning the faculty requirement, help him in recognizing wasteful utilization and optimize the utilization of the existing teaching faculty. The five input parameters under the control of the administrator help him in these objectives. The model is dependent on the estimation procedure for student count, and the input parameter which plays a vital role in this estimation is course curriculum details, and in particular course curriculum fractions. These are determined either by curriculum specification or historical data. Of these, course curriculum fractions determined by curriculum specification are of special importance, since not much could be done to the fractions based on historical data. An administrator might have recognized some of the courses as being wasteful in the sense that they have a low student count, though they may satisfy the minimum section size requirement. This may be due to either of the following reasons:

1. The courses are service courses and similar courses are offered in different curricula.
2. The courses are offered in both the semesters.

To overcome this low student count, an administrator will introduce curriculum changes and would like to study the effect on the teaching faculty requirement. These changes will involve grouping of similar courses taught in different curricula into one single course, and/or dropping a course from one of the semesters. In the case where the courses are offered only in one semester instead of two semesters, the change involves alteration of the modification factor applied to course curriculum fraction, for the appropriate curriculum. But the change which involves replacement of a group of similar service courses by a single course requires a special mention. The best procedure would be to study the behavioral pattern of the student enrollment for these courses. The new course introduced would have the curriculum fractions, which will be a combination of the new curriculum requirements introduced and combined data available from the group of courses.

Similar procedures could be adapted for the introduction of a new course, which corresponds to an existing course. But in those cases where the courses introduced are completely new, then the course curriculum fractions must be based on curriculum requirement and judgement of the department heads.

The use of other input parameters are apparent and their data card type are given in Appendix E-4.

CHAPTER V

SENSITIVITY ANALYSIS

In the procedure for estimation of FTE teaching faculty requirement, many factors have been introduced to quantify the assessment of the qualitative factors by the administrator. Each administrator may consider an interval range of these parameters instead of a point estimate and this again may vary with the different administrators. Hence it would be necessary to consider the effect of changes with parameters on the FTE teaching faculty requirement. Since the 'Method 2' incorporates the 'Method 1' as a limiting case, only 'Method 2' will be considered for analysis. The FTE teaching faculty requirement for the j^{th} course can be written as,

$FTE_j = (FTE_1 + FTE_2)\frac{H_{jk}}{A}$, where

$FTE_1 = S_j \times P_{jk} \times F_1$, representing a constant load due to preparation,

and

$FTE_2 = \frac{K_j}{B_c} \times \omega_{jk} (1-F_1)$, representing the varying load due to student count

S_j = Number of sections for the j^{th} course

P_{jk} = preparation load factor for the j^{th} course, and k^{th} mode of instruction

F_1 = A fraction between 0 and 1 representing the proportion of the load attributed to preparation for the course.

K_j = Student count in the j^{th} course

B_c = Base student count representing one full load due to student count.

ω_{jk} = Varying load weighing factor for the j^{th} course, and k^{th} mode of instruction.

H_{jk} = Number of teaching hours in the k^{th} mode of instruction for the j^{th} course.

A = Base credit hours to represent one FTE teaching faculty load.

The factor H_{jk}/A represents the ratio of the number of hours the course is taught and the base credit hour constituting 1 FTE faculty load. To simplify the analysis H_{jk} is taken as equal to A. The effect of other factors on FTE_1, FTE_2 and FTE_j is analysed.

5.1 EFFECTS OF INPUT PARAMETER ON FTE_1

S_{jk} is a function of student count 'K_j' and the sum of desired and minimum section size 'R' represented by the following relationship.

$$S_{jk} = \text{Quotient of } \frac{K_j}{R} + K, \text{ where } \begin{array}{l} K=0 \text{ if } K_j \text{ MOD } R=0 \\ K=1 \text{ if } K_j \text{ MOD } R\neq 0 \end{array}$$

Hence FTE_1 is a right continuous step wise function as shown in Figure 5.1. The size of the step width is equal to 'R' and the step height is equal to $P_{jk} \times F_1$. Hence the desired and minimum section size, in particular their sum, define the step width and the product $P_{jk} \times F_1$ affect the step height. Of the two factors, P_{jk} and F_1, P_{jk} is an independent factor not having any effect on the other componend FTE_2. Hence for a fixed P_{jk}, the step height increases in direct proportion with F_1.

5.2 EFFECT OF INPUT PARAMETERS ON 'FTE_2'

FTE_2 is independent of the number of sections and hence is not affected by desired and minimum section sizes. It can be represented by a straight line with slope $\frac{\omega_{jk}}{B_c}(1-F_1)$, as shown in Figure 5.2. Here ω_{jk}, B_c and $(1-F_1)$ are all positive and hence the slope is always positive. Further since FTE_2 equals zero where student count is equal to zero, it passes through the origin. $1-F_1$ varies between 0 and 1 and hence the slope varies between 0 and $\frac{\omega_{jk}}{B_c}$. The slope decreases with the increase in student count and the effect of ω_{jk} is to modify this student count for the j^{th} course and k^{th} mode of instruction. Hence $\frac{\omega_{jk}}{B_c}$ can be designated by a single factor $1/M_c$, where M_c is the modified base student count. $(1-F_1)$ represents the proportion of the load attributed to the student count and increase in the proportion increases the slope.

5.3 CUMULATIVE EFFECT OF INPUT PARAMETERS

Since FTE_j is the sum of FTE_1 and FTE_2 it can be represented by a combination of linear and stepwise function, the slope of the linear portion being $1/M_c\ (1-F_1)$, step width equal to 'R' and step height equal to $P_{jk} \times F_1$. This is illustrated in Figure 5.3. The limiting cases of this graph are, purely stepwise function with no linear increase, when F_1 equals 1 and a purely linear function without any step when 'F_1' equals zero. The second of these cases is the Hoyt's line for estimation of teaching faculty requirement. Figures 5.4 to 5.11 represent the behavior of the fulltime equivalant teaching faculty requirement for the data specified in Table 5.3.1.