THE UNIVERSITY OF STIRLING

THE DEVELOPMENT AND APPLICATION OF MATHEMATICAL MODELS FOR PLANNING AND RESOURCE ALLOCATION AT THE UNIVERSITY OF STIRLING

by

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ABSTRACT

The objective of the research described in this dissertation is to examine the planning and resource allocation problems of universities and to investigate whether scientific management methods and in particular mathematical models can be used with advantage in this context. The approach adopted was to consider these questions in the particular case of one universtiy (the University of Stirling).

The national system of university planning and finance in the UK is described. This provides the framework within which the University's planning decisions are made. A description of the academic system and history of the University of Stirling leading up to the problems of planning for the 1977-82 quinquennium is then given.

A survey of work carried out elsewhere in this field is presented and a number of general purpose models for university planning developed elsewhere are described. This is followed by a general discussion of philosophies of resource allocation in UK universities.

For a number of reasons, it proved to be impractical to attempt to adapt one of the general purpose models developed elsewhere to Stirling University's planning problems. Hence, a planning model is constructed from first principles, a modular form being used. This model is then used to investigate possible development plans for the 1977-82 quinqunnium.

After general consideration of possible growth during the quinquennium the model is used to attempt to explore consequences of possible development plans. The first study which was carried out (the 'base-line' study) was based on achieving desired expansion through simply extrapolating present developments. This study projected certain undesirable consequences (such as some Stirling departments becoming excessively large).

This study was followed by another which took into account likely introduction of new academic developments and certain other factors suggested as desirable by University decision-makers.

A comprehensive critique of these plans is presented. In particular, the University's chance of obtaining desired student numbers in certain areas is explored. This is followed by two sensitivity analyses. In the first, consequences of possible shortfalls in student numbers in different subject areas are considered. The second considers consequences of possible changes in University internal resource allocation policy. The consequences of the latter turn out to be far more far-reaching.

The possibility of further work is discussed. Possible improvements in the University's information system are considered and the feasibility of introducing a planning programme budgeting system is discussed.

The major conclusion to emerge from this study is that it proved possible to build a mathematical model of the University which can be usefully employed for planning and in particular for devising and testing quinquennial plans. This approach has the advantage that the implications of a given plan for all significant resources can be assessed. It also enables a wider range of plans to be investigated and full sensitivity analyses to be carried out.

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APPENDICES

List of Abbreviations and Acronyms

AC	Academic Council
AUT	Association of University Teachers
BA	Bachelor of Arts
CAMPUS	Comprehensive Analytical Methods of Planning in University Systems
CERI	Centre for Educational Research and Innovation
CSL	Computer Simulation Model
GUS	Generalized University Simulation
HIS	Hochschule Information System
HMSO	Her Majesty's Stationery Office
ICLM	Induced Course Load Matrix
IFORS	International Federation of Operational Research Societies
IMHE	Institutional Management in Higher Education (programme)
MEd	Master of Education
MLit	Master of Letters
MSc	Master of Science
NCHEMS	National Centre of Higher Education Management Systems
OECD	Organisation for Economic Co-operation and Development
PG	Postgraduate
PPBS	Planning Programming and Budgeting Systems
ROBUS	Robert Ball's University of Stirling model
RRPM	Resource Requirements Prediction Model
SEARCH	System for Exploring Alternative Resource Commitments in Higher Education
SRG	Systems Research Group
TUSS	Total University Simulation System
UCCA	Universities Central Council on Admissions
UG	Undergraduate
UGC	University Grants Committee
UK	United Kingdom
USA	United States of America
USSR	Union of Soviet Socialist Republics
WICHE	Western Interstate Commission for Higher Education

CHAPTER 1

DECISION-MAKING RESOURCES ALLOCATION and PLANNING in UK UNIVERSITIES

1.1 Introduction

The objective of the research described in this dissertation was to examine planning and resource allocation problems of Universities and to investigate whether scientific management methods and in particular mathematical models could be used with advantage in this context. The approach adopted was to consider these questions in the particular case of one University (the University of Stirling). After reviewing the planning and resource allocation problems of the University of Stirling in the light of the national system of University planning and finance, a model was developed and used to investigate the University's medium term development plans. A critical evaluation of the work is presented and suggestions for further research made.

The dissertation is organised into ten Chapters. In Chapter 1 the structure and financing of the UK system of University Education is described. Hence it is possible to appreciate the administrative framework within which a University takes its decisions and any relevant constraints on its freedom of action.

A history of the University of Stirling is presented in Chapter 2 together with an outline of its academic development. This then leads on to a general discussion of the planning and resource allocation problems of the University.

Chapter 3 contains a broad survey of attempts by other workers to apply management science methods to University administration. Work done in developing general purpose mathematical models of Universities for planning is described in Chapter 4. Chapter 5 presents a general discussion of the methods and philosophy of resource allocation within Universities, giving special emphasis to the U.K. situation.

The planning problems of the University of Stirling were reviewed in the light of this work and it became apparent that there were possible advantages to be obtained from the use of a mathematical model of the University. For a number of reasons, however, it was found impracticable to utilise any of the general-purpose models developed elsewhere; thus it was necessary to develop a model from first principles. An outline of this model is presented in Chapter 6 with appropriate technical details being included in an appendix.

The model thus developed was employed in investigating tentative plans for the quinquennium 1977-82. (This study is described in Chapter 7). A sensitivity analysis which investigates the consequences of the University failing to reach certain of its targets and also the effect of possible changes in resource allocation policy is provided in Chapter 8.

In Chapter 9 possibilities for future work in the field such as the possibility of applying the model to other institutions and possible experiments with PPBS and management information systems are considered. Some broad conclusions and recommendations are presented in Chapter 10.

1.2 The University system in the United Kingdom

Anexcellent description of the development of the UK University system from its mediaeval origins up to the present day is presented by Mountford (1966). Scottish Universities have a distinct historical background from their counterparts in England and still have certain academic and organisational differences. They are, however, fully integrated into the national UK system of University planning and finance. Although under the Government's White Paper on Devolution (1975) it was proposed that Scottish Universities should remain the responsibility of the UK government, this proposal proved very contentious and there was considerable pressure to have responsibility for the Universities transferred to the proposed Scottish Assembly.

1.3 Relationship between the Universities and the State in the UK

Until near the end of the nineteenth century Parliament confined its responsibilities towards Universities to the regulation of their Charters, making only negligible financial contributions. At this time University income comprised mainly of revenue from foundations and investments, grants from local authorities and student fees. Towards the end of the century, grants to Universities from Central Government began to be made in significant amounts and in 1919 the University Grants Committee (U.G.C.) was established to help administer these grants. The original terms of reference of the UGC were:-
"To enquire into the financial needs of University education in the UK and to advise the Government as to the application of any grants that may be made by Parliament towards meeting them".

This remit was augmented in 1946 and 1952 by the following.
"To collect, examine and make available information relating to University Education throughout the United Kingdom" and "to assist in consultation with the Universities and other bodies concerned in the preparation and execution of such plans for the development of the Universities as may from time to time be required in order to ensure they are fully adequate to national needs".

Thus the U.G.C. acquired responsibility both for the keeping of statistical records and for planning the development of the University system in the light of national needs.

Broadly speaking the UGC's function is to act as a buffer or intermediary between the Government and the Universities in order to enable resources to be allocated to the Universities without direct Governmental interference in their affairs. Thus, hopefully, the national interest and the requirement of adequate supervision of public expenditure on the one hand can be reconciled with academic freedom and autonomy of the Universities on the other. The UGC has a full-time chairman and vice-chairman and nearly twenty part-time members. Most of the membership is drawn from the Universities but there are also representatives from Government, industry and other educational sectors. The useful summary of the functions of the UGC can be found in its own publication "UGC" (1970).

1.4 UGC Procedure - the Grant System

The UGC allocates three types of grants to Universities: recurrent, non recurrent and equipment grants.

(i) Recurrent grants are intended to finance running expenditure of Universities such as salaries, consumables, books and periodicals for the library, maintenance of premises and so on. These grants were determined for a fixed five year period (or quinquennium) thus giving rise to the name "Quinquennial Grant System".

Around two years from the end of a quinquennium, a University receives an informal visit from members of the UGC. Each University is then asked to submit detailed and reasoned proposals for its development during the succeeding quinquennium in the light of some general guidance concerning the likely development of the University system as a whole. This plan is the University's "Quinquennial Submission". When the estimates from all Universities have been considered, the UGC assesses what it regards as a reasonable total need. In making such an estimate, however, the UGC must take cognizance not only of the plans forwarded by the individual Universities, but also such factors as potential demand for University places, national needs for qualified graduates and the likely availability of resources. Parliament examines the UGC's requirement for funds; and in the light of this, and national educational policy, agrees a global sum (subject to an annual confirmatory vote) for each year of the ensuing quinquennium.

The UGC then has the task of apportioning the money voted by Parliament between the Universities. These allocations are given in the form of 'block grants' with no strings attached which means that each University has complete freedom over the internal disposition of its allocation. Some broad guidance is given to each University, however, concerning national needs and priorities and how the UGC sees an institution's future development within this framework. Thus, in practice, no University would undertake a major change in policy without careful thought and consultation with the UGC. As the UGC (1967) stated in its memorandum of general guidance

"The Committee hopes that universities will find it helpful to have the considerations mentioned in this memorandum before them when they come to decide their own development policies and priorities within the quinquennium. Each University is free to determine the distribution of its annual block grant in the light of the guidance, general and particular, which the committee have given. It would, however, be in accordance with generally accepted convention that the committee be consulted before any major new developments outside the framework set by the University's quinquennial submission and guidance contained in this general memorandum and individual letter of allocation are undertaken".

The system of quinquennial block grants gives the Universities genuine flexibility in their internal resource allocation and allows them to make coherent medium-term plans. There are however two difficulties associated with this system. Firstly, the planning horizon varies over the quinquennium from over five years to one year. A more serious problem is the erosion of real value of the grants by inflation. Until around the middle of the 1972-77 quinquennium, the University grants were supplemented for inflation using an index of University costs known as the Tress-Brown index. Under this system Universities received automatic supplementation for 50% of their increased costs and the other 50% was sometimes secured upon representations to the Government from the UGC. Grants were automatically supplemented in full for any increases in academic salaries.

Following the rapid increase in the rate of inflation during 1973-5 and cut-backs in public expenditure on Education, the quinquennial system was virtually abandoned and a provisional ad-hoc system of yearly grants introduced. It is, however, hoped that this will prove to be a temporary expedient since the UGC is hoping to return to the quinquennial system once the rate of inflation has abated and the future of public expenditure on education becomes clearer.

In the meantime other systems of grant allocation, such as the rolling triennium (which will be discussed later in this dissertation) are being proposed. Finally the introduction of the system of 'cash limits' for public expenditure means that Universities will no longer automatically receive supplementation even for rises in academic salaries.

(ii) Non-recurrent grants are given for capital and related expenditure such as financing approved building work, the purchase of sites and properties and payment of associated professional fees. The Government has the responsibility of fixing the total value of grant-aided building work that can be started during a given financial year, the UGC's functions being to distribute this work between different Universities and to control building standards and costs. This work is carried out by the architectural division of the UGC's secretariat. It does not tamper with matters such as architectural style or design but lays down strict standards of permissable cost per unit area for different kinds of space (lecture room, office, laboratory etc). The allocation of space for different types of accommodation is also strictly controlled using a system of norms, (eg so many square metres of office space for a lecturer etc). The introduction of a new building programme at a University is usually a lengthy process with five years or more elapsing between the initial plans and completion of the building. By 1975 new building at Universities had virtually come to a halt and was likely to be severely curtailed during the next few years at least.

(iii) Equipment grants and furniture grants are allocated to each University in the form of annual sums fixed for a number of years in advance. Until recently Universities were free to accumulate this money in a separate fund, but because of the subsequent large balances which were accumulated by the Universities, the system was changed so that the funds were held by the Paymaster General and disbursed to the Universities as and when required. This change of procedure which meant that Universities have lost access to a source of readily available cash, has considerably exacerbated the cash-flow problems of certain institutions (including Stirling). Universities are, however, free to deploy their grants on equipment and furniture in any way they feel best.

1.5 The Planning Function of the UGC

As we have seen the UGC has responsibility (taking into account Government policy) for the formulation of a broad strategy for the development of the University system as a whole and for individual institutions within this system. This involves the UGC in a continuous dialogue both with the Universities and the Government. Through this dialogue it arranges for the collection and analysis of a wide range of statistics about University numbers and costs and gives Universities informal advice and guidance about their development. There are, however, three mechanisms available to the UGC for more formally exercising their planning functions.

(i) Through recurrent grants

When informing a University of its quinquennial grant, the UGC offers a certain amount of guidance through a general memorandum of guidance (in which it outlines the prospects for the University system as a whole) and in an individual letter of allocation to each University. The letter of allocation generally contains the following information:-

a) A statement of student numbers (distinguishing between undergraduates and postgraduates and between Arts and Science based students) on which the grant for the final year of the quinquennium is based. The pattern of development of student numbers through the quinquennium toward this target is not, however, specified.

b) Specific comments on proposals put forward by the Universities and which the UGC wished either to encourage or discourage. For instance, the letter of guidance to Stirling for 1972/77 stated that one of the two proposed postgraduate courses in Education had not been taken into account in assessing the grant, and that developments in Swedish were strongly discouraged. Although the UGC indicate that certain proposals had been ignored in fixing the block grant, the relationship between the block grant and the individual items contained is not clearly specified. This point is discussed in a paper by J C Walne (1973). Walne states that during the 1967-72 quinquennium, the UGC used a system of arbitrary weightings for this purpose. This was found to be unsatisfactory and a regression analysis of University costs which took into account a number of factors such as the number of departments, mean student load per department, number of taught postgraduate courses etc, was used for the succeeding quinquennium. The UGC however, have refused to make the details of their regression analysis public on the grounds that to do so must inevitably stultify resource allocation discussions within Universities. A C Morris' (1972) article on this subject is also worthy of note.

In the final analysis, however, a University is free to ignore the UGC's advice and spend its block grant on any legitimate purpose it thinks fit. As discussed earlier, however, in practice no University would reject the UGC's advice without considerable thought and consultation.

It is the general impression in British Universities that the amount of specific advice given by the UGC in the above way is increasing over the years.

(ii) Through capital projects

Since the UGC have to sanction all building projects, this gives them an effective veto power over certain developments. For instance there has never been any question of new developments in Engineering at Stirling because the UGC have always maintained that they were unwilling to supply the necessary capital requirements when resources elsewhere were still not fully utilized.

(iii) Offering incentives

If the UGC feels that a certain need is not being fully met it may invite a few or all Universities to consider whether, if the necessary funds were made available, they might be prepared to fulfil that need. Providing the proposed development is academically acceptable, Universities will generally co-operate on such matters. For example, Stirling University received specially-earmarked funds for the development of short courses in Technological Economics for industrialists during its early years.

1.6 Freedom of Decision-Taking for Individual Universities

In this section we shall explore, in the light of the previous discussions, the areas of freedom that a University possesses over its internal decision-making. Owing to the block grant principle, the University has complete autonomy over the internal apportionment of its recurrent grant. In other words it is able to 'divide the University cake' amongst competing internal claims in any manner that it wishes, although, as we have seen, this freedom is qualified by the convention that a University has the responsibility to exercise this power within the framework of national needs and policies and in the light of the guidance given by the UGC.

More specifically the UGC (1964) in its quinquennial survey entitled 'University Development 1957-62' surveyed six areas in which they believed that ".... the Universities should have a wide measure of self-determination". These areas were:;

1. The selection of students.
2. Appointment of academic staff.
3. Determination of the content of University education and control of degree standards.
4. Determination of size and rate of growth.

5. Establishment of balance between teaching, research and advanced study; selection of research projects and freedom of publication.
6. Allocation of current income among the various categories of expenditure.

We have previously described how freedom (6) is tempered in the light of the national interest. Although under (4) an institution has control over its size and growth rate, failure to co-operate with the UCC's expansion plans might prove deleterious to an institution's long-term interests. To quote from the Robbins report (1963)
"If when all the reasons for change have been explained the institution still prefers not to co-operate, it is better that it should be allowed to follow its own path. This being so, it must not complain if various benefits going to co-operating institutions do not come its way".

Thus, although Universities are required to be generally responsive to national needs, the quinquennial planning system and block grant principle do, nevertheless, afford a fair measure of self-determination to individual institutions.

1.7 Objectives of decision-taking in the University context

Decision-making involves choosing between a number of alternative courses of action. Rational evaluation of these alternative options will then depend on some prior specification of objectives. This may present certain difficulties in the University context since Universities pursue diffuse and sometimes even conflicting objectives.

Several workers have attempted to specify (and in some cases evaluate) these objectives. Blaug (1969) claims that Universities serve multiple objectives and that their operations can be assessed in principle in terms of the effectiveness with which each of the varying objectives is achieved. He tentatively suggests the following objectives.

1. Vocational objectives including maximising lifetime income for graduates.
2. Selection of most able leadership for government and research.
3. Promotion of scholarship and scientific research.
4. Cultivation of talent for the sake of self-enrichment.
5. Preservation and dissemination of cultural values.

Some suggested measures of performance in meeting these objectives are given:-

- Vocational objectives - in terms of discounted future earnings.
- Cultural objectives - according to some index that assigns more weight to arts than science graduates.
- Research output in terms of number of publications.

Unfortunately some of these measures are rather vague and open to objection. For instance evaluating research output in terms of number of publications ignores the question of some research findings being much more significant than others (other authors have suggested approaching this problem by an index of the number of citations a publication receives in bibliography).

Even if satisfactory performance measures are devised however, it would be necessary to obtain a system of weighting for different objectives since a particular decision may well have implications for a number of objectives. Thus it can be seen that we are some way from a purely formal objective evaluation of the relationship of decision-making and objectives in the University context.

A more general description of objectives of Universities approached from a historical standpoint is given by J Clark Kerr (1964). Beard, Healey and Holloway (1968) give an exhaustive analysis of the objectives of the teaching activities of Universities and discuss how programmes of study and courses relate to these objectives.

Sims (1973) argues that the rational evaluation of activities depends on the prior specification of the objectives sought by those activities but "Because of conflicting and changing values of faculty and students any statement of aims that was widely accepted would be so vague and generalized as to be operationally useless for evaluating performance".

He argues however, that the absence of clearly defined objectives need not hinder this evaluation if problems are approached from a different viewpoint. The approach suggested is to accurately describe the existing state ('what is') and seek to move incrementally towards a state offering greater utility ('what will result') by choosing from an identifiable set of feasible alternatives. In this way it would be possible to assess subjectively the extent to which an improved state has been achieved.

It seems that this pragmatic approach could well be valuable in a practical situation although the use of the concept of utility does imply a grasp of objectives even if it is impossible to articulate them.

Sims further argues that the inputs and outputs which relate to particular courses of action should be marshalled so as to assist rather than determine the basis of subjective evaluations. Given the present state of the art, this seems a sensible approach to practical problems and will be the one broadly followed in this dissertation.

BIBLIOGRAPHY : Chapter 1

1 Beard, Healey and Holloway (1969) Objectives in Higher Education, Society for Research into Higher Education

2 Blaug, M (1968) The Productivity of Universities, Economics of Education, Vol 2, Penguin, pp 313-325

3 Kerr, J Clark (1964) The Uses of the University, Harvard University Press

4 Morris, A C (1972) The UGC and the mystery of the Quinquennial cake. Times higher Educational Supplement (July 1972)

5 Mountford, Sir J (1966) British Univerisities, Oxford University Press, pp 1-49

6 Robbins, Lord (1963) Committee on Higher Education, Report of Committee under Chairmanship of Lord Robbins, HMSO

7 Sims, M (1973) Accounting Information in Universities, Higher Education Review, Vol 5 No 3, Summer 1973, pp 3-24

8 UGC (1970) The University Grants Committee, HMSO

9 UGC (1967) Memorandum of Guidance, HMSO

10 UGC (1964) University Development 1957-62: a quinquennial study, HMSO

11 Walne, J C (1973) Cost Analysis at the University Grants Committee, Higher Education, Vol 2 No 2, pp 228-235

12 White Paper on Devolution (1975) Our Changing Democracy, HMSO

CHAPTER 2

THE UNIVERSITY OF STIRLING - HISTORY, ACADEMIC STRUCTURE, PLANNING AND RESOURCE ALLOCATION PROBLEMS

2.1 Preamble

In this chapter we shall briefly describe the origins, broad objectives and academic structure of the University of Stirling. We shall then consider the particular planning and resource allocation problems of the University, given the flexibility of decision making in British Universities described in the first Chapter.

2.2 University Origins

Although King James VI of Scotland in the early years of the seventeenth century expressed an intention of founding a university in Stirling, no progress was made on this project until the early 1960s. At this time the climate of national opinion was strongly in favour of further University expansion. Already progress had been made in setting up a number of new Universities in England (Sussex, Warwick, Lancaster etc) and the Robbins report (1963) recommended that six new Universities, including one in Scotland should be set up forthwith. In the event it was decided to go ahead only with the new University in Scotland. It is possible that the Government may have been partially influenced by its regional economic development policy in arriving at this decision and, in the event, the arrival of the University had a considerable effect on the local economy (Brownrigg 1974). A number of towns in Scotland were interested in becoming hosts to the new University (Falkirk, Inverness, Cumbernauld, etc) but in July 1964 it was decided that the University should be located in the Airthrey Estate adjoining Stirling.

2.3 Academic Development - General Considerations

In 1965 an Academic Planning Board was instituted to draw up plans for the academic development of the new Institution. This body produced its first report (1965) in which it proposed broad academic aims for the new University.

"The University should aim at promoting the general powers of mind of its students; it should produce men and women who are not merely specialists but cultivated men and women with particular skills; it should play an important part in the advancement of learning and transmit a common culture and common standard of citizenship".

More specifically, the report recommended that in the early years the University should concentrate on three broad fields of study - arts and humanities; basic sciences including mathematics and the social sciences. The concept of a rigid faculty structure was rejected; instead the report envisaged that undergraduate and postgraduate courses and research should cross conventional discipline boundaries and that interdisciplinary study should be made an important and integral part of the University's academic life.

Some very tentative suggestions about growth of student numbers are included in the report, initial intakes of around 150 students are suggested for the first two or three years, while a target student population of the order of 4000 students by 1976/77 was envisaged.

2.4 The University's Academic Structure

In order to be able to satisfy the broad academic objectives described above, the University developed a flexible academic structure. This structure has important implications for planning and resource allocation problems described later and is significantly different from the usual systems found in Scotland and the rest of the U.K.

Stirling is the only University in the UK which operates a semester system. It cannot, however, be described as a pure semester system since in such a system a student can enter the University in any semester and, in general, all courses are on offer in any semester. At Stirling a student may enter the University only in the Autumn semester and, in general, first, third, fifth and seventh semester courses are available in the Autumn semester and second, fourth, sixth and eighth semester courses are available in the Spring. Thus there are elements of the academic year system present in the Stirling structure.

The basic unit of study at Stirling is the semester course unit which corresponds to the study of an academic subject for one semester. It was considered that such a unit, which would occupy around a third of a student's available time for study in a given semester, could comprise a viable academic unit.

The Undergraduate degree (the BA), which can be taken either as a General or Honours Degree, is divided in two parts (Part I and Part II). Part I, which is common to all students, normally lasts for three semesters while Part II involves a further three semesters' study for the General Degree and five semesters for the Honours Degree.

The Part I is broadly based in order to try to give students an opportunity of studying unfamiliar subjects. In order to pass Part I, a student must pass eight semester course units (taking up to three in any semester) including one subject studied for the whole three semesters (Major) and another studied for two semesters (subsidiary). In general a student may take any combination of subjects he wishes, normally the only prohibited combinations being due to the exigencies of the teaching timetable.

In Part Two the student can take either a General or Honours Degree programme of studies. In order to obtain a general degree a student must satisfactorily complete a further seven semester courses in Part Two in such a way that he completes a General degree major (in all, six semester course units of a particular subject taken over not less than five semesters) and a General degree subsidiary (four semester course units of a subject including at least one in Part Two).

Honours degree programmes involve study in depth in Part II of one (single honours) or two (joint honours) subjects. Each honours degree programme is individually specified since there are no detailed University regulations concerning the composition of such a degree. Normally, however, provision is made to give the student the opportunity to take from time to time a course from outside his major field of study.

Thus the University attempts to carry out the remit of the Academic Planning Board by providing a broadly based Part I for all students followed by further broadly based programmes in Part II for General students and appropriate training in depth for Honours students. There is some evidence that students have taken advantage of their opportunities to study a wide range of subjects in Part I (Cottrell 1972).

2.5 Physical Development

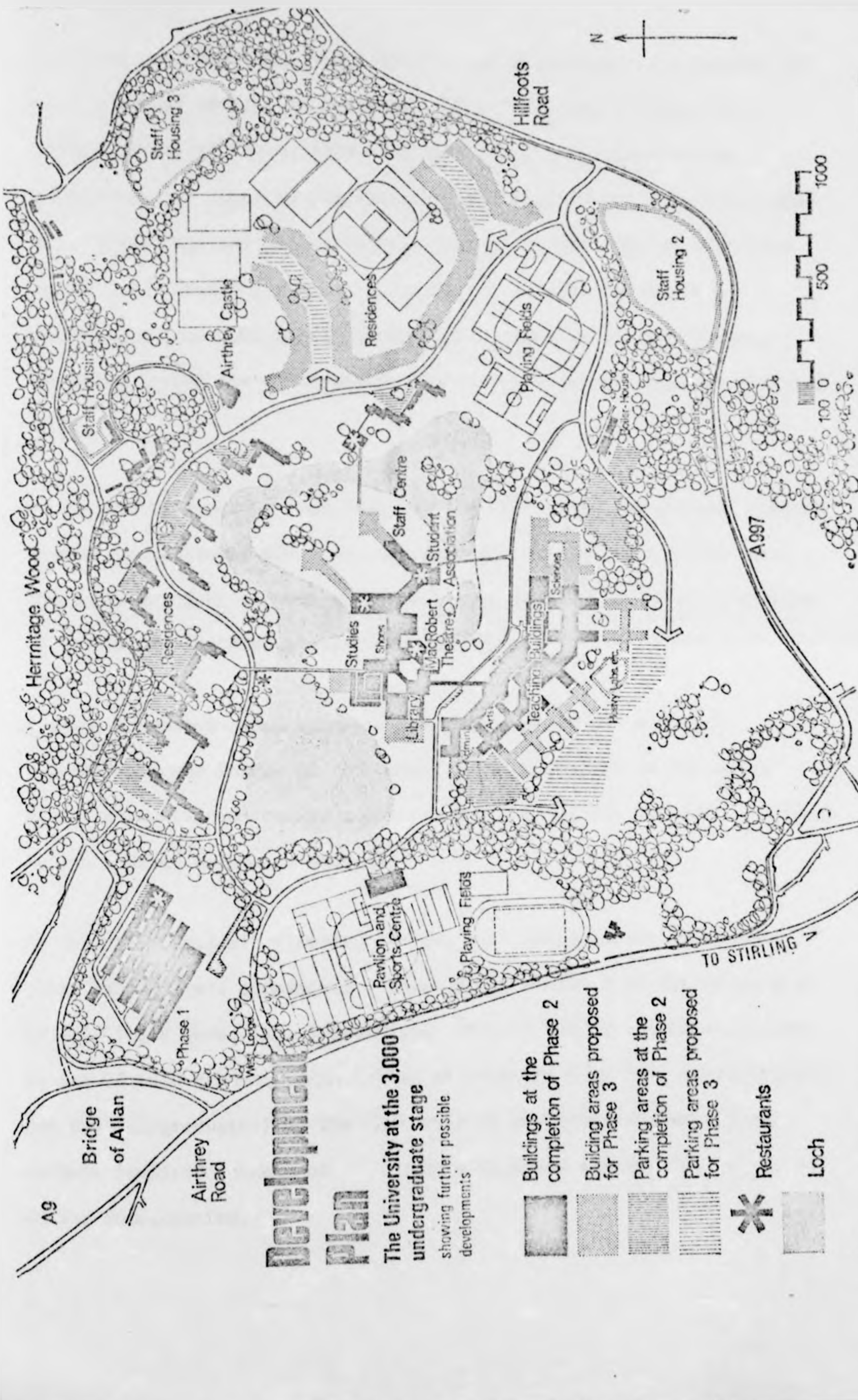
As described earlier, it was decided to locate the University in the Airthrey estate to the north east of Stirling. This estate, which had at one time been privately owned, was then owned by the Ministry of Health and consists of around 300 acres of mature parkland, a wooded hillside of around 63 acres and an artificial loch of 23 acres (see Map 1).

It was felt that the University could best make an undisturbed beginning if its academic activities could, during its early years, take place well away from the major building sites. For this reason a simple but permanent preliminary building called Pathfoot (after a prehistoric village on the site) was constructed on the north-west corner of the estate. This building comprised an area of about 130,000 square feet and was completed in ten months in time for the first student intake in 1967.

Whilst the University began its activities in Pathfoot, work was started on the major academic buildings which were centred on the loch (Cottrell Building). The first part of this accommodation became available in 1970, whilst by 1974 the University had sufficient academic accommodation for over 3500 students.

Because the University is constructed in a comparatively lightly populated area, it was decided at an early date that a major provision of student residence would be necessary. These were constructed on the opposite side of the loch to the major academic buildings and by 1974, accommodation for about 1750 students was available.

MAP 1


Development Plan
The University at the 3,000 undergraduate stage
showing further possible developments
Buildings at the completion of Phase 2
Building areas proposed for Phase 3
Parking areas at the completion of Phase 2
Parking areas proposed for Phase 3
Restaurants
Loch
A9
Bridge of Allan
Airthrey Road
Phase 1
Herritage Wood
Staff Housing 1
Staff Housing 3
Airthrey Castle
Residences
Residences
Studies
Library
MacRobert Theatre
Student Association
Staff Centre
Teaching Buildings
Sciences
Playing Fields
Playing Fields
Pavilion and Sports Centre
Staff Housing 2
Hillfoots Road
A997
TO STIRLING
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100 0 500 1000

2.6 University Development

The first students (approximately 150 undergraduates and a handful of postgraduates) arrived in September 1967. This was followed by a further intake of 150 in 1968. In 1969 since the students were forthcoming and capacity was available the University decided to admit 300 students instead of its initial target of 150. During this time demand for University places in the UK was increasing sharply; according to the UCCA report (1969) the percentage of the relevant age group trying for a University place almost doubled between 1965 and 1969.

By the end of academic year 1969/70, the University had a total student population of around 600. At that time all academic activities were housed in Pathfoot and all students stayed in lodgings or at home since no University residences were yet completed.

A major expansion phase began in the Autumn of 1970. A greatly expanded student intake of 600 undergraduates arrived as the first blocks of residences became available and some of the academic buildings in the central area were opened.

At this time academic planning for the next quinquennium (academic years 1972/77) was commencing. These plans outlined in the University of Stirling's Quinquennial Submission 1972/77 (1971) envisage a growth to around 4000 students (consisting of approximately 3550 undergraduates and 450 postgraduates) by the last year of the quinquennium. These targets involved intakes of over a thousand students by the end of the quinquennium.

In January 1973, the reply from the UGC in the form of the quinquennial letter was received. This letter pruned considerably the student numbers proposed in the Quinquennial submission. A target of 3342 students (3042 undergraduates and 300 postgraduates) for the final year of the quinquennium was set out. The Arts:Science mix for undergraduates was given as 2135:907 and quite detailed recommendations as to the composition of postgraduate numbers were made. It also assumed a much slower build-up of postgraduate numbers than in the past and expressly forbade the University from substituting postgraduates for undergraduates, should undergraduate numbers show a shortfall. The letter also included some specific comments on proposed academic developments and asked for a 2% reduction (in real terms) of the cost per student.

In the event it proved impossible to achieve these targets. The major reason for this was that the demand for University education had flattened out during the early seventies, and thus the University was in the position of attempting to expand in the tail-end of the national expansion. This situation was exacerbated by the adverse publicity the University received following the Queen's visit in 1972. Following the rapid inflation of 1974 and cut-backs in expenditure on Universities, the quinquennial system was at least temporarily abandoned and replaced by a series of ad-hoc one year plans. It seemed, however, that once the situation stabilized a return to a quinquennial system (or at least a planning horizon greater than one year) would be made. Hence it was necessary to plan at least tentatively for the 1977-82 quinquennium.

2.7 General Description of the University's Planning Problems

(i) Degree of control of the University over its own pattern of development

Since, in general terms, the levels of resources allocated by the University to different subject areas will be related in some ways to the numbers of students studying in those areas, the pattern of student registrations will have a considerable influence on the future of the University. Owing to the University's flexible academic structure students may pursue studies in any subject area they wish and change courses freely. The only constraint operative upon them is that the programme of studies chosen must be viable (ie it must satisfy the degree regulations).

Given this situation the only controls that the University can effectively apply is through the admissions system. Here, although the University operates a common entry policy, a student has to declare on his UCCA form the subject areas he intends to specialise in (though he is under no obligation to actually study these subjects once admitted). This information is, however, valuable since experience has shown that the numbers of students who study particular academic programmes in Part II of the degree course may be predicted from progamme choices of the UCCA forms of entrants.

The University can control to some extent the total numbers admitted by the level of offers made to applicants. It could exert indirect control on numbers studying in different subject areas through varying entry requirements according to subject choice specified on a student's UCCA form. Nevertheless because of the academic flexibility available at Stirling, the future shape of the University will depend to an important extent on the vagaries of student choice. This may create certain problems for a University.

(a) The University may not develop in a path that it considers desirable.

(b) Student choice can be fickle and could change suddenly especially in an uncertain economic climate. It is generally a slow process to reallocate University resources (since academic staff have tenure; in a situation of no overall growth it is necessary to do this through a process of not filling vacancies). Thus it would easily be possible to envisage a situation in which student registrations were changing much more quickly than University resources could be reallocated to meet these new demands.

We shall now give some detailed considerations to particular problem areas:

(ii) Student numbers

As described earlier the University has some control in at least the upper level of its total student numbers through its admissions system. However, since the early seventies, it has failed to keep pace with its planned expansion programme and will have probably only around 2100 students by the end of the 1972/77 quinquennium instead of the target of over 3300. As mentioned earlier, this problem is partially associated with demand for University education levelling off during the period, although local factors may also be important. Amongst these are the adverse publicity following the Queen's visit to Stirling in 1972 and the Scottish tradition of entering one's local University.

This situation creates a number of problems. Apart from the general question of the viability of a University of around 2000 students, the University commissioned buildings and appointed staff ahead of the planned development programme and hence has under-utilized resources.

(iii) Subject distribution

"It simply will not do to allow Universities and Polytechnics to produce whatever people they fancy or to relate the number and kinds of places they provide to the applicants that come forward" said Lord Crowther-Hunt (1975) in a speech in London. Lord Crowther-Hunt was Minister of State for Education at the time and this speech highlighted some of the difficulties of the University. Since very early years, Stirling has had problems with obtaining an equitable distribution of students over all subject areas. For example although it was originally intended that one-third of all courses studied should be in Science, in practice only about a half of this number were actually taken in Science. Since a large proportion of these were taken in Biological subjects, the Physical Sciences numbers were in some cases almost derisory. Fear that the University might "degenerate into a liberal arts college" were voiced in some quarters.

Furthermore, the distribution of students amongst the remaining subjects was very uneven. Student numbers in the fields of History, English, Sociology and Psychology tended to be disproportionately large compared with other areas. This raises the question as to whether it is in the best interests of the University to have such an uneven distribution of student registrations. There is also the question of national interest as raised by Lord Crowther-Hunt. Is the University justified in expanding developments in, say, History and English indefinitely to meet expanding future student demand in these areas?

As was described earlier the University might attempt to influence this situation by applying different entry criteria according to subjects which students express interest in on their UCCA forms. This could entail raising entry requirements in certain areas and perhaps lowering them in others. A difficulty with raising entry requirements is that this must inevitably involve reductions in total student numbers and thus conflict with the University's overall numbers objectives. It may not be much help to the University to achieve balance simply by cutting Arts and Social Science numbers in order to keep them in line with Science. There remains, however, the option of lowering entry requirements in areas such as the Physical Sciences which the University particularly wants to foster. Two main arguments are usually presented against this policy.

(1) If a prospective student got wind of this policy he/she would indicate interests in Physical Sciences no matter what the true study intentions were.

(2) Candidates with poorer entry qualifications might experience difficulty in successfully completing their courses.

However there are counter arguments to the above.

(1) Such action implies detailed 'inside knowledge' and a high degree of duplicity amongst relatively inexperienced people who are applying for University. In any case a student who indicates interests in Science, although having no scientific background would be immediately suspect.

(2) In a study carried out by the author it was found that there was some tendency for candidates with better entry qualifications to obtain better degrees. No tendency, however, was found for a higher proportion of minimally qualified entrants to drop out than others. The sample size was however, small and it is possible that a tendency to drop out might set in should entry requirements be further reduced.

The University could attempt to directly influence subject distribution by applying quotas in certain areas. This would however tend to defeat the purpose of the system since the object of the flexibility in the University's academic structure was to facilitate the possibility of changing courses. Another practical difficulty is that in many cases students would need to take particular courses in order to satisfactorily complete a degree programme. It seems to the author that any attempt to apply a system of quotas other than in a very limited way inexorably leads to restructuring the University's entire academic system. This would not only involve the University in a number of years' change-over period; but would also pose difficult questions concerning the identity and purpose of the University.

(iv) Finance

Generally the University's financial situation has deteriorated as the financial prospects of the Higher Education System as a whole have worsened. As previously mentioned, the University has two particular problems. Physical capacity has been provided for well over 3000 students and the University has to bear the expense of maintaining this surplus capacity. In addition, the University has appointed academic staff ahead of students demand, hence there is a measure of over-staffing of academic posts.

2.8 Summary

Thus it can be seen that the University is on a difficult planning situation. It faces the problem of attempting to draw up plans for the period 1977-82 and beyond in a very uncertain environment. There is little doubt that the University will wish to expand during this period, partly in order to grow to a more viable size, partly in order to fill its excess capacity. The expansion problem, however, is difficult in the light of subject distribution and financial problems. Thus any techniques which we might develop which could help to elucidate the situation could be very valuable.

BIBLIOGRAPHY : Chapter 2

13 Academic Planning Board of the University of Stirling (1965) First Report of the Academic Planning Board, University of Stirling

14 Brownrigg, M (1974) A Study on Economic Impact: the University of Stirling, Scottish Academic Press

15 Cottrell, T L (1972) Interdisciplinary Studies, Times Higher Educational Supplement (July 1975)

16 Hunt, Lord Crowther (1975) Times Higher Educational Supplement (May 1975)

17 Robbins, Lord (1963) op cit (No 6)

18 UCCA (1969) Seventh Report, Eyre and Spottiswoode Ltd

19 UCCA (1971) Tenth Report, Eyre and Spottiswoode Ltd

20 UGC (1973) Quinquennial letter to the University of Stirling

21 University of Stirling (1971) University of Stirling's Quinquennial Submission for 1972-77, University of Stirling

CHAPTER 3

A REVIEW OF THE APPLICATION OF MANAGEMENT SCIENCE METHODS TO PLANNING AND DECISION-MAKING IN UNIVERSITIES

3.1 Overview

Management science is concerned with the application of the scientific method to management problems. These methods have proved very valuable in approaching problems of planning and decision-making first in the military sphere (during the Second World War) and later in industry. See, for instance, Waddington (1973) and Tomlinson (1971).

The question then naturally arises as to whether these methods might prove to be of some value in the University context particularly with regard to the specific problems of the University of Stirling. An obvious way of attempting to consider this question is to survey developments in this field. We shall consider work carried out both in the UK and elsewhere. Although some of the work carried out outside the UK may be in institutions which belong to very different national University systems, the concepts and methodology developed could well be relevant to our own situation.

3.2 Historical perspective

Although accounts of successful applications of management science to military and industrial problems have appeared since the end of the Second World War, applications in the field of education have only appeared in significant numbers since the early sixties. We can only speculate about the reasons for this comparatively late development. It could be that the management science approach did not at first prove worthwhile in the education field, or it could be associated with the objectives of the systems being less clearly defined than in the industrial or military setting. Other possibilities are fears that such an approach might undermine traditional academic values or simply a conservative attitude towards a scientific approach to management in Universities.

As Sir Eric Ashby (1963) wrote about British academics

"All over the country these groups of scholars, who would not make a decision about the shape of a leaf or the derivation of a word or the author of a manuscript without painstakingly assembling the evidence, make decisions about admissions policy, size of universities, staff-student ratios, content of courses and similar issues based on dubious assumptions, scrappy data and mere hunch .... although dedicated to the pursuit of knowledge, they have until recently resolutely declined to pursue knowledge about themselves".

An early paper entitled 'Education - rich problems and poor markets' calling for management scientists to devote more effort to the field of education was written by Platt (1962). Platt stated that his purpose was

"to invite management scientists and operational analysisits to add education to their agenda; education is a system and set of subsystems potentially susceptible to analysis design and perhaps eventually a little optimisation".

He also discusses the skills which such workers could bring to bear on these problems, such as the ability to formulate alternative policies and the capacity for measuring the costs and benefits of various courses of action.

William G Sheppard (1965) in an address to a joint meeting of the Institute of Management Sciences and the Operations Research Society of America referred to Platt's paper and suggested that there was a great disparity between the needs of education for management science and the present effort. He outlined a number of areas where such an analytical approach might prove useful such as in the resource allocation problems within Universities and the question of quantifying the relationships between the needs for teachers and students and their potential supply. He stressed, however, the importance of human problems and the dangers that the simplification of the conception of the educational system inherent in such an analytical attack could tend to put restrictions on innovation, encourage conformity and lead to mediocrity.

One of the earliest bibliographies of work in this field was provided by R J Rath (1968). In this survey Rath analyses 41 IFORS (International Federation of Operational Research Societies) abstracts on education from the period November 1961 to December 1965. Seventeen of these forty-one abstracts are relevant to universities. Of these, seven deal with University operations (mainly timetabling or 'scheduling'), five deal with forecasting (student admissions, academic success, demographic trends etc), four deal with evaluation of educational technology, and one with a mathematic model of an educational institution.

Rath also reported a growth in research activity in the field within Universities. He found ten institutions with offices of campus planning or institutional research institutes.

Burton V Dean (1968) in a critique of Rath's paper observes that most effort had been involved in applying existing management science methods to University operations rather than developing new areas of management science which were applicable to University problems.

3.3 State of the Art at present

An excellent survey of recent research carried out in this field is presented by R G Schroeder (1973).

We shall now consider some specific problem areas where the adoption of a management science approach has proved helpful.

(i) University timetabling (sometimes called scheduling)

As we saw earlier in Rath's paper, a good proportion of the earliest successfully implemented work was carried out in this area. Oakford's work (1965 and 1967) in which he reports a very successful algorithm for scheduling students, staff and lecture rooms is worthy of note. More recently Longford-Smith (1971) has attempted to derive a relationship between the classroom mix (ie distribution of classrooms of different sizes) and its ability to meet random student demands for courses. After making certain assumptions about class sizes he develops a mathematical model of the process of assigning courses to classrooms and develops measures of overflow. Tomei (1969) also provides another account of the work done in this field in the USA. A report by the Department of Instructional Studies of Cincinnati University (1969) however, revealed that only about one third out of about 90 institutions surveyed had actually implemented work in this field.

Of the work carried out in this field in the UK, that of Gaile Thornley (1968) is particularly interesting. Dr Thornley used a heuristic model to attempt to devise a timetable for the University of Lancaster. The basic tenet of this work was that a timetable had to meet certain basic objectives before it could be considered feasible. Beyond this it should attempt to meet other objectives. Measurement of the effectiveness with which these objectives are met can be employed as a measure of performance.

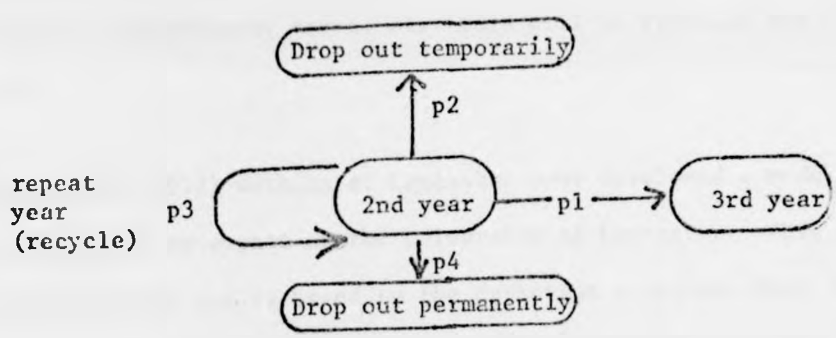
The index of performance is constructed through assignment of a given number of points for avoiding important subject clashes, further points for obtaining a satisfactory spread of classes throughout the week, along with an extra score for classes that take place at favourable hours. The model generates timetables heuristically progressing toward timetables with higher points scores under various headings and the correspondingly higher utilities. Although the assignment of points may be to some extent arbitrary, this line of research seems promising.

(ii) Student flow models

Much research effort has been devoted to problems associated with forecasting the admission of students to programmes of study and developing models of student progress through a University system. The progression of students through the University, proceeding normally, repeating sessions, dropping out and possibly being readmitted, has important consequences for the future growth and hence resource requirements of an institution. Although this problem is of greatest importance in U.S. Universities where students have considerable discretion over the time they take over a degree programme, it has also been of importance at the University of Stirling. An excellent summary of work carried out in this area is presented by C C Lovell et alia (1971). Most models developed in this area are based either on a ratio technique or use a Markovian approach. The basis of the ratio approach is the idea that the ratio of a particular cohort of students who progress from one level of an academic programme to another may be taken as the probability of progressing between these two stages. (For instance a historically determined proportion of the first year class in a particular subject may progress to the second year).

If we assume that these ratios can remain constant from one time period to the next we have the basis of a tool for predicting student numbers at different levels of an academic programme.

The basic assumption of a Markovian model is that the probability of an entity moving from one state to another during a given time interval depends only on the present state of the entity and is independent of the past history of the entity. It is further assumed that these probabilities (transition probabilities) remain constant from one time period to the next. It thus would seem plausible to construct a Markovian model of student transitions through a University system. For instance, considering students in the second year of a given course, at the end of the year they may either



progress to the next level of the course, repeat the year or drop out either temporarily or permanently. Thus a Markov model of the whole system may be developed, although this can turn out to be rather complex for a large system. For practical examples of these types of models see Harden et alia (1971) or Marshall and Oliver (1970).

R Hall (1975) has used a modification of the ratio technique for the purpose of forecasting student flows. This model is based on consideration of the proportions of given student entries to have reached given academic levels a number of time periods after entry. Further details of this type of model are given in Chapter 6.

(iii) Manpower planning : Academic staff flows

Manpower planning is of considerable importance to all large organisations. Given a particular level of staffing of an organisation and a specified recruitment and promotion policy it is important to be able to forecast the future composition of the organisation. Of particular importance is the question as to whether the organisation will have sufficient experienced staff for its needs in the future and whether a satisfactory career structure will be provided for its employees.

Simpson et alia (1971) working at Lancaster have developed a model for forecasting staff movements at the University of Lancaster. This is an aggregated model and is based on the Markovian principle that the probability of an entity moving from one state to another during a particular time period depends only on the initial state of that entity. Thus if we consider an academic staff member on a particular point of the salary scale; at the end of the time period (a year) he can either move up to the next point on the scale (providing he has not reached the maximum), leave through retirement or possibly obtaining a post elsewhere, or be promoted to the next grade. The transition probabilities can be obtained from historical information. Unfortunately during a period such as the mid-seventies when University resources are under severe restraint, historically determined transition probabilities are likely to be invalid.

Oliver (1968) has constructed a model of tenured and non-tenured academic staff movements at Berkeley. His analysis indicated that equilibrium could not be reached with existing tenure promotion rates at Berkeley.

Gray (1975) has described a manpower model which has been developed at a private University in the USA and which had been used to investigate the effect of an early retirement policy on the career structure of academic staff. (Incidentally this investigation came to the conclusion that early retirement was only a palliative and not long term solution to the problem of designing satisfactory career structures).

Hopkins (1972) conducted a study of the effect of an early retirement plan at Stanford. He found that early retirements could be offered at about the same cost by inducing highly paid full professors to retire early and replacing them with assistant professors at a lower salary.

Berman (1975) has described a manpower model of the system of higher education in the USSR.

(iv) Models for Optimal Resource Allocation

An obvious difficulty with any attempt to allocate resources in any sense optimally is the problem of specification of University objectives. If we use conventional linear programming techniques we need to develop a unidimensional objective function (eg maximisation of profit, minimisation of cost) and this is not really practicable in the University context with its multiple, sometimes conflicting goals measurable only in different dimensions.

Lee and Clayton (1972) however suggest a possible way of handling the multiple goals of Universities using goal programming. Goal programming is an extension of linear programming that can cope with the problem of multiple goals and also handle objective functions composed of elements in different dimensions. It is necessary for the decision maker to provide an ordinal ranking of goals in order of importance and the technique minimises the deviations between the stated goals and what can be achieved within a given set of constraints. More specifically three types of solution are provided by the goal programming approach:-

1) Identification of input (resource) requirements necessary to obtain all desired goals.
2) Degree of goal attainment possible with specific inputs.
3) Degree of goal attainment possible under various combinations of inputs and goal structures.

The authors have developed a goal programming model for allocating the total salary budget of a college among various grades of academic staff, non-academic staff and graduate assistants while considering the numerous goals of the college. Amongst these goals were adequate salary increases, desired academic staff/student ratios, desired distribution of academic staff with respect to rank, desired academic staff:non academic staff ratio, desired academic staff/graduate assistant ratio and the minimisation of cost. Among the constraints were total numbers of academic staff, distribution of academic staff, numbers of non-academic staff, numbers of graduate assistants, overall salary increase and total payroll. The authors report that this model's results proved helpful particularly in highlighting situations in which a given combination of goals were incompatible with the resources available and hence a trade-off would be required.

Lee and Moore (1972) report a goal programming model for University admissions planning. This model took cognizance of a variety of academic goals such as University admissions standards, residence occupation rates, etc.

K A Wallhaus (1974) also describes a goal programming model for resource allocation and planning in higher education.

Although these developments using goal programming are very promising it should be remembered that it is still necessary to quantify output and to rank 'objectives', a contentious task in the University context.

(v) Cost Models

Some important work has been carried out in the development of simple cost models of Universities. Of major importance of the work carried out in the UK has been that of Bottomly at the University of Bradford (1971). Bottomly was interested in the possibilities of securing economies in the cost of educating students, particularly in the context of University expansion. A considerable part of this work considers economies of scale both in the use of academic staff and through using buildings more intensively. We shall consider the implications of this work in more detail in Chapter 5. In addition, Bottomly has done some very important conceptual work in the field of University costs. He distinguishes between financial cost which is concerned with actual cash outflow from the University and economic cost which is related to the demand of the University for the factors of production. He also defines the meaning of marginal costs, opportunity costs and incremental costs to the University context. These concepts are further discussed in Pickford (1975.) A description of the uses of cost models in the USA is given by James Farmer (1973) and Colby H Springer (1973).

(vi) Organisational Theory

Some preliminary work has been carried out in the very important area of assessing the effectiveness of University government and administration. Rivett et alia at Sussex (1974) have approached this problem in two ways

(a) Using a systems approach and

(b) from a behavioural point of view.

It may fairly be said, however, that this work is still at a very preliminary stage and little of immediate practical value has resulted from this work (see Lars Thulin's (1974) critique of this work).

Further work has been carried out in this field in Japan at the University of Hiroshima (see Yokoo et alia (1974)) but again progress has been very limited.

(vii) Planning Programming and Budgeting Systems (PPBS)

Planning programming and budgeting systems are a fairly recent managerial innovation designed to relate the objectives of an organisation much more closely to its budgeting process. Traditionally budgets and accounts are object orientated (eg so much for salaries, so much for postage, maintenance, etc). The purpose of a programme budget is to relate costs to the actual programmes which are run to meet the organisation's objectives. Thus, hopefully the implementation of PPBS should directly improve the whole decision-making process of an organisation.

One of the first papers to discuss the application of a PPBS approach to University decision-making was published by Hitch (1968) and was entitled "Systems approach to decision-making in the Department of Defence and the University of California". In this paper Hitch discusses and contrasts his experiences in implementing PPBS in the Defence Department and at the University of California.

At the Defence department, Hitch and his co-workers had reasonable success in devising a programme structure which related to the goals of the department. They defined eight or nine major programmes under which were grouped a large number of programme elements. For instance, one of the major programmes was the strategic retaliatory force (force capable of waging all-out nuclear war). The programme elements were weapon systems and force units whose principle mission was strategic retaliation (B-52 bombers, B-58 bombers, minuteman missiles, polaris submarines).

In general the PPBS approach worked well for the Air-force which consisted in the main of distinct self-contained weapon systems designed for specific missions which could readily be assigned to the appropriate programmes. It worked much less well for the Army where many of the forces had general purposes and hence could not easily be assigned to a particular programme.

At the University of California, Hitch encountered some of the same difficulties in applying PPBS that he had previously encountered in the Army. There was great difficulty in deciding on the University's major programmes and related programme elements. Because of this the author believed that the formal PPBS approach should be modified to that of projecting future resource and money requirements in such a manner "(a) that the programme structure focuses attention on the key policy decision affecting resource requirements

(b) that the programmed requirements can be used as (or translated into) budget categories."

Other interesting papers on PPBS were published by the SRC (1970) and Van Wyjk (1969).

Van Wyjk proposes a possible University programme structure. He divides the University into six main programmes which he further divides into sub-programmes as follows:-

1. <u>Instruction</u>
    - 1.1 Humanities
    - 1.2 Social science
    - 1.3 Natural science
    - 1.4 Applied science
    - 1.5 Health science
    - 1.6 Law

2. <u>Research</u>
    - 2.1 Basic research
    - 2.2 Applied research

3. <u>Public Service</u>
    - 3.1 University extension.
    - 3.2 Cultural activities

4. <u>Library</u>

5. Student Services

   5.1 Residences

   5.2 Financial assistance

   5.3 Health

   5.4 Alumni

6. Support

These programmes are used to fulfil the basic objectives of the University which he defines as follows

(1) the acquisition of new information.

(2) the dissemination of existing information.

(3) the preservation and retrieval of information.

(4) problem solving.

(5) service to society.

There remains however the problem of relating the programmes to the achievement of objectives and quantifying this relationship.

An interesting application of programme budgeting in Europe is that by Chalmers University of Technology, Sweden (see Apelquist et alia (1971)). The authors defined five major programmes which could be further subdivided into a number of sub-programmes. These five major programmes were:-

1. UG Engineering education.
2. UG Science and Social Science education.
3. Technical research and graduate training.
4. Research and graduate training in social science.
5. External services.

The authors developed measures of effectiveness for the performance of the programmes and also developed a cost accounting system which could be used to relate University costs to programmes on which they were incurred.

Fielden (1969) gives an interesting account of partial implementation of PPBS systems in the universities of California, Ohio state and Pittsburg in the USA. In a further article (1973) he reviews applications of PPBS in Universities and comments on lack of success which he attributes to three basic causes:-

(a) The setting of objectives in a classical sense is neither sensible nor feasible. There are conflicts of objectives between university, society and other groups.

(b) Inseparability of university activities and problems of apportionment of academic time.

(c) Use of output measures to show effectiveness of operations presents difficulties.

The problem of implementing PPBS systems in Universities is also discussed by Weathersby and Balderston (1971) in their excellent review of PPBS. "To our knowledge a total comprehensive implementation of PPBS has not been achieved in any college or university in the United States."

(viii) University simulation models

A number of attempts have been made to develop University simulation models for the prediction of University resources. These models will be discussed in the next Chapter.

BIBLIOGRAPHY : Chapter 3

22 Applequist et alia (1971) The Development of Planning, Programming and Budgeting Systems, Studies in Institutional Management in Higher Education, CERI, OECD, Paris

23 Ashby, Sir Eric (1963) Introduction: decision-making in the academic world, Sociological Studies in British University Education Monography No 7, The Sociological Review, University of Keele

24 Ball, R (1975) Some Problems in University Planning in Developing Countries, Proceedings of Seventh IFORS Conference, North Holland, pp 601-616

25 Bermont, M (1975) Problems of Specialist Manpower Modelling, Proceedings of Seventh IFORS Conference, North Holland, pp 677-687

26 Bottomly, J (1971) Costs and Potential Economies, Studies in Institutional Management in Higher Education, CERI, OECD, Paris

27 Dean, B V (1973) Critique of Management Science in University Operations, Management Science, Vol 14, No 6 (February 1968) pp B-385-7

28 Farmer, J (1973) Why Cost Analysis in Higher Education, Professional seminar, Programme on Institutional Management in Higher Education, CERI, OECD, Paris

29 Fielden, J (1969) Analytical Planning and Improved Resource Allocation in British Universities, University of London Press

30 Fielden, J (1973) Concept of PPBS and Approaches to Application, IMHE Programme, CERI, OECD

31 Gray (1975) Report on Education Systems: Workshop Proceedings of Seventh IFORS Conference, North Holland, pp 586-7

32 Harden, W R, et alia (1971) Projection of enrollment distribution with enrollment ceilings by Markov Processes, Sociol-Economic Planning Science, Vol 5 (1971) pp 467-473

33 Hitch, C (1968) A systems approach to decision making in the Department of Defence and in the University of California, Operational Research Quarterly, 1968, Special Conference Edition, pp 37-45

34 Hopkins, D (1974) Faculty early retirement programs, Operations Research 22 (1974) pp 455-467

35 Lee and Clayton (1972) A goal programming model for Academic Resource Allocation, Management Science, Vol 18, No 8, April 1972, pp B395-408

36 Lee and Moore (1972) A model for administrative decision making in academic institutions, Proceedings of Fourth Annual Meeting of the American Institute of Decisions Science, New Orleans

37 Longwood-Smith, R (1971) Accommodating student demand for courses by varying the class-room size mix, Journal of the OR Society of America, Vol 19, No 4, July-August 1971, pp 862-874

38 Lovell, C C (1971) Student flow models: a review and conceptualisation, Technical Report No 24, NCHEMS at WICHE, Boulder, Colorado

BIBLIOGRAPHY : Chapter 3

22 Applequist et alia (1971) The Development of Planning, Programming and Budgeting Systems, Studies in Institutional Management in Higher Education, CERI, OECD, Paris

23 Ashby, Sir Eric (1963) Introduction: decision-making in the academic world, Sociological Studies in British University Education Monography No 7, The Sociological Review, University of Keele

24 Ball, R (1975) Some Problems in University Planning in Developing Countries, Proceedings of Seventh IFORS Conference, North Holland, pp 601-616

25 Bermant, M (1975) Problems of Specialist Manpower Modelling, Proceedings of Seventh IFORS Conference, North Holland, pp 677-687

26 Bottomly, J (1971) Costs and Potential Economies, Studies in Institutional Management in Higher Education, CERI, OECD, Paris

27 Dean, B V (1973) Critique of Management Science in University Operations, Management Science, Vol 14, No 6 (February 1968) pp B-385-7

28 Farmer, J (1973) Why Cost Analysis in Higher Education, Professional seminar, Programme on Institutional Management in Higher Education, CERI, OECD, Paris

29 Fielden, J (1969) Analytical Planning and Improved Resource Allocation in British Universities, University of London Press

30 Fielden, J (1973) Concept of PPBS and Approaches to Application, IMHE Programme, CERI, OECD

31 Gray (1975) Report on Education Systems: Workshop Proceedings of Seventh IFORS Conference, North Holland, pp 586-7

32 Harden, W R, et alia (1971) Projection of enrollment distribution with enrollment ceilings by Markov Processes, Sociol-Economic Planning Science, Vol 5 (1971) pp 467-473

33 Hitch, C (1968) A systems approach to decision making in the Department of Defence and in the University of California, Operational Research Quarterly, 1968, Special Conference Edition, pp 37-45

34 Hopkins, D (1974) Faculty early retirement programs, Operations Research 22 (1974) pp 455-467

35 Lee and Clayton (1972) A goal programming model for Academic Resource Allocation, Management Science, Vol 18, No 8, April 1972, pp B395-408

36 Lee and Moore (1972) A model for administrative decision making in academic institutions, Proceedings of Fourth Annual Meeting of the American Institute of Decisions Science, New Orleans

37 Longwood-Smith, R (1971) Accommodating student demand for courses by varying the class-room size mix, Journal of the OR Society of America, Vol 19, No 4, July-August 1971, pp 862-874

38 Lovell, C C (1971) Student flow models: a review and conceptualisation, Technical Report No 24, NCHEMS at WICHE, Boulder, Colorado

39 Marshall and Oliver (1970) A constant workload model for student attendance and enrollment, Operations Research, Vol 18, No 2, 1970, pp 193-206

40 Oakford, R, et alia (1967) School scheduling practice and theory, Journal of Educational Data Processing (1967) pp 16-50

41 Oliver, R (1968) An equilibrium model of faculty appointments, promotions and quota restriction, Report No 69-10 Ford Research Programme in University Administration, University of California Berkeley

42 Pickford, M (1974) University Expansion and Finance, Sussex University Press, pp 5-29

43 Platt, W J (1962) Education: rich problems and poor markets, Management Science, Vol 4, No 8, July 1962, pp 408-418

44 Rath, R J (1968) Management science in university operations, Management Science, Vol 14, No 6 (February 1968) pp B373-384

45 Rivett, P, et alia (1974) Comparative effectiveness of alternative administrative structures, IMHE programme, CERI, OECD, Paris

46 Sheppard, W G (1965) Operations research in education, Management Science, Vol 11, No 4, February 1965, pp C13-19

47 Shroeder, R G (1973) A survey of management science in university operation, Management Science, Vol 19, No 8, April 1973, pp 895-806

48 Simpson, M et alia (1971) Planning University Development, Studies in Institutional Management in Higher Education, CERI, OECD, pp 99-107

49 Springer, C H (1973) A pilot investigation of the cost estimation model at San Fernand's State College, Professional Seminar, Programme on Institutional Management in Higher Education, CERI, OECD, Paris

50 Systems Research Group (1970) Objectives, program structure and evaluation in higher education, Systems Research Group Report

51 Thornley, V G (1968) University Timetabling: A quantitative study of the interaction between the course structure and resource level, PhD dissertation, University of Lancaster

52 Thulin, L (1974) Comparative effectiveness of alternative administrative structures, Evaluation report programme on Institutional Management in Higher Education, CERI, OECD, Paris

53 Tomlinson, R, OR Comes of Age, Tavistock

54 Van Wyk, (1969) Planning Programming and Budgeting Systems in Universities, Paper to Institute of Management Science Meeting, Atlanta (October 1969)

55 Waddington (1973) OR in World War 2, Elek Science

56 Wallhaus, R (1974) A resource allocation and planning model for higher education, Decision models in Academic Administration, Kent State University Press, pp 97-108

57 Weathersby and Balderstore (1971) PPBS in higher education planning and management, Part I, an overview, Ford Research Programme in University Administration, University of California Berkeley

58 Yokoo, et alia (1974) Japanese patterns of institutional management in higher education, IMHE programme CERI, OECD, Paris

CHAPTER 4

UNIVERSITY SIMULATION MODELS

4.1 Preamble

A number of workers have attempted to construct University simulation models. The purpose of such models has been to enable Universities to predict their resource requirements (staff, space, finance, etc) under different operating policies and given different student inputs. These simulation models are all deterministic. As Mitchell (1972) says "Simulations can be and are used which are completely deterministic. The aim in these cases would be to study the workings of large and complex systems under various operating conditions".

Thus in the University context such a model could be used to investigate for example, the consequences of changing maximum class sizes, staffing ratios, salary scales, or for investigating the effects of admitting an increased proportion of Science based students. Simulation models do not give optimum solutions; it is up to the user of the model to suggest and investigate alternative policies using the model.

As J Morris and J R Brown state (1974) "Simulation models developed for use in academic administration generally link outputs to inputs in a deterministic sense. Planning is then accomplished using 'what would happen if' approaches which focus on the sensitivity of the modelled system's output measure to input variations. In contrast mathematical models (ref to Goal programming models) are optimisation models. They therefore seek to obtain desired output objectives as function of inputs".

Such models enable the consequences of a decision for an institution as a whole (and not simply an isolated part of it) to be assessed.

4.2 An Outline Survey of Models in Use

There have been a number of attempts mainly in Europe and North America to develop University simulation models. A feature of a number of these efforts is the production of flexible models which can be readily adapted for use by many institutions (usually within the same national University system). One of the first surveys of such models is given by Weathersby and Weinstein (1970). An excellent recent survey of work carried out in this field is given by K M Hussain (1973). We shall now broadly outline the work that has been carried out in different parts of the world.

(a) North America

The best known and most widely implemented models in North America are the R.R.P.M. series of models (developed at Boulder Colorado) and the CAMPUS series of models (developed at the University of Toronto).

The RRPM models (an acronym for Resource Requirements Prediction Models) originate from a decision of the U.S. office of Education to support a proposal for a model to be developed at NCHEMS (National Centre for Higher Education Management Systems) at Boulder, Colorado which could be of general use to institutions of higher education in the U.S. This project resulted in the production of the RRPM models, which were fundamentally based on a model called CSL (Computer Simulation Model) produced by Weathersby (1967) in California. A number of pilot implementations were made with this original model after which the model was refined and more sophisticated versions were produced. (See Hussain & Martin (1971) and Huff (1972)).

The CAMPUS (Comprehensive Analytical Methods for Planning in University Systems) series of models originate from the work done by Professor R Judy for the Bladen Commission which was considering the financing of higher education in Canada. This work culminated in the development of a pilot simulation model of the Faculty of Arts and Sciences at the University of Toronto (Judy and Levene (1965)).

The Ford Foundation then provided further finance for Judy and Levene's group (the Systems Research Group) to produce a general University model (CAMPUS V). This model had a number of defects (especially poor documentation) and was later superseded by a number of improved versions.

A further series of models called SEARCH models (System for Exploring Alternative Resource Commitments in Higher Education) have been developed by the firm of management consultants Peat, Marwick, Mitchell of New York (Keane and Daniel (1970), Strive and Nelson (1972)). This is a more aggregated model than those described earlier and it is especially relevant to the situation of the small private college in the United States.

A brief survey of other models developed in the U.S. will be given later in this Chapter.

(b) Europe

A considerable amount of work has been done in this field at the Hochschule Information System in West Germany. This is an organisation, situated in Hanover and supported by the Volkswagen Foundation. Its objective is the production of models and operational systems which would be relevant to all institutions of higher education in Germany. This organisation has produced two general purpose simulation models for German institutions, HIS'A' and 'B'. (Dettweiler and Frey (1972)).

These models are particularly orientated towards forecasting space requirements in order to try to help cope with the chronic problems of under-capacity in the German University system.

Models have also been developed at the University of Utrecht in the Netherlands (de Nie (1974)). These models are of particular interest in that they have been developed entirely out of the resources of one University institution.

(c) Japan

Shimada (1972) has developed a simulation model of a Japanese University using systems dynamics methods.

4.3 Some Technical Details of the Models

It would be tedious to embark on an exhaustive description of the technical details of all the models. Instead outline details of one model will be given and the others will be compared. Further details are supplied in Appendices 1 and 2.

In order to appreciate fully the models developed in North America a general understanding of the academic systems pertaining to that area is required. In this system a student studies a specific set of courses (required or electives), each course carrying a specific amount of credit measured in credit hours (this often corresponds to the number of hours the course is taught each week). This set of courses, leading to an objective (usually a degree) is called a student program. A program may consist of courses taken from a wide range of subject options although constraints involving the study of some compulsory courses from the students' major subject are usually imposed. Generally a degree is awarded for obtaining a required number of credits subject to all compulsory courses having been successfully completed.

(a) The RRPM models

The logical structure of the model RRPM 1.6 can be conceived as divided into six phases. These are:-

1. Institutional definitions.
2. Induced course load matrix (ICLM) specification.
3. Calculation of full time equivalent academic staff.
4. " " teaching costs other than academic staff salaries.
5. " " non-teaching costs.
6. Report preparation.

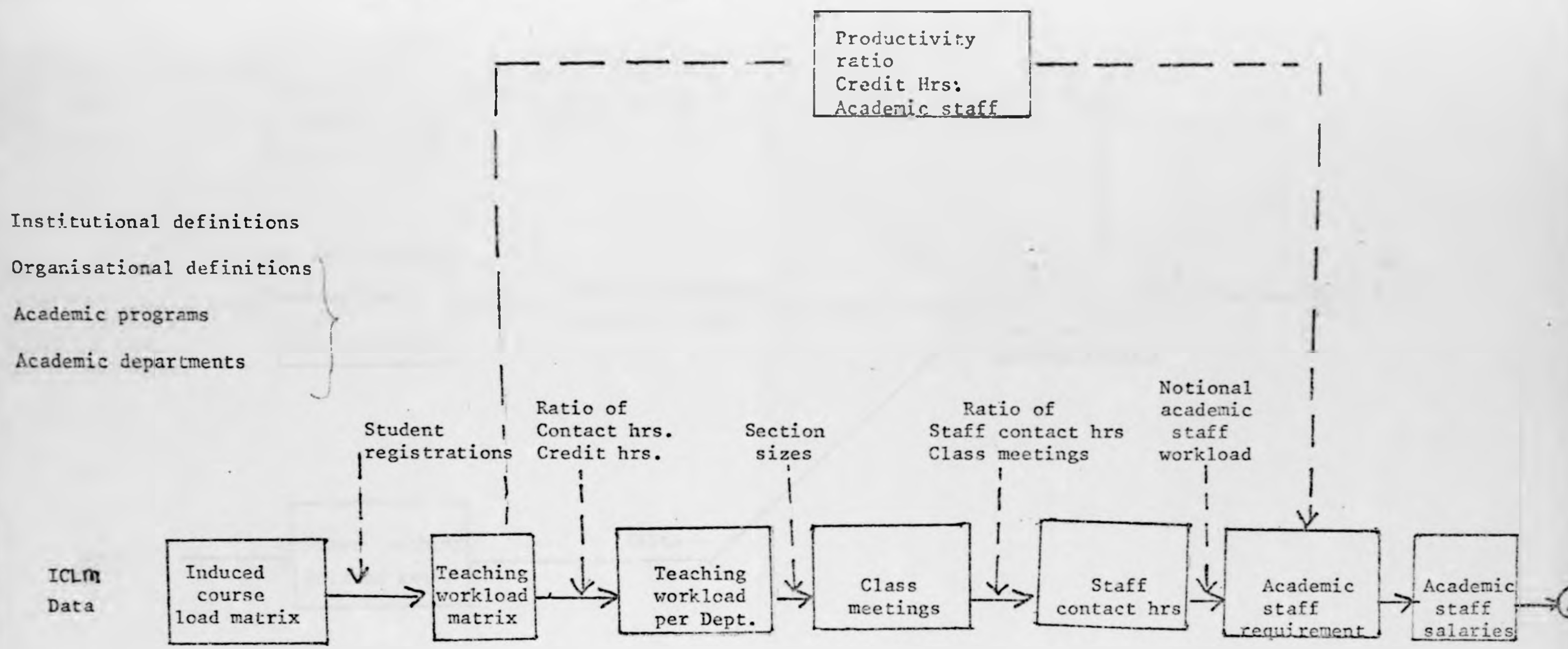
A detailed diagram of the logic of RRPM 1.6 (taken from Clark, Huff Haight and Collard (1973)) is given in figure 4.1.

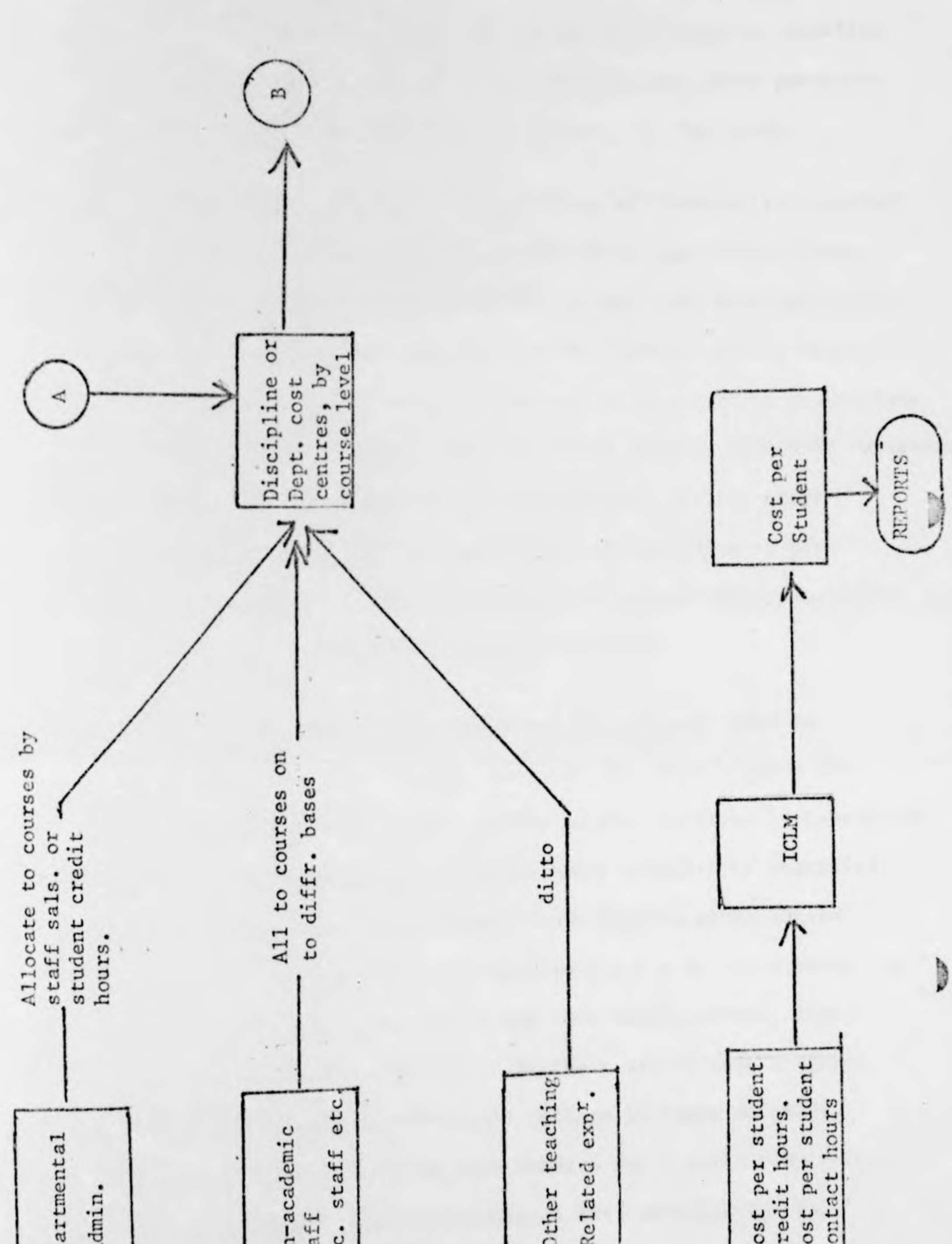
Phase one of the model allows the institution to define certain parameters related to its organisation and academic structure and also give a list of its degree programs together with the disciplines (or departments) who give the courses of which the programs are comprised.

Phase two of the model attempts to establish a relationship between the academic programs on offer and the teaching loads on the departments who provide the courses. As mentioned earlier a student taking a particular program of studies will generally take courses of more than one department. (Thus, for example, a student who is taking the mathematics program may also generate loads on the Physics, History and English Depts as well as the Mathematics Dept). Such loads can be estimated by using the induced course load matrix (ICLM). This matrix is made up of the average number of credit hours taken by a student on a given program in each department or discipline.

By multiplying the enrollment in different programs by the appropriate elements of the induced course load matrix, the workload on each department in terms of student credit hours can be calculated. Further exposition of these ideas together with a simple example are given in Appendix 1.

Fig. 4.1 Logic Flow of RRPM 1.6




Factors relating admin to other parameters.
Departmental Admin.
Allocate to courses by staff sals. or student credit hours.
Factors relating no. of academic staff to some other parameter.
Non-academic staff Sec. staff etc
All to courses on to diffr. bases
ditto
Other teaching Related expr.
ditto
A
Discipline or Dept. cost centres, by course level
B
B
Cost per student Credit hours. Cost per student Contact hours
ICLM
Cost per Student
REPORTS

The third phase is used for estimating the levels of academic staffing which would be necessary to cope with the teaching loads thus generated. Two alternative methods of doing this are provided by the model.

(i) The simpler method involves using a series of "productivity ratios"; the productivity ratio being the number of student credit hours that would be expected to be provided by each full time equivalent staff member. Thus, for instance, if 4912 student credit hours are "produced" in first year History and the appropriate productivity ratio is 359 student credit hours per staff member, then this corresponds to 4912/359 = 13.66 academic staff. The division of this staff between different grades can be carried out according to pre-determined ratios. It is also possible to weight the productivity ratio to allow for different levels of courses.

(ii) The more complex method involves using an approach based on student contact hours. In this approach the ratio between the number of hours that a student spends in the classroom or laboratory (contact hours) and number of credit hours received is specified. Thus the number of student contact hours which a given course involves can be estimated. The maximum class size for a particular course (section size) is read in and thus total academic staff contact hours can be determined. If there exists some notional workload per academic staff member defined in terms of staff contact hours, then staffing requirements for a particular course can be established. The advantages of this approach is that staffing is much more closely related to work actually carried out and the effects of changing certain parameters (such as maximum class size) can easily be determined.

Phase Four calculates direct teaching costs other than academic staff salaries. These costs include departmental administration costs, secretarial costs, equipment and other related academic expenditure. Each type of cost is calculated for the department (or discipline) as a whole and then reallocated to the various courses on one of a number of possible bases, such as in proportion to a course's staffing requirement or total student credit hours involved in the course.

Phase Five calculates the cost of each student program which is carried out on the following basis: the cost per student credit hour of each discipline in a given academic year can be obtained simply by dividing all costs allocated to that cost centre by the number of credit hours produced. Now the induced course load matrix gives the average number of credit hours taken in each discipline by a student in a typical program. Hence the cost of each student program can simply be obtained by multiplying the appropriate program element by the appropriate cost and then summing (a simple example is demonstrated in Appendix 2).

A series of equations is also provided for estimating non-teaching costs (eg research, public service etc).

Phase Six of the model deals with the generation of output reports. These are of four kinds. The first is a series of organisational reports that provide traditional line item budgets detailing personnel and financial requirements for various organisational units. Various levels of aggregation can be chosen (eg department, faculty, college). The second series of reports gives the program budget for an institution as a whole. This report indicates the numbers of students registered for each program of study, the cost of each student program and the total cost of each program as a whole. The third report gives a financial summary for the institution as a whole and displays a breakdown of expenditure by activity (eg general academic instruction, research, etc.) The final report simply gives a general display of all parametric data on the file.

This version of the RRPM model does not give any indication of the utilisation of academic space. This is covered, however, in the earlier and rather more comprehensive model RRPM 1.3 (Hussain and Martin 1971).

(b) CAMPUS models

In general the basic logic of CAMPUS is very similar to that of RRPM although CAMPUS is an even more comprehensive and detailed model. The major differences concern the level of detail employed in the calculation of teaching loads. We have seen that the calculation of teaching loads in RRPM is carried out using an induced course load matrix representing the student credit hour load induced on teaching departments by student programmes. In CAMPUS the load induced is in terms of activities and is measured in contact hours. An activity in this context is defined as any basic component of instruction involved in giving a course (such as a lecture, laboratory tutorial etc). Thus one course can involve the performing of a number of activities. No less than sixteen data elements have to be supplied for each activity. These are listed in Table 4.1.

Although such extensive detail gives great flexibility to the models, it has the disadvantage of requiring an enormous information system. For instance a university could easily hold around 2000 activities; this would require an information system providing around 30,000 data items. A further problem is that at this level of disaggregation there is the possibility of the induced course load matrix not being a consistent indicator of the future session's choices. This problem is discussed by Jewett et al (1970), Brenerman and Hopkins (1969).

Table 4.1

Data required by CAMPUS model (for each activity)

- Credit-hours (per term or semester)
- Contact hours (per week)
- Type of activity (lecture, lab, seminar etc).

Resources required

- Personnel by type (prof., graduate assistant, etc).
- equipment

Space required

- Type
- Size
- Duration of activity in weeks

Identification Data

- name and/or number
- discipline or department offering activity
- level (academic year) of activity
- max. no. in class
- min. enrollment allowed
- class size policy

CAMPUS deals very comprehensively with space requirements; the need for various kinds of teaching and office space is calculated and a special 'space matching' facility which calculates space shortages and construction costs of each type of space is provided.

Also available is an academic staff flow model which enables the flows of academic staff between time periods to be forecast taking into account rates of resignation, sabbatical leave and promotion policies, etc.

The model also possesses the facility of calculating total revenue taking into account both tuition fees from students and also revenue from public funds under formula financing schemes (under such schemes the University grant from its funding agency is calculated using a formula; usually related in some way to student numbers - see J A Muller (1964)).

Thus CAMPUS is probably the most detailed and comprehensive model available; its chief disadvantage being the enormous data base required for successful operation.

(c) SEARCH

Some details of the logic of this model are provided by Peat, Marwick Mitchell (1971). This model is specifically intended for use by small North American private colleges - sometimes with only a few hundred students. Its level of aggregation is much higher than the previously described models, no information at the departmental level being provided. Instead the model operates on total student registrations for particular academic years which it then relates to other planning variables. It is most useful in situations where broad policy decisions are being investigated (eg effect of an increase in tuition fees). Fairly detailed financial information at the institutional level is provided with details of student aid plans, endowment funds and physical plant replacement funds. The model can be run on a time-sharing facility.

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(d) HIS

The West German University system allows students wide academic freedom, with, until recently, little constraint on the maximum period of studies or even their location and scope (see Wightman 1971). In general the West German University student spends considerably longer than the minimum period in obtaining his degree and this has exacerbated the serious problem of under-capacity in West German universities. (See Radcliffe 1970). Because of this the HIS models are specifically orientated to the problem of forecasting the capacity of an institution to teach students given existing levels of academic staff and physical space.

Like CAMPUS and RRPM this model uses an induced course load matrix to relate the registrations on student programs to teaching load on departments. According to Dettweiler and Frey (1972) however, there is considerable difficulty in the construction of the induced course load matrix because of the fragmentary and incomplete data on student registrations that exist in most German Universities.

The model works by first calculating the necessary capacity given likely student registrations and then the students that can be taught given existing capacity. Because of the complexity of the relationship between student registrations and teaching capacity, an iterative procedure is used to arrive at target intakes.

(e) T.U.S.S.

Two models have been developed at the University of Utrecht. One model (TUSS-3) is a very detailed model which is based on the individual teaching activity and can be used for forecasting resource requirements of an individual faculty. A more aggregated model (TUSS-2) is used for predicting resource requirements at the University level. An interesting feature of this model has been its adaption for the purposes of training University administrators through the development of a management game (Hussain 1974, die Nie 1974). This game is entitled University Simulation Game (USG).

(f) Industrial Dynamics Model of a Japanese University

This model was developed for a private Japanese University and uses the technique of Systems dynamics (see Forrester 1961). Since finance is a major problem in private Japanese Universities, the model concentrates particularly on financial aspects including tuition fees and government aid. In this paper Shimada (1972) describes the application of this model to forecasting future development in the Law Faculty.

(g) Other models

As mentioned earlier a number of other models have been developed particularly in North America. Since it would be tedious to go into details of each one and since they illustrate few new principles, they will simply be noted below together with the appropriate references.

G.U.S. (Generalized University Model) implemented at the University of Texas, USA (Ruefli 1970).

A model for Michigan State University (Koenig et al 1968 and 1969).

Tulane University Model (Firmin et al 1967).

Fascism and RCM for US Air Force Academy (Van Wyjk and Russell 1972, Allison 1970).

University of Copenhagen Model (Hammer-Jespersen 1972).

HELP and PLANTRAN developed by the Mid West Research Institute (Van Wijk and Russell 1972).

4.4 Costs of implementing simulation models

Costs involved in implementing simulation models are of two sorts, development costs and operating costs. Development costs are the costs involved in constructing a model or in adapting an existing general purpose model to the needs of a specific institution. This also includes costs of validating the model, generation of data and personnel training.

Operational costs comprise the costs of running the model and maintaining the data base. Some data on development costs is available for the general purpose models. It was found in the pilot implementations of RRPM that total development costs ranged from $21,000 to $100,000 with an average of $50,000. Copies of software however are available for a nominal fee of $50.

Since CAMPUS is controlled by the Systems Research Group, a commercial organisation it is difficult to obtain precise data on costs. There is, however, a fee of $12,500 to $25,000 payable for use of the software alone. In addition the costs of consulting and training is likely to vary from $5000 to over $50,000.

HIS supplies its software free of charge but estimates a development cost of up to $25,000.

Operational costs of the models are difficult to calculate, much depending on the method an institution uses for costing its computer time. Krampf and Heinlein (1974) quote a cost of $300 for running RRPM at a medium size institution (20 departments, 40 majors, 4000 students, $10,000,000 budget).

For this amount it is possible to obtain a complete five-year simulation with a full set of analyses and all reports (since no information is given as to the method of assessing the cost of computer time, however, we must regard this result with some scepticism).

4.5 Experiences with the implementation of simulation models

Reports of implementations of simulation models in Universities are of two kinds, firstly accounts of practical experiences of implementation of models and secondly surveys of implementations over a number of institutions.

Taking the former accounts, Forman (1974) discusses the problems of implementing CAMPUS models in the Ontario Community Colleges. He describes the political problems he and his co-workers encountered in dealing with academics and administrators. In many cases the project was delayed through the necessity of implementing satisfactory data collection systems. A description of some of the experiments carried out in a particular college are also given.

G M Andrew and M D Alexander (1974) discuss experiences of implementing CAMPUS planning systems at the Universities of Colorado and Minnesota. They give an interesting discussion of the problems of implementing planning systems in mature institutions and of the importance of being able to distinguish effectively between control variables and constraints. According to the authors some success has been achieved at Minnesota.

At Colorado the model has been fully operational at one campus and is used extensively in master planning. Various components of the model are in operation at the other two campuses. Further details of this are presented by Alexander (1973).

Surveys of implementation of simulation models are given by Krampf and Heinlein (ibid) and Cicely Watson (1974).

Krampf and Heinlein quote the following institutions as having implemented simulation models; University of Colorado, Stanford, State University of New York, Wheaton College, Thomas College and the University of Minnesota.

Cicely Watson's survey is into the extent of application of simulation models into higher education in Canada. She found that ten institutions in Canada were using either RRPM 1-6 or one of the WHICE models closely related to it. She also found that a version of the CAMPUS model was being used for the entire College of Applied Arts and Technology Systems of Ontario. Only two of the twelve largest Canadian Universities were found however to be carrying out any mathematical modelling work whatsoever.

4.6 A critique of the use of University Simulation Models

Simulation models have a number of advantages among which is the ability to quickly test out the possible future effect of different operating policies or different inputs in a dynamic situation.

A number of beneficial side-effects of employing such models may also possibly accrue. Among these is that they require administrators to think more formally about the decisions that must be made, thus imposing a definite logic upon the decision maker. Another is that the consistency and comprehensiveness of internal information systems may be improved.

There are however a number of dangers in the use of such models. One is that the output should only be interpreted as giving a broad general indication of future trends. As Krampf and Heinlein (ibid) state: "If model results are not used in the sense of providing only 'ball park' figures with which one can start to operate, erroneous conclusions can result since the detailed output is a function of roughly estimated inputs. Misusing the data in this manner is a frequent error".

Other possible drawbacks of using such models are the development costs of the model and the costs involved in providing suitable information systems.

Walhaus (1974) in a paper discussing particularly the PRPM models states that deficiencies of simulation models can be broadly classified into two categories:-

1. Inaccurate Reflection of Reality - The model does not produce results consistent with what actually happens, perhaps due to invalid linearity or stability assumptions, a level of aggregation that clouds certain significant variables, mis-representation of trends over time, omission of programs with significant cost implications and so forth.

2. Ease and value of experimentation - The value of the planning information produced by using the model relative to the cost and effort required to run the model needs improvement, perhaps because the output reports are inadequate in content, presentation or overwhelming volume; computer requirements are large in terms of both run time and storage; the input preparations are burdensome and complex; the sequential mode of simulation prohibits investigating many alternatives etc.

BIBLIOGRAPHY : Chapter 4

59 Alexander, M D (1973) The Implementation of CAMPUS/COLORADO at the University of Colorado, Boulder, Colorado, Proceedings of Association for Institutional Research, Annual Conference 1973

60 Allison, S (1970) A computer model for estimating resources and costs of an Air Froce Resident Technical Training Course, RANK report WN-7044-PR

61 Andrew, G M and Alexander, M D (1974) The Minesota and Colorado Experiences with the Campus Planning Systems, Decision Models in Academic Administration, Kent State University Press, pp 65-68

62 Breneman, D (1969) The stability of faculty input coefficients in linear workload models at the University of California, Paper 69-4 Ford Research in University Administration, University of California, Berkeley

63 Clark, Huff, Haight and Collard (1973) Introduction to the Resource, Requirement Production Model 1.6, NCHEMS at WICHE Technical Report 34A, Boulder, Colorado

64 Dettweller and Frey (1972) Simultations modelle für die Hoschschulplanug, HIS, Brief 19, Hanover

65 Firmin et alia (1967) University Cost Structure and Behaviour Cost Simulation Model, Final Report NSF-C 541 Louisiana, Tulane University

66 Forman, L (1974) Impact of the CAMPUS model on Decision Processes in the Ontario Community Colleges, Decision Models in Academic Administration, Kent State University Press, pp 47-64

67 Forrester, J (1961) Industrial Dynamics, MIT Press

68 Hussain, K M (1973) Institutional Planning Models in Higher Education, IMHE programme, CERI, OECD

69 Hussain, K M (1974) Gaming Models in Higher Education, IMHE programme, CERI, OECD

70 Hussain, K and Martin (1971) A resource requirement prodiction model RRPM-1, Report on the pilot studies, Technical Report 21, NCHEMS at WICHE, Boulder, Colorado

71 Huff, D (1972) Implementation of NCHEMS planning models and management tools at California State University, NCHEMS at WICHE, Boulder, Colorado

72 Jewett, F et alia (1970) The feasibility of analytic models for academic planning, A preliminary analysis of seven quarters observations on the induced course load matrix, Office of Chancellor, California State Colleges, California

73 Judy and Levene (1965) A new tool for educational administrators, Report to the Commission on Financing Higher Education, University of Toronto Press

74 Judy, Levene and Centner (1970) CAMPUS V Documentation, Vol I-VI, Institute for Quantitative Analysis in Social and Economic Policy, University of Toronto

75 Keane and Daniel (1970) Systems for exploring alternative resource commitment in higher education (SEARCH), Peat, Marwick, Mitchell, New York.

76 Koenig et alia (1968) "A systems model of management, planning and resource allocation in institutions of higher education." Final Report, Project C-518 NSF Michigan, Michigan State University.

77 Koenig (1969) A prototype planning and resource allocation programme for higher education. Socio-economic planning science, Vol 2, Pergamon Press.

78 Kramf and Heinlein (1974). The effectiveness of simulation models in academic administration. Decision Models in Academic Administration, Kent State University Press pp 91-6.

79 J A Miller (1964). State budgeting for higher education. Institution of public administration, University of Michigan. pp 94-110.

80 G Mitchell (1973). Operational Research - English University Press, pp 220.

81 J G Morris and J R Brown (1974). The application of mathematical models to academic decision making; Decision Models in Academic Administration, Kent State University Press, pp 131-135.

82 J de Nie (1974). Private Communication, Rijksuniverseteit de Utrecht.

83 J de Nie (1974). Manual for using University simulation game. IMHE programme CERI/OECD.

84 Peat, Marwick, Mitchell (1971). "SEARCH": A Computer Model Users Manual. Peat Marwick Mitchell and Co, New York.

85 T W Ruefli (1970). "The generalised University simulation," Graduate School of Business, University of Texas, Texas.

86 T Shimada (1972). Industrial dynamics model of a Japanese University. Proceedings of 6th IFORS Conference Dublin.

87 Strive and Nelson (1972). "SEARCH": A College Planning Model, Peat Marwick Mitchell and Co.

88 R Wallhaus (1974). A resource allocation and planning model for higher education. Decision Models in Academic Administration, Kent State University Press, pp 97-107.

89 Cicely Watson (1974). Canadian experience in the application of quantitative models for educational decision making. Journal of the International Society of Educational Planners. Vol 1 No 1 pp 10-19.

90 G B Weathersby and Weinstein (1970). A structural comparison of analytical models for university planning. Paper P-12 Berkeley:Ford Foundation Programme for Research into University Administration.

91 Margaret Whiteman (1971). The Faces of Germany, Harrap.

92 Van Wjyk and Russell (1972). State of the art in educational cost modelling, Systems Research Group report, Toronto, Canada.

CHAPTER 5

RESOURCE ALLOCATION IN UNIVERSITIES

5.1 Preamble

A good understanding of the principles and practice of resource allocation policies in Universities is necessary if satisfactory models for University planning and resource allocation are to be devised. These policies will be investigated in this Chapter.

In the first chapter we examined the national system of University finance and found that a University has considerable freedom of action over the internal apportionment of its recurrent grant. In other words subject to certain constraints, and in the light of any advice offered by the UGC, it has freedom to "cut the University cake" between internal claimants as it wishes. In addition to this freedom to allocate recurrent grants between competing internal claims, the University also has freedom over the internal disposition of physical space that is already provided.

In this Chapter we shall consider first of all policies for allocation of recurrent grant which will be followed by a consideration of procedures for allocation of physical space.

5.2 Allocation of recurrent grant

Table 5.1 illustrates the division of the University of Stirling's recurrent grant between different budget headings for the year 1974/5. It will be noticed that academic salaries comprise a very substantial proportion of this total grant. The freedom that an institution has to decide on the proportion of its budget to spend on this item is in practice severely circumscribed. This is partly owing to the tenure system under which an institution guarantees employment to academic staff after an initial probationary period and partly because the UGC

TABLE 5.1

DISPOSITION OF RECURRENT GRANT
BETWEEN BUDGET HEADS FOR ACADEMIC YEAR 1974/5

	Budget Head	% of Recurrent Grant
1.	Administration	9.2
2a.	Academic Depts: Teaching	52.9
2b.	" " : Services	7.5
3.	Maintenance of Premises	23.5
4.	General Education Expenditure	2.0
5.	Student Facilities & Amenities	3.4
6.	Miscellaneous	1.3
7.	Capital expenditure from revenue	0.7
8.	Allocation from Reserve	(0.5)
		100.0

Academic Departments : Teaching	%
Salaries of Academic Staff	74.4
Departmental Salaries	17.7
Departmental & Laboratory Maintenance	7.9
	100.0

generally indicate broad overall student:staff ratios for the University system as a whole. Nevertheless, the University has the responsibility of dividing whatever global number of academic staff which may be decided upon between competing internal claims.

5.2.1 Academic Staff Allocation : General Principles

Thus, a University has the problem of dividing available academic resources between different subject areas. Each department or subject has to carry out the functions of teaching, research and administration but, traditionally, such allocations have been based on the teaching functions only with the objective of making teaching loads "equitable" (any departure from this policy usually implied an exceptional situation with regard to one of the other functions). It is assumed that academic staff will carry out research and administrative duties in their remaining time. As Bottomley (1971) remarked, one of the consequences of this approach is that a decision to increase teaching effort devoted to a given subject area implies also a pro-rata expansion in research effort also.

If, however, we are going to follow the traditional approach it will be necessary to devise equitable measures of teaching effort. Here Rudd (1968) raises an interesting question - he states that in most forms of productive work, an increase in scale of the work results in a reduction in cost of each unit produced (ie returns to scale accrue). Thus, the question arises as to what extent, if any, this process takes place in the University teaching situation. We shall now consider relevant research work which has been carried out in this area.

Layard and Verry (1975) have carried out a study into the costs of a number of departments of the same subject in different UK universities. For each subject they attempted to relate total departmental costs to student numbers studying in that department through the regression equation $C = A_0 + A_1U + A_2P$ where C is total cost of department (including academic salaries, non-academic salaries, consumables, etc). U and P are the nos. of UG and PG student years produced by that department. A_0, A_1, A_2 are constants.

Clearly, if fixed costs form a significant proportion of total department costs then significant economies of scale are indicated and this would correspond to a relatively high value of the constant A_0.

In practice, however, only in the case of social science did Layard and Verry find that the value of A_0 differed from zero at the 10% significance level. (In fact for Science subjects A_0 had a negative value - corresponding to diseconomies of scale.) Broadly the same results were obtained when the authors took research into account. Thus, the authors also came to the conclusion that, in general, returns to scale were absent in University teaching. (Some other interesting results were given in this paper - the very high marginal costs of postgraduates relative to undergraduates and the discovery of significant returns to scale in Universities central administration expenditure). These results are also discussed in Verry's paper (1973).

Research studies carried out at the University of Bradford, however, yielded rather different results. These results are discussed in the papers by Dunworth and Bottomley (1973) and Dunworth and Dasey (1972) of the University of Bradford.

Dunworth and Bottomley examined the effect of increased student enrolment on the unit cost per fte student for a number of departments at the University of Bradford. These studies assumed that the quality of student education would remain unimpaired (ie no increase in academic staff teaching hours, no reduction in number of hours of instruction received by the students and no increase in maximum class sizes). In general, these researchers found that unit costs fell as enrolment increased although the overall downward fall was punctuated by regular jumps. These jump points correspond to levels of student enrolments necessitating replication of a particular type of class meeting. These researchers examined nine departments at the University of Bradford and found that if enrolment was increased to the "trough" before the jump point closest to twice present enrolment then the cost per student of providing teaching staff fell from between 18% to 48% with an average of 31%. Thus, economies are associated with the fact that the size of lectures (in which students play no active role) can be increased indefinitely without affecting the quality of student education and that any unused capacity on other types of class meeting becomes of less significance as total enrolment grows. Dunworth and Dasey also point out that economies can never be realised whilst expansion of student population is matched by pro-rata increases in academic staffing through the employment of student:staff ratios.

However, Norman (1973) working at Lancaster reports that potential economies of scale to be obtained at the University of Lancaster are of appreciably less significance than those reported by the Bradford workers. He ascribes this to the different teaching methods employed at Lancaster who give greater emphasis to small group teaching and less emphasis to lectures than Bradford. He did, however, agree that significant economies of scale could be obtained by expanding small, newly established departments with low student numbers.

Rudd (ibid) postulates that since Universities persist in allocating academic staff on the basis of student:staff ratios then no economies of scale could appear in a cost function even where they existed. Instead departments receive additional staff in line with additional student numbers and these additional staff proliferate options; the growth of such options keeps down the numbers of students on each course and so ensures that courses continue to be run at uneconomic levels.

Clearly the foregoing discussion has a crucial bearing in considering the appropriate method of staff allocation for an institution to employ.

5.2.2 Academic Staff allocations : methods

(a) Student : staff ratio methods

Such techniques involve allocating staff to a subject or department directly on the basis of student numbers studying the subject. It is possible to give postgraduates a heavier weighting than undergraduates. As we have seen in the previous section use of this method assumes that no returns to scale occur in University teaching. It also means (assuming that the ratio is held constant) that any increase in student numbers implies a pro-rata increase in resources.

(b) Modified student : staff ratio method

Fielden and Lockwood (1973) describe how the University of Sheffield have modified the student:staff ratio technique to take account of economies of scale. Using this approach a department's predicted ratio was given by

$$s/t = 1.18t^{0.5} + 5.55$$

where s is the mean of the weighted and unweighted student equivalent and t is the academic staff equivalent.

Departments whose actual student:staff ratios turns out to be significantly more unfavourable than that predicted by the formula may receive priority when additional staff are allocated.

(c) Workload models

Another promising technique for use in staff allocation is the workload model. The basis of this approach is an attempt to develop a mathematical model of teaching work involved in presenting a subject's courses and allocating academic staff according to total workload generated. Surveys of some of the work carried out in this field are presented in Fielden and Lockwood (ibid) and by Birch and Calvert (1974).

Birch and Calvert begin by examining one very simple model for departmental staff allocation.

$$T = \frac{s}{g} \cdot \frac{1}{t}$$

where T = number of full time equivalent staff (in a subject)

s = number of full time equivalent students (in a subject)

g = average group (class size)

1 = average tuition load (formal timetabled "teacher

contact" hourse/week/average group (g))

and t = notional teaching load (formal timetabled "class contact" hours/week/fte teacher)

The authors then proceed to discuss elaborations of the model. Some classes such as lectures have in practice almost no theoretically maximum size. Hence, the term representing the weekly teaching hours can be broken down into straight lecture hours and smaller group seminar hours. A further sophistication could be the introduction of two levels of student (ie undergraduate and postgraduate).

Simpson et alia (1971) have introduced a similar type of model at Lancaster University. This model, however, also takes into account lecture and seminar preparation and "post-mortem" time (ie time for discussing written work). Further details are given in Appendix 3.

A model based on similar principles has been used at the University of Stirling (see Anon (1969) and Ball (1973)). This model takes account of workload involved in preparing and undertaking lectures, tutorials, laboratories and language laboratories. It also makes allowance for correcting essay and lab. books and marking examinations. Further details of this model are given in Appendix 4. This model will be one of the options available for staff allocation in the planning model to be discussed in Chapter 6.

Workload models have the disadvantage that they may require considerable quantities of data, can involve lengthy calculation and may not easily be assimilated by the non-numerate. Nevertheless, as Fielden and Lockwood (ibid) remark:

"the workload approach represents a real attempt to relate resources to effort and we believe that further research and development on its application should be carried out."

(d) Other methods of staff allocation

We have already described (see Chapter 4) the credit-hour approach and contact hour approach which are popular methods of staff allocation in the US Universities.

Dundee University have been using a staff allocation method based on unit costs. This is based on the so-called 'Q ratio' which is the unit cost (per fte student) of a Dundee department divided by the mean UK University cost for the appropriate subject group multiplied by 100. Subjects with low Q ratios are given priority when additional resources are allocated. There are a number of drawbacks to this approach. Firstly, national statistics are always two or three years out of date. A much more serious matter, however, is the question of the validity of using national norms in the context of a particular institution. As Fielden and Lockwood have observed "Some formulae and ratios will only be valid in the statistical sense when applied to an entire population."

5.2.3 Allocation of non-academic (technical and secretarial staff)

In general, it has been the practice of most UK Universities (including Stirling) to allocate secretarial staff to subject areas broadly in line with levels of academic staffing in that area. A sophistication of this system which is sometimes suggested is weighting academic staff according to seniority.

Technical staff have also been allocated in relation to academic staff in experimental subjects. Other policies sometimes suggested are the allocation of staff in relation to weighted student numbers (taking into account the experimental work done in a department) or in relation to areas of laboratory floor space allocated to a subject.

5.2.4 Other departmental expenditure

This expenditure comprises consumables, travel, stationery, and hospitality. This expenditure will depend partly on the nature of the subject (eg experimental subjects will generally have greater expenditure on consumables). In the past the level of expenditure on these items for each subject has been arrived at by a process of negotiation and bargaining. A reasonable approach towards forecasting this expenditure might be to assume that it varies in relation to total departmental salary levels.

5.3 Allocation of Space

(a) Lecture theatre and seminar room space

At Stirling, lecture theatre and seminar room space is centrally controlled and centrally allocated according to requirements. This obviates the diseconomies associated with departmental control of individual seminar rooms which can be severely underutilized.

(b) Office space

In general, office space is related to levels of academic and non-academic staffing. This is done through a series of space norms, there being different norms for the various grades of academic staff and for non-academic staff.

At Stirling the building is of a uniform structure. Hence, there are no physical problems in reallocating office space from one subject area to another such as would be the case if the University consisted of a series of separate departmental buildings.

(c) Research laboratory space

At present, it is the policy to allocate research laboratory space in relation to academic staff numbers and postgraduate student numbers in experimental subject areas. Again, because of the type of building structure in use at Stirling, there should be no insuperable physical difficulties in reallocating such space from one subject area to another.

(d) Teaching laboratory space

Each laboratory subject has a certain number of teaching laboratory rooms (of varying size) allocated to it. Capacity provided is broadly in line with expected student numbers although there is no simple relationship. Again the space is reasonably flexible and there is a possibility of reallocating such space between subjects.

5.4 Alternative approaches to University resource allocation: decentralized decision-making

In this Chapter so far we have considered what are basically centralised methods of resource allocation. Each subject or department is allocated so many academic staff, so many secretaries, so much departmental expenditure, so much physical space, etc. The question arises as to whether it would be possible to decentralize such decisions. For example, each subject area could be given a certain block of finance and would have discretion to decide how to divide the money between different categories of staff, consumables, travel, etc. It has even been suggested that space could be included by charging subjects an imputed rent for the space they occupy (see Pickford (1974)). We shall discuss this alternative approach in some detail in Chapter 10.

5.5 Summary

In this Chapter we have outlined possible approaches and policies to resource allocation in Universities. The crucial importance of the allocation of academic staff can be really appreciated. Not only do academic staff salaries absorb a considerable proportion of the available budget but a number of other resources are related to academic staffing levels. It is clear that additional research into the question of academic staff allocation could be important.

BIBLIOGRAPHY : Chapter 5

93 Anon (1969). How the cake is cut at Stirling, Nature 224, 18th October.

94 R Ball (1973). Use of analytical models in staff allocation at the University of Stirling. Proceedings of TIMS XX Conference, Tel Aviv, Vol 2, pp 699-702.

95 D Birch and J Calvert (1974). A review of academic staffing formulae Educational Administration Bulletin, Vol 3 No 1, pp 32-41.

96 J Bottomley et alia (1971). Costs and potential economies, Studies in Institutional Management in Higher Education, CERI, OECD.

97 J Dunworth and R Dasey (1972). Potential economies in academic staff. Universities Quarterly, Vol 26, No 2, pp 219-230.

98 J Dunworth and Bottomley (1973). Potential economies of scale at the University of Bradford, Higher Education, Vol 2, No 2, pp 225-228.

99 J Fielden and Lockwood (1973). Planning and Management in Universities. Sussex University Press, page 236.

100 ibid. pp. 227-228.

101 ibid. page 228.

102 ibid. page 226.

103 Layard and Verry (1975). Cost Functions in University Teaching and Research, The Economic Journal,

104 J M Norman (1973). An empirical study of undergraduate teaching loads in a University. Higher Education, Vol 2, No 2, pp 222-224.

105 M Pickford (1974). University expansion and finance. University of Sussex Press, pp 174-187.

106 E Rudd (1968). Some thoughts on staff:student ratios. Universities Quarterly, Vol 23, No 1.

107 M G Simpson et alia (1971). Planning University Development, Studies in Institutional Management in Higher Education, CERI, OECD, pp 43-68.

108 Verry (1973). Economies of Scale, Higher Education, Vol 2, No 2, pp 214-219.

CHAPTER 6

OUTLINE AND DETAILS OF THE 'ROBUS' SIMULATION MODEL DEVELOPED AT STIRLING UNIVERSITY

6.1 Overview

If we consider the work carried out into problems of University planning and resource allocation described in Chapters 3 and 4, we find that it is possible to assign such studies to one of two categories.

Category I - Studies on a component or part of the University system only (eg student flow models, staffing models).

Category II - Studies on the whole University system (systems approach)
eg optimal resource allocation models
University simulation models
PPBS
Organisational theory.

The particular problems of Stirling University were described in Chapter 2. In particular, the short to medium terms situation of possible future expansion in a very uncertain environment was outlined. Given this situation, a model which could investigate the resource consequences of various patterns of growth and different operating policies could be very useful. Such a model could be a University simulation model such as is described in Chapter 4. Although results obtained using such a model would only give a very broad indication of future likely development they might, nevertheless, be of interest to decison-makers. It was felt that other approaches such as models for optimal resource allocation did not offer a high enough likelihood of useful results to make the work cost-effective.

6.2 Approach to model construction

The feasibility of adapting any of the general purpose University simulation models to the Stirling situation was considered. In considering this proposition we are confronted with the problem that these general purpose models were, on the whole, developed for University systems which differ considerably from that of the UK. Not only do we find a different academic structure in such institutions but also different resource allocation policies and methods of finance. In some cases the major problem areas that they were constructed to handle are also different. Owing to these factors it is likely that a prohibitive amount of reprogramming and restructuring effort would be required in order to adapt a particular model to the Stirling situation with the danger that, after such extensive alterations, the model might not be completely coherent.

Thus, it seems that there could be significant advantages in attempting to construct a model for Stirling from first principles. The question then arises, however, as to whether to construct a model which relates to Stirling only or whether to construct a general purpose model which other UK Universities might adapt to their needs. It was eventually decided, however, to construct a model that specifically related to Stirling for the following reasons.

1) The existence of fundamental differences between the academic structure found at Stirling and that usually adopted in the UK. (eg Stirling's semester system is unique within the UK).

2) The additional effort and expense involved in producing general purpose models (SRG, NCHEMS and HIS all had large quantities of finance available).

3) Any such model produced by the author would inevitably be produced with the Stirling situation in mind. This could provide a source of implicit error for another institution.

This is not to say, however, that a model which related specifically to Stirling should be irrelevant to other UK University institutions. The conceptual approach and techniques developed in this dissertation should be of considerable value to other UK institutions who might be considering the development of their own models.

6.3 Scope of the Model

An important decision is the level of detail that such a model should contain. As we have seen in Chapter 4,models developed elsewhere have varied from the extremely detailed such as CAMPUS (containing details of every individual teaching activity) to the highly aggregated such as SEARCH which provides information simply on the overall financial implications of particular plans. Of course,the level of detail provided should be appropriate to handle the most significant problems of an institution.

In Chapter 2 it was apparent that many of Stirling's problems related to the level of individual subject, (eg uneven growth of student numbers in different subject areas) hence this level of detail will be provided. In addition to students and staff (academic and non-academic) it was decided that the model should also relate to physical space and finance since both may have an important bearing on future development plans.

6.4 Structure of the Model

It was decided that such an inevitably complex model should have a modular structure. This implies that the model will be broken down into a number of small models (modules) each of which relate to a particular aspect of the University system. A master model operates the modules in the correct sequence and ensures that necessary information is transmitted. The modular structure has the advantage of clarity in that various components of the system are more clearly distinguished and implication of changes in one part of the system for the rest easily identified.

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6.5 Computational Aspects

Because of the heavy amount of computation that would be involved in using the model it was obvious from an early stage that the use of computing facilities would be highly desirable.

Accordingly a program was written in FORTRAN IV and stored on disc on the University's Elliot 4130 computer. It was convenient to make the master model the main program and the sub-modules its subroutines.

The model was operated using the batch processing mode although it was possible to edit the model using the KOS (Kent-on-line system) time sharing facility. A complete listing of this program together with explanatory notes and flowcharts is presented in Appendix 6.

6.6 Development of the Model

A prototype model ROBUS I was first developed. This model was constructed in order to ensure that the development was feasible and to overcome significant difficulties. Having successfully completed ROBUS I a more sophisticated and much more flexible model ROBUS II was constructed. It is the details of ROBUS II which are described in this dissertation.

6.7 Technical outline of the Model

The model consisted of a main model and the following sub-models (modules).

a) Modules relating to students

Student flow module

Notional class size module

Student equivalent module

b) Modules relating to staff

Academic staff - policy "A" (workload)

Academic staff - policy "B" (student:staff ratio)

Non-academic staff

c) Modules relating to physical space

Lecture and seminar room space

Teaching laboratory space

Research laboratory space

Office space

d) Modules relating to finance

Finance module

An outline flow chart of the ROBUS II model is given in Fig. 6.1.

6.8 Technical Details of the Model

Some of the most important technical details of the models are described in this section. Full technical details together with a complete program listing and sample output are presented in Appendix 6.

Master module

The function of this model, as explained earlier, is to call the other modules in the appropriate sequence and to transmit relevant information. Provision is made for calling only those modules required for a particular study - for example if no information on physical space is required then it is possible to omit the space modules.

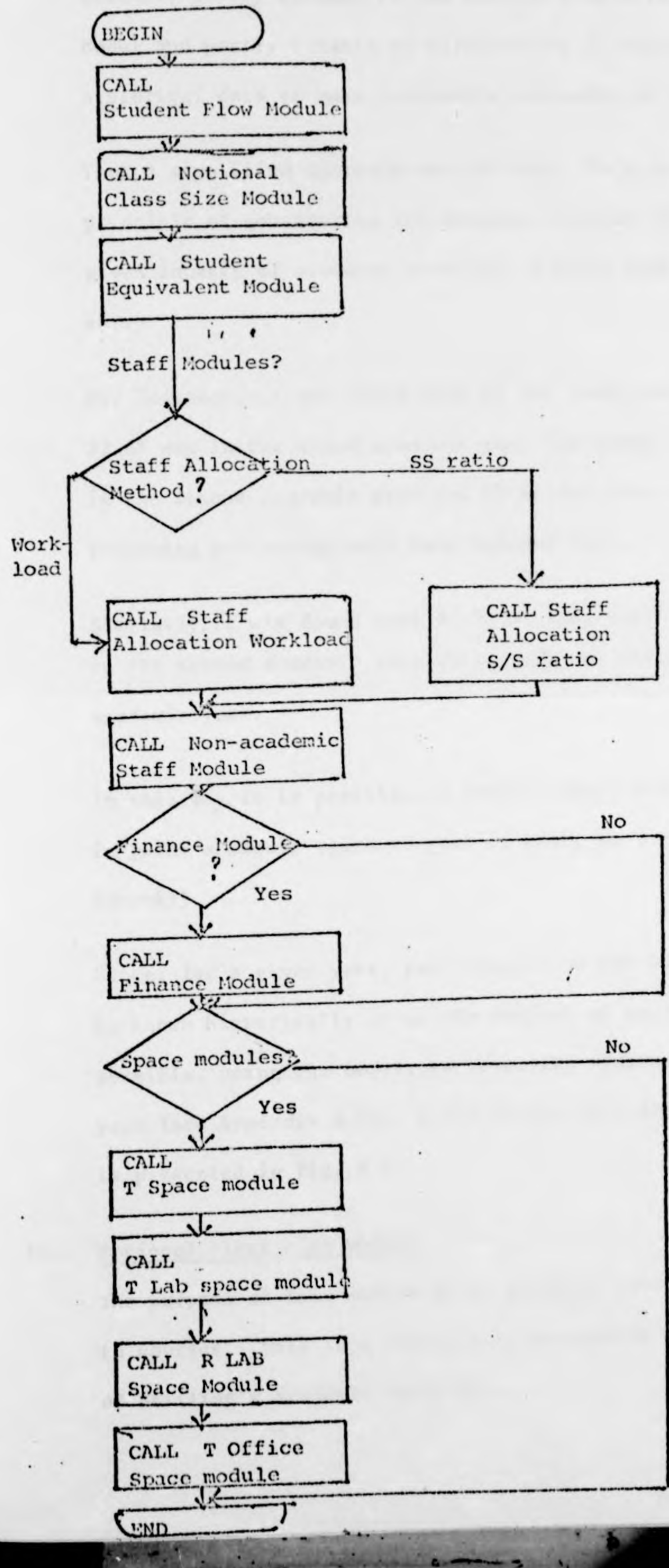
6.8.1 Modules relating to students

(i) Student flow module

This module simulates the flow of students through the University's academic system. This flow is complicated by the irregular academic progress made by a significant proportion of students. Some students find it necessary to repeat courses; others find it necessary to leave the University (either temporarily or permanently).

An initial attempt was made to construct a Markovian model of the academic system which considered transitions through all possible

Fig. 6.1 Outline Flow Chart of ROBUS model



states of the academic system. This approach was abandoned, however, partly because of the extreme complexity of the resulting model and partly because of difficulties in obtaining sufficient historical data to make reasonable estimates of parameter values.

Thus, a simplified approach was adopted. This was based on the principle of considering the progress through the academic system that given intakes of students have made a given number of years after entry.

For instance, it was found that of the entry two years previously 77.8% was in the third academic year (ie normal progress), 5.6% was in the second academic year and 1% in the first academic year (the remaining percentage will have dropped out).

Similarly, it was found that 87.5% of last year's entry was now in the second academic year while 4.2% was still in the first academic year.

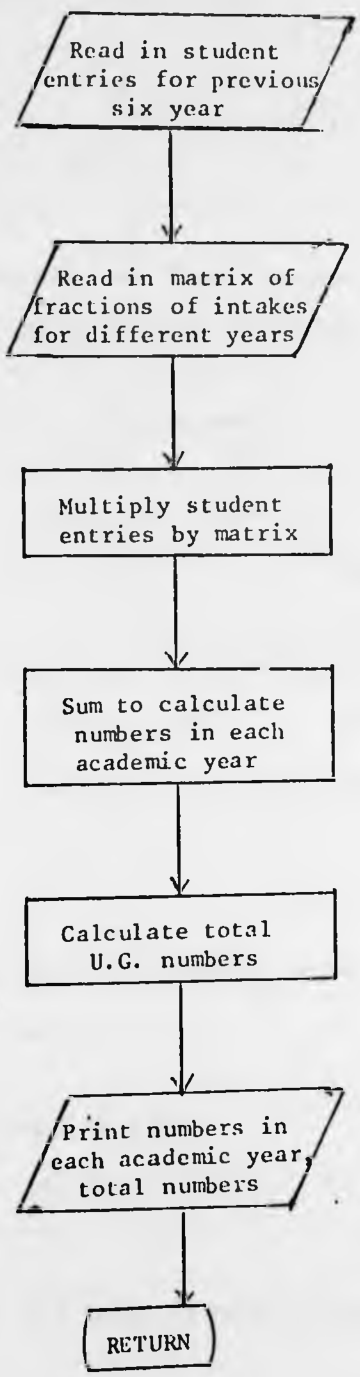
In this way, it is possible to build a model which relates numbers in given academic years to year of entry to the University (see Inset 6.1).

Since, for a given year, past intakes to the University will either be known historically or be the subject of projections, it will be possible, using the model, to calculate numbers in any academic year (see Appendix 6.B). A simplified flow diagram of this model is presented in Fig. 6.2.

(ii) Notional class size module

The purpose of this module is to simulate the assignment of students to courses. This is a fairly complex process owing to the nature of Stirling's academic structure.

Fig. 6.2 Student Flow Module : Flow Diagram (Simplified)



INSET 6.1 - STUDENT FLOW MODULE

Suppose Y_t is 1st year entry in year t

Y_{t-1} " " " " " " t-1

Y_{t-2} " " " " " " t-2

etc

Then the following relationship was found between the academic year of the student and his year of entry to the University.

			Year of entry			
Academic Year	t	t-1	t-2	t-3	t-4	t-5
N5 (5th year) =					$.027\ Y_{t-4}$	$.006\ Y_{t-5}$
N4 (4th year) =				$.487\ Y_{t-3}$	$.085\ Y_{t-4}$	
N3 (3rd year) =	$.049\ Y_t$		$.778\ Y_{t-2}$	$.116\ Y_{t-3}$	$.004\ Y_{t-4}$	
N2 (2nd year) =		$.875\ Y_{t-1}$	$.056\ Y_{t-2}$	$.002\ Y_{t-3}$		
N1 (1st year) =	$1.000\ Y_t$	$.042\ Y_{t-1}$	$.001\ Y_{t-2}$	$.002\ Y_{t-3}$		

∴ Total student numbers in the University is obtained simply by adding numbers in each academic year.

$$\text{Total Nos.} = N1 + N2 + N3 + N4 + N5$$

$$= 1.049Y_t + .917\ Y_{t-1} + .835\ Y_{t-2} + .603\ Y_{t-3} + .116\ Y_{t-4} + .012\ Y_{t-5}$$

An example of the use of this model is given in appendix 6.B.

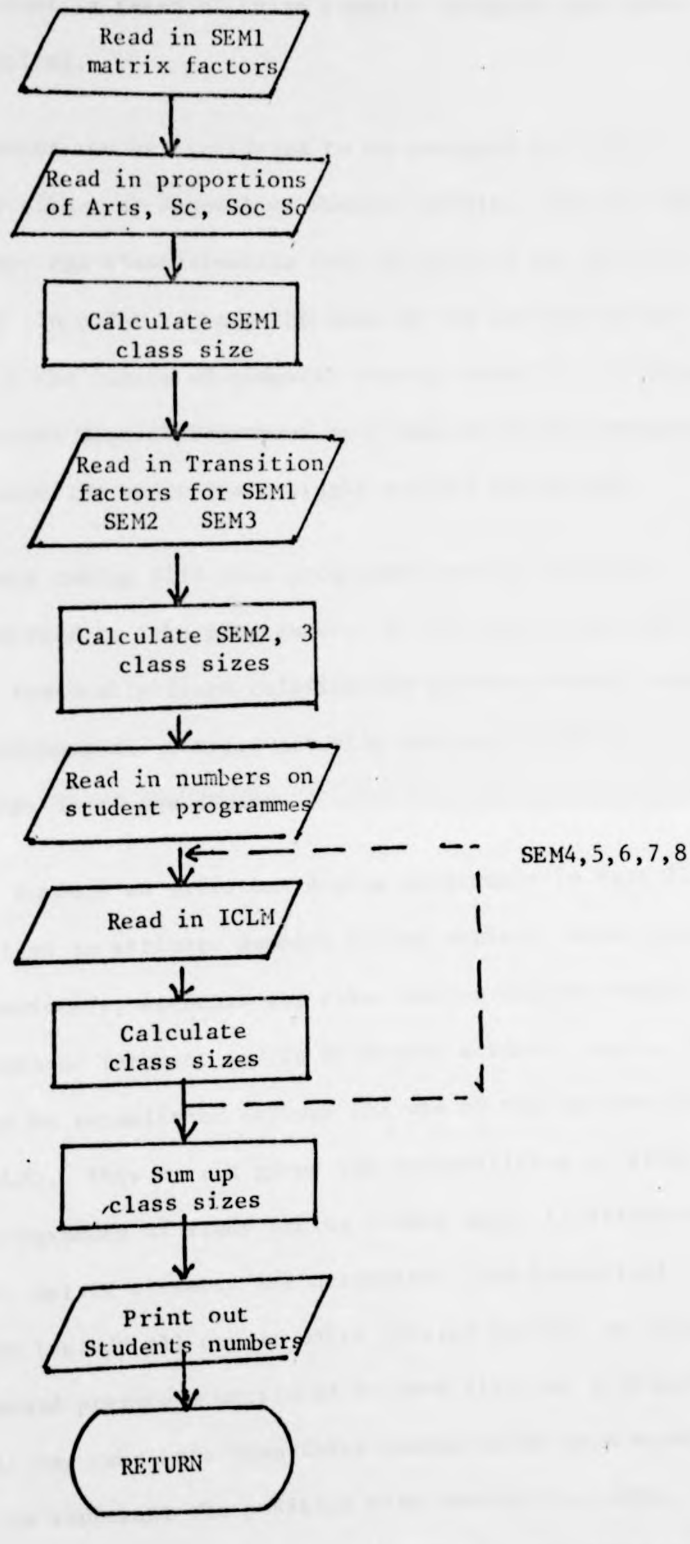
Academic departments provide courses in different subject areas but (as explained in Chapter 2) a student on a given programme of study may take courses from a number of different subject areas and even from different years of study.

For simplicity we shall assume that each academic department puts on courses in one subject. This is generally the case at Stirling with minor exceptions (eg the Philosophy department provides courses in both Philosophy and Religious Studies). Thus, in this case we shall assume that the department is split into a Philosophy department providing courses in Philosophy and a Religious Studies Department providing courses in Religious Studies.

As is described in Chapter 2 the academic structure at Stirling consists of a broadly based Part I and a Part II in which some element of specialization is possible. Generally, departments offer only one available course unit in each of the three semesters that comprise Part I (although occasionally a second unit is offered as a minor). In each semester of Part II each Department offers generally three or more semester units. (Note, as we have mentioned previously, three course-units in any semester comprises a full academic load for a student.)

The approach to forecasting class sizes is as follows. In Part I, numbers of first year students taking semester 1 class sizes is calculated. This can be done by considering the programmes of study the students indicated on their application. On this basis students can be broadly divided into three groups - Arts based, Science-based, and Social Science based - and it has been found that an approximately consistent proportion of each of these groups take subjects offered in the first semester. Student numbers in the other semesters of Part I can be derived by considering the historically-derived proportion

Fig. 6.3 Notional Class Size Module



of a cohort of students who proceed from one semester of a subject to the next (account is taken of third semester students who take first semester units).

In Part II a student can be considered to be assigned to a given degree programme either at General or Honours levels. (In the case of General degrees the classification used is that of the General degree subject.) In order to keep the size of the problem within bounds and within the limits of computer storage capacity, students taking joint Honours degree programmes or General degree programmes are divided between the appropriate single subject programmes.

Number of students taking different programmes can be forecast from numbers admitted to take programmes. It has been found empirically that there is a reasonably fixed relationship between student numbers admitted to programmes and numbers actually undertaking these programmes in Part II of the degree.

Having forecast numbers on different degree programmes in Part II the problem is then to estimate numbers taking various course options. As mentioned previously, students may take courses outside their major subject area of interest and in different academic years. This relationship can be established through the use of the Induced Course Load Matrix (ICLM). This matrix gives the probabilities of students on particular programmes of study taking course units in different subjects. These matrix elements are determined from historical information.(1) To include all course units offered in such an induced course matrix would produce a matrix of extreme size and diffuseness. Since no student can take more than three course units in a semester it is possible to represent the position with respect to course registration in given subjects, by three classes in each semester. A student taking 1 class in a subject will take the '1' class, a

(1) and are subject to statistical fluctuations (see page 97)

student taking 2 classes will take the '1' and '2' classes and a student taking all three units will take the '1', '2' and '3' units. Thus we have "notional class sizes". As an example the ICLM for semester 5 and 6 are shown in Table 6.1.

From the forecast of student numbers taking a given programme and from the induced course load matrix it is possible to forecast the future notional class size. It is necessary to sum student numbers assigned to each notional class size from different years of study. A very simplified representation of the flow diagram of this module is presented in Figure 6.3. Full details of this module are provided in Appendix 6.C.

(iii) Student equivalent module

This module calculates the full time equivalent (fte) student numbers in each department. This is the number of students who could be conceived to be studying a subject on a full time basis. For example, a student taking two semester-course units in Biology and one in Psychology could be conceived to be 2/3 of a fte in Biology and 1/3 in Psychology. Thus, if we divide students between departments according to the course units studied at a given time, it is possible to obtain an estimate of full time student equivalents attached to that department. Full details are given in Appendix 6.D.

6.8.2 Staff modules

(iv) Staff Allocation

There are two alternative staff allocation policies provided: a workload option and a student:staff ratio option. These were discussed in Chapter 5.

a) Workload option

The principle of this approach is that staff should be allocated

Table 6.1 Induced course load matrix for Sem5 (Hons and General)

This matrix covers the following programmes (Hons and General)

1	Maths	15	Physics
2	Economics	16	Chemistry
3	Sociology	17	Psychology
4	English	18	Biochemistry
5	History	19	Technological Economics
6	Philosophy	20	Education and Biology
7	Accountancy & Bus. Law	21	" and Chemistry
8	Religious Studies	22	" and English
9	Man. Sc. & Chemistry	23	" and French
10	Computing Science	24	" and German
11	French	25	" and History
12	German	26	" and Maths
13	Spanish	27	" and Spanish
14	Biology		

Only non-zero matrix elements are shown; the following code is used for subject:

A	Maths - 31	B	German - 49
A	Economics - 41	B	Spanish - 60
A	Sociology - 47	C	Biology - 25
A	English - 55	C	Physics - 33
A	History - 69	C	Chemistry - 34
A	Philosophy - 71	C	Psychology - 46
A	Acc. & Bus. Law - 43	C	Int. Sc. - 38
A	Religious St. - 72	C	Fine Arts & Music - 75
A	Man. Sc. - 19	C	Biochemistry - 29
A	Comp. Sc. - 32	C	Education - 01
B	French - 57		

(Explanation of Cats A, B, C given on page 98)

These codes comprise the first two digits in the course code, the third diget refers to the number of the course in that semester and the fourth refers to the semester number.

Thus 4725 corresponds to the 2nd course in the fifth semester for sociology.

Induced Course Load Matrix: Sem5 Hons (sample)

1. MATHS (programme)

3115	3125	3135	3215	0115
1.000	1.000	.167	.667	.167

2. ECONOMICS

4114	4125	4135	3115	4715	6915	7115
1.000	1.000	.308	.022	.043	.132	.022

4315	1915
.220	.066

4313	4713	6913
.044	.033	.066

5511	3213
.022	.022

3. SOCIOLOGY

4715	4725	4735	4115
1.000	1.000	.676	.029

4613	7211
.029	.029

4. ENGLISH

5515	5525	5535	4715	6915	7115	0115
1.000	.994	.024	.012	.018	.048	.072

4613	4713	6013	6913
.012	.024	.012	.012

7111	7511
.024	.060

5. HISTORY

6915	6925	6935	4115	4715	5515	7115
1.000	.929	.048	.048	.048	.309	.048

5513
.024

1911	4311	4711	5511	4111	7111	7211	7511
.024	.024	.095	.048	.024	.024	.024	.071

6. PHILOSOPHY

$\frac{7115}{1.000}$	$\frac{7125}{.943}$	$\frac{7135}{.286}$	$\frac{4615}{.029}$	$\frac{6915}{.029}$	$\frac{7215}{.029}$	$\frac{5515}{.086}$
$\frac{7213}{.029}$						
$\frac{7511}{.057}$						

and so on for programmes 7 - 27

Induced Course Load Matrix: Sem5 General (sample)

1. MATHS

$\frac{3115}{1.000}$	$\frac{3125}{.000}$	$\frac{3215}{.667}$	$\frac{3213}{.333}$

2. ECONOMICS

$\frac{4115}{1.000}$	$\frac{4125}{.378}$	$\frac{4135}{.000}$	$\frac{4715}{.108}$	$\frac{6915}{.216}$	$\frac{7115}{.054}$	$\frac{4315}{.297}$	$\frac{1915}{.108}$
$\frac{1913}{.054}$	$\frac{5513}{.054}$	$\frac{4713}{.108}$	$\frac{0113}{.054}$				
$\frac{1911}{0.54}$	$\frac{4311}{.054}$	$\frac{6011}{.054}$	$\frac{5511}{.054}$	$\frac{4711}{.027}$			

3. SOCIOLOGY

$\frac{4715}{1.000}$	$\frac{4725}{.327}$	$\frac{4735}{.005}$	$\frac{5515}{.073}$	$\frac{4615}{.200}$	$\frac{6915}{.091}$	$\frac{7115}{.018}$	
$\frac{5513}{.018}$	$\frac{4613}{.091}$	$\frac{3213}{.018}$	$\frac{6913}{.018}$	$\frac{6013}{.018}$	$\frac{7113}{.018}$	$\frac{0113}{.018}$	
$\frac{4311}{.055}$	$\frac{4611}{.145}$	$\frac{6911}{.055}$	$\frac{7111}{.018}$	$\frac{5511}{.018}$	$\frac{7211}{.036}$	$\frac{3111}{.018}$	$\frac{7511}{.036}$

4. ENGLISH

$\frac{5515}{1.000}$	$\frac{5525}{.697}$	$\frac{5535}{.000}$	$\frac{4115}{.013}$	$\frac{4615}{.039}$	$\frac{4715}{.053}$	$\frac{6915}{.072}$	$\frac{7115}{.053}$
$\frac{7215}{.026}$	$\frac{0115}{.125}$						
$\frac{4613}{.052}$	$\frac{4713}{.092}$	$\frac{6913}{.013}$	$\frac{7213}{.013}$	$\frac{0113}{.013}$			
$\frac{7111}{.026}$	$\frac{7211}{.026}$	$\frac{7511}{.039}$	$\frac{4311}{.026}$	$\frac{4611}{.013}$	$\frac{5711}{.013}$		

5. HISTORY

6915	6925	4115	4715	5515	7115	4315	7215
1.000	.376	.059	.212	.212	.047	.012	.106
						1915	0115
						.012	.094
4613	4713	2513	0113	5513	5713	7113	7213
.024	.024	.024	.071	.012	.024	.024	.012
							4113
							.012
4611	4711	5511	7111	6011	7521	7211	
.012	.024	.024	.047	.012	.035	.012	

6. PHILOSOPHY

7115	7125	7135	4615	4715	5515	6915	7215
1.000	.476	.000	.095	.285	.143	.190	.095
4611	4711	7511					
.095	.095	.190					

and so on for programmes 7 - 27

Note

The data for these induced course load matrices are based on student registrations for academic years 1973/4 and 1974/5. Because of subsequent academic development and the fact that student numbers were then very small it is difficult to include data from earlier academic years than this. Stability was observed to be good for programmes with substantial student enrolments. Owing to statistical fluctuations it was less good for programmes with low student enrolments. Nevertheless it should be possible to improve these statistics by recalculating the induced course local matrix yearly. (This subject is discussed further in Section 9.2).

to a department on the basis of workload generated by its teaching commitments. The model attempts to quantify all elements of workload involved in the preparation and presentation of a course (eg giving and preparing lectures, seminars, tutorials, etc). This model assumes a standard method of teaching the course although in practice each course will involve a different mix of teaching activites. The basis of this approach, however, is to allocate resources on some reasonable basis for teaching a course and devolve the decision as to their exact utilisation to the department concerned.

Since notional class sizes are used in the model, departments gain additional resources only for additional students attracted. Simply proliferating options without any addition in total student registration brings no additional resources.

Certain subject groups necessarily involve different teaching activities from others (eg experimental subjects involve teaching laboratories). Thus all subjects are divided into three categories with appropriate modifications to the model being made for each category. These three categories are:

Cat 'A' General non-experimental subjects

Cat 'B' Language subjects

Cat 'C' Experimental subjects

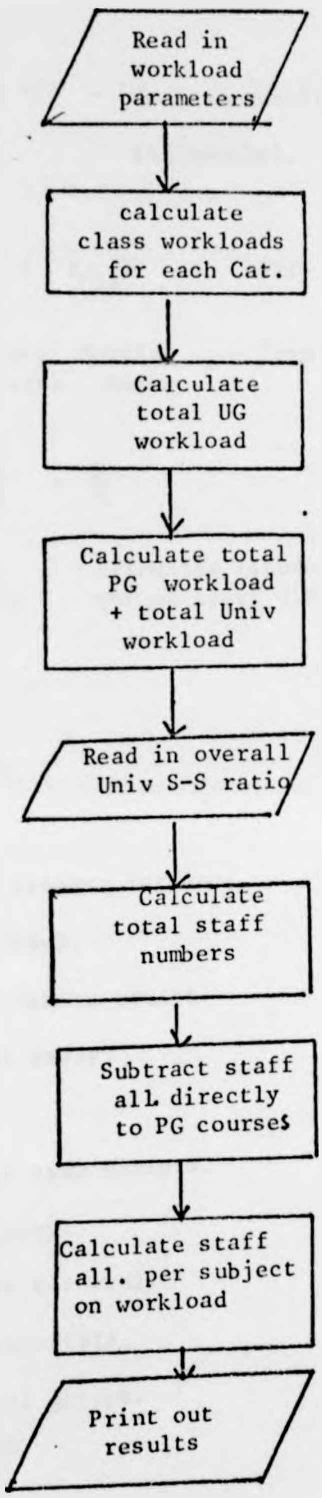
(Assignment of subjects to categories are given in Table 6.1)

The workload model for Category 'A' subjects is given in Inset 6.2, and a simplified flow diagram presented in Figure 6.4. Further technical details are supplied in Appendix 5 and 6.E.

b) <u>Student:staff ratio option</u>

This module divides available academic staff between departments according to total student equivalents attached to each department. It is possible to give additional weighting to postgraduate students. Further technical details are given in Appendix 6.F.

Fig 6.4 Staff Allocation : Workload (simplified)



INSET 6.2

Workload model for CAT 'A' - General non-lab subjects (eg English, Maths, Philosophy).

$$X = mL + Nx \left(Wxw + E/_{14}\right) + Fxtp\, x \left\{ \left[\frac{N}{4n} \right] + 1 \right\}$$

Giving and preparing lectures — Marking Essays — Marking Exams — Preparing of tutorials

$$+ \; Fxtg \; x \left\{ \left[\frac{N}{n} \right] + 1 \right\} + \frac{N}{6}$$

Giving tutorials — allowance (students for out of class disc. etc.

Explanation of symbols

[ ]	Int. part of
m	Time to give + prepare lectures.
L	No of lectures/week.
N	No of students taking course.
w	Time to correct essay.
W	Essay freq.
E	Time to correct exam scripts.
F	Tutorial frequency.
tp	Time to prepare tutorials.
tg	Time to give tutorials.
n	Nos. in tutorial groups.
X	Weekly workload

(v) Non-academic staff module

This module calculates the number of non-academic staff (ie secretarial and technical staff) which are required by each department. It is the policy to allocate such staff in direct relation to the numbers of academic staff (of course, technical staff are allocated to laboratory subjects only). (See Appendix 6.G)

6.8.3 Space Modules

(vi) Teaching space module

The function of this module is the forecasting of occupancy and utilization of lecture theatre and seminar room space in a given year with a view to estimating the adequacy of physical space available.

The basis for forecasting future lecture class sizes is the plausible assumption that the size of such classes will vary broadly in line with the number of full time equivalent students studying that subject in a given semester.

Hence, if we know student equivalents and class sizes for a given subject and semester in a given base year, we can make the following estimate:-

$$\text{Future class size} = \begin{array}{c}\text{Base year}\\ \text{class size}\end{array} \times \frac{\text{Future years student equivalents in that subject and semester}}{\text{Base year's student equivalents}}$$

There is, however, an additonal complication in that new options in particular subjects may be introduced causing consequent reduction in size of existing options. A facility for providing additional options has, however, been incorporated into the model, the assumption being made that such options will have average class sizes and that the size of existing options will be reduced pro-rata.

On many courses small group classes (seminars) are held in addition to the formal lecture sessions. Such sessions are repeated when the class exceeds this minimum group size. The total number of seminar-room hours required can be deduced from a knowledge of the weekly number of seminar hours per student and the usual student numbers in a given seminar group.

Then it follows that the number of seminar-room hours required for a particular course will be given by

$$\text{No of hours required} = \text{No of seminar hours/student/week} \times \left\{ \left[\frac{\text{Class size}}{\text{No of students in sem. group}} \right] + 1 \right\}$$

(Note[ ] represents integral part of)

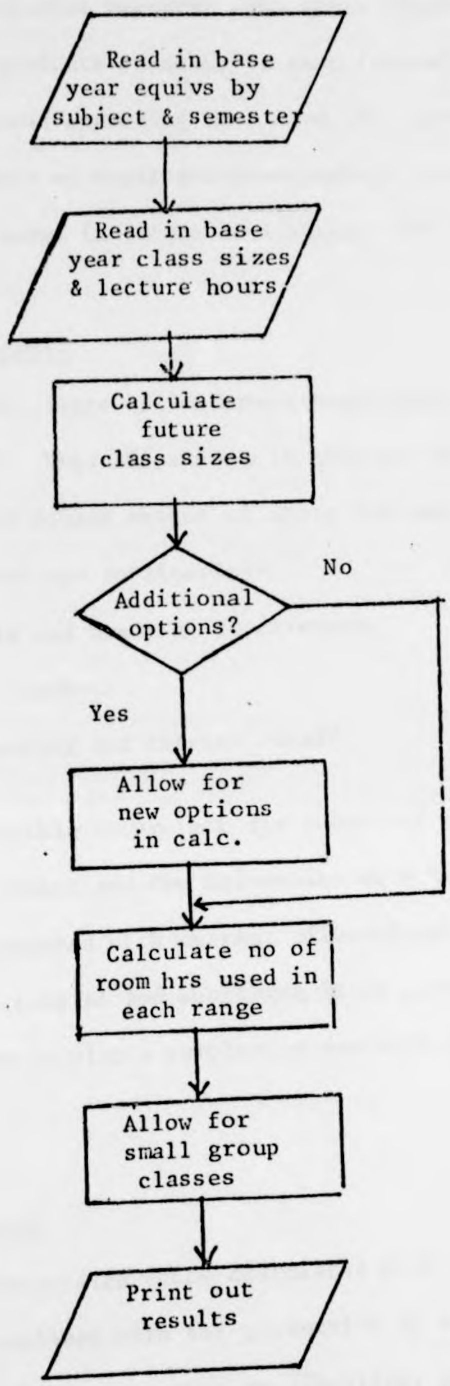
Teaching rooms available are divided into a number of size categories and hence rooms hours available in each category can be calculated. The rooms hours required by each class is assigned to the appropriate size category so that the overall utilization of each size category can be determined.

Naturally, there are certain inherent errors inevitably involved in any attempt to forecast future class sizes. The future popularity of different options may fluctuate considerably, for instance. Nevertheless this approach should yield at least a broad indication of the adequacy of teaching space. An outline flow diagram is presented in Fig. 6.5. For technical details see Appendix 6.I.

(vii) <u>Teaching laboratory space module</u>

The purpose of this module is the projection of the future adequacy of teaching space provided by laboratory subjects. This task is simplified by the fact that future class sizes have already been calculated by the previous module. Thus, if the number, length and maximum size of laboratory sessions required by each course are known, it is possible to calculate the total laboratory hours required quite simply and comparison with likely available space can be made. (App. 6.J)

Fig 6.5 Teaching Space Module (simplified)



(viii) Research Laboratory Space

This module estimates research lab. space required by academic staff and postgraduate students in experimental subjects. Such space is allocated according to a norm of a given number of square metres per member of staff and postgraduate student. It is possible to vary these norms in future situations. (cf Appendix 6.K)

(IX) Office Space Module

This module calculates office space requirement for academic and non-academic staff. This allocation is made on the basis of a norm of a given number of square metres of space for each grade of staff. The following grades are applicable:-

Professors and heads of departments.

Tutorial teachers

Other teaching and clerical staff.

Thus it is possible to project the amount of office space required for each department and the University as a whole and these projections can then be compared with current allocations. As mentioned earlier, if there is a surplus and shortages, it is possible to switch space from a department with a surplus to one with a shortage.

6.8.4 Finance

(X) Financial Module

This module calculates costs associated with each academic department and costs associated with the production of each full time equivalent student. Overhead costs such as libraries, computer maintenance and catering will be ignored in this calculation which considers only costs such as salaries etc which can be directly attributed to departments.

Academic salaries are first calculated. For this purpose it is necessary to calculate the number of academic staff in each grade which can be done from a knowledge of the appropriate ratio of senior staff. The mid point of the salary scale for each grade is employed in this calculation.

Non-academic salaries (ie technical and secretarial staff) can be estimated in a similar manner, again using mid points of appropriate salary scales. Thus, total departmental salary costs can be calculated.

In addition, there remains the further problem of estimating other departmental expenditure (ie postage, travel, consumables etc). The approach employed was to calculate the fraction of the total departmental salary bill that such expenditure represented during two base years. This fraction was then applied to future years' salary bills to obtain an estimate of this expenditure. Thus, having calculated total departmental expenditure by dividing by total full time equivalent students, it is possible to obtain an estimate of cost per student of each department. It is important that this financial data is treated with some caution; it is not the function of the University to produce students at minimum cost and this information will only give one a very general indication of the efficiency with which resources are being utilized.

6.9 Data Sources

In order to use the model, accurate data on the following aspects of the Universities operations must be collected.

a) Student statistics.

b) Physical space information.

c) Financial information.

a) Student statistics

It is necessary to collect historical information on students and their subject choices in order to derive the proportion of cohorts proceeding from one semester to the next in Part I; the induced course load matrix in Part II etc.

This information is provided by the students records office who maintain computerized files of students together with the subjects they are studying and programmes of studies (in Part II) etc.

b) Physical Space

It is necessary to know the availability of the different varieties of physical space and (where applicable) the department to whom the space has been allocated. This information is available in manual form from the Estates and Buildings Office.

c) Financial information

This information is obtained from the Finance Office and the University accounts. More general comments on these data sources together with a consideration of the possibilities of establishing an integrated management information system will be discussed in Chapter 9.

6.10 Operation of the model

The model can be used in two broad ways:-

a) To test the effect of changes in input to the University system (eg investigation of effect of an increase or reduction in the proportion of Science-based students admitted to the University, effect of a fall-off in student numbers.)

b) Testing the effect of changes in operating policy (eg effect of using a student:staff ratio approach instead of a workload approach for academic staff allocation or alteration of space norms.) Should it be wished to entirely change the basis of a policy, rewriting one of the modules might prove necessary. (For instance supposing that technical staff were related to numbers of square metres of floor space available rather than numbers of academic staff).

CHAPTER 7

USE OF THE "ROBUS" MODEL IN PRACTICE - APPLICATION OF THE MODEL TO PLANNING FOR QUINQUENNIUM 1977-82 AND BEYOND

7.1 The Planning scenario and applicability of the model

In the first chapter of this dissertation the system of University planning which has been operative in the U.K. is described. As we have seen, the UGC, in the light of discussions with the Government and submissions from the Universities, make decisions on student number targets and resources for a fixed five year period (the quinquennium). In general it is necessary for the University to begin drawing up its quinquennial plans at least two years before the end of the quinquennium. Thus, it was necessary to commence planning for the 1977-82 quinquennium in 1975, which is the starting date for these projections.

Even at the time this study was carried out the position with regard to the next quinquennium was rather uncertain. Because of the prevailing high rate of inflation, the quinquennial system had broken down and been replaced by ad-hoc one year settlements. Nevertheless as UGC were determined to restore the quinquennial system if at all possible, it was necessary for the University to plan, at least tentatively, for the 1977-82 quinquennium.

We must now consider to what extent the model can help us in this task. Hopefully the model could prove to be useful in the following ways.

(i) The most significant resource implications for any suggested development plan can easily be derived for each year of the plan.

(ii) A much wider range of plans can be explored than would otherwise be possible.

(iii) It should be possible to carry out much more comprehensive sensitivity analyses in attempting to investigate the likely consequences of any subsequent deviations from planned targets.

(iv) Possible changes in the structure of University planning system are being aired. In particular the possibility of change from a fixed quinquennial system to a rolling triennium system is being discussed (see Lord Crowther-Hunt (1975)). Under a rolling triennial system a complete plan for a three year period would be carried out annually. The use of the model might be helpful in adjusting to such a change and, in particular, at least reduce the amount of labour associated with a yearly planning exercise of this sort.

Thus, to summarise the availability of the model will not make any fundamental changes to the planning process. Decisions will still be taken by academics based on academic criteria. The use of the model can make explicit resource implications of a decision and may make alternative policies easier to examine. Of course many important relevant aspects of a plan are entirely subjective and must be given due weighting. However, to quote Simpson et alia (1971) "There have, of course, been many examples, both in universities and elsewhere, of planning decisions involving highly subjective matters being taken with little or no reference being made to the quantifiable aspects. In fact the existence of the former is often used as an excuse to ignore the latter - surely a most unfortunate attitude."

7.2 Growth Pattern of Aggregate Student Numbers

Planning for a quinquennium usually starts with some consideration of a possible global target for student numbers. Having established this target consideration is given to individual academic developments. In the light of this more detailed planning, overall target figures may be adjusted.

In early 1975 the University's academic decision-makers (council) were of the opinion that aggregate student numbers somewhere in the 3500-4000 region would be a desirable target to aim at for the end of the quinquennium. Indeed a number of factors seemed to suggest, prima facie, that this could be an appropriate target.

(i) From the foundation of the University it was planned that the University should have over 3000 students within a reasonable time period. Indeed physical facilities believed adequate for such numbers were already provided.

(ii) At this larger size one could expect a more academically satisfactory range of subject choices and options to be available. In a broad sense, the University would become more "viable".

(iii) According to the UGC at the time (letter of 24 April 1975) it was expected that the number of full-time and sandwich students in the University system would grow from 250,000 in 1974-5 to possibly 320,000 in 1981-2, with disproportionately higher growth in Scotland. Given this statement by the UGC it was natural for the University to wish to participate fully in such an expansion, especially in a situation where other Scottish Universities might be limited by physical constraints. Indeed in the same letter the UGC tentatively suggested that in considering its plans for the next quinquennium, Stirling should consider the possibility of a substantial expansion.

For these reasons the University's academic decision-makers tentatively suggested a target of 3420 undergraduates and 355 postgraduates as a possible target for 1981/2.

It was at the same time, however, considered desirable that reasonably smooth growth in student numbers towards the target was desirable for the following reasons.

(i) Teaching departments could find difficulties in coping with sudden very large influxes of additional students.

(ii) Such large influxes of students over short time periods cause inbalance in student numbers between different academic years (which some academics regard as undesirable).

The student flow module was used to experiment with different patterns of student intake and one was found which gave a very steady build up of overall students numbers through the quinquennium of around 10% per annum for most of the years). These figures are presented in table 7.1.

Although this pattern of growth gives a steady build up of student numbers one important consequence should, however, be pointed out. Since intake is increasing up to 1981/2, further growth in total student numbers will occur after 1981/2 even if intake is held constant at the level of the final year of the quinquennium. To stabalize aggregate student numbers at the 1981/2 level it would be necessary to actually reduce intake in the following years (a course of action which it is felt the University might be very unwilling to take). In order to obtain a stable student population in 1981/2 it would be necessary to increase intake very sharply early in the quinquennium and then level off. This, however, would not only have the disadvantage of too sudden expansion which is outlined earlier, but could also cast considerable doubt on the University's ability to attract this number of students at such an early date. This discussion does show, however, that when devising plans for the next quinquennium it is important to think ahead and discover any built-in implications for the quinquennium after next.

If we take the plausible assumption that postgraduate numbers remain at slightly over 10% of total undergraduate numbers we obtain the growth pattern shown in Table 7.2.

TABLE 7.1

PROJECTED GROWTH OF UNDERGRADUATE STUDENTS NUMBERS 1975-82 AND BEYOND

Year	Intake	% Increase in intake over previous years	Total UG nos	% Growth of total UG nos
1974/5	500	-	1942	-
1975/6	575	15.0	1933	-0.5
1976/7	675	17.4	2033	5.2
1977/8	750	11.1	2249	10.6
1978/9	825	10.0	2520	12.1
1979/80	900	9.1	2796	11.0
1980/1	1000	11.1	3090	10.5
1981/2	1100	10.0	3404	10.2
1982/3	1100	0.0	3672	7.9
1983/4	1100	0.0	3825	4.2
1984/5	1100	0.0	3898	1.9
1985/6	1100	0.0	3911	0.3

Note: Drop in total numbers in 1975/6 is caused by significant reduction in first year intake from 1973 onwards.

TABLE 7.2

PROJECTED GROWTH OF TOTAL STUDENT NUMBERS

Year	Undergraduate numbers	Postgraduate numbers	Total
1974/5	1942	187	2129
1975/6	1933	200	2133
1976/7	2033	210	2243
1977/8	2249	235	2484
1978/9	2520	260	2780
1979/80	2796	290	3086
1980/1	3090	320	3410
1981/2	3404	355	3759

7.3 Feasibility of aggregate student number targets

When considering possible targets for student numbers, however, it is important to consider the question as to whether the corresponding student demand is likely to be forthcoming. In past quinquennia the University has sometimes been in the position of not being able to fulfil its student number targets.

If we examine Table 7.1 we see that in order to achieve its global targets it would be necessary for the University to increase its first-year intake from an expected 575 in 1975 to the region of 1100 by the year 1981. (This is, of course, assuming that drop-out rate, proportions recycling etc, do not change significantly during this period). Thus, we are proposing to virtually double our first year intake over a seven year period, and it is very important to consider the feasibility of this aim.

We must first consider the most important factors which can influence aggregate demand for University education. Amongst these should be the following:-

(i) Population of qualified school leavers.

(ii) Proportion of qualified school leavers who desire University education.

(iii) Stirling University's attractiveness relative to other (particularly Scottish) universities.

Since historically 75-80% of Stirling students have Scottish origins it will be necessary to study the situation in Scotland with particular care.

Projections of the 17 year old age group populations and number of qualified school leavers for the period up to the mid-1980's which were supplied by the Scottish Education Dept (1975) are shown in Table 7.3. An average annual growth rate of 1.5% for growth in population of 17 year olds and 6.0% for growth of University qualified school-leavers and further education students is projected. For obvious reasons we can place much more confidence in the accuracy of the population projections than the projection of school leavers qualified for University entrance. It should also be noted that after the end of the 1977-82 quinquennium a substantial drop in the population of the 17 year old age group occurs.

As mentioned earlier, a further critical parameter is the proportion of school leavers qualified for University entrance who decide to apply. This is difficult to predict in a variable economic situation and we shall tentatively assume that it remains constant.

The 6% per annum growth rate of University entry qualified school-leavers throughout the next quinquennium which was predicted by the SED has been a source of some controversy. Apparently these figures are based on a ten year regression analysis and it has been suggested that insufficient weight has been given to recent trends. Accordingly we will make the conservative assumption of a 5% growth rate in University entry qualified school-leavers throughout the quinquennium. Thus, given our assumption that a constant proportion of qualified school leavers apply for University, this implies that numbers of students gaining University entrance in Scotland should increase by 5% per annum. Table 7.4 illustrates some consequences of this projection. For each year of the quinquennium the projected growth of the Scottish University system is presented along with the projected growth of Stirling University's intake during the period in question. As can be seen from this table, the planned growth in Stirling's intake compared with

TABLE 7.3

SCOTTISH EDUCATION DEPARTMENT'S STATISTICS ON SCHOOL LEAVERS QUALIFIED FOR UNIVERSITY ENTRANCE (ACTUAL AND PROJECTED)

Actuals	Population Aged 17	Qualified School and FE Leavers under 21
1962-3	72,300	6,665
1963-4	88,400	7,725
1964-5	96,700	9,727
1965-6	84,400	9,939
1966-7	82,300	10,486
1967-8	79,700	11,366
1968-9	77,700	12,572
1969-70	77,500	13,809
1970-1	78,200	15,287
1971-2	79,600	16,387
1972-3	80,800	16,888
Projections		
1973-4	83,500	17,893
1974-5	85,800	19,159
1975-6	86,900	20,834
1976-7	87,000	21,923
1977-8	89,300	23,290
1978-9	89,000	24,465
1979-80	91,800	25,819
1980-1	91,000	26,857
1984-5	86,500	29,112
Total Growth		
1962-3 to 1972-3	11.8%	153.4%
1967-8 to 1972-3	1.4%	48.6%
1972-3 to 1980-1	12.6%	59.0%
Average Annual Growth		
1962-3 to 1972-3	1.1%	9.7%
1967-8 to 1972-3	0.3%	8.2%
1972-3 to 1980-1	1.5%	6.0%

TABLE 7.4

PROJECTED GROWTH OF INTAKE INTO THE SCOTTISH UNIVERSITY SYSTEM

Year	Total Projected Intake	Growth in system intake	Target Stirling intake	Stirling growth of intake	Stirling Growth / System Growth
1974/5	10,400	-	500	-	-
1975/6	10,920	520	575	75	14.4%
1976/7	11,470	550	675	100	18.2
1977/8	12,040	570	750	75	13.2
1978/9	12,640	600	825	75	12.5
1979/80	13,270	630	900	75	11.9
1980/1	13,935	665	1,000	100	15.0
1981/2	14,630	695	1,100	100	14.3

the projected growth of the Scottish University system as a whole is a modest figure (typically 12-15% of the growth of the whole system). Thus it would appear that the growth targets for Stirling are perfectly feasible in relation to the planned growth of the Scottish Universities as a whole. Much will depend on whether Stirling can advance its reputation in the immediate future and the capacity of the other Scottish Universities for expansion. It is possible that a physical limit of capacity in some subject areas in some Universities may soon be reached and it is highly unlikely in the prevailing economic climate that additional capacity could be provided.

Availability of student accommodation may also become a constraint, and this is potentially a very serious problem for Glasgow, Edinburgh and Aberdeen which is in the throes of a North-Sea oil boom.

Nevertheless, it is important to bear in mind past failures to achieve student target levels and attempt to anticipate any problems this might cause. Thus, it will be important to carry out appropriate sensitivity analyses. The long term situation ought also to be borne in mind; as mentioned earlier demographic factors in relation to a declining population of 17 year olds may create problems in the period after 1981/2.

7.4 Outline of Planned Projections

As a first step to carrying out a projection over the next quinquennium it might be useful to carry out a preliminary study in which present trends are simply extrapolated. This will be called the "base-line" study and will:-

(i) Include no new academic developments.

(ii) Assumes present trends continue (ie proportion of students in various subject areas remain approximately as present). This projection establishes a base against which we can compare further projections.

This study will then be followed by a further projection which does take new developments into account and also certain targets (eg concerning proportion of science students) suggested desirable by the Council.

In the following chapter a full sensitivity analysis will be carried out in which the consequences of both failure to achieve particular targets and possible changes in policy will be examined. Arising from this analysis possible alternative plans will be suggested. Existing programmes and departments are shown in Table 7.5.A.

7.5 "Base-Line" Study

As explained in the previous section, the aim of this projection is to explore the consequences of present trends being continued throughout the next quinquennium. Thus, we shall assume that no new academic developments are undertaken and that proportions of students studying different subject areas remain approximately as at present.

7.5.1 Policies, resources and student inputs

The workload model staff allocation option was used since this method had been adopted for planning during the previous quinquennium. (The effect of adopting a different policy will be discussed in the next chapter). Other policies, such as those pertaining to the allocation of physical space, remain as described in Chapter 5. Since this projection assumes no new academic developments and that proportions of students in existing subjects areas remain as before, it follows that the proportions of students who enter the various academic programmes each year should remain approximately constant. These numbers are given in Table 7.5.B. Costs are based on price levels (including academic staff salaries) of June 1975).

Table 7.5.A

EXISTING PROGRAMMES

1. Maths
2. Economics
3. Sociology
4. English
5. History
6. Philosophy
7. Accountancy & Bus. Law
8. Religious Studies
9. Management Science
10. Computing Science
11. French
12. German
13. Spanish
14. Biology
15. Physics
16. Chemistry
17. Psychology
18. Biochemistry
19. Technological Economics
20. Education and Biology
21. " and Chemistry
22. " and English
23. " and French
24. " and German
25. " and History
26. " and Maths
27. " and Spanish

Note: As explained in Chapter 6 most students on most joint programmes are split between the single program.

DEPARTMENT (subjects)

1. Maths
2. Economics
3. Sociology
4. English
5. History
6. Philosophy
7. Accountancy & Bus. Law
8. Relgious Studies
9. Management Science
10. Computing Science
11. French
12. German
13. Spanish
14. Biology
15. Physics
16. Chemistry
17. Psychology
18. Integrated Science
19. Fine Arts
20. Biochemistry
21. Education

TABLE 7.5.B

BASE LINE STUDY : INDICATIVE PROGRAMMES OF STUDENTS ADMITTED

Programme	1975-6	76-7	77-8	78-9	79-80	80-1	81-2
1. Maths	7	8	9	10	11	12	13
2. Economics	27	32	35	39	42	47	52
3. Sociology	58	68	76	83	91	101	111
4. English	90	105	116	128	140	156	171
5. History	70	82	91	100	109	121	133
6. Philosophy	10	12	14	15	16	18	20
7. Acc. & Bus. Law	62	72	80	88	96	107	118
8. Religious Studies	3	4	5	5	5	6	7
9. Management Science	2	3	3	3	4	4	4
10. Computing Science	3	4	5	5	5	6	7
11. French	62	74	81	90	98	109	120
12. German	9	11	12	13	14	16	18
13. Spanish	6	7	8	8	9	10	11
14. Biology	64	75	82	92	100	111	122
15. Physics	8	9	11	12	13	14	15
16. Chemistry	12	14	16	17	19	21	23
17. Psychology	68	79	87	97	106	117	129
18. Biochemistry	6	7	8	8	9	10	11
19. Technological Econ.	8	9	11	12	13	14	15
20. Educ. & Biology)							
21. Educ. & Chemistry)							
22. Educ. & English)							
23. Educ. & French)	Students wishing to take these programmes apply for the non-Education subject						
24. Educ. & German)							
25. Educ. & History)							
26. Educ. & Maths)							
27. Educ. & Spanish)							
	575	675	750	825	900	1000	1100

7.5.2 "Base-line" study : results

(i) Student numbers and academic staffing

Resultant staff allocation for each subject for each year of the quinquennium is presented in Table 7.6. Some observations can be made from these results.

It can be seen that attempting to develop in this way is likely to result in certain subject areas acquiring very large numbers of academic staff. For example this projection predicts 42 staff in Psychology, 40 in Sociology and 38 in English. The question as to what is the maximum desirable level of academic staff in a given subject area is a highly debatable one. There are certain advantages which may accrue from large size; a wider range of expertise resulting in a more comprehensive range of optional courses, for instance, or the possibility of setting up a "centre of excellence" in a particular subject area. (The University of Essex for example has deliberately created a small number of large departments with just this end in view). On the other hand it may well be undesirable (particularly in a small University) for a few subjects to develop to such an extent that they might tend to dominate the rest of the University. There is also the question as to whether the University is happy with these particular subject areas (Sociology, Psychology and English) securing what might become a pre-eminent position.

Table 7.7 presents some of the largest departments in these subject areas in both Scotland and the U.K. (source: Commonwealth Universities Yearbook, 1974). This survey indicates that on the basis of this projection some Stirling departments would become amongst the largest in the U.K.

TABLE 7.6

BASE LINE STUDY : PROJECTED ACADEMIC STAFFING

Subject	1975-6	76-7	77-8	78-9	79-80	80-1	81-2
1. Maths	7	8	8	9	10	11	12
2. Economics	19	20	22	25	27	29	32
3. Sociology	21	22	25	28	32	36	40
4. English	19	20	23	26	30	34	38
5. History	16	17	20	23	25	29	32
6. Philosophy	11	12	13	15	16	18	20
7. Acc. & Bus. Law	9	9	11	12	14	15	17
8. Religious Studies	6	6	7	8	8	9	10
9. Management Science	10	10	11	12	13	14	15
10. Computing Science	8	8	8	9	10	11	12
11. French	12	13	15	16	19	21	23
12. German	9	10	11	12	13	14	16
13. Spanish	7	7	8	9	9	10	11
14. Biology	18	18	21	23	26	29	33
15. Physics	9	9	10	11	11	12	13
16. Chemistry	11	11	13	14	15	16	18
17. Psychology	23	24	27	30	34	38	42
18. Int. Science	3	3	3	3	4	4	4
19. Fine Arts	3	3	3	4	4	4	4
20. Biochemistry	7	7	7	8	8	9	10
21. Education	9	9	10	12	13	15	16
TOTAL	237	246	276	309	341	378	418

TABLE 7.7

SOME LARGE SUBJECT DEPARTMENTS IN SCOTLAND AND THE UK

Psychology

Sussex	26	-	Academic staff
Glasgow	15	-	" "
Strathclyde	14	-	" "

Stirling 1981/2 projection - 42 academic staff

Sociology

Manchester	35	-	Academic staff
Edinburgh	27	-	" "
Aberdeen	22	-	" "

Stirling 1981/2 projection - 40 academic staff

English

Leeds	40	-	Academic staff
Edinburgh	40	-	" "
Glasgow	24	-	" "

Stirling 1981/2 projection - 38 academic staff

History

Manchester	38	-	Academic staff
Edinburgh	34	-	" "
Glasgow	33	-	" "

Stirling 1981/2 projection - 32 academic staff

TABLE 7.8

BASE LINE STUDY : PROJECTED STUDENT : STAFF RATIOS

Subject	1975-6	76-7	77-8	78-9	79-80	80-1	81-2
1. Maths	4.4	4.4	4.9	4.8	4.8	4.8	5.0
2. Economics	8.3	8.5	8.7	8.5	8.7	8.9	8.9
3. Sociology	13.2	13.2	12.8	12.8	12.4	12.2	12.1
4. English	14.1	14.0	13.5	13.4	12.8	12.5	12.3
5. History	12.9	13.0.	12.2	11.9	12.1	11.5	11.5
6. Philosophy	8.8	8.7	9.0	8.7	9.1	8.9	8.9
7. Acc. & Bus. Law	11.2	11.0	10.1	10.3	9.9	10.2	9.8
8. Religious Studies	4.5	4.6	4.7	4.6	5.3	5.2	5.2
9. Management Science	3.7	4.1	4.3	4.4	4.5	4.6	4.9
10. Computing Science	4.0	4.1	4.7	4.5	4.7	4.7	4.9
11. French	8.1	7.8	7.4	7.8	7.4	7.4	7.4
12. German	5.6	5.3	5.4	5.5	5.7	6.0	5.8
13. Spanish	3.3	3.4	3.5	3.5	3.9	3.9	3.9
14. Biology	10.2	10.6	9.9	10.2	10.0	9.9	9.6
15. Physics	2.2	2.3	2.2	2.2	2.5	2.6	2.7
16. Chemistry	5.9	6.2	5.7	6.0	6.2	6.4	6.3
17. Psychology	12.0	12.0	11.7	11.9	11.5	11.4	11.3
18. Integrated Science	1.5	1.8	2.2	2.5	2.0	2.3	2.5
19. Fine Arts	6.4	7.1	8.2	7.3	7.9	8.7	9.7
20. Biochemistry	4.3	4.1	4.7	4.6	5.2	4.9	4.9
21. Education	11.7	11.9	12.7	11.7	12.0	11.6	12.0

Resulting student:staff ratios throughout the quinquennium are shown in Table 7.8. It can be seen that by the end of the quinquennium no subject has a ratio significantly more unfavourable than 12:1. A general tendency throughout the quinquennium is for the student:staff ratios of subjects with large student numbers to gradually fall and for the ratios of subjects with low student numbers to rise (although some of these departments still have very low ratios at the end of the quinquennium). This occurs because subjects with small numbers are using their resources more effectively at the end of the quinquennium thus releasing additional resources for large student number subjects.

Student:staff ratios are very low in some subjects even at the end of the quinquennium indicating that there is ample scope for this process to continue. Units costs are based on pricing levels (including academic staff salaries) of June 1975 .

(ii) Finance

A table of unit cost per full time student equivalent is presented in Table 7.9. These costs are of course in any case generally higher for Science and other experimental subjects because of the costs of employing technical staff and consequential higher levels of departmental expenditure.

The trend discussed in the previous section can, however, be detected in that unit cost of subjects with large student numbers tend to rise throughout the quinquennium whilst unit costs of subjects with small student numbers tend to fall; eg unit costs for English rise from £384 to £442 during the quinquennium whilst those for Physics fall from £4144 to £3535 and those for Chemistry fall from £1614 to £1470. Fig 7.1 shows projected variations in unit costs for a certain subject over the quinquennium.

Fig. 7.1 Some unit costs: Base line projection

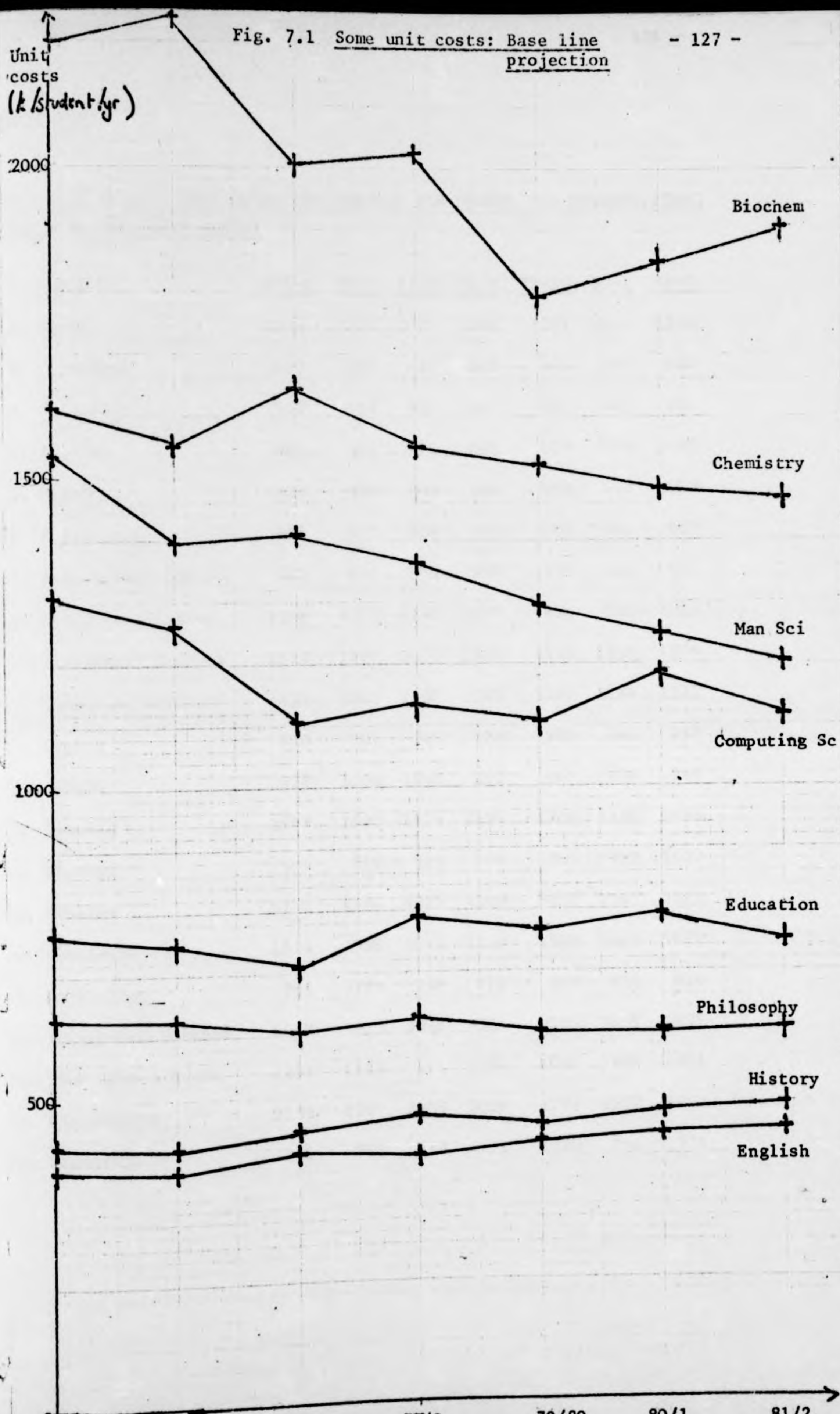


TABLE 7.9

BASE LINE STUDY : UNIT COSTS PER SUBJECT (IN POUNDS/fte STUDENT/YEAR) (BASED ON JUNE 1975 COSTS)

Subject	1975-6	76-7	77-8	78-9	79-80	80-1	81-2
1. Maths	1213	1207	1070	1069	1101	1163	1102
2. Economics	677	655	639	662	646	631	637
3. Sociology	417	419	437	440	455	463	468
4. English	384	383	410	403	423	439	442
5. History	428	420	444	469	453	477	483
6. Philosophy	635	630	604	627	600	603	607
7. Acc. & Bus. Law	467	472	563	539	550	540	561
8. Religious Studies	1150	1117	1133	1137	996	985	1011
9. Management Science	1539	1398	1409	1363	1295	1249	1205
10. Computing Science	1311	1260	1106	1137	1107	1184	1117
11. French	693	707	746	722	752	742	767
12. German	927	1008	1048	999	953	905	948
13. Spanish	1677	1590	1514	1524	1365	1396	1473
14. Biology	949	914	969	964	969	982	1022
15. Physics	4144	3954	4221	4346	3833	3780	3535
16. Chemistry	1614	1556	1641	1554	1522	1482	1470
17. Psychology	781	774	790	776	808	810	816
18. Integrated Science	5617	4911	3935	3521	4590	3856	3606
19. Fine Arts & Music	1251	1129	971	1136	1044	954	851
20. Biochemistry	2199	2267	2005	2026	1793	1850	1904
21. Education	762	753	713	795	770	796	775

As explained earlier increases in staff numbers in subject areas with few students results in resources being used more effectively and enable additional resources to be allocated to subjects with larger student numbers.

It is clear, however, that further economics should still be available for even at the end of the quinquennium, unit costs are comparatively high in a number of subject areas.

(iii) Space

The projected situation with respect to different categories of physical space will now be considered. Categories of space in question are:-

(a) Lecture and seminar room space.

(b) Teaching lab space.

(c) Research lab space.

(d) Office space.

(a) Lecture and Seminar Room Space

The projected utilisation of lecture theatre and seminar room space during the next quinquennium is presented in Table 7.10. These results suggest that on the basis of this projection the University's need for this type of space should be satisfied. It is, of course, important when analysing these results not to consider each size category in isolation. The module allocates each class to the minimum size category into which it can fit. It is in practice, of course, always possible to hold a class in a larger room and hence the utilisation of adjacent room size categories must be considered. For example in 1981/2 we find that the projected utilisation of 41-60 place rooms appears high (92.5%) but that there is a correspondingly low utilisation of the next largest size room size category (61-80 seats having 27.5% utilisation).

Seminar room space is particularly important but this projection implies that utilisation will have reached only 70% by the end of the quinquennium.

In practice it is important that projected space utilisation should not tend towards 100%. Although very high utilisation may appear to indicate that space is being used very efficiently, in this situation space availability would become an over-riding constraint on the teaching timetable, with probably severe damage to the flexibility of the University's academic system.

(b) Teaching Lab Space

The position with respect to teaching laboratory space in 1981/2 is summarised in Table 7.11.

It seems there could be capacity problems in the Biological Sciences by the end of the quinquennium. The projected demand for the largest Biology lab is considerably in excess of capacity. This demand could, however, be met by splitting some of the larger classes and assigning them to the 30 or 40 seat laboratory. If this was done then demand for laboratory space could be barely met from existing capacity.

Biochemistry, too, would appear to come very close to filling existing capacity by the end of the quinquennium. Laboratory space in the Physical Sciences, however, is projected to be under-utilised. Hence there arises the possibility of switching space from the Physical sciences to the Biological sciences. Because of the University's uniform building structure this is perfectly feasible in practice.

Thus, to summarise the position, it is likely that total teaching laboratory capacity would be adequate but it could prove necessary to switch space from Physical science to Biological science.

(c) Research Lab Space

The position with respect to research lab space at the end of the quinquennium is indicated in Table 7.12(a). These results indicate that total research laboratory capacity will not be quite adequate by the end of the quinquennium if present space norms are adhered to. Also indicated is the need for a reallocation of substantial amounts of space from the Physical sciences to the Biological Sciences and Psychology towards the end of the quinquennium. This should be feasible, given the flexible design of the University laboratories and that no separate departmental buildings exist.

(d) Office Space

The results of the office space projection are given in Table 7.12(b). The indication is that total designated space together with the reserve area should be just about adequate for requirements at the end of the quinquennium.

The areas designated to certain subjects, however, (such as Chemistry, Maths, Management Science and Education) are substantially in excess of requirements and it will be necessary by the end of the quinquennium to reallocate this surplus to subjects with deficiencies in office space. Such a reallocation, however, should not present too many problems. A given subject is allocated a certain number of offices in a particular corridor with no clear demarcation lines from other subjects and thus in no sense can anyone conceive of "owning" a given block of offices as might be the case if separate departmental buildings had been constructed.

Thus, to summarise, total office-space should be adequate providing the University is prepared to exercise flexibility in the reallocation of this space.

TABLE 7.10

LECTURE AND SEMINAR SPACE UTILIZATION

Type of Room (Capacity)	Hours Available	% Utilization						
		75/6	76/7	77/8	78/9	79/80	80/1	81/2
1 - 24	920	56.0	56.0	59.0	62.0	65.0	67.0	70.0
25 - 40	80	41.2	50.0	48.7	45.0	40.0	42.5	37.5
41 - 60	40	132.5	107.5	82.5	82.5	72.5	80.0	92.5
61 - 80	80	10.0	32.5	47.5	42.5	31.3	33.8	27.5
81 - 110	40	37.5	15.0	10.0	32.5	92.5	92.5	77.5
111 - 150	40	37.5	30.0	25.0	25.0	20.0	27.5	47.5
151 - 250	120	7.5	7.5	11.7	12.5	12.5	14.2	15.0
251 - 350	40	7.5	20.0	20.0	40.0	50.0	50.0	67.5

TABLE 7.11

TEACHING LAB UTILIZATION (1981/2) - "BASE-LINE" PROJECTION

Biology					
Lab capacities (places)	12	30	46	70	
Hours used	-	-	8	64	
% Utilization	0.0	0.0	22.2	177.8	
Physics					
Lab capacities (places)	5	8	12	21	25
Hours used	12	-	-	4	8
% Utilization	33.3	0.0	0.0	11.11	22.2
Chemistry					
Lab capacities (places)	18	26	43	45	
Hours used	11	-	4	20	
% Utilization	15.3	0.0	11.1	55.6	
Psychology					
Lab capacities (places)	20	41	61	90	
Hours used	-	-	-	31	
% Utilization	0.0	0.0	0.0	86.1	
Int. Science					
Lab Capacities (places)	2	24			
Hours used	-	16			
% Utilization	0.0	44.4			
Biochemistry					
Lab capacities (places)	12				
Hours used	68				
% Utilization	94.4				

TABLE 7.12(a)

RESEARCH LAB SPACE - "BASE-LINE" PROJECTION

Subject	75/6	81/2	Total area Designated
Biology	595 sq.m.	1045 sq.m.	724 sq.m.
Physics	165	264	438
Chemistry	220	374	617
Psychology	484	858	606
Int. Science	33	44	33
Biochemistry	121	187	109
	1617	2772	2527

TABLE 7.12(b)

OFFICE SPACE

Subject	75/6	81/2	Total area Designated
Maths	101 Sq.m.	181 sq.m.	416 sq.m.
Economics	282	482	460
Sociology	309	604	424
English	282	570	420
History	242	482	358
Philosophy	167	296	155
Acc. & Bus. Law	128	255	140
Religous Studies	88	149	100
Management Sc.	149	221	380
Computing Sc.	115	181	80
French	181	348	368
German	128	242	235
Spanish	101	167	120
Biology	269	495	485
Physics	128	194	144
Chemistry	167	269	538
Psychology	348	631	545
Int. Science	40	61	80
F. Arts & Music	40	61	40
Biochemistry	101	149	104
Education	128	242	395
Reserve	-	-	286
Total	3494	6280	6273

7.6 Revised Projection : Academic Council Assumptions

This revised projection is based on the same overall growth pattern in total student numbers as in the base-line projection but takes into account certain objectives, assumptions and constraints suggested by the Academic Council. These are the following:-

(i) Total Resources

The UGC has hinted that overall resources may be reduced during the quinquennium and that as a result the global student:staff ratio for the University as a whole may be allowed to deteriorate from 9:1 to 10:1 over the quinquennium (this corresponds to an effective reduction in level of funding of 10%). If this deterioration is assumed to take place gradually over the quinquennium a plausible path could be:-

1975/6 and 1976/7	9.0:1
1977/8	9.2:1
1978/9	9.4:1
1979/80	9.6:1
1980/1	9.8:1
1981/2	10.0:1

(ii) Proportion of Science Undergraduates

In the early part of this dissertation we remarked that the original University development plan envisaged that around 1/3 of the University's undergraduates should study science-based subjects. Unfortunately, in practice, it has not been possible to achieve this target (largely owing to the lack of student interest in studying the physical sciences) and the proportion of science-based undergraduates in the University has remained at a little over 15%. Thus the Academic Council now regard the original target of 33% science-based students as a fairly long-term aim. Nevertheless, INSET 7.1

%fte UGs 75/6	Subject	%fte UGs in 1981/82
0.7	Physics	1.4
1.6	Computing Science	2.1
1.4	Biochemistry	2.4
1.5	Maths	2.7
3.0	Chemistry	4.6
7.7	Biology	9.2

For further discussion see Chapt. 8.1

it was still hoped to substantially improve the proportion of science-based students by the end of the quinquennium and it was suggested that a reasonable objective might be to increase the proportion of science-based undergraduates by 50%, thus bringing the overall proportion of science-based undergraduates up to 23%. Such an improvement, however, could only be possible if there were substantial increases in the Physical Sciences area, since Biology may be near saturation. Proportions of fte UGs at beginning and end of the quinquennium is given in inset 7.1 opposite, (projections)

(iii) New Academic Developments

The advent of a new quinquennium affords a University the possibility of planning new academic developments in the hope that approval and, thus, support may be obtained from the UGC. Prospects of such development are particularly important to institutions contemplating future growth. Such academic development can take place in two ways:-

(1) Extending an existing programme of study (eg introducing a single Honours programme in a subject area which could previously only be studied as part of a joint Honours degree; introducing into a general degree programme a subject which was previously only offered as a Part I minor).

(2) Making innovations in subject areas not offered previously at Stirling. Certain proposed new academic developments were tentatively adopted by the Council for possible introduction during the quinquennium. A list of these proposed developments is presented in Table 7.13. It was estimated that if these developments were to become fully viable they might involve something in the order of fifty additional academic staff by the end of the quinquennium. Since it has been assumed that by this time the overall student: staff ratio will have deteriorated to 10:1, such developments would therefore need to attract around 500 student equivalents to obtain their full quota of associated students.

TABLE 7.13

MAJOR NEW PROJECTED DEVELOPMENTS

Undergraduate

Programmes in new subject areas

Single Honours programme in Environmental Science

Single Honours programme in Political Studies

Developments in existing subject area

Single Honours in Spanish (at present only available as part of a combined Honours degree).

Single Honours in Accountancy & Business Law (at present only available as part of a combined Honours degree).

General and Combined Honours programmes in Music (previously only available as a Part I minor).

Miscellaneous Developments in Part I (eg communication media, film studies, further developments in Fine Arts)

Postgraduate Developments

M.Lit. in Scottish Studies

M.Sc. in Social Administration

M.Sc. in Applied Social Research

M.Sc. in Aquaculture

M.Ed. in Research Methodology.

If this growth is achieved then such new developments will account for around 13% of total University student numbers by the end of the quinquennium and for 30% of the projected growth during this period. Thus, the remainder of the projected growth would be expected to occur in existing developments.

These new developements would be phased in gradually during the quinquennium. Such an approach has obvious advantages for administrative convenience and, in any case, is inescapable in the case of new degree programmes which take three or four years to build up to their full complement.

If we assume an approximately uniform build up in student numbers in new developments we have the following:-

Year	Student Nos. Taking New Developments	Corresponding Academic staff Nos.
1977/8	104	11
1978/9	208	22
1979/80	310	32
1980/1	400	41
1981/2	492	49

(iv) Undergraduate, Postgraduate Projections

It was decided that, in view of subject distribution at Stirling, it would be appropriate to maintain approximately the same ratio of undergraduates to postgraduates as had existed previously. It was also decided that postgraduate studies should similarly have a proportionate share of new academic developments.

7.7 Approach to projection (Academic Council assumptions)

Firstly, it is important to decide how to incorporate new academic developments into the analysis. Such developments will constitute around 4% of the University's total activity in the first year of the quinquennium, growing to around 13% of total activity by the final year of the quinquennium. These new developments will interact with the rest of the University system (ie students in existing programmes of study will take courses in new development subject areas and vice versa)

Because of the flexible mode of construction of the model there are no inherent difficulties in introducing new programmes of study or new subjects. Since, however, new developments will, even by the end of the quinquennium, constitute only a small proportion of total University activity it may be sensible to treat such developments as an aggregated quantity which is independent of the rest of the system. This approach can be justified on the following grounds.

(1) The total projected size of new developments is reasonably small compared with existing developments.

(2) Since there is no historical information on interactions between new developments and existing developments it would be necessary to estimate them subjectively. Thus the model data would become an intimate mixture of the historically derived and the subjectively estimated.

(3) Although it is perfectly feasible to introduce new programmes and subjects into the model, considerable additional effort would be required to harmonize the data base. For instance it would be necessary to revise the induced course load matrix for most years of the quinquennium to allow for these developments. It is very doubtful whether any additional information which could be obtained would justify such substantial additional effort.

TABLE 7.14

ADMISSION TO PROGRAMMES : PROJECTION ON ACADEMIC COUNCIL ASSUMPTIONS

	Programme	75/6	76/7	77/8	78/9	79/80	80/1	81/2
1.	Maths	7	14	18	24	27	30	32
2.	Economics	27	30	28	30	33	37	39
3.	Sociology	58	65	61	65	70	78	83
4.	English	90	101	93	99	108	120	128
5.	History	70	78	73	77	85	94	100
6.	Philosophy	10	11	11	12	13	14	15
7.	Acc. & B.L.	62	70	65	69	76	84	89
8.	Religous Studies	3	4	4	4	4	4	5
9.	Management Sc.	2	3	3	3	3	4	4
10.	Computing Sc.	3	5	6	7	8	9	9
11.	French	62	71	67	70	76	84	90
12.	German	9	10	10	10	11	12	13
13.	Spanish	6	7	6	7	7	8	8
14.	Biology	64	78	80	91	100	111	118
15.	Physics	8	14	17	23	25	28	30
16.	Chemistry	12	18	21	28	30	33	36
17.	Psychology	68	76	71	75	81	92	96
18.	Biochemistry	6	9	12	15	17	18	20
19.	Tech. Ec.	8	11	13	16	17	19	21
20.	Educ. & Biology	Students wishing to take these subjects apply for the non-Education subject.						
21.	Educ. & Chemistry							
22.	Educ. & English							
23.	Educ. & French							
24.	Educ. & German							
25.	Educ. & History							
26.	Educ. & Maths							
27.	Educ. & Spanish							

Thus the following growth pattern of aggregate student numbers will be assumed.

Year	Undergraduate Existing Dev.	Undergraduate New Dev.	Undergraduate Total	Postgraduate Existing Dev.	Postgraduate New Dev.	Postgraduate Total
1975/6	1933	-	1933	200	-	200
1976/7	2033	-	2033	210	-	210
1977/8	2154	95	2249	226	9	235
1978/9	2331	189	2520	241	19	260
1979/80	2514	282	2796	262	28	290
1980/1	2727	363	3090	283	37	320
1981/2	2960	444	3404	307	48	355

The intake of undergraduates to programmes assumed for this projection is given in Table 7.14.

7.8 Results of projection (Academic Council assumptions)

(i) Academic staffing and student numbers

The projected build up of academic staff over the quinquennium is given in Table 7.15. In this projection problems associated with certain departments reaching excessively large sizes are considerably eased. For instance at the end of the quinquennium Psychology has 32 staff (previously 42), Sociology has 29 staff (previously 40) and English has 26 staff (previously 38). The reduction is caused partly by the introduction of new developments, increase in proportion of Science students and the reduction in the overall level of University resources. Thus from this aspect these results could be considered a considerable improvement over the base line projection which showed some subjects gaining over 40 staff and becoming amongst the biggest in the U.K.

TABLE 7.15

ACADEMIC STAFFING : PROJECTION ON ACADEMIC COUNCIL ASSUMPTIONS

	Department	75/6	76/7	77/8	78/9	79/80	80/1	81/2
1.	Maths	7	8	8	9	10	11	11
2.	Economics	19	20	21	22	23	24	26
3.	Sociology	21	22	23	24	26	27	29
4.	English	19	20	20	22	23	24	26
5.	History	16	17	18	19	20	21	23
6 .	Philosophy	11	11	12	12	13	14	15
7.	Acc. & B.L.	9	9	10	10	11	12	12
8.	Religous Studies	6	6	7	7	7	7	7
9.	Management Sc.	10	10	11	11	11	12	13
10.	Computing Sc.	8	8	8	9	9	10	10
11.	French	12	13	13	14	14	15	16
12.	German	9	10	10	10	11	11	12
13.	Spanish	7	7	7	7	8	8	8
14.	Biology	18	19	20	22	24	26	27
15.	Physics	9	9	10	10	10	11	11
16.	Chemistry	11	11	12	13	15	16	17
17.	Psychology	23	24	25	27	29	30	32
18.	Int. Science	3	3	3	3	3	4	4
19.	Fine Arts	3	3	3	3	3	3	3
20.	Biochemistry	7	7	7	7	8	9	9
21.	Education	9	9	10	10	11	12	13
	TOTAL	237	246	258	270	289	307	325
	New Developments	-	-	11	22	32	41	49

TABLE 7.16

STUDENT-STAFF RATIO - PROJECTION ON ACADEMIC COUNCIL ASSUMPTIONS

	Subject	75/6	76/7	77/8	78/9	79/80	80/1	81/2
1.	Maths	4.4	4.7	5.4	6.0	6.4	6.8	7.7
2.	Economics	8.3	8.5	8.6	8.9	8.9	9.3	9.2
3.	Sociology	13.2	13.1	13.1	13.1	12.8	13.2	13.3
4.	English	14.1	13.9	14.6	13.8	13.7	13.8	13.7
5.	History	12.9	12.9	12.7	12.5	12.4	12.6	12.4
6.	Philosophy	8.8	9.4	8.8	9.2	9.2	9.4	9.5
7.	Acc. & B.L.	11.2	11.0	10.4	10.9	10.7	10.2	11.0
8.	Religous Studies	4.5	4.5	4.3	5.0	4.4	4.8	5.6
9.	Management Sc.	3.7	4.2	4.3	4.8	5.1	5.3	5.3
10.	Computing Sc.	4.0	4.2	4.6	4.8	5.7	5.8	6.4
11.	French	8.1	7.7	7.8	7.7	8.0	8.0	8.0
12.	German	5.6	5.2	5.5	5.8	5.6	5.9	5.6
13.	Spanish	3.3	3.4	3.7	3.8	3.7	3.9	3.9
14.	Biology	10.2	10.3	10.7	11.0	11.2	11.4	11.8
15.	Physics	2.2	2.4	2.5	3.2	3.8	4.0	4.7
16.	Chemistry	5.9	6.6	6.6	7.3	7.7	8.2	8.7
17.	Psychology	12.0	12.1	12.2	12.0	11.9	12.2	12.4
18.	Int. Sc.	15.	1.9	2.5	3.4	3.8	3.2	3.5
19.	Fine Arts	6.4	7.0	7.5	7.9	8.4	9.6	10.4
20.	Biochemistry	4.3	4.1	4.8	6.1	6.7	7.4	8.4
21.	Education	11.7	11.9	12.3	13.0	12.9	13.0	12.8
New Developments		-	-	9.2	9.4	9.6	9.8	10.0

Resulting student:staff ratios for this projection are given in Table 7.16. A point to note is that the student:staff ratio for medium or large non-Science departments has either marginally or only very slightly declined over the quinquennium in spite of the fact that this projection assumes at 10% cut in overall resources. This is thanks to the improved performance in the Sciences assumed in this projection (ie Maths changes from 4.4:1 over the quinquennium to 7.7:1, Computing Science changes from 4.0:1 to 6.4:1, Biology from 10.2:1 to 11.8:1, Physics from 2.2:1 to 4.7:1, Chemistry from 5.9:1 to 8.7:1 and Biochemistry from 4.3:1 to 8.3:1). Thus, in general, the reduction in overall level of resources is compensated by the more effective utilisation of resources by the Science-based subjects owing to their increased size.

(ii) Finance

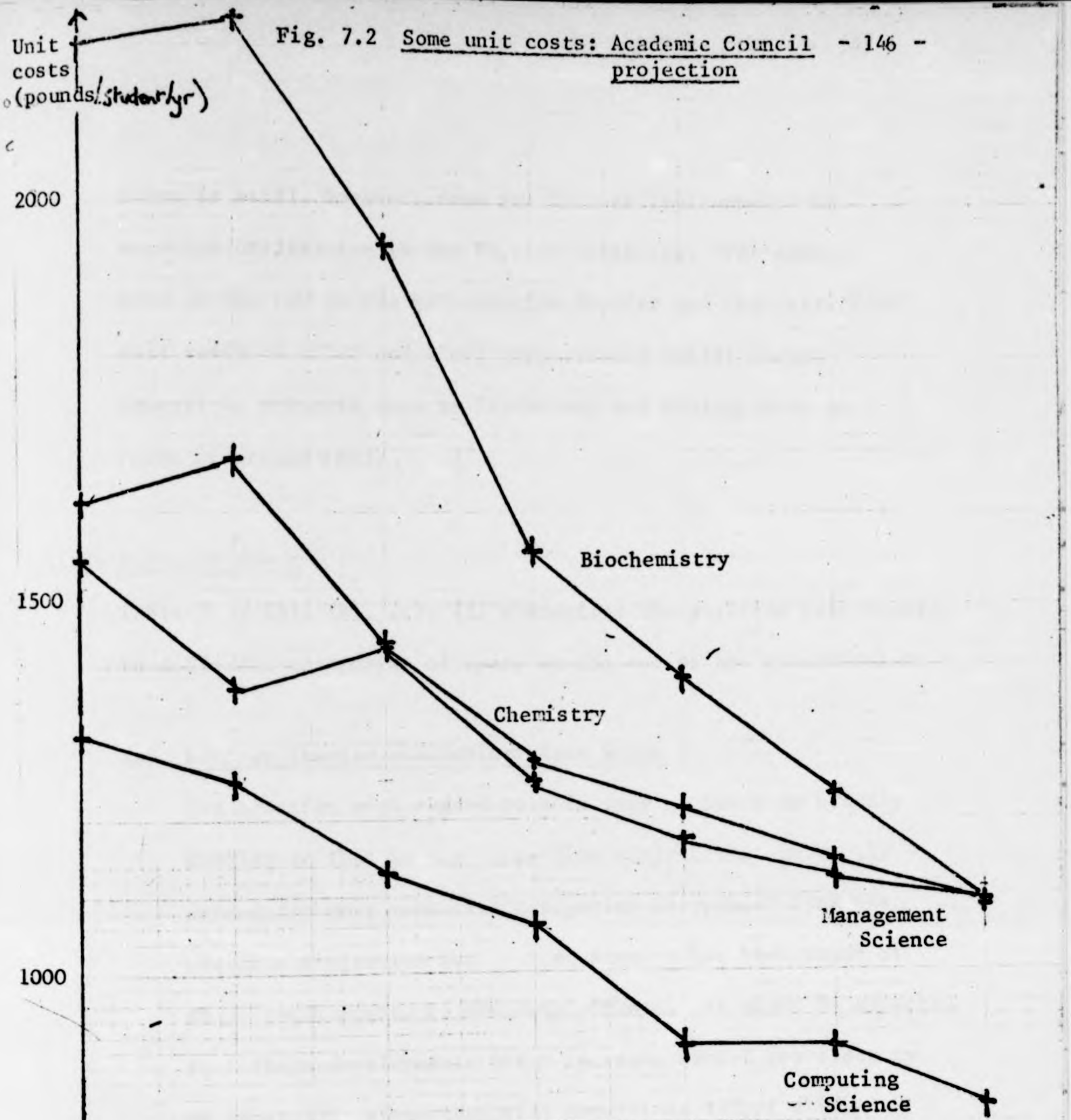
Unit costs (calculated on the same basis as before) over the quinquennium for this projection are shown in Table 7.17. These results are consistent with the conclusions in the last section in that resources available to medium and large non-science subjects remain broadly constant in spite of the cut in overall funding assumed during the quinquennium. This is shown in these results by broadly constant unit costs in these subjects during the quinquennium. As expected there are substantial reductions in projected unit costs for Science subjects (especially in the Physical sciences where, for instance, unit costs for Physics reduce from £4144 to £2098, Maths from £1213 to £732, etc). Thus, as explained earlier, more effective utilization of resources (though higher student numbers in the generally rather small science departments has compensated for the overall reduction in funding allowing unit costs to remain broadly stable elswhere). Fig. 7.2 exhibits the variation in unit costs for certain subjects over the quinquennium.

TABLE 7.17

PROJECTED UNIT COSTS : PROJECTION ON ACADEMIC COUNCIL ASSUMPTIONS
(IN POUNDS/fte STUDENT/YEAR)

	Subject	75/6	76/7	77/8	78/9	79/80	80/1	81/2
1.	Maths	1213	1126	973	860	823	819	732
2.	Economics	677	654	639	626	638	610	604
3.	Sociology	417	422	436	429	434	425	421
4.	English	384	388	370	390	403	397	393
5.	History	428	425	425	438	438	427	450
6.	Philosophy	635	597	622	594	585	570	572
7.	Acc. & B. Law	467	476	515	489	532	547	508
8.	Religous Studies	1150	1152	1245	1035	1224	1122	962
9.	Management Science	1539	1370	1428	1251	1177	1126	1107
10.	Computing Science	1311	1248	1131	1063	901	900	824
11.	French	693	722	709	713	682	696	701
12.	German	927	1031	972	912	1007	958	983
13.	Spanish	1677	1613	1459	1423	1452	1370	1354
14.	Biology	949	947	906	883	873	852	824
15.	Physics	4144	3862	3834	3103	2503	2421	2098
16.	Chemistry	1614	1671	1433	1278	1216	1148	1081
17.	Psychology	781	769	760	770	777	852	747
18.	Int. Sc.	5617	4488	3453	2575	2316	2826	2568
19.	Fine Arts	1251	1138	1062	1016	948	837	770
20.	Biochemistry	2199	2267	1944	1547	1382	1234	1087
21.	Education	762	753	740	696	731	716	724

Fig. 7.2 Some unit costs: Academic Council projection



There is still, however, room for further improvements in resource utilisation in the Physical sciences. For example even at the end of the quinquennium Physics and Chemistry have unit costs of £2098 and £1081 respectively whilst larger laboratory subjects such as Psychology and Biology have unit costs of around £800.

(iii) <u>Physical Space</u>

Table 7.18 (a), (b), (c), (d) summarises the position with regard to different categories of space at the end of the quinquennium.

(a) <u>Lecture Theatre and Seminar Room Space</u>

The position with regard to this type of space is broadly similar to that in the base-line projection. Generally demand for most room size categories is reduced from the previous projection but no account has been taken of space requirements of new developments. It might be expected that these developments might increase demand for space by at least 13% (since they will constitute 13% of student numbers), but this is uncertain as is the question of the distribution of this demand over the different room size categories. Nevertheless, it would appear that the availability of this type of space should be adequate to meet requirements. because projected utilization in each category is substantially less than 100%.

(b) Teaching Lab Utilization

Again the situation is broadly as before except that utilization of space in the Sciences has increased. The teaching lab space available for Biology and Biochemistry promises to be barely adequate even if Biology classes are split in order to effectively utilise all space allocated. There does, however, appear to be still some excess capacity in the Physical Science whilst Psychology's demands on its laboratory space is reduced from the earlier projection. Teaching laboratory space will have to be provided for one of the University's new developments (Earth and Environmental Sciences) from the existing stock. With a flexible approach to the possibility of subjects sharing space or space reallocation these problems should not prove insurmountable.

(c) Research Lab Space

This situation which is outlined in Table 7.18 (c) is broadly similar to that outlined in the previous projections. Total capacity will be barely adequate if we take into account the likely research lab demands of new developments (Earth and Environmental Science). Again it will be necessary for substantial transfers of space from that designated to the Physical Sciences to the Biological Sciences in order to meet all requirements.

(d) Office Space

This situation is outlined in Table 7.18 (d). It differs from the base line study in that even after allowing for the requirements of new developments there is some spare capacity at the end of the quinquennium. This, of course, is because owing to the reduction in funding there are now less academic and non-academic staff requiring space at the end of the quinquennium.

The block of office space held in reserve will not be adequate to meet all the requirements of the new developments, the rest will have to be met from those subjects whose designated areas are surplus to requirements.

As mentioned previously because of the uniform structure of University buildings there is no physical barrier to such a reallocation.

TABLE 7.18

PHYSICAL SPACE : PROJECTIONS ON ACADEMIC COUNCIL ASSUMPTIONS

(a) Lecture and Seminar Space 1981/2

Class Size	Hours Avail.	A.C. Projection % Utilization	Base-line projection % Utilization
0 - 24	920	64.0	70.0
25 - 40	80	46.3	37.5
41 - 60	40	82.5	92.5
61 - 80	80	25.0	27.5
81-110	40	82.5	77.5
110-150	40	47.5	47.5
151-250	120	15.0	15.0
251-350	40	40.0	67.5

(Note: New Developments not taken into consideration).

TABLE 7.18 (Continued)

PHYSICAL SPACE : PROJECTIONS ON ACADEMIC COUNCIL ASSUMPTIONS

(b) Teaching Lab Utilization (1981/2)

Biology

Lab Cap. (space)	12	30	40	70	
Hours used	-	-	8	68	
% Utilization	0.0	0.0	22.2	188.8	

Physics

Lab Cap.(space)	5	8	12	21	25
Hours used	-	-	12	4	8
% Utilization	0.0	0.0	16.6	11.1	22.2

Chemistry

Lab Cap. (space)	18	26	43	45
Hours used	3	4	4	32
% Utilization	4.1	11.1	11.1	88.9

Psychology

Lab Cap. (space)	20	41	61	90
Hours used	-	-	4	24
% Utilization	0.0	0.0	11.1	66.7

Int. Science

Lab Cap. (space)	2	24
Hours used	-	20
% Utilization	-	55.5

Biochemistry

Lab Cap. (space)	12
Hours used	88
% Utilization	122.2

TABLE 7.18 (Continued)

PHYSICAL SPACE : PROJECTIONS ON ACADEMIC COUNCIL ASSUMPTIONS

(c) Research Lab Space (1981/2)

Subject	75/6	81/2	Capacity
Biology	594 sq.m.	880 sq.m.	724 sq.m.
Physics	165	220	438
Chemistry	220	330	617
Psychology	484	693	606
Int. Science	33	44	33
Biochemistry	121	165	109
	1617	2332	2527

New Developments Earth and Environmental Science 200-300 sq. metres.

TABLE 7.18 (Continued)

PHYSICAL SPACE : PROJECTIONS ON ACADEMIC COUNCIL ASSUMPTIONS

(d) Office Space (1981/2)

Subject	1975/6	1981/2	Total area designated
Maths	101	167	416
Economics	282	389	460
Sociology	309	436	424
English	282	389	420
History	242	348	358
Philosophy	167	221	155
Acc. & Bus. Law	128	181	140
Religious Studies	88	101	100
Management Science	149	194	380
Computing Science	115	149	80
French	181	242	368
German	128	181	235
Spanish	101	128	120
Biology	269	402	485
Physics	128	167	144
Chemistry	167	255	538
Psychology	348	482	545
Integrated Science	40	61	80
Fine Arts & Music	40	40	40
Biochemistry	101	128	104
Education	128	194	395
New Dev	-	761	286
Total	3494	5616	6273

BIBLIOGRAPHY : Chapter 7

109 Commonwealth Universities Yearbook (1974). Commonwealth Universities Yearbook, Association of Commonwealth Universities.

110 Lord Crowther Hunt (1975). Times Higher Educational Supplement, May 1975.

111 Scottish Education Dept (1975). Letter to University of St Andrews (9/5/75) (from J S Fearn Esq).

112 M G Simpson et alia (1971). Planning University Development - Studies in Institutional Management in Higher Education. CERI, OECD, Paris. Page 21.

113 UGC (1975). Letter to University of Stirling (24/4/75). (Ref 39/125/02).

CHAPTER 8

REVIEW AND SENSITIVITY ANALYSIS

8.1 Plausibility of Assumptions in Academic Council's projection

The projection described in the latter half of the previous chapter incorporates a number of developments suggested by the Council. Our purpose in this Chapter is to examine the possibility of actually being able to achieve this development and explore possible consequences of failing to meet certain targets. The most important developments incorporated into this projection were:-

(1) Certain new academic developments would be made; these would attract their corresponding quota of students according to the prevailing overall student:staff ratio for a given year (eg if 50 staff were allocated to new developments and the prevailing overall student:staff ratio was 10:1, then we would expect 500 students to be studying the new developments).

(2) The proportion of Science undergraduates in the University was hoped to increase to around 23% overall by the end of the quinquennium.

The likely student demand for new suggested academic developments together with a review of the situation with regard to the sciences will be examined in the light of statistics produced by the University Central Council on Admissions (UCCA) for the years 1970-4. These statistics give information on the numbers of students applying for and gaining admittance to UK Universities through the UCCA scheme. These statistics do not, however, distinguish students of Scottish origin and we have mentioned before that over 75% of Stirling students come from Scotland. Even if such figures were issued, they would be inconclusive since three of the eight Scottish Universities (Glasgow, Strathclyde and Aberdeen) make admissions outwith the UCCA scheme. Thus, we shall have to base our analysis on UK statistics, which, hopefully, should give a broad indication of the general position, whilst bearing in mind possibilities of a "Scottish dimension" in some cases.

Our approach will be to consider the potential demand for our projected developments and for Science-based subjects during the period 1970-4. Two factors are likely to be very significant in trying to assess possible student demand for a subject. These are:-

(i) Total volume of student demand for that subject (measured in terms of total applications).

(ii) Fraction of total applicants for a subject actually admitted to University.

Factor (i) establishes the global demand for a particular area of study whilst factor (ii) measures how well such demand is being met from existing University programmes.

It was decided that it could be useful to attempt to devise an index of potential student demand for a particular subject or subject area which incorporated both the above factors.

Such an index could be:-

$$\text{Potential demand index} = \frac{\text{Total applications}}{\text{\% of applicants admitted}}$$

Thus, the value of this index will be increased by a rise in total applications for a given subject area (indicating increased demand) and also by a decrease in the proportion of students admitted (usually corresponding to an increase in unsatisfied demand; although an increase in unsatisfactory applicants could in certain cases be a contributory cause).

It should be understood, however, that the behaviour of this index may be statistically invalid for subjects which have very low numbers of total applicants or a low proportion of applicants who are admitted. As remarked earlier changes from year to year in proportion of qualified applicants applying for a given subject may also give rise to misleading interpretations of the index.

This index, of course, only gives a rough and ready indication of the prevailing situation and should be interpreted with some caution. It does, however, have the advantage of being readily understandable and does combine the two factors felt to be most significant.

Major new developments (ie new degree or joint-degree programmes or an extension of an existing development into a degree programme) were tentatively planned in the following fields:-

- Music
- Spanish (ext. of joint-degree programme to full degree programme)
- Accountancy and Business Law
- Political Studies
- Earth and Environmental Science

Earth and Environmental Science impinges on a range of subject areas; hence the UCCA statistics for Geology, other environmental sciences and geography were considered. In the absence of any clearly defined Political studies category, the closest apparent category, Government and Public Administration was used instead.

For each of the above subject categories, total numbers of UCCA applicants and total numbers subsequently admitted to University through UCCA during the period 1970/4 is shown in Table 8.1a. Also shown (in Table 8.1b) is the corresponding demand index for each subject category (with that for English also included for purposes of comparison). Some general deductions can be made from this table.

- The index of potential demand is substantial for subjects in the earth and environmental sciences area. Since, during most of the period in question, less than 50% of potential applicants were admitted, there would appear to be considerable unsatisfied demand in this area. Although the subject categories chosen do not correspond exactly to earth and

Table 8.1a Numbers Applying and Admitted to University through UCCA: New Developments

Subject	1974 A	1974 B	1973 A	1973 B	1972 A	1972 B	1971 A	1971 B	1970 A	1970 B
Earth & Envir. Sci										
35 Geology	1111	658	1196	626	1123	611	1196	547	1096	562
37 Other Envi Sc	871	349	831	295	715	220	645	186	479	174
42 Geogra.	4072	1968	4399	1789	4459	1765	4432	1675	4310	1690
Political Studies										
44 Govt & PA	600	441	603	405	668	380	719	349	612	303
60 Spanish	234	200	294	215	264	222	281	199	299	222
43 Account.	1033	409	776	315	514	179	442	169	383	323
75 Music	988	590	967	473	870	481	817	447	743	403

A = Number applying
B = Number admitted

Table 8.1b New Developments - Potential Demand Index

Subject	1974	1973	1972	1971	1970
Earth & Envir. Sci					
35 Geology	19	23	21	26	21
37 Other Envi Sci	22	24	24	22	13
42 Geogra.	85	107	111	116	111
Pol. Studies					
44 Govt & PA	8	9	12	15	12
60 Spanish	3	4	3	4	4
43 Account.	26	19	15	12	5
75 Music	16	20	16	15	14
English (for comparison)	114	127	140	144	134

environmental science, there does appear at least to be some possibility of obtaining substantial student numbers in this subject area.

Accountancy seems to be an important growth area with a rapid rise of the demand index over the period in question. In most years only around 40% of applicants are admitted which suggests evidence of substantial unsatisfied demand in this area.

- For music, the index of demand has been at a reasonable level although fairly stagnant over the period in question. Spanish has had a uniformly very low index, and the fact that around 85% of all applicants were admitted suggests adequate, or very possibly, excess capacity available in this subject area. It may well be that arguments for introducing the Honours degree in Spanish may have to be made on the basis of this development complementing other work in modern languages rather than any likelihood of substantial student numbers appearing to take this option.

- The outlook for political studies does not appear very promising judging from the index for Government and public administration. Certain reservations about this conclusion, however, must be made owing to the uncertainty as to how well this category represents the political studies field.

- The second major development was the plan to increase the proportion of science undergraduates from around 17% during the present quinquennium to around 23% by the end of the next. This implies, of course, a more than proportional increase in Science students as the University expands.

Table 8.2a presents the relevant statistics on applications and admissions to University through UCCA for Science subjects during the period 1970-4 and Table 8.2b presents the corresponding potential demand indices.

- It can be seen that student demand in the Biological Sciences area has, on the whole, been reasonably stable although there has occured a swing from the more specialised Biology and Zoology courses to the more general Biology courses. A swing in this direction is in Stirling's favour since it offers broader Biological science programmes. Since only around 60% of all applicants for Biology are admitted to University, there could well be scope for further growth in this area.

- Unfortunately, the potential for further expansion in Biochemistry seems somewhat discouraging since the pattern of University admission for this subject during recent years has been one of falling demand and rising percentages admitted (in fact the demand index has been halved during the period in question).

- In the physical sciences, we find that the demand index for Mathematics has dropped substantially during the period under review. Nevertheless, this remains a very popular subject nationally with around 5000 applicants per year and should provide scope for Stirling to add to its present rather meagre numbers. The position with regard to Chemistry and Physics seem very difficult and, in the circumstances, it is not surprizing that Stirling has encountered difficulty in obtaining adequate student numbers in these areas. The index for Chemistry, in particular, has dropped to just over half its previous level with around 90% of all applicants being admitted. Since some applicants will not obtain even the minimum University entry qualificaitons, this figure suggests that even minimally qualified applicants are admitted, and may indicate substantial space capacity in this subject area.

Table 8.2a Numbers Applying and Admitted to University through UCCA: Science Subjects

Subject	1974 A	1974 B	1973 A	1973 B	1972 A	1972 B	1971 A	1971 B	1970 A	1970 B
25 Biology	1958	1454	1873	1254	1680	1033	1652	924	1481	927
26 Botany	238	272*	213	268	285	304	312	293	341	344
27 Zoology	935	705	953	656	1272	740	1428	747	1351	749
29 Biochem.	1085	1063	1088	983	1287	908	1279	814	1246	736
31 Maths	4744	3467	5000	3523	5451	3687	6041	3909	5453	3641
33 Physics	2471	2064	2479	2091	2807	2280	3017	2507	2795	2450
34 Chem.	2194	2021	2392	2105	2857	2460	3405	2723	3545	2889
55 English	5582	2762	5858	2692	6047	2628	5897	2427	5747	2457

Table 8.2b Index of Potential Demand: Science Students

Subject	1974	1973	1972	1971	1970
25 Biology	26	28	28	30	24
26 Botany	2	2	3	3	3
27 Zoology	12	24	27	27	25
29 Biochem.	11	12	18	20	21
31 Maths	65	71	80	93	85
33 Physics	29	32	35	36	40
34 Chem.	24	27	33	43	44
55 English	114	127	140	144	134

* Some years more students were admitted for Botany than who actually applied - this may be due to students being admitted who originally applied for some other subject.

Thus, to summarise the above arguments, Stirling has been attempting to develop its Science activities at a time when national student demand for Science courses has been either stagnant or contracting. Unless this trend is reversed, it could prove difficult for Stirling to achieve even its very modest targets for Science numbers next quinquennium.

We must examine the question as to whether there is any action Stirling can undertake to improve its prospects with regard to Science numbers. Obviously improved reputations of the Stirling science departments would be useful in this connection although, essentially, this is a long-term process and there are unlikely to be many Nobel prize winners at Stirling in the near future! Visits to schools by members of staff and visits by schools to Stirling University are helpful. Another problem is that Stirling may well be asking for more demanding entry qualifications than other universities. As we have previously mentioned in Chapter 2, at present students are admitted to the University as a whole and roughly the same entry requirements demanded for all areas of study. Thus, it could well be that Stirling is asking for more demanding entry requirements than other institutions - there is evidence that minimal entry requirements a accepted for admission by some Universities for Science subjects. For example the UCCA publish statistics of the upper and lower quartiles 'A' level score of applicants admitted to different subjects through their clearing scheme. (These scores are based on a candidate's best three A level results with 5 points for an A, 4 for a B, 3 for a C, 2 for a D, and 1 for an E. Thus, any candidates admitted to University should normally have a minimum score of 2 and maximum score of 15). These statistics for candidates admitted by UCCA through clearing in 1974 are presented in Table 8.2c. Now minimum qualifications accepted by Stirling for candidates with A level qualifications is two Cs (six points). It can be seen that these requirements are generally less exacting than average for arts and social science and rather more exacting than average for physical science. This subject is discussed further in Chapter 9.7.

Table 8.2c Upper and Lower Quartile Scores of Candidates Accepted Through UCCA Clearing Scheme (1974)

Subject	Upper Quartile	Lower Quartile
Medicine	12	8
Civil Engineering	8	4
Mining Engineering	7	3
Biology	7	4
Mathematics	8	4
Physics	8	3
Chemistry	7	3
Economics	8	6
Accountancy	6	5
Law	10	7
Psychology	8	5
Sociology	8	6
English	10	7
French	8	5
Spanish	8	4
History	10	6

8.2 Sensitivity Analysis - (1) External changes

The analysis of section 8.1 indicates that there are reasonable grounds for questioning whether the University will achieve the targets adopted in the projection based on the Academic Council assumptions. Such doubts relate both the University's prospects of obtaining its target numbers in new development subject areas and also to obtaining its desired increase in the proportion of Science undergraduates. In this section we shall explore the consequences of making pessimistic assumptions about these factors. These assumptions are as follows:-

(i) Total student number targets as in previous projection.

(ii) New academic developments attract only 50% of projected student enrolment but still absorb 80% of previously projected resources. This assumption is plausible on the grounds that if new developments as a whole fail to attract sufficient student numbers, it is inevitable that some will be quite small and small subject areas tend to have higher levels of resources in relation to student numbers. In addition, there is inevitably some tendency to allocate academic staff ahead of student enrolment in such developments.

(iii) The proportion of students studying Science subjects remains at around that of the present quinquennium (ie 15-17%).

8.2.1 Results of projection (pessimistic assumptions)

(a) Student numbers and academic staffing

The pattern of academic staffing resulting from this projection is presented in Table 8.3. In general these results do not differ greatly from those resulting from the previous projections based on Academic Council assumptions. Broadly speaking Science subjects have marginally reduced staff numbers at the end of the quinquennium (eg Chemistry is now 15 instead of 17, Biochemistry 8 instead of 9 etc). Correspondingly, increases (although by no means dramatic ones) are observed for the larger Arts and Social Science subjects (eg English increases from 26 to 30, Sociology from 29 to 32, Psychology from 32 to 34). Thus, even under these pessimistic assumptions, the largest subjects do not obtain excessively large staff numbers.

Table 8.4 presents variations in student:staff ratios over the quinquennium. In the previous projection, it will be remembered that the more effective utilization of resources in Science subjects meant that student:staff ratios could be held reasonably stable elsewhere. This, of course, can now no longer hold and there is a general slight deterioration in ratio over the quinquennium (the most adverse ratio is English which reaches 14.5 by the end of the quinquennium). This deterioration is, however, not drastic and occurs gradually over the period in question.

(b) Finance

Unit costs for different subjects for the quinquennium are presented in Table 8.5. These costs are consistent with the analysis given in the previous section. Unit costs of Science subjects are not reduced as greatly as in the former projection and elsewhere in the medium and larger size subject areas there is generally a moderate and gradual reduction in unit costs indicating a reduction in resources to these areas. Fig. 8.1 shows diagramatically variation in unit costs over the quinquennium.

(c) Space

The situation with respect to physical space is broadly similar to that shown in the previous projection and is summarised in Appendix 7. The major difference is that reductions in numbers of science-based students and staff result in a slight easing of pressure on teaching laboratory and research laboratory space.

Table 8.3 SENSITIVITY ANALYSIS (1) - ACADEMIC STAFFING

	Subject	75/6	76/7	77/8	78/9	79/80	80/1	81/2
1.	Maths	7	8	8	8	9	9	10
2.	Economics	19	21	21	23	24	25	27
3.	Sociology	21	22	24	25	27	30	32
4.	English	19	20	21	23	25	28	30
5.	History	16	17	18	20	22	23	25
6.	Philosophy	11	12	12	13	14	15	16
7.	Acc. & Bus. Law	9	10	10	11	12	13	13
8.	Religious St.	6	6	7	7	7	8	8
9.	Management Sci.	10	10	10	11	11	12	12
10.	Computing Sci.	8	8	8	8	9	9	9
11.	French	12	13	14	15	16	17	18
12.	German	9	10	10	11	11	12	13
13.	Spanish	7	7	7	8	8	9	9
14.	Biology	18	19	20	21	22	24	26
15.	Physics	9	9	9	10	10	10	10
16.	Chemistry	11	11	12	13	13	14	15
17.	Psychology	23	24	25	27	29	32	34
18.	Integ. Sci.	3	3	3	3	3	3	3
19.	Fine Arts	3	3	3	3	3	3	4
20.	Biochemistry	7	7	7	7	7	7	8
21.	Education	9	9	10	11	11	12	13
	New Development	-	-	9	18	28	33	39
	Total	237	249	269	295	321	348	376

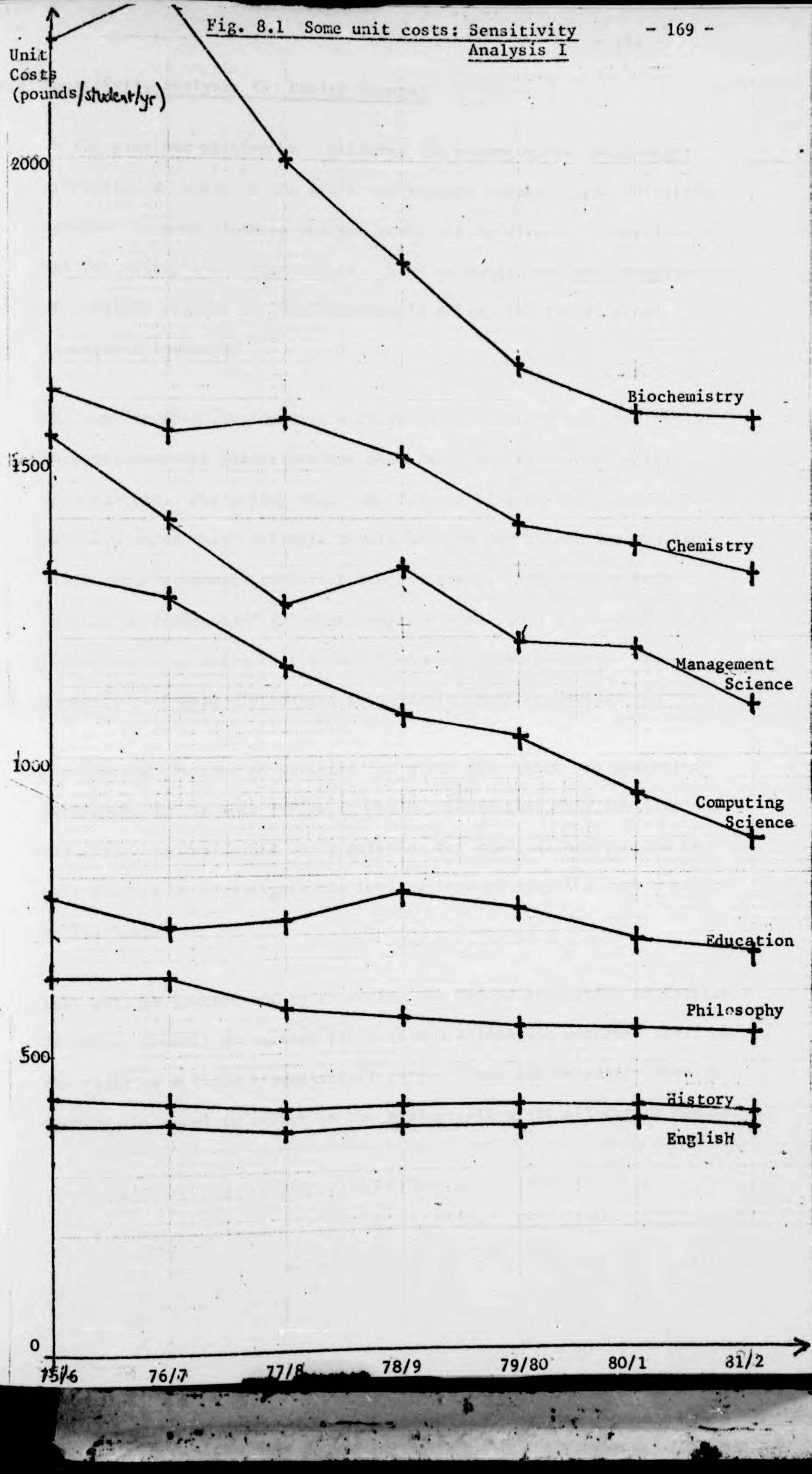
Table 8.4 SENSITIVITY ANALYSIS (1) - STUDENT:STAFF RATIOS

	Subject	75/6	76/7	77/8	78/9	79/80	80/1	81/2
1.	Maths	4.4	4.4	4.48	5.1	5.1	5.5	5.4
2.	Economics	8.3	8.1	8.8	8.8	9.2	9.7	9.7
3.	Sociology	13.2	13.2	13.0	13.7	13.8	13.6	13.9
4.	English	14.1	14.1	14.6	14.7	14.7	14.2	14.5
5.	History	12.9	13.0	13.4	13.2	13.1	13.7	13.2
6.	Philosophy	8.8	8.7	9.5	9.6	9.8	10.1	10.3
7.	Acc. & Bus. Law	11.2	10.0	10.8	10.9	11.0	11.1	11.2
8.	Religious St.	4.5	4.6	4.6	5.0	5.0	5.3	6.0
9.	Management Sci.	3.7	4.1	4.5	4.6	5.0	5.0	5.1
10.	Computing Sci.	4.0	4.1	4.5	4.9	5.0	5.5	5.4
11.	French	8.1	7.8	7.9	8.0	8.2	8.5	8.4
12.	German	5.6	5.2	5.8	5.8	6.5	6.6	6.7
13.	Spanish	3.3	3.4	4.0	3.7	4.1	4.1	4.4
14.	Biology	10.2	10.0	10.3	10.9	11.1	11.1	11.2
15.	Physics	2.2	2.4	2.4	2.4	2.8	2.8	3.1
16.	Chemistry	5.9	6.2	6.0	6.2	6.7	6.7	7.5
17.	Psychology	12.0	12.0	12.4	12.6	12.8	12.6	13.0
18.	Integ. Sci.	1.5	1.8	2.1	2.5	2.5	2.9	3.2
19.	Fine Arts	6.4	7.0	8.1	9.2	10.2	10.9	8.9
20.	Biochemistry	4.3	4.0	4.7	5.1	5.5	5.9	5.8
21.	Education	11.7	12.5	12.6	12.3	13.5	13.6	13.8

Table 8.5 SENSITIVITY ANALYSIS (1) - UNIT COSTS (IN POUNDS/fte STUDENT/YEAR)

	Subject	75/6	76/7	77/8	78/9	79/80	80/1	81/2
1.	Maths	1213	1200	1097	1023	1012	923	958
2.	Economics	677	682	628	645	616	582	581
3.	Sociology	417	419	434	409	404	409	404
4.	English	384	383	366	377	371	385	372
5.	History	428	419	404	412	414	408	399
6.	Philosophy	635	632	578	599	541	538	529
7.	Acc. & Bus. Law	467	534	496	518	508	495	454
8.	Religious St.	1150	1117	1167	1067	955	960	877
9.	Management Sci.	1539	1398	1258	1320	1192	1181	1085
10.	Computing Sci.	1311	1268	1152	1071	1029	939	860
11.	French	693	706	696	691	680	653	623
12.	German	927	1004	917	974	872	828	813
13.	Spanish	1677	1590	1383	1451	1308	1294	1187
14.	Biology	949	972	941	885	860	863	844
15.	Physics	4144	3915	3795	3979	3409	3199	2850
16.	Chemistry	1614	1544	1569	1503	1392	1356	1306
17.	Psychology	781	733	745	732	718	728	707
18.	Integ. Sci.	5617	4911	4242	3520	3459	3040	2741
19.	Fine Arts	1251	1152	989	870	786	736	928
20.	Biochemistry	2199	2318	2000	1827	1660	1579	1569
21.	Education	762	717	724	769	739	685	665

Fig. 8.1 Some unit costs: Sensitivity Analysis I



8.3 Sensitivity analysis (2) Policy Changes

In the previous section we considered the consequences which might arise from a change in the projected student intake in the University system. In general, these changes could not be directly controlled by the University's decision-makers. Here we shall consider consequences of possible changes in the University's policy for its internal resource allocation.

The considerable freedom that a University in the UK has over its own internal resource allocation has been described elsewhere in this dissertation. One policy which has far-reaching implications is the decision as to which criteria should be used for allocating available staff members between different subject areas. This is not only because academic staff salaries comprise nearly half the University's budget but also owing to the fact that many other resources are directly or indirectly related to academic staffing levels.

A review and critique of policies for staff allocation was presented in Chapter 5. In this review it was mentioned that many institutions use direct student:staff ratio policies for staff allocation and in this section we investigate the implications of adopting such a policy at Stirling.

This will be carried out by repeating the second projection of Chapter 7 (Academic Council assumption projections) allocating academic staff on the basis of a fixed student:staff ratio. This can be easily done by causing the model to switch in the appropriate staff allocation module.

8.3.1 Results of projection

(a) Academic staffing and student numbers

The results of this projection in terms of allocation of academic staff is presented in Table 8.6. Unlike the workload model policy this method of staffing allows no staffing element which is independent of student numbers. Thus, an obvious deduction is that those subject areas with large student numbers will receive rather more staff than before whilst those areas with small numbers are cut-back further.

A consequence of this is that we are again in danger of certain subjects having possibly excessively large numbers of academic staff by the end of the quinquennium. (Sociology with 39 staff, Psychology with 40 staff and English with 36 staff for example may become amongst the largest departments of their type in the UK).

Conversely, areas with small student numbers may be reduced to very small academic staff numbers indeed. Physics staff numbers, for example, vary from two to five during the quinquennium. This raises the question as to how many academic staff a subject area requires before it can be considered "viable". From the academic point of view "viability" corresponds to the number of academic staff necessary to give a reasonable covering of the subject matter of that subject. This is a very debatable question which will not be pursued further although in the author's opinion, in general, most subjects can be adequately covered with relatively small numbers of academic staff. There is, however, the further question as to whether a department is viable with respect to the workload generated by its teaching commitments. For instance, there is a single Honours programme in Physics taught by the Physics department which, even allowing for no optional courses must involve 15-16 semester course units, most of which include laboratories. Even if very small student numbers were taking each course it is doubtful if it would be possible to cope with the resulting workload with less than four or five staff. Essentially the University may find itself in a position where either it must provide a minimum level of staffing to maintain a programme or take the decision to abandon the programme. A decision to abandon a program should not however be taken entirely on the grounds that the level of academic staffing justified under this method of staff allocation are insufficient to mount the programme. For instance, before taking a decision to abandon its Honours Physics programme, the University should consider the implications of this decision for the remainder of the Physical science and on the academic viability of the University as a whole.

Considerable practical problems may be encountered in any attempt to switch from a given policy of staff allocation to a radically different one. This is because such a shift could involve a reduction in numbers of staff currently teaching a subject. Since existing staff may have tenure and since the rate of resignations in some areas may be very low, it may prove impossible in the short term to reduce staffing levels in given areas. For this reason it could take a number of years in a growth situation to fully implement a change in staff allocation policy.

Column A on Table 8.6 indicates the existing levels of academic staffing. Column B indicates the closest it would be possible to get to the projected staffing for 1981/82 assuming no redundancy and assuming 10% resignations in all departments in this period.

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Column A on Table 8.6 indicates the existing levels of academic staffing. Column B indicates the closest it would be possible to get to the projected staffing for 1981/82 assuming no redundancy and assuming 10% resignations in all departments in this period.

(b) Finance

Table 8.7 gives projected unit costs over the quinquennium. Since academic staff are now allocated directly in relation to student numbers, it might be expected that broadly similar subjects have approximately the same unit costs. Small variations are related to difference in level of departmental allocations and fluctuations associated with the fact that academic staff allocations have to be rounded off to integer quantities. Table 8.7 indicates a general fall in units costs throughout the quinquennium associated with the assumed reduction in resources. Generally, by the end of the quinquennium, unit costs are between £500 and £600 for a non-laboratory subject and between £900 and £1000 for a laboratory subject.

(c) Physical space

This projection is identical to that carried out under the Academic Council assumptions except for staff allocation policy employed. Hence, class sizes are identical to those of this earlier projection and the situation with regard to lecture and seminar room space and teaching laboratory space is unchanged. The overall situation with regard to academic office space is also broadly the same (although, of course, different switches of room from one subject area to another will be required). Demands on research laboratory space, however, is eased owing to reductions in science-based staff numbers.

8.4 General Observation on Sensititivity Analysis

In the sensitivity analysis carried out in this chapter, it is clear that a change in internal resource allocation policy made a greater change in the future shape of the University than some quite pessimistic assumptions about external circumstances. This emphasizes the importance of University decision-makers taking a considered and informed decision on University resource allocation policy.

TABLE 8.6

ACADEMIC STAFF ALLOCATION USING STUDENT STAFF RATIO APPROACH TO STAFF ALLOCATION

		76/7	77/8	78/9	79/80	80/1	81/2	A	B
1.	Maths	4	5	6	7	8	8	10	9
2.	Economics	19	20	21	22	23	25	16.5	24
3.	Sociology	33	33	34	36	36	39	23	38
4.	English	31	31	32	33	34	36	24.5	35
5.	History	24	25	25	26	27	28	17	27
6.	Philosophy	11	12	12	13	13	14	13	14
7.	Acc. & Bus. Law	11	11	12	12	12	13	7	13
8.	Religous Studies	3	3	3	3	3	4	4	4
9.	Management Sc.	5	5	6	6	7	7	7.5	7
10.	Computing Sc.	4	4	5	5	6	6	5	6
11.	French	11	11	11	12	12	13	12	13
12.	German	6	6	6	[illegible]	7	7	10	9
13.	Spanish	3	3	3	3	3	3	4	4
14.	Biology	22	24	26	29	31	32	19	31
15.	Physics	2	3	3	4	5	5	7	6
16.	Chemistry	7	9	10	12	14	15	13	14
17.	Psychology	33	33	35	36	38	40	25	39
18.	Int Sc.	1	1	1	1	1	1	4	4
19.	Fine Arts	2	2	2	3	3	3	2	3
20.	Biochemistry	3	4	5	6	7	8	4	8
21.	Education	12	13	14	15	16	17	16	16
	Total	247	258	272	290	307	324	243.5	324

Col. A - indicates existing staffing

Col. B - indicates nearest possible approach to projected targets for 1981/82 assuming 10% resignations up to 1981/82 and no redundancies.

TABLE 8.7

ACADEMIC STAFF ALLOCATION USING STUDENT:STAFF RATIOS
- PROJECTION OF UNIT COSTS (IN POUNDS/fte STUDENT/YEAR)

	Subject	76/7	77/8	78/9	79/80	80/1	81/2
1.	Maths	588	612	571	585	559	499
2.	Economics	627	614	593	594	589	585
3.	Sociology	642	617	608	610	583	568
4.	English	618	588	579	571	562	553
5.	History	607	600	578	572	560	543
6.	Philosophy	597	622	594	585	536	525
7.	Acc. & Bus.Law	631	601	612	571	547	543
8.	Religous Studies	581	517	522	508	466	562
9.	Management Sc.	685	612	627	590	639	588
10.	Computing Sc.	651	590	604	512	526	482
11.	French	631	619	585	601	563	562
12.	German	603	568	533	505	583	558
13.	Spanish	670	606	591	539	508	454
14.	Biology	1091	1101	1046	1051	1030	981
15.	Physics	785	1138	1135	1025	1059	917
16.	Chemistry	1033	1031	966	980	987	954
17.	Psychology	1054	1005	1006	970	959	933
18.	Int. Sc.	1363	1048	782	703	621	565
19.	Fine Arts	691	645	617	948	837	770
20.	Biochemistry	952	1127	1094	1024	983	976
21.	Education	1047	979	984	979	954	948

8.5 Changes in the National System of University Planning

In Chapter 7 we referred to Lord Crowther-Hunt's remarks about the possibility of changing from the present system of fixed quinquennia to rolling triennia. Under the quinquennial system a comprehensive planning exercise has to be undertaken for a five year period about two years before the start of the quinquennium. This plan is then informally revised throughout the quinquennium, the planning horizon shrinking accordingly.

Under the rolling triennium system plans would be made for a three year period with formal revision (including submission to the UGC) being carried out annually. Under this system a constant planning horizon of three years could be obtained, although in order to operate this system successfully it would be necessary to develop informally a planning strategy for a longer time-scale than three years.

Under such a system where plans or modifications have to be notified to the UGC on an annual basis, a model such as ROBUS would be very useful because formal planning exercises would have to be undertaken much more frequently and the facility of being able to test out quickly and easily the implications of different policies would be invaluable.

CHAPTER 9

CRITIQUE OF STUDY AND POSSIBLE AREAS FOR FUTURE RESEARCH

9.1 University's control over its development

In Chapter 2 we have discussed the extent to which the University's decision-makers have control over the University's development and problems arising from this. We observed that since students are inputs to the University system and since resource allocation is directly related to student teaching load, the future shape of the University is largely determined by student subject choice. Since once within the University, students have complete flexibility over their courses of study (subject to satisfying the University's degree regulations), the admissions stage is where the University has most opportunity of asserting control.

As we have described previously, although a student is expected to indicate on his UCCA application form his intended programme of studies, the University maintains a common entrance policy of admission to the University as a whole rather than to the individual programme. Owing to this, the University has more or less uniform entry criteria no matter which subject a student expressed interest in studying. The possibility arises as to whether less demanding entry requirements can be demanded for subject areas which are underscribed and the controversy related to this proposal is summarised in Chapter 2.

There are, however, further ways in which the University can gain more control over its own development. Amongst these are :

(a) Imposition of quotas

If a given subject area should be in danger of being oversubscribed relative to the resources available to it and the University was either unable or unwilling to provide additional resources, then it might establish quotas for that subject (ie limits to enrollments on various courses). A difficult problem associated with such policies would be in deciding to which students such restrictions should apply. Serious problems could arise if exclusion from a course unit directly affected a student's ability to complete his degree programme. Nevertheless, students could perhaps be prohibited from taking oversubscribed subjects as a minor and this might enable modest reductions in student load to be made in some areas.

(b) Changes in Academic Structure

The University's academic structure has been laboriously improved over a ten-year period, with many teething troubles being overcome in the early years. Thus a prohibitive amount of work could be involved in any attempt to effect fundamental changes. There is, however, one possible modification which would maintain basically the present structure and enable the University's decision-makers to exercise more control over University development.

Under the present system students are admitted to the University as a whole (although specifying an intended programme of studies on their UCCA forms). They study a broad range of subjects for Part I and then enter either Honours or General degree programmes in Part II. There is no requirement that these programmes should bear any relationship to those indicated on a student's original application. The following advantages are ascribed to this sytem:

1) A student can broaden his outlook by studying a wider range of subjects than are generally available elsewhere.
2) Flexibility - a student has the chance to acquaint himself with subjects that he did not have the opportunity to study at school. If successful, he may decide to specialise in this subject area.

A possible modification to the system would be for a student to be assigned to his programme of study (according to the programme applied for on his UCCA form) from the beginning of his studies. The structures of Part I and Part II could remain unchanged and loads generated on different departments could be calculated using the notional class size module. It would be necessary, however, to permit a change of programme only on permission being granted by the University. In this situation the availability of the ROBUS model could be very helpful. The effect of such proposed transfers on departmental student loads can be assessed and a forecast of resource implications can be made. Permission could be granted or withheld depending on the results of these projections.

This proposal, unfortunately, reduces student academic freedom but any attempt by University decision-makers to establish further control over its development ipso facto reduces student freedom. A further problem is that the University is presenting students with the opportunity to sample new subjects, yet possibly denying them the opportunity of furthering their studies when the students find such subjects attractive.

In some situations the University may have to consider whether it is possible to divert resources from one area to another to meet changes in student demand. In practice this may be impossible particularly with regard to academic staff. Since most staff have tenure, it is not possible to make staff redundant and indirect methods such as not filling vacancies and reallocating the posts elsewhere, have to be used. Vacancies are, however, random and may occur extremely infrequently in some areas.

9.2 Further Work : Development of an integrated management information system

W J Kinneven (1973) defines a management information system as:
"A management information system is an organised method of providing past, present and projected information related to internal operations and projected intelligence. It supports the planning, control and operational functions of an organisation by furnishing uniform information in a proper time frame to assist the decision-making process". It is important to note that this definition includes the concept of linking the information system closely to the decision-making process.

It is common fallacy that management information systems must involve the use of the computer. This is not so; it is perfectly possible to have an adequate manual information system so long as the information provided is systematically related to the decisions to be taken. The use of a computer, however, does bestow some important advantages.

- the ability to store large quantities of information.
- the ability to retrieve quickly relevant information.
- the ability to effect any arbitrary processing operation on the data (eg aggregate the data in various ways).

(See Joel E Ross (1970).)

According to Charles R Thomas (1973) although most of the technology and tools relating to management information systems are common to both the commercial and University situations, there are some significant differences between the systems themselves. Commercial applications involve reasonably small numbers of inter-related systems with well-defined relationships between them. Usually very large numbers of data elements are involved. On the other hand, Higher Education Systems consist of many separate systems which traditionally had not well-defined working relationships. Data items are, however, in comparison with commercial systems, relatively small.

At present, there is no integrated management information system in existence at Stirling. As mentioned in Chapter 6, most important data exists in separate and for most purposes independent sources. To recap on the University's major sources of information we have:;

1) Student records

Information relating to students including programmes of study and course units taken is held by the academic office. This information is computerised.

2) Space

Records of buildings giving both quantities and allocation of different types of space available.

3) Finance

Information on finance incorporating all the University's financial transactions is held by the Finance Officer. This system is partially computerised although at present entirely independent of system (1).

Designing an integrated management system would involve designing a system which brought all relevant information together under the same system. It would be beneficial to computerise such a system partly for the reasons described earlier and partly because important components of the system are already computerised. The advantages such a system might have are:-

(i) From the point of view of using the planning model it is important that the basic parameters of this model are regularly updated. This is necessary since student behaviour can in some circumstances be very changeable (workers at Boulder, Colorado, for instance, have found that the induced course load matrix can become unstable under certain conditions). A fully integrated management information system should make generation of basic data much simpler (it might be possible, for instance, to program the computer to generate the induced course load matrix from student registration data).

(ii) Such a system should help ensure the consistency and reliability of data. This consistency is of particular importance with reference to data supplied to the U.G.C. At present, there may be a danger of inconsistency between data supplied by the student records office and that supplied by the Finance Office.

(iii) A general improvement in managerial efficiency resulting from more reliable and consistent data systems.

The following problems could be involved in the development of such a system.

a) Costs involved in developing the system. Although this could be substantial there seems to be no reason why the cost of operating such a system should be significantly greater than the cost of maintaining present systems (and it could well be less).

b) The problem inherent in all such systems is that once an erroneous data element is fed into the system, it can have a cumulative effect throughout.

In spite of these caveats there is, however, in the author's opinion ample justification for some study into the cost effectiveness of the development of such a system at Stirling University.

9.3 Further work : Development of PPBS

Work which has been carried out elsewhere (mainly in the USA and Continental Europe) into the development of PPBS systems in Universities together with an account of particular difficulties encountered by these researchers have been documented in Chapter 3.

According to Ott (1972) the hallmarks of a PPBS system in a University are

1) Specification of the objectives to be achieved by the University.
2) Investigation of alternative means of achieving those objectives.
3) Minimization of cost or comparison of costs and benefits (when the benefits can be quantified).
4) Systematical use of analysis throughout the process.

Thus, inherent in the design of a PPBS system is the process of specification of objectives, devising programmes that can be used to achieve this objective and budgeting on the basis of these programmes.

Considerable difficulties have been encountered by researchers who have attempted to apply PPBS to the University situation. In the opinion of the author these difficulties fall into four main categories.

1) Definition of objectives.
2) Definition of programmes.
3) Apportioning resources (such as academic staff) between programmes.
4) Measuring the effectiveness with which the programmes meet the objectives.

These problems could be approached as follows; the University can be conceived as having four major objectives

1) Imparting certain cognitive skills to students.
2) Imparting certain vocational skills to students.
3) Preservation and extension of knowledge.
4) Public service (eg consultancy service, service of members on Government and public committees).

A University attempts to meet its first two commitments through its teaching programmes, it broadly attempts to meet the third objective through its research programmes. The fourth objective can be met in a number of ways (eg short course programme, consultancy service, extra mural programme etc).

Apportioning resources between programmes does present some difficulty especially in the case of academic staff. Fortunately we have, however, some useful information in this subject thanks to studies carried out by the UGC (1970) in which fairly extensive study was carried out into the use of academic staff time.

Measurement of the effectiveness with which programmes are achieving their objective present many more problems however. It might be suggested that measures of "efficiency" such as cost per student equivalent, staff:student ratio and utilisation of teaching space can be used. However as Dyer (1972) cogently points out, the "efficient" operation of a system which is not properly designed to achieve its primary objectives can hardly be considered "efficient" in a global sense. The reliance on these statistics for planning and operating decisions can screen or cloud the perceptions of the purpose and responsibilities of a system of higher education.

Thus, to summarise, it is felt by the author that a PPBS system is a considerable help in attempting to relate the decision-making processes of an institution much more closely to its objectives. In implementing such a system, the model described in this dissertation would be of considerable value in enabling a researcher to explore alternative means of achieving objectives. In view of the difficulties experienced elsewhere with such systems, however, and the limited resources of Stirling, it might be advantageous to monitor progress elsewhere until there is evidence that some of the major difficulties are being overcome.

9.4 Further Work : Extension of work to other UK Universities

The model described in this dissertation was for the reasons described in Chapter 6 specifically related to the University of Stirling.

It should be possible, however, to extend this work to other UK Universities. It would obviously not be possible to use this model directly owing to differences in academic structure and resource allocation philosophy. Nevertheless, it should be possible to adapt the model to other UK Universities taking advantage of the concepts and insights developed here.

9.5 Objectives and Optimization

Throughout this study we have encountered problems related to the lack of clear definition of University objectives. It could be useful for the University to attempt to articulate its objectives although this might be an internally devisive operation. This also raises the question as to who has the right to set these objectives. To what extent is this the prerogative of the University academics and how much say should society as a whole (who after all provide the University's resources) have in the matter?

It might be interesting as an experiment to consider particular sets of objectives and attempt to carry out an optimal resource allocation exercise based on goal programming as described in Chapter 3. In the opinion of the author, however, because of serious doubts about the cost-effectiveness of work in this area, any resources committed to such an investigation should be strictly limited.

9.6 Resource allocation

Further research into University resource allocation policy could be valuable. This subject is further discussed in Appendix 8.

9.7 Possible Measures of Stirling's potential for obtaining additional Science Students.

As mentioned earlier in this dissertation, Stirling's entry qualifications for students wishing to study science subjects are, on the whole, rather more demanding than those of many other universities. This causes loss of students through two causes:

(i) Some students fail to achieve Stirling entry requirements.

(ii) A feature of the UCCA system is that students are allowed to retain conditional offers of places from two universities. Many students will perhaps accept a high offer from a university with well established science tradition and the lowest offer as a form of insurance policy. Under present policies Stirling is likely to miss out on both counts. Thus many students will not include Stirling on the choices they maintain, even though many of these may well eventually achieve present Stirling entry standards.

If we can obtain reliable statistics of Highers and A level examination results we can estimate potential demand for a given subject for any given level of entry qualifications demanded. In this way it would be possible to assess the "opportunity cost" in terms of potential students lost through a particular level of entry qualification.

BIBLIOGRAPHY: Chapter 9

114 Dyer, James S (1972) The use of PPBS in a public system of Higher education: Is it cost-effective?, Planning Programming and Budgeting, Markham Publishing Company, p 360

115 Kinneven, W J (1973) Academic Computers in Service, Fossey-Bass Inc, San Francisco, p 66

116 Ott, David J and Ott, A F (1972) The budget process, Planning Programming and Budgeting, Markham Publishing Company, p 44

117 Ross, Joel E (1970) Management by Information System, Prentice-Hall, Inc

118 Thomas, Charles R (1973) Data System Design, Professional Seminar IMHE programme, CERI/OECD, Paris

119 UGC (1970) Survey into use of Academic Staff Time

CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

10.1 General Remarks

A colleague once remarked that the field of education was a "half-way house" between the "hard" technological areas in which management science methods had been applied with considerable success and the "soft" sociological areas where there was a meagre record of successful applications. In this chapter we shall attempt to evaluate the work carried out in this dissertation and explore one or two broader issues arising from this work. Incidentally, the amount of work being carried out by researchers in this field has expanded considerably since Platt wrote his paper ("Education : rich problems and poor markets") in the early sixties. If we review the dates of work cited in this dissertation we find that almost all are post 1965 with a large proportion of these emanating from the 1970's.

10.2 Evaluation of the research

When evaluating a piece of research in the management science area an important consideration is whether the results of research have been successfully implemented. We are not here, however, considering a situation (such as might be the case with problems which involved devising a set of optimal bus routes) in which a given set of results is adopted at a particular point in time and perhaps updated at regular intervals. Instead, University planning is an on-going and continuous process and successful implementation in this field would constitute a continuing contribution to improving the planning process.

The results generated by this report were used by the Committee for Academic Development in drawing-up initial plans for the 1977-82 quinquennium. Although it is now clear that there will not be a quinquennial settlement as such and previous expansion targets are to be drastically pruned, the model is being used to investigate this changed situation. Results obtained from the model have also proved useful to other University Committees (such as the Science Planning group in considering future laboratory needs). It is intended to refine the model further in the light of experience obtained from its use in practice. This tool will also be available to meet possible changes in the national system of planning and grant allocation (such as a move towards a system based on rolling triennia).

A further criterion for evaluating the worth of a piece of work in the management sciences is whether the net benefits arising from the work exceed the costs of carrying out the research. Again it is impossible to evaluate the benefits from the study in direct financial terms. Hopefully, the work will result in "better management" in the broadest sense. Also, since the work relates inputs to a rather complex system to the future development of that system, it may give greater control of that development to University decision-makers. On the cost side of the equation, apart from a small quantity of consumables and some computer time (the marginal cost of which is very low since the machine has substantial spare capacity), the most important cost is the opportunity cost of the research time of the author. Since this work complemented other work which was required by the University administration evaluation of such costs presents considerable difficulty.

It is also important to consider the value of the dissertation as a piece of academic research and, in particular, its value to other researchers in the field. As explained earlier it is felt unlikely that other researchers could usefully use the models developed here in a "off the peg" way. It is, however, hoped that concepts and insights presented here might prove useful in their research. It is also hoped that the preliminary chapters of the dissertation will present a reasonably comprehensive review of the overall field to any individual who was considering commencing research in it.

10.3 Critique of the approach used in this dissertation; some broader issues

There are a number of objections and caveats which can be levelled against the use of models for planning in Universities. Some are based on what are, frankly, misconceptions about the nature and purpose of such models but may, nevertheless, be important if such misconceptions persist in the minds of decision-makers. Other objections may have more substance in fact.

A good example of the objections resulting from misconceptions of the use of models is illustrated by the controversy in the A.U.T. bulletin (1974). Here it transpired that the opponents of this approach were under the impression that management science methods could only be applied to profit maximisation contexts and something similar was about to be applied in the University situation.

A more common misconception (and perhaps one that over-enthusiastic practioners may have done something to foster) is that such models actually "take over" the decision-making process and reduce genuine political issues and matters of principle to bogus technical ones. It is hoped, however, that throughout this dissertation the point has been clearly made that no decisions can ever be made by these tools. The University decision-maker has exactly the same decisions confronting him as before although, hopefully, better and more relevant information of the consequences of the decision will be available to him. In many situations purely subjective considerations such as the academic merit of a particular programme of study will be of crucial importance. It also follows, of course, that the availability of appropriate models will not necessarily prevent a poor decison-maker taking unwise decisions. In practice, however, it is sometimes found that decision-makers themselves may treat matters of principle as simply technical matters. An example of this is the tendency of decision-makers to treat different methods of staff allocation as simply different techniques for doing basically the same thing. In this situation it was necessary to point out that a considered decision was called for, as the method chosen could have important consequences for the University's future development.

A further objection to the use of models in this context (and an objection with some substance) concerns the questions of the validity and credibility of the model itself. In questioning the validity of the model there is the point that the model-builder may introduce biases and prejudices of his own (even if only on a subconscious level) into his model. (This argument of course applies in other fields, witness the argument about the Treasury's economic models in 1976). This objection seems insuperable since, in the author's opinion, a totally objective statement, position or mathematical model is impossible. It is inevitable that the individual making the statement, taking the position and building the model will be "biased" by the totality of the experiences of his lifetime. We cannot, however, circumvent this problem simply by abandoning the use of mathematical models. The planning process has to go on and even if the planner does not use a formal mathematical model, it is inevitable that he will nevertheless use some sort of conceptual or mental model on which to base his plans and this model will be just as liable to bias. If the assumptions on which a mathematical model is constructed are clearly stated, then obvious biases may become apparent. Unfortunately, however, it is possible that some assumptions will be implicitly embedded into the model and thus be only accessible to the technical expert. The author is not aware of any conscious biases in the model developed in this dissertation but then there cannot be any absolute standards of objectivity and what appears objective to one individual may appear biased to another. There is no easy answer to this problem in the author's opinion; the best solution is for the users of models to be aware of these problems when using model results and exercise appropriate vigilance.

Now we must consider the question of the credibility of the model. It could be argued that decisions in Universities are taken by many individuals who have little understanding of modelling or have even any background in quantitative methods whatsoever. To what extent can modelling work be credible to these groups? It should be possible, however, to explain the ideas and concepts on which the models are based to these groups although it has to be conceded that the finer details are only accessible to the expert. Looking at this matter from a common sense point of view, the author feels that the credibility of the model and the credibility of the model builder are intimately related. If the model builder has a record of providing useful information in a variety of decision-making situations, it is likely that he will have built up a degree of confidence in his expertise that will lend credibility to his more sophisticated models. The situation is little different from that pertaining to other technical experts. For instance, information provided by an accountant is generally accepted by decision-makers who may have little knowledge of accounting practice, providing the information given in the past has proved to be accurate.

A further problem with relation to the credibility of the model is the question of accuracy, consistency and objectivity of the data used in it. The data sources used for this model have been described earlier. The standard of accuracy has been found to be high and checks have shown the data to be generally consistent from one year to another. As described earlier, however, possible problems of consistency of the induced course load matrix could arise since some elements have been, of necessity, calculated from rather scanty information.

There is also a problem of objectivity of the information - ie does the information supplied depend on the use to which it is to be put? The author feels that this is not a serious problem as far as this study is concerned but could present difficulties if, say, a PPBS study was undertaken. If such a study were to be undertaken it would be necessary to make use of statistics collected by the UGC into the use of academic time (see section 9.3). Since this data was collected from a questionnaire filled in by academic staff, there is the possibility that respondents may have been influenced in completing the document by consideration of possible future uses of the information. Certainly a cynic might well question some of the apparently very heavy workloads claimed.

An additional problem is the interpretation of the output of the computer. We have mentioned earlier the problem of credibility of the model. Sometimes, however, the opposite tendency occurs and the output of a computer is treated as if it were printed on tablets of stone. It has been pointed out earlier that the results provided by the model give only a broad indication of future development. Another danger is a tendency to view the University as a collection of unrelated academic developments or departments, rather than as an integrated whole. This is especially unfortunate in a University such as Stirling with its very inter-dependent academic structure. Thus for example there may be a danger that development in, say, Spanish will be viewed purely in terms of unit cost per student for that subject, without considering, for example, the contribution of Spanish to studies in modern languages, to Arts programmes in general, and to the University as a whole.

10.4 Use of Models in Providing Incentives

In this section we shall discuss the possible role of a model in devising incentives for rewarding individuals or departments who use their resources more effectively. To do this, models must give such departments some benefits from their improved efficiency. An example of a model that does provide such benefits is the workload model for staff allocation. This model is based on a course being taught by a notional set of teaching activities. If a department manages to use its resources more effectively and provide the same standard of education with lower actual workload, then any resources saved can be used at that departments discretion. (It is assumed that departments will not lower the standard of education that is provided). A workload model which simply modelled teaching activities actually undertaken could not provide any incentives for improved use of resources. Indeed there would be built in incentives for inefficiency - the more inefficiently resources were used the more resources would be obtained by that department.

Another issue which can be raised is consideration of the possibility of whether it might be possible to delegate the decision of choosing between different kinds of resources to the individual decision-making units (sometimes called "virement"). Owing to the grants system in which capital expenditure and equipment are financed by separate funds, there are obvious difficulties associated with any attempt to provide virement between these resources. There remains the question, however, whether one could allow the decision-making unit to decide, given a particular level of resources, what mix of academic staff, non-academic staff and departmental expenditure it wished to acquire. This could be facilitated using the model. The model could be used as before, calculating levels of academic, non-academic staff and departmental expenditure for given projected student registrations. Having done this, total resources could be presented as a "block grant" to the individual department who could make the decision for themselves, say, between one senior lecturer and two secretaries or between a technician and consumables.

Unfortunately, however, it is likely that severe practical difficulties would arise essentially because decisions between these different kinds of resources involve the University in commitments over different time scales. Decisions on departmental expenditure (consumables, travel, hospitality, etc) generally commit the University for one year only whereas a decision to employ a member of academic staff is, because of the system of tenure, essentially a commitment to employment up to retirement. This element of inflexibility is exacerbated by the fact that it is usually impossible to redeploy a specialist from one area to another. Of course, it is possible to vary the level of staffing in a subject area by not filling vacancies but, as explained previously, vacancies occur randomly and very infrequently in some areas.

Secretarial staff and technical staff do not have tenure but, in practice, in a situation where one group of workers has tenure it is politically very difficult to treat any other group differently. Flexibility is much greater in these cases, however, since it is generally possible to reallocate such workers between departments and the turnover of staff is in any case much greater.

Thus, to summarise the argument, meaningful virement must include some degree of choice between academic staff and other resources: whilst the present tenure arrangements hold, it is most unlikely that a University would be willing to relinquish its centralized control of academic staffing levels. Nevertheless this is a topic worth considering further. An interesting case study of an attempt to introduce virement is provided by the Lancaster group (1971).

10.5 General Conclusions and Recommendations

In spite of reservations discussed in previous sections, it is nevertheless felt that results generated by the model described in this dissertation can be of value to decision-makers in practical situations.

The following broad recommendations could be made arising from this work.

(1) The model should continue to be used in future planning situations and should be revised in the light of experiences gained in such studies.

(2) The University might find it valuable (for the reasons discussed in Chapter 9) to further develop and integrate its information system.

(3) Although the idea of introducing a comprehensive PPBS system is an interesting one, it is suggested that because of practical difficulties involved, it may not be worthwhile carrying out work in this area in the immediate future. Instead it is suggested that progress elsewhere in this field be monitored.

(4) It might be useful to carry out further work on the subject of University objectives and the evaluation of their achievement (although such a study could prove fraught with difficulty). If, through carrying out such a study, it should prove possible for the University to define its objectives and desired future growth pattern, then it is likely that the model might be helpful in devising programmes for achieving these aims.

BIBLIOGRAPHY: Chapter 10

120 Simpson, M G, et alia, Planning University Development, IMHE programme, CERI/OECE, Paris, pp 109-115.

APPENDIX 1

RRPM Model - Use of Induced Course Load Matrix in Calculation of Departmental or Discipline Teaching Loads.

The induced course load matrix (ICLM) establishes a relationship between the programmes of study offered and the subject disciplines which are studied. For example a student who is taking a mathematics programme may generate loads on the Physics, History and English departments as well as the Mathematics department.

In the RRPM model this matrix indicates the average nos. of credit hours taken by a student in a given programme in each department or discipline.

$$
\begin{array}{ll|cccccc}
 & \text{Dept.} & 1 & 2 & \cdots & j & \cdots & m \\
\hline
\text{Programme} & 1 & A_{11} & A_{12} & \cdots & A_{1j} & \cdots & A_{1m} \\
 & 2 & A_{21} & A_{22} & \cdots & A_{2j} & \cdots & A_{2m} \\
 & \vdots & \vdots & \vdots & & \vdots & & \vdots \\
 & i & A_{i1} & A_{i2} & \cdots & A_{ij} & \cdots & A_{im} \\
 & \vdots & \vdots & \vdots & & \vdots & & \vdots \\
 & n & A_{n1} & A_{n2} & \cdots & A_{nj} & \cdots & A_{nm}
\end{array}
$$

X_{ij} represents the average number of credit hours taken by a student enrolled for programme i in an academic department j.

For example the average first year student enrolled on a history programme might take 16.0 credit hours in history, 3.9 in biology, 3.7 in fine arts and 6.4 in business studies. The appropriate row of the matrix for such a programme would read

Programme	Department			
	History	Biology	Fine Arts	Business Studies
History:1st year	16.0	3.9	3.7	6.4

Having derived the induced course load matrix, it is possible to deduce the load on each department from a knowledge of total student enrolment in each programme of study. The workload (in terms of credit hours) generated by enrolment on particular programmes is given by simply multiplying the enrolment by the appropriate row elements in the induced course load matrix. For example if there are 80 first year history students enrolled then the load generated by these students will be:-

History	80 x 16.0 = 1280	credit	hours
Biology	80 x 3.9 = 312	"	"
Fine Arts	80 x 3.7 = 296	"	"
Business Studies	80 x 6.4 = 512	"	"

By repeating this process for all academic programmes and then by summing for each department or discipline, the total credit load on each department can be found.

Expressing the foregoing argument in a more concise and mathematical form we have:-

Let the vector $\underset{\sim}{Z}$ represent enrolment in programmes

$$Z = \begin{pmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_m \end{pmatrix}$$

Where Z_1, Z_2 - - - Z_m are forecasts of students enrolled for programmes 1, 2, - - - m.

We have already defined the induced course load matrix $\underline{A}$.

Hence if we multiply our induced course load matrix with our vector of enrolment in programmes, we get the vector $\underline{B}$.

$$\underline{B} = \underline{A} \times \underline{Z}$$

$$\begin{array}{ccccccccc}
= A_{11}Z_1 & + & A_{12}Z_2 & + & \cdots\cdots\cdots & + & A_{1m}Z_m & = & B_1 \\
A_{21}Z_1 & + & A_{22}Z_2 & + & \cdots\cdots\cdots & + & A_{2m}Z_m & = & B_2 \\
\vdots & & \vdots & & & & \vdots & & \vdots \\
A_{i1}Z_1 & + & A_{i2}Z_2 & + & \cdots\cdots\cdots & + & A_{im}Z_m & = & B_i \\
\vdots & & \vdots & & & & \vdots & & \vdots \\
A_{n1}Z_1 & + & A_{n2}Z_2 & + & \cdots\cdots\cdots & + & A_{nm}Z_m & = & B_m
\end{array}$$

Each element of $\underline{B}$ represents the total credit load on each department brought about by forecast enrolment.

APPENDIX 2

The RRPM Model - Calculation of Cost of a Student Programme

Total costs of an academic department or discipline can be calculated by adding to departmental staff salaries the direct teaching costs calculated in phase four. The cost per credit hour of a particular discipline in a given academic year can be obtained by dividing the total cost of that discipline by the numbers of credit hours produced. Now the induced course load matrix gives the average numbers of credit hours taken in each discipline by a student studying a given programme. Hence the cost of each student programme may be obtained simply by multiplying the numbers of credit hours taken in each discipline by the cost of a credit hour in that discipline summing over all disciplines.

Thus referring to the example cited in Appendix I, if the cost of a student credit hour in first year history, biology, fine arts and business studies turns out to be \$30.00, \$33.69, \$34.71 and \$20.90 then the cost of each student programme in history will be given by

$$\$(16.0 \times 30.00) + (3.9 \times 33.69) + (3.7 \times 34.71) + (6.4 \times 20.9) = \$873.58$$

Appendix 3

Workload model used at Lancaster University

This model neglected all time spent on college activities, university and departmental administration and examinations, and found that the UG teaching load in any one year of studies can be approximately described by an expresion of the form

$$L = i(1 + p) + c\left\{\left[\frac{N}{n}\right] + \frac{m}{z}\right\}(1 + q/s) + Nr$$

plus any load due to practical or language laboratory work

L = teaching load

i = no. of lectures

p = preparation time per lecture

c = no. of seminar sessions per course

N = no. of students/course combinations

n = no. of students in a seminar group

m = no. of courses run

q = preparation time/seminar week/member of staff

s = number of seminar sessions in a course/seminar week/member of staff

r = "post-mortem" time per student per course

[ ] = integral part of

In this model the first term corresponds to the load involved in giving and preparing lectures

- the second term corresponds to the load involved in giving and preparing seminars, tutorials and problem classes
- the third term corresponds to post-mortem time (ie time spent on answering questions from students arising from seminars)

APPENDIX 4

DETAILS OF WORKLOAD MODEL USED AT STIRLING

The approach adopted is to attempt to model the workloads involved in various activities in the presentation of a course unit. In practice, of course, departments will teach their courses in a number of different ways. The philosophy behind this model is that resources should be allocated on some reasonable basis for teaching a course, with the decision as to exactly how such resources should be employed in practice being devolved to the individual departments concerned.

It was felt that the workload involved in different activities was related in a number of different ways to student numbers.

(1) Workload independent of student numbers

It was felt that this was the case for example (within very wide limits) for the workload involved in preparation and presentation of lectures.

(2) Workload directly proportional to student numbers

This was generally assumed to be the case for marking essays, correcting examination scripts etc.

(3) Workload increases as a step function with increase in student numbers

It was felt that for certain activities such as giving tutorials or laboratories workload rises in a series of jumps as the student numbers increase. (eg in the case of holding a laboratory, workload remains constant until student numbers exceed laboratory capacity when it becomes necessary to repeat the lab).

Since certain activities can only take place with particular groups of subjects (eg laboratories can only take place in association with Science subjects), subjects are divided into different groups.

The categories are:-

A. General, non-lab subjects (eg English, Maths, Philosophy).

B. Language subjects (eg French, German, Spanish).

C. Laboratory subjects (eg Biology, Physics, etc).

D. Education.

<u>For Category A subjects the model is:-</u>

$$X = \underbrace{mL}_{\substack{\text{Giving \&} \\ \text{Preparing} \\ \text{lectures}}} + Nx(\underbrace{Wxw}_{\substack{\text{Marking} \\ \text{essays}}} + \underbrace{\frac{E}{14}}_{\substack{\text{Marking} \\ \text{exams}}})$$

$$+ F \times tp \times \{\underbrace{\left[\frac{N}{4n}\right]}_{\substack{\text{Preparation} \\ \text{of tutorials}}} + 1\} + F \times tg \times \{\underbrace{\left[\frac{N}{n}\right]}_{\substack{\text{Giving} \\ \text{tutorials}}} + 1\} + \underbrace{\frac{N}{6}}_{\substack{\text{Allowance/student for} \\ \text{out of class discussion etc.}}}$$

<u>Explanation of symbols</u>

$[\;]$	Integral part of
X	Weekly course workload (in hours per week).
m	Time to give and prepare lectures.
L	No. of lectures per week.
N	No. of students taking the course.
W	Weekly essay frequency
w	Time to correct essay.
E	Time to correct exam script
F	Weekly tutorial frequency.
tp	Time to prepare tutorials.
tg	Time to give tutorials.
n	Nos. in tutorial group.

Category B - Language Subjects

The structure of the model is the same as for Category A. There is also the following term to allow for the preparation and presentation of language laboratories.

$$S \times sx \; \{ \left[\frac{N}{r} \right] + 1 \}$$

s   Time to give and prepare language labs.

S   Weekly frequency of language labs.

r   No. of students in language labs.

Category C - Laboratory Subjects

Again the structure of the model is broadly the same as in Category A but with additional terms to allow for workload involved in giving laboratories and correcting lab books. These are:-

$$N \times we + \{ \left[\frac{N}{p} \right] + 1 \} Q + qo \frac{Q}{4} + qo^{1} \left[\frac{N}{p} \right] {}^{Q}/_{4}$$

Correcting lab books.	Giving Lab.	Preparing labs	Time to replicate lab if repeats are necessary.

Q - No. of hours of lab work per week.

we - Time to correct a lab book.

qo - Time to prepare an experiment for a standard (4 hr) laboratory.

qo^1 - Time to replicate experiment as class grows.

Category D - Education

This is treated as a Category C subject with additional allowance for teaching practices outwith the normal academic year.

Setting of parameter values

Parameter values were set by agreement of representatives of different subject areas. These parameters were different for different areas and also for different semesters (for instance weekly essay frequency was higher for Category A subjects than Category C).

Class sizes

Class sizes which are the inputs to the model are described in Appendix 6.C.

Setting of parameter values

Parameter values were set by agreement of representatives of different subject areas. These parameters were different for different areas and also for different semesters (for instance weekly essay frequency was higher for Category A subjects than Category C).

Class sizes

Class sizes which are the inputs to the model are described in Appendix 6.C.

APPENDIX 5

General Computing Details

5.1 Structure

As explained in Chapter 6 the program consists of a series of subroutines which are controlled by means of a main program. Each subprogram corresponds to one of the sub-modules of the model.

5.2 Program Access

The program is stored on disc on the University's Elliot 4130 computer. This is convenient because of the physically large size of the program and has the additional advantage that it obviates possible card reader faults. In addition the files can be edited by the use of the KOS on line terminal.

5.3 Storage

The storage requirements of the model are considerable, thus the SEGMENTATION facility was used to reduce the total amount of store required. With this facility in use the program can be run with a 64K store.

APPENDIX 6

Description and Details of the Modules

In this appendix we present more detailed explanations of the modules and discuss the operation of the computer program.

The components of this appendix are:

Appendix 6A		Main program
	6B	Student Flow Module
	6C	Notional Class Size Module
	6D	Student Equivalent Module
	6E	Staff Allocation Module (workload option)
	6F	Staff Allocation Module (student/staff ratio option)
	6G	Non-academic Staff Module
	6H	Finance Module
	6I	Teaching Space Module (lecture and seminar rooms)
	6J	Teaching Space Module (laboratory space)
	6K	Research Lab Space
	6L	Academic Office Space

Where appropriate the following information will be supplied for each module. (Sample ouput is from sensitivity analysis I year 1977/8, see Chapter 8)

1. Name of subroutine
2. General description of module
3. Detailed description of program
4. Variable definition
5. Flow chart
6. Program listing
7. Sample output (only most important parts of output are provided)

APPENDIX 6A

Main program

6A1 Name of subroutine - None (main program)

6A2 General description of model

The purpose of this model is to bring the sub-models into operation at appropriate times and control the passing of information through the system. Facilities are provided for choosing the staff allocation option required and the space modules and finance modules may be called or not called depending on the particular situation being investigated.

6A3 Detailed description of program

Line	
1589-95	COMMON block
1597-99	Call modules relating to students
1600-05	Read in variable LALL (if LALL = 1 use workload model for staff allocation, if LALL = 0 use student:staff ratios)
1607-09	Read in variable KALL (if KALL = 1 do not operate finance module) otherwise operate.
1611-15	Read in variable MALL (if MALL = 1 do not operate space module) otherwise operate

6A4 Variable Definition

LALL - A dummy which allows a choice of staff allocation method to be made

KALL - A dummy allowing possibility of operating finance modules

MALL - A dummy allowing possibility of operating space modules

APPENDIX 6A

Main program

6A1 Name of subroutine - None (main program)

6A2 General description of model

The purpose of this model is to bring the sub-models into operation at appropriate times and control the passing of information through the system. Facilities are provided for choosing the staff allocation option required and the space modules and finance modules may be called or not called depending on the particular situation being investigated.

6A3 Detailed description of program

Line

1589-95 COMMON block

1597-99 Call modules relating to students

1600-05 Read in variable LALL (if LALL = 1 use workload model for staff allocation, if LALL = 0 use student:staff ratios)

1607-09 Read in variable KALL (if KALL = 1 do not operate finance module) otherwise operate.

1611-15 Read in variable MALL (if MALL = 1 do not operate space module) otherwise operate

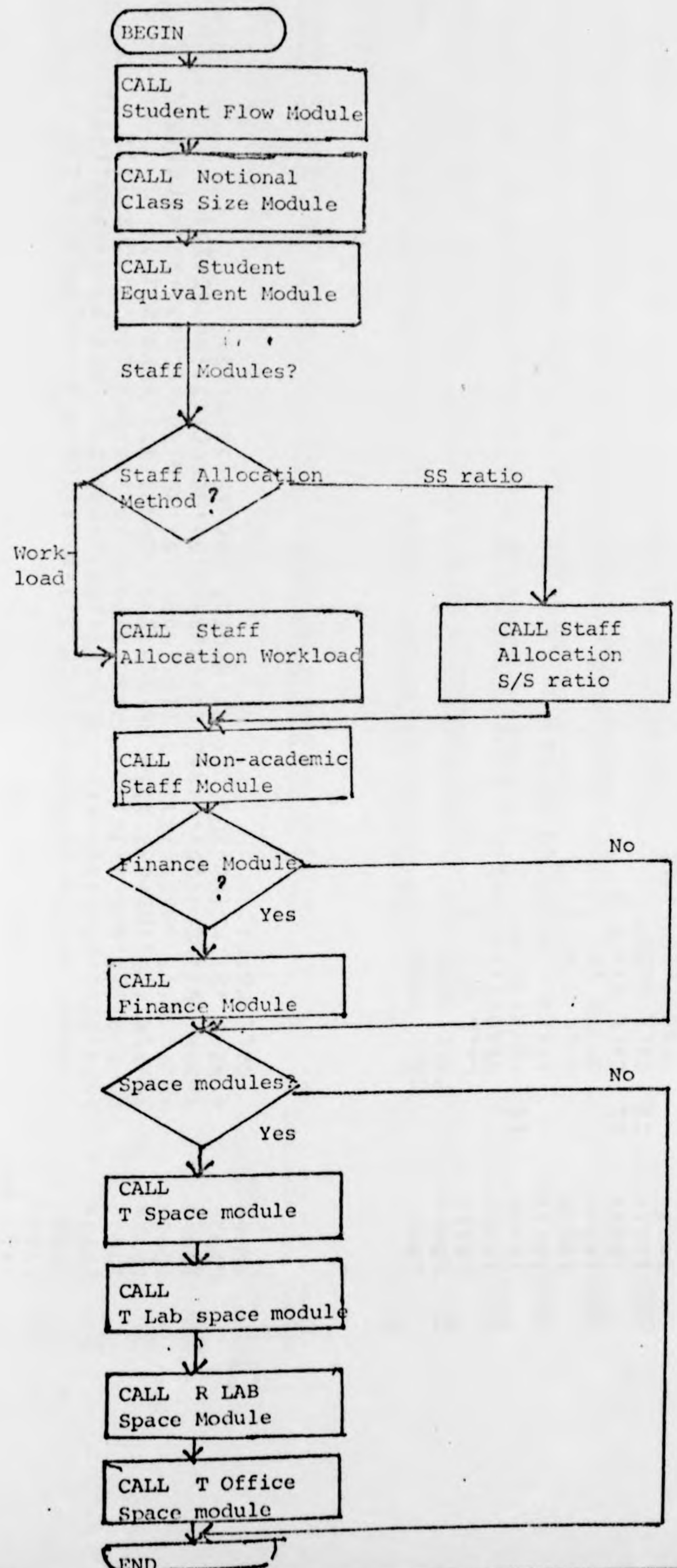
6A4 Variable Definition

LALL - A dummy which allows a choice of staff allocation method to be made

KALL - A dummy allowing possibility of operating finance modules

MALL - A dummy allowing possibility of operating space modules

6A5 Flow Diagram - Main Program



```
@ASSIGN;    1;DC150;RB60.RBFILES:

      COMMON MYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
     1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150), KF9(150),NPGR1(30),
     2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
     3NBPGR1(15),NBPGR2(15), NBPGCR(15),NCPGR1(15),NCPGR2(15),
     4NCPGCR(15),MAST(15),MCST(15),MBST(15),XEQ(30),SEQ(30,9),NAPR(15),
     5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),
     6 N3(3 ,2),MSTUD,SEQTOT(30),NPGTOT,NXCLAS(30,5,12)
      CALL SGTRAC

      CALL STUDFL
      CALL NOTCLS
      CALL STUDEQ
      READ(7,10) LALL
   10 FORMAT(I2)
      IF(LALL.EQ.0) GO TO 11
      CALL STAFF1
      GO TO 12
   11 CALL STAFF 2
   12 CALL NACST
      READ(7,10) KALL
      IF(KALL.EQ.0) GO TO 13
      CALL FINMOD
      READ(7,10) MALL
      IF(MALL.EQ.0) GO TO 13
      CALL TSPACE
      CALL TLABSP
      CALL RLABSP
      CALL TOFFSP
   13 STOP
      END
```

APPENDIX 6B

Student Flow Module

6B1 Name of Subroutine STUDFL

6B2 General description of module

The purpose of this module is to simulate flows of students through the University system. It works on the basis that it is possible to observe proportions of particular first year intakes that reach given academic levels a given number of years after entering the University. For instance it was found that studying in the second academic year of the University was 87.5% of last year's first year intake, 5.6% of the year prior to that and 0.2% of the year prior to that.

Thus, if we are considering year t , and

Y_t	is first year entry in year		t
Y_{t-1}	"	"	t-1
Y_{t-2}	"	"	t-2
Y_{t-2}	"	"	t-r

Then the number of students in the second academic year will be given by

$$N2 = .875Y_{t-1} + .056Y_{t-2} + .002Y_{t-3}$$

In this way we can construct the matrix showing the proportions of each year of entry that has reached given levels of academic progress. (See Chapter 6, insert 1).

6B3 Detailed Description of Program

1- 9 COMMON statement

10 DIMENSION statement

14-16 Read in new first year entries for previous six years (NY(I))

17-21 Read in matrix relating proportion of cohorts from particular historical years I, who have reached academic year J

22-26 Multiply above matrix by vector of first year student entries

27-32 Sum up total student numbers in each academic year

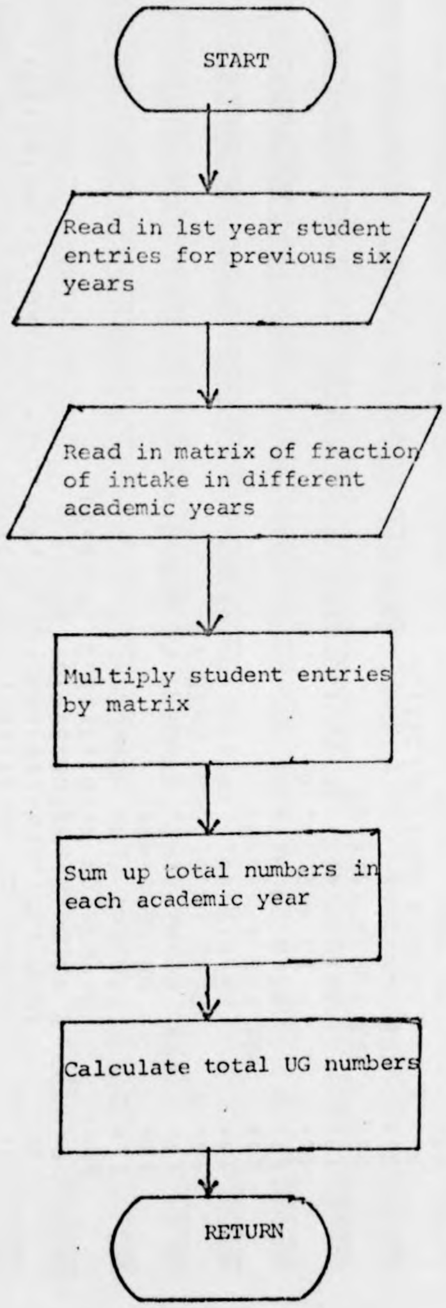
33-37 Sum up total undergraduate numbers in University

38-49 Write out numbers in each academic year

6B4 Definition of Variables

NTOT	Total number of undergraduate students in University
NY(I)	Number of first year students admitted to the University in year I (I = 1 → present year, I = 2 → previous year etc.)
NYR(I)	Number of students in academic year J
YF(I,J)	Fraction of students entering University in historical year I at present in academic year J
YX(I, J)	Numbers of students entering University in historical year I at present in academic year J

6B5 Flow Diagram : Student Flow Module



```
;ASSIGN;     1;DC;50;RB56.RBFILES;

      SUBROUTINE STUDFL
      COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
     1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150),KF9(150),NPGR1(30),
     2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
     3NBPGR1(15),NBPGR2(15),NBPGCR(15),NCPGR1(15),NCPGR2(15),
     4NCPGCR(15),MAST(15),MBST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
     5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),
     6 N3(30,2),MSTUD,SEQTOT(30)
      DIMENSION NY(8),YF(8,5),YX(8,5)
C     STUDENT FLOW MODULE
      WRITE(2,499)
  499 FORMAT(1H1,'STUDENT FLOW MOD')
C     READ IN STUDENT ENTRIES
      READ(7,401) (NY(I),I=1,6)
  401 FORMAT (6I5)
C     READ IN MATRIX
        DO 402 I=1,6
      READ(7,403)(YF(I,J),J=1,5)
  403 FORMAT(5F5.3)
  402 CONTINUE
C     MATRIX MULTIPLICATION
      DO 404  I=1,6
      DO 404  J=1,5
      YX(I,J)=NY(I)*YF(I,J)
  404 CONTINUE
C     SUM UP TOTALS  FOR ACADEMIC YRS
      DO 405 J=1,5
      NYR(J)=0
      DO 405 I=1,6
      NYR(J)=NYR(J)+YX(I,J)
  405 CONTINUE
C     OUTPUT
        NTOT=0
          DO 411 I=1,5
          NTOT=NTOT+NYR(I)
  411  CONTINUE
      WRITE(2,406)
  406 FORMAT (1X, 20H STUDENT   NUMBERS  )
```

```
      WRITE(2,407)
  407 FORMAT(1H0,30H ACADEMIC  YR    STUDENT NOS  )
      DO 408 J=1,5
      WRITE(2,409) J, NYR(J)
  409 FORMAT(I5,14X, I5)
  408 CONTINUE
      WRITE(2,410) NTOT
  410 FORMAT(16H TOT  STUDENTS =, I4)
      RETURN
      END
```

6B7 Sample Output

```
STUDENT FLOW MOD
 STUDENT   NUMBERS

 ACADEMIC  YR    STUDENT NOS
   1                 734
   2                 623
   3                 544
   4                 285
   5                  16
TOT  STUDENTS =2202
```

APPENDIX 6C

Notional Class Size Module

6C1 Name of subroutine: NOTCLS

6C2 General description of Module

This module attempts to simulate the registration of students to courses.

As described in Section 6.8(ii) the method employed in Part I is the consideration of the historically determined proportions of particular cohorts of students who proceed from one semester of a subject to the next.

First, however, it is necessary to calculate semester one class sizes. It has been found historically that if students are divided into broad categories of Science, Social Science and Art, according to their intended future programmes, that a reasonably constant proportion of each of these groups take any of the semester one courses in question. Thus if an intake is divided into proportions intending to study Arts, Science and Social Science based programmes, it is a simple matter to calculate numbers in semester one courses.

Semester two and three courses are calculated on the basis of historically determined proportions of semester one classes proceeding onwards. Additional minor courses are based on proportions of total student registrations.

As described in Chapter 6 the approach used to forecast class sizes in Part II is based on forecasting enrolment in programmes and using an induced course load matrix to calculate class sizes. Enrolment on programmes is calculated on the basis of an historically determined proportion of an initial enrolment (see Table 6C1). Now there are many possible course options available in any given Part II semester. The maximum number that a student can register for however is three. Thus total registrations can be represented by assuming three classes only in each semester of Part II. Thus a student who takes only one course is considered to take the course designated '1'; students who take two courses are considered to take courses designated '1' and '2' and students who take all three courses are, of course, considered to be taking courses designated '1', '2' and '3'. (Hence the term <u>notional</u> class sizes.) An attempt to include all courses available would lead to an induced course matrix of enormous size, complexity and diffuseness.

Hence by multiplying the vector of projected enrolment in Honours or General programmes with the appropriate induced course load matrix it is possible to estimate future enrolment in particular courses of study.

TABLE 6C1 Relationship of enrollment in Part II programmes to programme student's initially entered to study

Programme of Entry	Average proportion of entry studying programme in SEMS 5-6 Hons	Gen	
1. Maths	.259	.130	
2. Economics	.331	.252	
3. Sociology	.425	.490	
4. English	.341	.313	
5. History	.321	.465	
6. Philosophy	1.123	.442	
7. Acc. & Bus. Law	.331	.252	
8. Religious Studies	.292	.763	
9. Management Science	.331	.252	
10. Computing Science	.667	1.000	
11. French	.198	.156	
12. German	.826	.499	
13. Spanish	.500	1.000	
14. Biology	.312	.291	
15. Physics	.259	.250	
16. Chemistry	.637	.150	
17. Psychology	.422	.368	
18. Biochemistry	1.402	.322	
19. Technological Economics	.330	.250	
20. Education + Biology	.042	.072	Note: Since it was not possible to apply for these programmes directly, fractions are related to no. entering to study non-Education part of programme
21. Education + Chemistry	.090	.090	
22. Education + English	.105	.103	
23. Education + French	.034	.038	
24. Education + German	.149	.202	
25. Education + History	.053	.139	
26. Education + Maths	.085	.153	
27. Education + Spanish	.034	.038	

6C3 <u>Detailed description of program</u>

53-9 Definition of COMMON block

60-63 DIMENSION statement

67-72 Read in number of subjects (NDEP) and names

73-78 Zero array NCLAS (I,J,K)

85-91 Read in array X(I,J,K) - Proportion of students Arts, (K = 1), Science (K = 2) or Social Science based (K = 3) taking Jth option in subject I (and write out array).

93-98 Read in fraction of enrolment intending to study Arts based; Science based and Social Science based programmes.

99-102 Calculate numbers of students intending to study Arts based; Science based and Social Science based programmes.

104-09 Multiply matrix X(I,J,K) by vector of numbers intending to study programs in each area. Sum up numbers in each class.

112-23 Write out Semester 1 class sizes. Format: subject name: students taking major unit; students taking minor unit (where applicable).

125-27 Read in fractions taking SEM2 minors

128-31 Calculate numbers taking SEM2 minor courses (total student numbers × fractions)

133-34 Read in transition factors for SEM1 major → SEM2 major courses

136-38 Calculate student numbers on SEM2 major courses (Semester 1 numbers × transition factors)

139-49 Normalization (to ensure that correct total numbers of semester courses corresponding to number expected from total enrolment).

Calculate normalization factor
Adjust class sizes using normalization factor

150-58 Print out SEM2 class sizes

Appropriate departmental headings
Appropriate class sizes (including major and minor courses)

160-62 Read in fraction of SEM3 students taking minor courses

163-66 Calculate numbers taking SEM3 minors (total SEM3 student numbers × above fractions)

168-70 Read in numbers in previous years SEM1 major class

171-72 Read in transition factors

173-76 Calculate numbers on SEM3 major courses

178-81 Read in proportions of SEM3 students taking SEM1 courses

182-85 Calculate numbers of SEM3 students taking SEM1 courses

Normalization

187-89 Read in average number of semester units taken by a semester 3 student

190-95 Calculate normalization factor

196-200 Adjust class sizes by appropriate normalization factor

201-09 Write out SEM3 class sizes with appropriate headings

210-17 For all Part I classes. If major class size (J = 1) is zero, replace major with minor class size and vice versa.

PART TWO

219 Put variable NP2 = 2nd year student numbers

220 Read in number of Part II programmes

222 Read in programme titles

225-30 Write out programme titles (together with appropriate introductory statements)

242-45 Read in semester number (4 to 8)

247-48 Read in proportion of Honours students

249-51 Calculate total numbers of students on Honours + General programmes

252-55 Read in fractions of students taking individual Honours and General programmes for a given semester

256-66 Calculate numbers on all such programmes (and print out results)

267-281 Read in induced course load matrix for Honours and
288-300 General programmes (and print out)

282-87 Multiply number on programmes with ICLM (result numbers of students from each programme taking a particular course;
301-05 arrays NH(I,J), NG(I,J)

312-15 Zero arrays KF(J)

316-19 Sum up numbers taking each class

320-24 Write out part class sizes KF(J)

325-51 Class sizes are stored under appropriate variable names

For SEM 4 → KF4(I)
SEM 5 → KF5(I)
SEM 6 → KF6(I)
SEM 7 → KF7(I)
SEM 8 → KF8(I)

Variable NP2 put equal to appropriate year student numbers
If appropriate return to beginning of loop.

353-58 Zero array KCLAS (I,J,K)

359-64 SEM1 - Add to SEM1 class numbers - courses taken by students in SEMS 3 and 5

365-71 SEM2 - Add to SEM2 class numbers - courses taken by students in SEMS 4 and 6

372-76 Add to SEM3 course numbers - courses taken by students in SEM5

377-92 Assign arrays KF4 - KF8 to modified arrays KCLAS (I,J,K)

393-97 Add to SEM4 course numbers, course units taken by students in SEM6

398-418 Print out notional class sizes under appropriate headings

419-22 Read in number of education department

423-26 Education SEM9 nos. Assign to appropriate superscripted variable

427-28 Write out education SEM9 numbers

POSTGRADUATES

423-37 Read in PG numbers attached to each department (include research, interdisciplinary research and PG courses)

438-43 Write out above numbers

444-49 Calculate total PG numbers

APPENDIX 6C

4 Definition of Variables

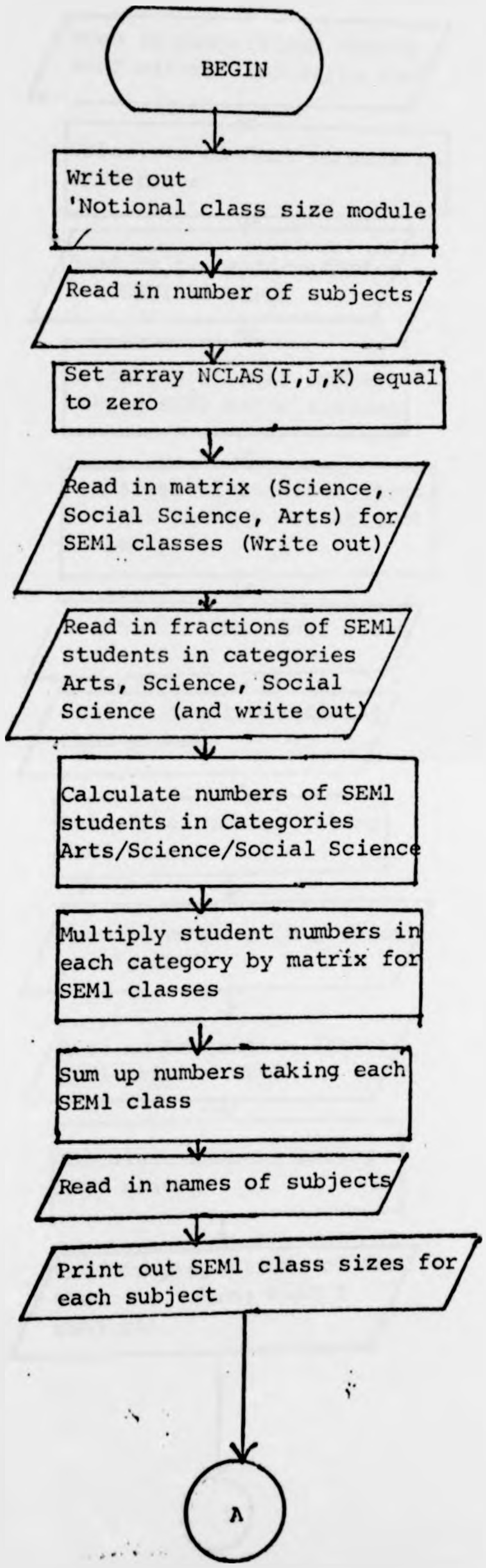
ADEP (I)	Names of subjects (alphanumeric)
APROG (I)	Names of academic programmes (alphanumeric)
ATRAN (I)	Proportion of students taking SEM1 major courses proceeding to SEM2
FART	Proportion of SEM1 students classified as intending to study Arts programmes
FSCI	Proportion of SEM1 students classified as intending to study Science programmes
FSOC	Proportion of SEM1 students classified as intending to study Social Science programmes
FGPR (I)	Fraction of students in a given (Part 2) semester studying a particular General degree programme I
FHPR (I)	Fraction of students in a given (Part 2) semester studying a particular Honours degree programme I
FHON	Proportion of students in a given (Part 2) semester studying Honours programmes
FNORM	SEM2 normalization factor
GNDRM	SEM3 normalization factor
GUNIT	Mean number of semester units studied by students in Semester 3
KCLAS (I,J,K)	Total student registrations on notional class for Subject I, semester J, option K
KF(F)	Number of students in a given (Part 2) semester taking a particular course unit J
KF4(J)-KF8(J)	Number of students in (SEM4-8) taking a particular course unit J
KZ	Number of course units available to a student in a given semester (including units from other semesters)
MCLAS(I)	Number of SEM1 units taking a SEM1 major unit in previous year
N3(I,J)	Numbers of SEM3 students taking a SEM1 course in subject I
N3TOT	Total course units studied by SEM3 students

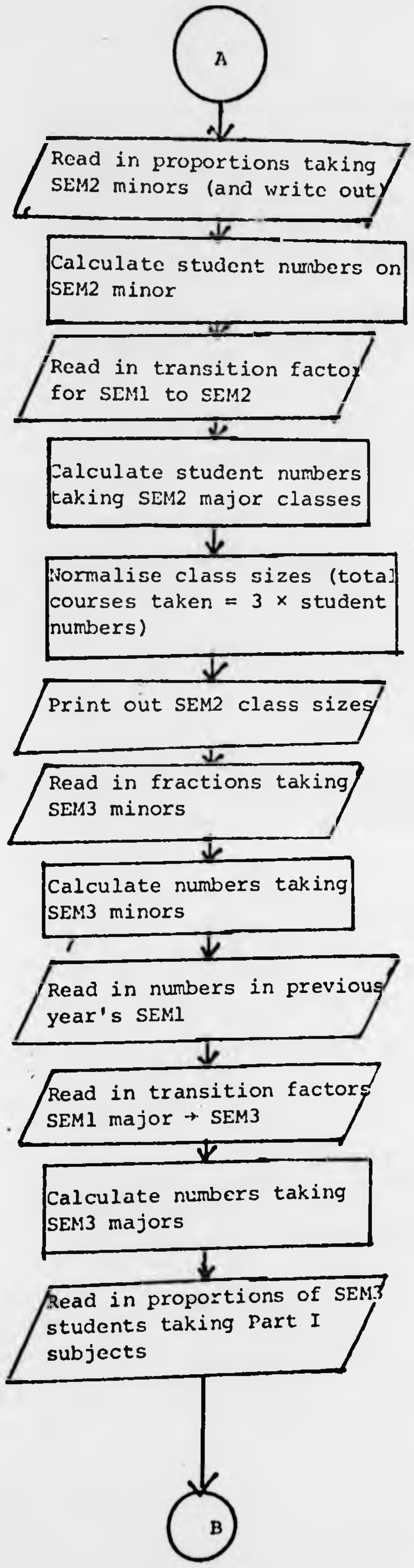
NCLAS(I,J,K)	Initial array of students taking subject I, semester J, option K (Part I only)
NDEP	No academic subjects offered
NEDCL	Class size - Education: Sem 9
NEDUC	Subjet number - education
NHON	Numbers of students studying for Honours programmes
NGEN	Numbers of students studying for General programmes
NHPR(I)	Numbers of students in given Part II semester studying a given Honours programme I
NGPR(I)	Numbers of students in given Part II semester studying a given General programme
NP2	Number of students in a given (Part 2) semester
NPGR1(I)	Number of full-time research students studying subject I
NPGR2(I)	Number of full-time (interdisciplinary) students studying subject I
NPGCR(I)	Number of full-time taught PG course students studying subject I
NPGTOT	Total number of PG students
NS(K)	Numbers of SEM1 students classified as intending to study Science, (I = 1), Social Science (I = 2) and Arts (I = 3) programmes
NSEM	Semester number
NZTOT	Total course units taken by SEM2 students
T2(I)	Proportions of Semester 2 students studying minor course in subject I
T3(I)	Proportion of Semester 3 students studying minor course in subject I
T3R(I)	Proportion of previous academic years students in SEM1 major course proceeding to subsequent SEM3 major course
T13R(I)	Proportion of SEM3 students taking a SEM1 course in subject I

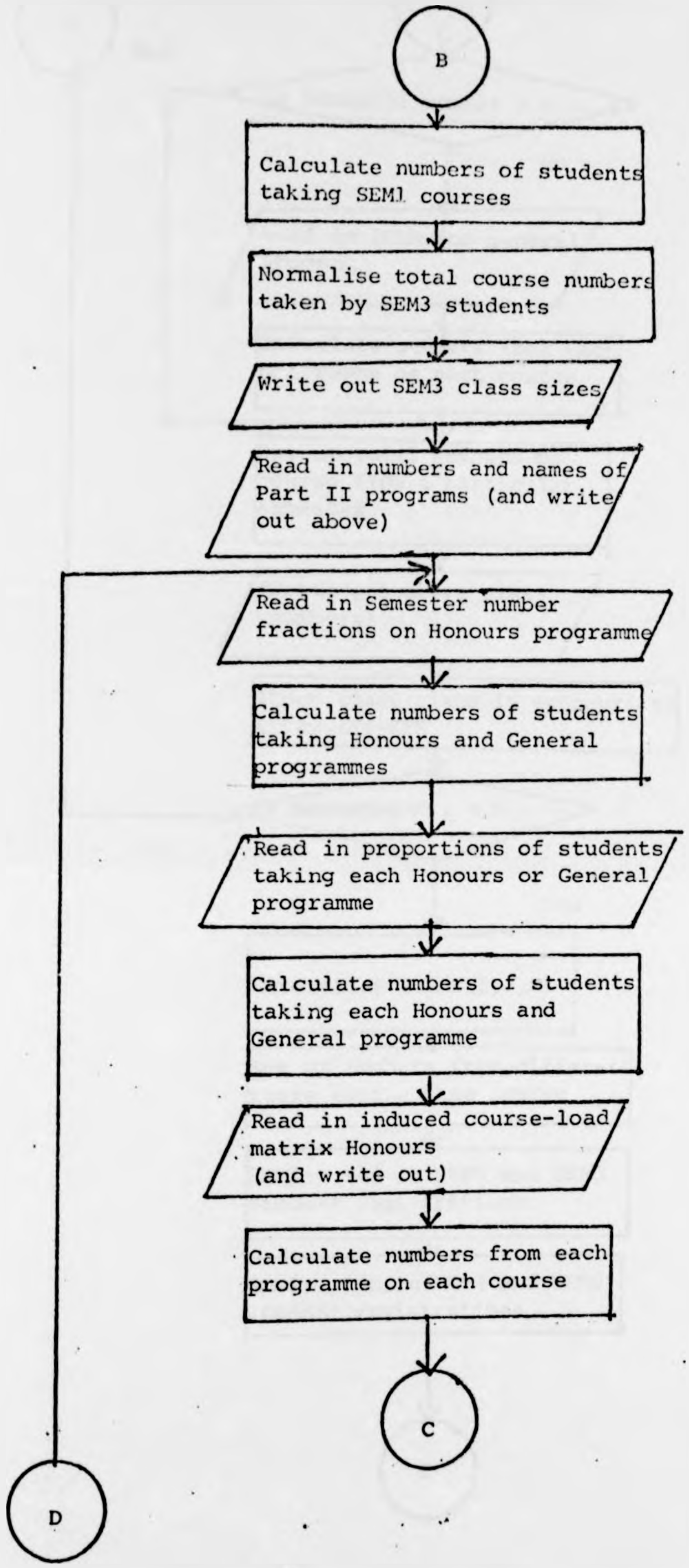
X(I,J,K)	Proportions of students in category K (K = 1 Science, K = 2 Social Science, K = 3 Arts) taking option J (J = 1 - major course, 2 = minor course) in subject I (SEM1)
Y(I,J,K)	Numbers of students in category K (K = 1 Science, K = 2 Social Science, K = 3 Arts) taking option J (J = 1 - major course, 2 = minor course) in subject I (SEM1)
XH(I,J)	Proportion of students studying Honours programme I taking course unit J
XG(I,J)	Proportion of students studying General programme I taking course unit J

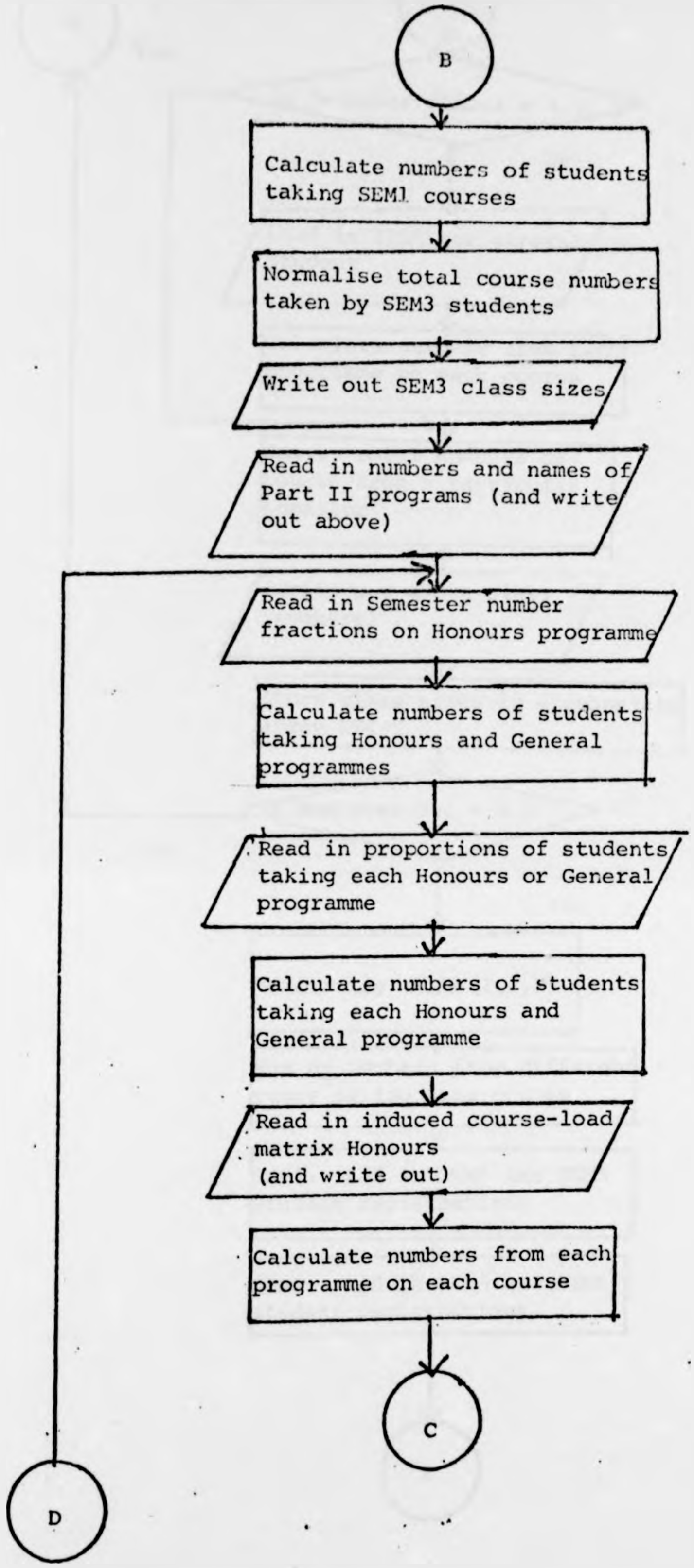
APPENDIX 6C

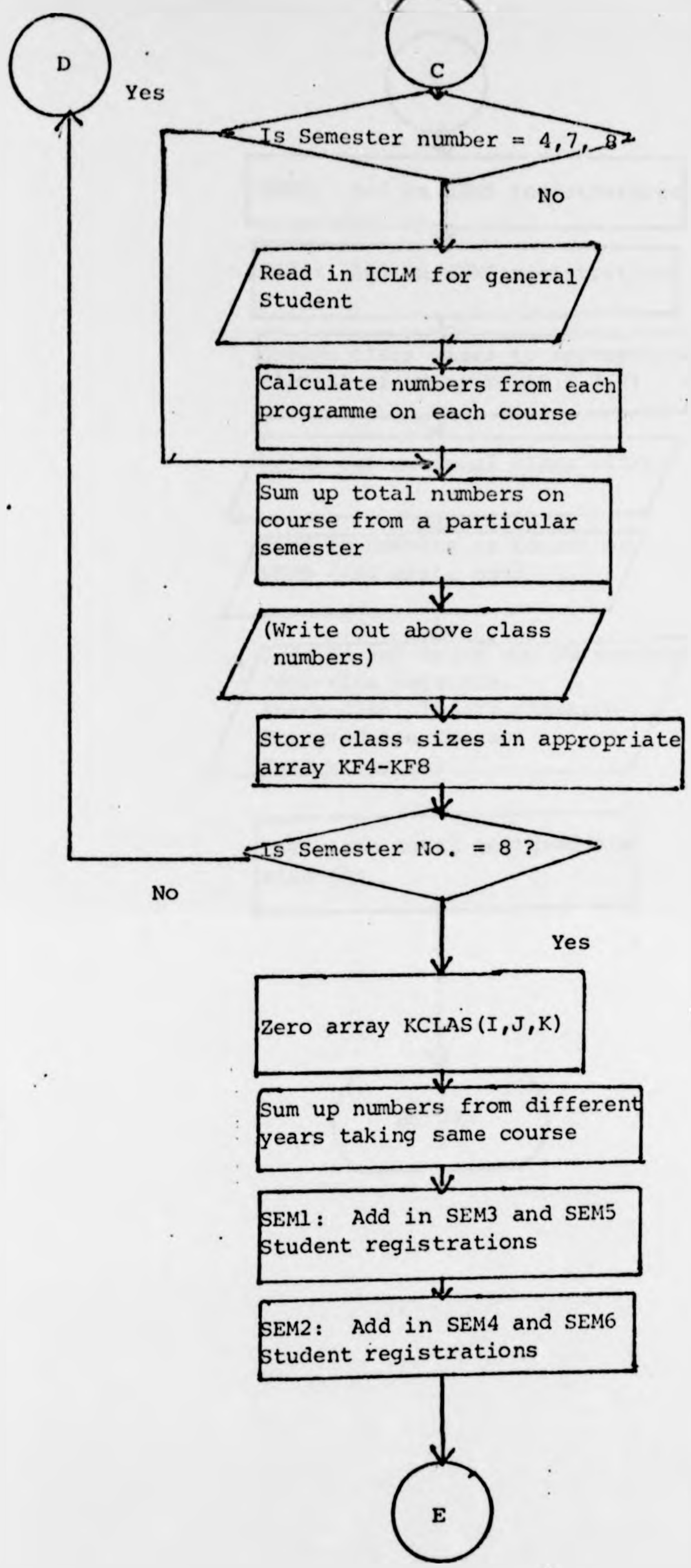
5 Flow diagram: Notional class size module

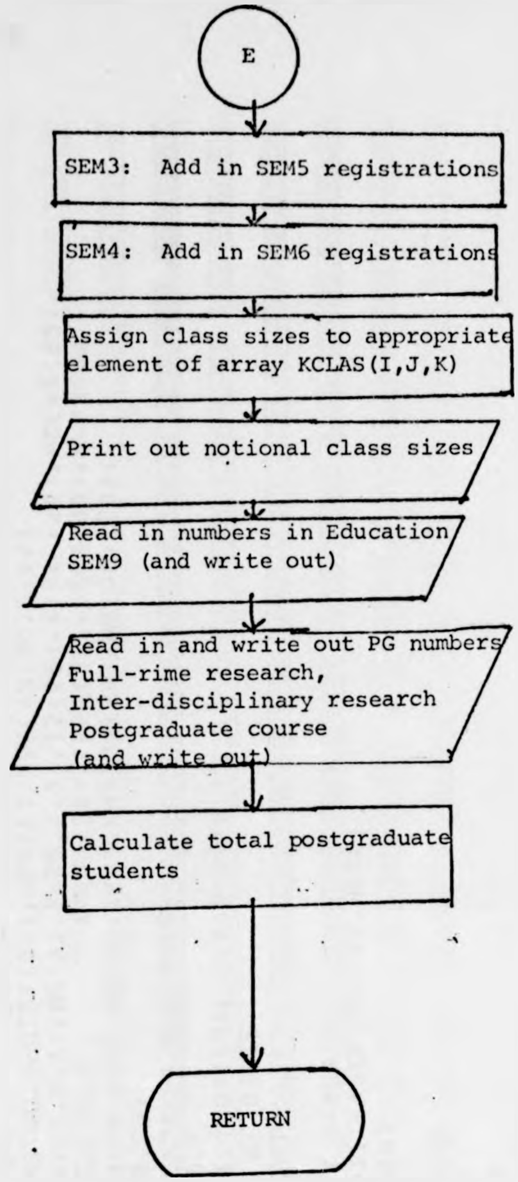



A
Read in proportions taking SEM2 minors (and write out)
Calculate student numbers on SEM2 minor
Read in transition factor for SEM1 to SEM2
Calculate student numbers taking SEM2 major classes
Normalise class sizes (total courses taken = 3 × student numbers)
Print out SEM2 class sizes
Read in fractions taking SEM3 minors
Calculate numbers taking SEM3 minors
Read in numbers in previous year's SEM1
Read in transition factors SEM1 major → SEM3
Calculate numbers taking SEM3 majors
Read in proportions of SEM3 students taking Part I subjects
B


B
Calculate numbers of students taking SEM1 courses
Normalise total course numbers taken by SEM3 students
Write out SEM3 class sizes
Read in numbers and names of Part II programs (and write out above)
Read in Semester number fractions on Honours programme
Calculate numbers of students taking Honours and General programmes
Read in proportions of students taking each Honours or General programme
Calculate numbers of students taking each Honours and General programme
Read in induced course-load matrix Honours (and write out)
Calculate numbers from each programme on each course
C
D


B
Calculate numbers of students taking SEM1 courses
Normalise total course numbers taken by SEM3 students
Write out SEM3 class sizes
Read in numbers and names of Part II programs (and write out above)
Read in Semester number fractions on Honours programme
Calculate numbers of students taking Honours and General programmes
Read in proportions of students taking each Honours or General programme
Calculate numbers of students taking each Honours and General programme
Read in induced course-load matrix Honours (and write out)
Calculate numbers from each programme on each course
C
D


D
C
Yes
Is Semester number = 4,7,8?
No
Read in ICLM for general Student
Calculate numbers from each programme on each course
Sum up total numbers on course from a particular semester
(Write out above class numbers)
Store class sizes in appropriate array KF4-KF8
Is Semester No. = 8 ?
No
Yes
Zero array KCLAS(I,J,K)
Sum up numbers from different years taking same course
SEM1: Add in SEM3 and SEM5 Student registrations
SEM2: Add in SEM4 and SEM6 Student registrations
E


E
SEM3: Add in SEM5 registrations
SEM4: Add in SEM6 registrations
Assign class sizes to appropriate element of array KCLAS(I,J,K)
Print out notional class sizes
Read in numbers in Education SEM9 (and write out)
Read in and write out PG numbers
Full-rime research,
Inter-disciplinary research
Postgraduate course
(and write out)
Calculate total postgraduate students
RETURN

```
&ASSIGN;     1:DC:50;RB51,RBFILES;

      SUBROUTINE NOTCLS
      COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
     1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150), KF9(150),NPGR1(30),
     2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
     3NBPGR1(15),NBPGR2(15), NBPGCR(15),NCPGR1(15),NCPGR2(15),
     4NCPGCR(15),MAST(15),MBST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
     5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),
     6 N3(30,2),MSTUD,SEQTOT(30),NPGTOT,MXCLAS(30,5,12)
      DIMENSION X(25,2,3),NS(3),Y(25,2,3),T2(25),ATRAN(25),MCLAS(25),
     1T3R(25),T13R(25,2),        APROB(30),FHPR(30),FGPR(30),NHPR(30),
     2NGPR(30),XH(30,120),XG(30,120),NH(30,120),NG(30,120),
     3 KF(120),T3(25)
C     NOTIONAL CLASS SIZE MODULE
      WRITE(2,102)
  102 FORMAT(1H1,'NOTIONAL CLASS SIZE')
C     READ IN NO OF DEPTS
      READ(7,1)NDEP
    1 FORMAT(I3)
C       READ DEPT NAMES
       READ(7,803) (ADEP(I),I=1,NDEP)
  803  FORMAT(8A10)
C     ZERO ARRAY
      DO 2 I=1,NDEP
      DO 2 J=1,3
      DO 2 K=1,3
       NCLAS(I,J,K)=0
    2 CONTINUE
C     SEMESTER I CLASSES
       WRITE(2,810)
  810 FORMAT(1H0,'SEM1 FACTORS')
C     READ IN SEM1 MATRIX
       WRITE(2,820)
  820  FORMAT(1H0,12X,' SC  SOCSC  ARTS')
      DO3 I=1,NDEP
      DO3 J=1,2
      READ(7,4)(X(I,J,K),K=1,3)
    4 FORMAT(3F5.3)
```

```
      WRITE(2,103) ADEP(I),J, (X(I,J,K),K=1,3)
  103 FORMAT(1X,A10,I2,3F6.3)
    3 CONTINUE
C     READ IN FRACTIONS STUDYING SC, SOC SC,ARTS
      READ(7,901) FSCI,FSOC,FART
  901 FORMAT(3F5.3)
       WRITE(2,812)
  812  FORMAT(1H0,'PROPS INT SC,SOC SC,ARTS PROGS')
       WRITE(2,104) FSCI ,FSOC,FART
  104  FORMAT(1H0,3F5.3)
C      CALCULATE FRACTION  IN SC ,SOC SC ARTS AREAS
       NS (1)=NYR(1)*FSCI
        NS(2)=NYR(1)*FSOC
       NS(3)=NYR(1)*FART
C      MATRIX  MULTIPLICATION
       DO 6 I=1,NDEP
       DO 6 J=1,2
       DO 6 K=1,3
       Y(I,J,K)=X(I,J,K)*NS(K)
       NCLAS(I,1,J)=NCLAS(I,1,J)+Y(I,J,K)
    6 CONTINUE
        WRITE(2,813)
  813 FORMAT(1H0,'PART ONE')
C      WRITE OUT SEM1 CLASS SIZES
       WRITE(2,7)
    7 FORMAT(1H1, 'SEM1 CLASS SIZES')
       WRITE(2,8)(ADEP(I),I=1,I2)
    8 FORMAT(1H0,9X,12A10)
       WRITE(2,9)(NCLAS(I,1,1),I=1,12)
    9  FORMAT('  MAJORS  ',12I10)
       WRITE(2,10)(NCLAS(I,1,2),I=1,12)
   10  FORMAT('  MINORS  ', 12I10)
       WRITE(2,8)(ADEP(I),I=13,NDEP)
       WRITE(2,9)(NCLAS(I,1,1),I=13,NDEP)
```

```
      WRITE(2,10)(NCLAS(I,1,2),I=13,NDEP)
C     SEMESTER 2
C     CALCULATE SEM2  MINORS
      READ(7,17)(T2(I),I=1,NDEP)
   17 FORMAT(16F5.3)
C     CALCULATE NOS ON SEM2 MINOR COURSES
      DO 18 I=1,NDEP
      NCLAS(I,2,2)=NYR(1)*T2(I)
   18 CONTINUE
C     CALCULATE SEM2  MAJORS
C     READ IN TRANSITION FACTORS
      READ(7,17)(ATRAN(I),I=1,NDEP)
C     CALCULATE MAJORS
      DO 19 I=1,NDEP
      NCLAS(I,2,1)=NCLAS(I,1,1)*ATRAN(I)
   19 CONTINUE
C     NORMALIZATION
      NZTOT=0
      DO 20 I=1,NDEP
      DO 20 K=1,2
      NZTOT=NZTOT+NCLAS(I,2,K)
   20 CONTINUE
       FNORM= 3.0*NYR(1)/NZTOT
      DO 21 I=1,NDEP
      DO 21 K=1,2
      NCLAS(I,2,K) =NCLAS(I,2,K)*FNORM
   21 CONTINUE
C     PRINT OUT SEM2 CLASS SIZES
      WRITE(2,22)
   22 FORMAT(1H0,'SEM2 CLASS SIZES')
```

```
      WRITE(2,8)(ADEP(I),I=1,12)
      WRITE(2,9)(NCLAS(I,2,1),I=1,12)
      WRITE(2,10)(NCLAS(I,2,2),I=1,12)
      WRITE(2,8)(ADEP(I),I=13,NDEP)
      WRITE(2,9)(NCLAS(I,2,1),I=13,NDEP)
      WRITE(2,10)(NCLAS(I,2,2),I=13,NDEP)
C     SEMESTER 3
C     CALCULATE SEM3 MINORS
C     READ IN FRACTIONS TAKING SEM3 MINORS
      READ(7,17)(T3(I),I=1,NDEP)
C     CALCULATE NOS TAKING SEM3 MINORS'
      DO 23 I=1,NDEP
      NCLAS(I,3,2)=NYR(2)*T3(I)
   23 CONTINUE
C     CALCULATE NOS TAKING SEM3 MAJORS
C     READ IN NOS IN PREVIOUS YRS SEM1
      READ(7,24)(MCLAS(I),I=1,NDEP)
   24 FORMAT(20I4)
C        READ IN TRANSION FACTORS
      READ(7,17) (T3R(I),I=1,NDEP)
C     CALCULATE  SEM3 MAJORS
      DO 25 I=1,NDEP
      NCLAS(I,3,1)=MCLAS(I)*T3R(I)
   25 CONTINUE
C     CALCULATE SEM3 NOS TAKING SEM1 CLASSES
C     READ IN PROPORTIONS
      DO 26 J=1,2
      READ(7,17)(T13R(I,J),I=1,NDEP)
   26 CONTINUE
      DO 27 I=1,NDEP
      DO 27 J=1,2
      N3(I,J)=NYR(2)*T13R(I,J)
```

```
   27 CONTINUE
C     NORMALIZATION
C     READ IN NO OF SEM UNITS TAKEN IN SEM3 PER STUDENT
      READ(7,28)GUNIT
   28    FORMAT(F5.3)
      N3TOT=0
      DO 29 I=1,NDEP
      DO 29 K=1,2
      N3TOT =N3TOT+ N3(I,K)*NCLAS(I,3,K)
   29 CONTINUE
        GNORM=GUNIT*1.0*NYR(2)/N3TOT
      DO 30 I=1,NDEP
      DO 30 K=1,2
      NCLAS(I,3,K)=NCLAS(I,3,K)*GNORM
        N3(I,K)=N3(I,K)*GNORM
   30 CONTINUE
C     WRITE OUT SEM3  CLASS SIZES
        WRITE(2,275)
  275   FORMAT(1H0,'SEM 3 CLASS SIZES')
      WRITE(2,8)(ADEP(I),I=1,12)
      WRITE(2,9)(NCLAS(I,3,1),I=1,12)
      WRITE(2,10)(NCLAS(I,3,2),I=1,12)
      WRITE(2,8)(ADEP(I),I=13,NDEP)
      WRITE(2,9) (NCLAS(I,3,1),I=13,NDEP)
      WRITE(2,10)(NCLAS(I,3,2),I=13,NDEP)
        DO 900 I=1,NDEP
        DO 900 J=1,3
        IF(NCLAS(I,J,1).EQ.0) GO TO 991
```

```
      GO TO 900

  991 NCLAS(I,J,1)=NCLAS(I,J,2)
      NCLAS(I,J,2) =0
  900 CONTINUE
C     PART TWO
      NP2 =NYR(2)
C     READ IN NO OF PART TWO  PROGRAMS
      READ(7,1) NPROG
      READ(7,803) (APROG(I),I=1,NPROG)
      WRITE(2,31)
   31 FORMAT(1H1,'PART TWO')
      WRITE(2,32)
   32 FORMAT(1H0, 'PROGRAM TITLES')
      DO 33 I=1,NPROG
      WRITE(2,34) APROG(I)
   34 FORMAT(1X,8A10)
   33 CONTINUE
C       ZERO ARRAYS
       JCR=5*NDEP
       DO 761 I=1,JCR
       KF(I)=0
       KF4(I)=0
       KF5(I)=0
       KF6(I)=0
       KF7(I)=0
       KF8(I)=0
       KF9(I)=0
  761 CONTINUE
C     READ SEMESTER NO
 7500 READ(7,1) NSEM
       WRITE(2,815) NSEM
  815  FORMAT(1H0, 'SEMESTER ',I4)
```

```
C     READ IN FRACTIONS TAKING HONS PROGS
      READ(7,344) FHON
  344 FORMAT(F5.3)
C     CALCULATE NOS ON HONS/GEN PROGRAMS
      NHON=NP2*FHON
      NGEN=NP2-NHON
C     READ IN FRACTIONS TAKING EACH PROGRAM
      READ(7,35) (FHPR(I),I=1,NPROG)
   35 FORMAT(16F5.4)
      READ(7,35) (FGPR(I),I=1,NPROG)
C     CALCULATE NOS ON EACH PROGRAM
      DO 36 I=1,NPROG
      NHPR(I)=NHON*FHPR(I)
      NGPR(I)=NGEN*FGPR(I)
   36 CONTINUE
        WRITE(2,821)
  821 FORMAT('NOS ON PROGS HON GEN')
        DO 816 I=1,NPROG
        WRITE(2,817) APROG(I),NHPR(I),NGPR(I)
  817 FORMAT(1X,A10,2I4)
  816 CONTINUE
C     READ IN INDUCED COURSE LOAD MATRIX
C      ICLM  FOR HONS STUDENTS
        IF(NSEM.EQ.5) KZ=5*NDEP
        IF(NSEM.EQ.6) KZ=5*NDEP
        IF(NSEM.EQ.4) KZ=4*NDEP
        IF(NSEM.EQ.7) KZ=3*NDEP
```

```
      IF(NSEM.EQ.8) KZ=3*NDEP
        WRITE(2,703)
  703 FORMAT(1H0,'IND CRSE LD MATRIX HON')
      DO 37 I=1,NPROG
      READ(7,17)(XH(I,J),J=1,KZ)
       WRITE(2,34) APROG(I)
       WRITE(2,704)(XH(I,J),J=1,KZ)
  704 FORMAT(1X,16F5.3)
   37 CONTINUE
C     CALCULATE NOS ON COURSES
      DO 39 I=1,NPROG
      DO 39 J=1,KZ
      NH(I,J)=NHPR(I)*XH(I,J)
   39 CONTINUE

C       GENERAL
       IF(NSEM.EQ.4) GO  TO 999
       IF(NSEM.EQ.7) GO TO 999
       IF(NSEM.EQ.8) GO TO 999
C       ICLM FOR GEN STUDENTS
       WRITE(2,705)
  705 FORMAT(1H0,'IND CRSE LD MATRIX GEN')
       DO 501 I=1,NPROG
       READ(7,17) (XG(I,J),J=1,KZ)
       WRITE(2,34) APROG(I)

       WRITE(2,704) (XG(I,J),J=1,KZ)
  501 CONTINUE
C        CALCULATE NOS ON COURSES
       DO 502 I=1,NPROG
       DO 502 J=1,KZ
       NG(I,J)=NGPR(I)*XG(I,J)
  502 CONTINUE
```

```
      GO TO 505
  999 DO 504 I=1,NPROG
       DO 504 J=1,KZ
      NG (I,J) =0
  504 CONTINUE
C     SUM UP NOS TAKING EACH COURSE
C     ZERO ARRAY
  505 DO 43 J=1,KZ
      KF(J)=0
   43 CONTINUE
      DO42 J=1,KZ
      DO42 I=1,NPROG
      KF(J)=KF(J)+NH(I,J)+NG(I,J)
   42 CONTINUE
C     WRITE OUT PART CLASS SIZES
      WRITE(2,7300) NSEM
 7300 FORMAT(1H0, 'PART CLASS SIZE  SEM',I2)
      WRITE (2,74)(KF(I),I=1,KZ)
   74 FORMAT(1X,20I5)
C     STORING CLASS  SIZES
      IF (NSEM.EQ.4) GO TO 76
      IF (NSEM.EQ.5) GO TO 77
      IF (NSEM.EQ.6) GO TO 78
      IF (NSEM.EQ.7) GO TO 79
      IF (NSEM.EQ.8) GO TO 80
   76 DO 99 I=1,KZ
      KF4(I)=KF(I)
```

```
   99 CONTINUE
      NP2=NYR(3)
      GO TO 7500
   77 DO 89 I=1,KZ
      KF5(I)=KF(I)
   89 CONTINUE
      GO TO 7500
   78 DO 81 I=1,KZ
      KF6(I)=KF(I)
   81 CONTINUE
       NP2=NYR(4)
      GO TO 7500
   79 DO 82 I=1,KZ
      KF7(I)=KF(I)
   82 CONTINUE
      GO TO 7500
   80 DO 85 I=1,KZ
      KF8(I)=KF(I)
   85 CONTINUE
C     NOTIONAL  CLASS SIZE TOTALS
C     ZERO ARRAY
      DO59 I=1,NDEP
      DO59 J=1,9
      DO59 K=1,3
      KCLAS(I,J,K)=0
   59 CONTINUE
C     SEMESTER 1.ADD IN SEM3,SEM5 NOS
C     MAJOR COURSES
      DO 60 I=1,NDEP
      LM=4*NDEP +I
      KCLAS(I,1,1)=NCLAS(I,1,1)+N3(I,1)+KF5(LM)
   60 CONTINUE
```

```
C     SEMESTER 2 :ADD IN SEM4 AND 6 NOS
C     MAJORS
      DO 62 I=1,NDEP
      LN=3*NDEP+I
                    LM=4*NDEP+I
      KCLAS(I,2,1)=NCLAS(I,2,1)+KF6(LM)+KF4(LN)
   62 CONTINUE
C     SEMESTER 3:ADD IN SEM5 COURSES
      DO 64 I=1,NDEP
      LN=3*NDEP+I
      KCLAS(I,3,1)=NCLAS(I,3,1)+KF5(LN)
   64 CONTINUE
C       PART 1 MINORS
        DO 101 I=1,NDEP
        DO 101 J=1,3
        KCLAS(I,J,2) =NCLAS(I,J,2)
  101   CONTINUE
C     SEM 4 TO8 NOT CLASS SIZES
C     SEMESTER 4
      DO 66 I=1,NDEP
      DO 66 K=1,3
      L=3-K
      KCLAS(I,4,K)=KF4(3*I-L)
      KCLAS(I,5,K)=KF5(3*I-L)
      KCLAS(I,6,K)=KF6(3*I-L)
      KCLAS(I,7,K)=KF7(3*I-L)
      KCLAS(I,8,K)=KF8(3*I-L)
   66 CONTINUE
```

```
C     ADD TO SEM4,UNITS TAKEN BY SEM6 CLASSES
      DO 67 I=1,NDEP
      L=3*NDEP+I
      KCLAS(I,4,1)=KCLAS(I,4,1)+KF6(L)
   67 CONTINUE
C     PRINT OUT NOTIONAL CLASS SIZES
      WRITE(2,88)(ADEP(I),I=1,12)
   88  FORMAT(3X,'SEM OPT ',12A10)
      DO 68 J=1,3
       DO 68 K=1,2
      WRITE(2,69)J,K,(KCLAS(I,J,K),I=1,12)
   69 FORMAT(1X,2I4,12I10)
   68 CONTINUE
      DO 70 J=4,8
      DO 70 K=1,3
      WRITE(2,69) J,K,(KCLAS(I,J,K),I=1,12)
   70 CONTINUE
      WRITE(2,88)(ADEP(I),I=13,NDEP)
      DO 71 J=1,3
      DO 71 K=1,2
      WRITE(2,69) J,K, (KCLAS(I,J,K),I=13,NDEP)
   71 CONTINUE
      DO 72 J=4,8
      DO 72 K=1,3
      WRITE(2,69) J,K,(KCLAS(I,J,K),I=13,NDEP)
   72 CONTINUE
C     EDUC SEM9
C     READ EDUCATION DEPT NOS
      READ(7,73) NEDUC
   73 FORMAT(I2)
      KCLAS(NEDUC,9,1)=NYR(5)
       KCLAS(NEDUC,9,2)=NYR(5)
       KA=3*NDEP-2
       KF9(KA)=NYR(5)
```

```
      WRITE(2,7301) KCLAS(NEDUC,9,1)
 7301 FORMAT('EDUCAT SEM9',I3)
C     POSTGRADUATES
C     PRINT OUT POSTGRADS
      WRITE(2,744)
  744  FORMAT(1H0,'POSTGRAD STUDENTS')
C       READ IN POSTGRAD NOS
        DO 91 I=1,NDEP
      READ(7,92) NPGR1(I),NPGR2(I),NPGCR(I)
   92 FORMAT(3I3)
   91 CONTINUE
      WRITE(2,93)
   93 FORMAT(10X,'  RES PG   ID RES PG  PG COURSE')
        DO 94 I=1,NDEP
        WRITE (2,95) ADEP(I),NPGR1(I),NPGR2(I),NPGCR(I)
   95 FORMAT(1X,A10,3I10)
   94 CONTINUE
C         CALCULATE TOTAL PG STUDENTS
      NPGTOT=0
      DO 9411 I=1,NDEP
      NPGTOT=NPGTOT+NPGR1(I)+NPGR2(I)+NPGCR(I)
 9411 CONTINUE
        RETURN
        END
```

298564

NOTIONAL CLASS SIZE

SEM1 FACTORS

		SC	SOCSC	ARTS
MATH	1	0.367	0.048	0.010
MATH	2	0.000	0.007	0.006
ECON	1	0.232	0.351	0.075
ECON	2	0.000	0.000	0.000
SOCIOL	1	0.138	0.532	0.268
SOCIOL	2	0.000	0.000	0.000
ENGLISH	1	0.075	0.257	0.628
ENGLISH	2	0.000	0.000	0.000
HISTORY	1	0.046	0.397	0.278
HISTORY	2	0.000	0.000	0.000
PHILOS	1	0.075	0.149	0.305
PHILOS	2	0.005	0.064	0.096
ACC&BL	1	0.018	0.186	0.015
ACC&BL	2	0.000	0.118	0.023
REL ST	1	0.016	0.053	0.072
REL ST	2	0.000	0.000	0.000
MAN SCI	1	0.148	0.078	0.005
MAN SCI	2	0.000	0.000	0.000
COMP SC	1	0.064	0.064	0.013
COMP SC	2	0.000	0.000	0.000
FRENCH	1	0.022	0.042	0.421
FRENCH	2	0.000	0.000	0.000
GERMAN	1	0.010	0.011	0.194
GERMAN	2	0.000	0.000	0.000
SPANISH	1	0.009	0.000	0.048
SPANISH	2	0.005	0.000	0.089
BIOLOGY	1	0.571	0.092	0.021
BIOLOGY	2	0.014	0.041	0.018
PHYSICS	1	0.116	0.003	0.001
PHYSICS	2	0.000	0.000	0.000
CHEM	1	0.438	0.041	0.002
CHEM	2	0.056	0.011	0.000
PSYCHOL	1	0.519	0.416	0.303
PSYCHOL	2	0.000	0.000	0.000
INT SCI	1	0.050	0.013	0.000
INT SCI	2	0.000	0.000	0.000
. F.ARTS	1	0.000	0.005	0.039
. F.ARTS	2	0.014	0.021	0.072
BIOCHEM	1	0.000	0.000	0.000
BIOCHEM	2	0.000	0.000	0.000
EDUCAT	1	0.000	0.000	0.000
EDUCAT	2	0.000	0.000	0.000

PROPS INT SC,SOC SC,ARTS PROGS

0.1830.4890.328

PART ONE

SEM1 CLASS SIZES

	MATH	ECON	SOCIOL	ENGLISH	HISTORY	PHILOS	ACC&BL	REL ST	MAN SCI
MAJORS	68	174	272	252	214	136	71	37	47
MINORS	3	0	0	0	0	45	47	0	0

	SPANISH	BIOLOGY	PHYSICS	CHEM	PSYCHOL	INT SCI	F.ARTS	BIOCHEM	EDUCAT
MAJORS	12	113	16	71	289	10	10	0	0
MINORS	21	19	0	10	0	0	25	0	0

SEM2 CLASS SIZES

	MATH	ECON	SOCIOL	ENGLISH	HISTORY	PHILOS	ACC&BL	REL ST	MAN SCI
MAJORS	44	168	257	261	223	123	59	42	48
MINORS	0	0	0	0	0	0	0	0	0

	SPANISH	BIOLOGY	PHYSICS	CHEM	PSYCHOL	INT SCI	F.ARTS	BIOCHEM	EDUCAT
MAJORS	12	126	15	69	224	9	11	0	0
MINORS	22	0	0	0	0	0	38	0	208

SEM 3 CLASS SIZES

	MATH	ECON	SOCIOL	ENGLISH	HISTORY	PHILOS	ACC&BL	REL ST	MAN SCI
MAJORS	29	120	174	196	153	66	49	17	17
MINORS	0	0	0	0	0	0	0	0	0

	SPANISH	BIOLOGY	PHYSICS	CHEM	PSYCHOL	INT SCI	F.ARTS	BIOCHEM	EDUCAT
MAJORS	12	68	8	30	152	0	0	0	0
MINORS	0	0	0	0	0	0	0	34	74

continued overleaf

COMP SC	FRENCH	GERMAN
33	118	50
0	0	0

COMP SC	FRENCH	GERMAN
56	96	44
0	0	12

COMP SC	FRENCH	GERMAN
18	67	30
0	0	0

PART TWO

PROGRAM TITLES
MATHS
ECON
SOCIOL
ENGLISH
HISTORY
PHIL
ACC&BL
REL ST
MAN SC
COMP SC
FRENCH
GERMAN
SPANISH
BIOLOGY
PHYSICS
CHEM
PSYCHOL
BIOCHEM
TECH EC
ED&BIOL
ED&CHEM
ED&ENG
ED&FREN
ED&GERM
ED&HIST
ED&MATH
ED&SPAN

The output for SEM5 only is given as an example

SEMESTER 5

NOS ON PROGS	HON	GEN
MATHS	2	1
ECON	9	8
SOCIOL	27	34
ENGLISH	34	34
HISTORY	25	39
PHIL	12	5
ACC&BL	22	18
REL ST	2	3
MAN SC	2	1
COMP SC	2	4
FRENCH	14	11
GERMAN	8	5
SPANISH	3	6
BIOLOGY	22	22
PHYSICS	2	2
CHEM	8	2
PSYCHOL	33	38
BIOCHEM	8	2
TECH EC	2	1
ED+BIOL	3	5
ED+CHEM	1	1
ED+ENG	10	11
ED&FREN	2	2
ED&GERM	1	2
ED&HIST	4	11
ED&MATH	0	1
ED&SPAN	0	0

```
IND CRSE LD MATRIX HON
  MATHS
1.000 1.000 0.520 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.667 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.167 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
  ECON
0.022 0.000 0.000 1.000 1.000 0.306 0.043 0.000 0.000 0.000 0.000 0.000 0.000 0.132 0.000 0.000 0.022
0.000 0.000 0.220 0.000 0.000 0.000 0.000 0.000 0.000 0.056 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.033 0.000 0.066 0.000 0.044 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.022 0.000 0.000 0.000 0.000 0.000 0.022 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
  SOCIOL
0.000 0.000 0.000 0.029 0.000 0.000 0.000 1.000 1.000 0.676 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
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0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.029
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.029 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
  ENGLISH
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.012 0.000 0.000 1.000 0.994 0.046 0.018 0.000 0.000 0.048
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.072 0.000 0.000 0.000
0.000 0.012 0.000 0.012 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.012 0.000 0.000 0.000 0.012
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.024 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.060 0.000 0.000
  HISTORY
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.048 0.000 0.000 0.309 0.000 0.000 1.000 0.929 0.068 0.048
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.024 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.024 0.095 0.048 0.000 0.024 0.024 0.024 0.024 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.071 0.000 0.000
```

```
      PHIL
0.0000.0000.0000.0000.00 0.0000.0000.0000.0000.0860.0000.0000.0290.0000.0001.000
0.9430.2860.0000.0000.00 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
0.0000.0000.0000.0000.00 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
0.0290.0000.0000.0000.00 0.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.000
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EU-CHEM
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  HISTORY
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PHIL
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FRENCH

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GERMAN

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SPANISH

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BIOLOGY

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PHYSICS

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PART CLASS SIZE SEM 5

6	2	1	49	34	2	86	38	19	112	65	1	88	43	1	21	13	3	43	0
0	9	2	1	12	4	0	7	3	1	32	11	9	15	13	8	9	1	0	57
38	24	4	3	2	17	10	7	71	43	32	6	0	0	0	0	0	10	8	0
66	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	3	5
0	0	0	4	1	1	3	1	1	1	2	2	1	8	0	0	0	0	0	0
6	0	11	0	0															

SEM	OPT	MATH	ECON	SOCIOL	ENGLISH	HISTORY	PHILOS	ACCSBL	REL ST	MAN SCI
1	1	69	176	295	271	230	148	82	46	55
1	2	3	0	0	0	0	45	47	0	0
2	1	44	169	300	270	224	126	81	50	48
2	2	0	0	0	0	0	0	0	0	0
3	1	29	120	177	197	153	66	49	17	17
3	2	0	0	0	0	0	0	0	0	0
4	1	12	73	109	128	156	38	53	13	14
4	2	6	15	69	90	66	16	15	2	0
4	3	1	2	2	19	5	8	0	1	0
5	1	6	49	86	112	86	21	43	9	12
5	2	2	34	38	65	43	13	0	2	4
5	3	1	2	19	1	1	3	0	1	0
6	1	7	47	73	96	85	17	44	7	6
6	2	1	33	45	59	36	8	8	1	1
6	3	1	5	20	3	1	3	0	0	0
7	1	2	12	29	47	30	13	24	2	4
7	2	2	10	29	47	30	13	24	2	4
7	3	2	10	29	36	26	13	0	2	2
8	1	2	13	29	41	28	13	24	2	3
8	2	0	0	0	0	0	0	0	0	0
8	3	0	0	0	0	0	0	0	0	0

COMP SC	FRENCH	GERMAN
56	118	50
0	0	0
53	96	46
0	0	12
18	67	30
0	0	0
18	61	29
7	23	9
0	2	1
7	32	15
3	11	13
1	9	8
7	34	19
3	18	9
1	9	6
2	16	9
2	16	9
2	14	8
2	15	8
0	0	0
0	0	0

SEM	OPT	SPANISH	BIOLOGY	PHYSICS	CHEM	PSYCHOL	INT SCI	F.ARTS	BIOCHEM	EDUCAT
1	1	13	121	16	72	314	10	35	0	0
1	2	21	19	0	10	0	0	25	0	0
2	1	13	126	15	69	229	9	27	0	222
2	2	22	0	0	0	0	0	38	0	0
3	1	12	68	8	33	157	0	0	34	78
3	2	0	0	0	0	0	0	0	0	0
4	1	15	85	5	24	156	5	0	15	66
4	2	10	64	4	12	63	0	0	0	0
4	3	0	5	1	1	38	0	0	0	0
5	1	9	57	4	17	71	6	0	10	66
5	2	1	38	3	10	43	0	0	8	0
5	3	0	24	2	7	32	0	0	0	0
6	1	11	55	4	14	65	3	0	10	67
6	2	1	34	3	10	40	0	0	8	0
6	3	0	22	2	6	30	0	0	0	0
7	1	3	26	2	10	35	0	0	9	22
7	2	3	26	2	10	35	0	0	9	0
7	3	0	23	2	9	35	0	0	9	0
8	1	3	24	2	9	35	0	0	9	9
8	2	0	0	0	0	0	0	0	0	0
8	3	0	0	0	0	0	0	0	0	0

EDUCAT SEM9 16

POSTGRAD STUDENTS

RES PG

	ID	RES PG	PG COURSE
MATH	3	0	0
ECON	1	7	25
SOCIOL	8	0	37
ENGLISH	6	0	0
HISTORY	4	0	0
PHILOS	6	0	0
ACC&BL	2	0	0
REL ST	1	0	0
MAN SCI	1	7	6
COMP SC	1	0	0
FRENCH	2	0	0
GERMAN	1	0	0
SPANISH	1	0	0
BIOLOGY	40	0	0
PHYSICS	7	0	0
CHEM	10	0	0
PSYCHOL	24	0	14
INT SCI	0	0	0
F.ARTS	0	0	0
BIOCHEM	5	0	0
EDUCAT	3	0	0

APPENDIX 6D

Student equivalent module

6D1 Name of subroutine: STUDEQ

6D2 General description of module

As is remarked in Chapter 6.8(iii) the purpose of this module is the calculation of the number of full time equivalent students who could be conceived to be studying in a given subject area. Since each course unit, however, occupies a definite proportion of each student's time it is possible to relate the number of course units being studied in a given semester to the number of full time equivalent students studying that subject in a given semester. This procedure is adopted in this module. The problem is very straightforward in the first two semesters where students normally take three semester units. In semester three the problem is slightly complicated by the fact that less than three units are taken on average and that some students also take units from semester 1.

A uniform procedure is used for all Part 2 semesters in that total student equivalents for a given semester are distributed between subjects in proportion to the numbers of semester units being taken in each subject. Due allowance is also made for the fact that some students study courses in other semesters (i.e. semester 5 students may be taking courses in semester 3 or 1).

Student equivalents attached to each department are then summed and postgraduate numbers are added.

APPENDIX 6

6D3 Detailed Description of Program

933-39 COMMON statement

940-41 DIMENSION statement

942-49 Zero array SEQ (I,J)

951-62 Calculate student equivalents corresponding to SEM1 and SEM2 students taking semester units in SEMS1 and 2 respectively

963-69 As above for Semester 3 students

970-74 Add semester 3 students taking SEM1 course units to appropriate subject total

976-85 Array KF4(I) to KF9(I) are allocated to appropriate columns of arrays KZ(I,J)

989-96 Calculate total semester units taken in a given semester

997-1008 Allocate student equivalents/semester/subject on basis.

$$\text{Number of student equivalents} = \text{Number of students in given semester} \times \frac{\text{Number of course units taken in that subject}}{\text{Total course units in that semester}}$$

1009-14 Allocate equivalent calculated above to subject (array SEQ(I,J) - semesters 4 - 9)

1015-19 Add in contribution to equivalents from SEM5 students taking SEM1 units

1020-25 Add in contribution to equivalents from SEM6 and 4 students taking SEM2 units

1026-30 As above for semester 6 students taking semester 4 units

1031-36 Sum up student equivalents over each semester

1037-40 Add in postgraduate numbers to total equivalents

Write out results

1042-47 Write out table headings

1048-64 Write out total undergraduate equivalents

" Write out total student (UG + PG) equivalents

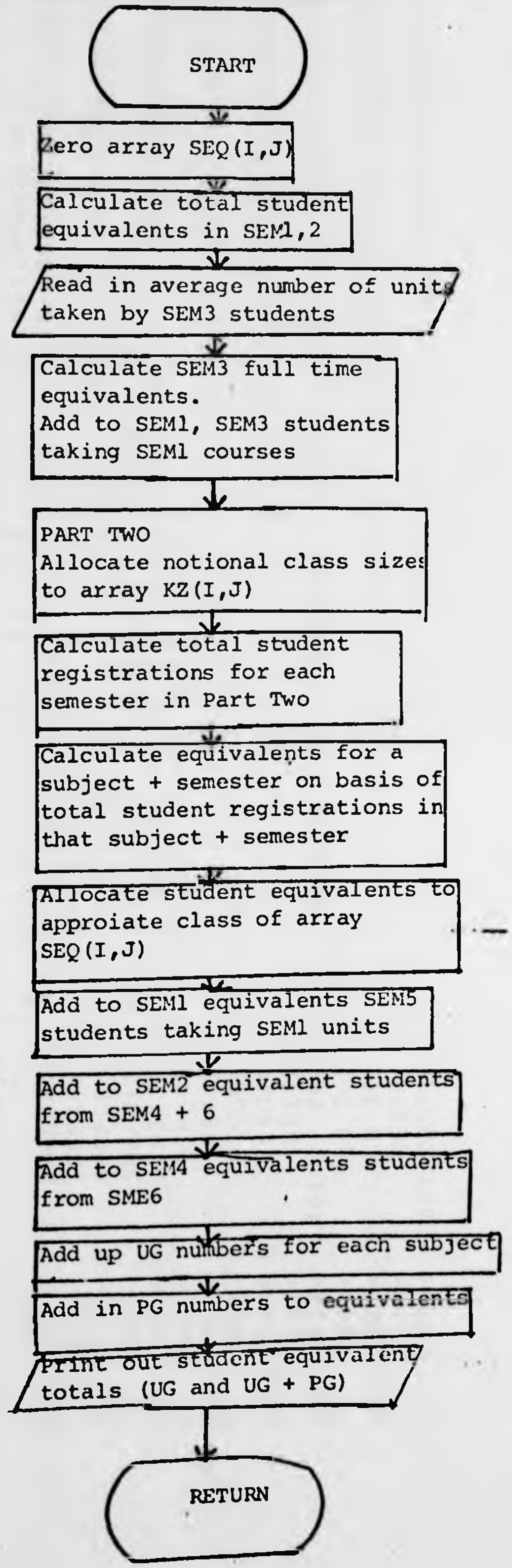
APPENDIX 6

6D4 Definition of Variables

GUNIT	Number of semester course units taken by semester 3 students
KTOT(J)	Total course units studied in semester J
KZ(I,J)	Total students registered for subject I in semester J
NSTUD(J)	Total undergraduate students registered in semester J
SEQ(I,J)	Number of full time equivalent students taking subject I in semester J
SEQTOT(I)	Total full time equivalent student numbers (UG + PG) taking subject I
XEQ(I)	Total full time equivalent student number (UG only) taking subject I

APPENDIX 6

6D Student Equivalent Module : Flow Diagram



6D6 Program Listing

```
      SEGMENT

&ASSIGN;   1;DC:50;R:54.RBFILES;

      SUBROUTINE STUDEQ
      COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
     1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150), KF9(150),NPGR1(30),
     2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
     3NBPGR1(15),NBPGR2(15), NBPGCR(15),NCPGR1(15),NCPGR2(15),
     4NCPGCR(15),MAST(15),MBST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
     5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),
     6 N3(30,2),MSTUD,SEQTOT(30),NPGTOT,NXCLAS(30,5,12)
      DIMENSION KZ(210,9),KTOT(9),XKEQ(210,9),
     1 NSTUD(9)
C     STUDENT EQUIVALENT MODULE
C     ZEROIN
      WRITE(2,401)
401   FORMAT(1H1,'STUDENT EQUIV MODULE')
      DO 301 I=1,NDEP
      DO 301 J=1,9
      SEQ(I,J)=0.0
301   CONTINUE
```

```
C      PART ONE
C      SEM1 AND 2
        DO 390 J=1,2
        KTOT(J)=0
        DO 390 I=1,NDEP
        DO 390 K=1,2
        KTOT(J)=KTOT(J)+NCLAS(I,J,K)
  390   CONTINUE
       DO 302 I=1,NDEP
       DO 302 J=1,2
       DO 302 K=1,2
       SEQ(I,J)=SEQ(I,J)+0.5*NYR(1)*NCLAS(I,J,K)/KTOT(J)
  302  CONTINUE
C      SEMESTER 3
        READ (7,28) GUNIT
   28   FORMAT(F5.3)
       DO 303 I=1,NDEP
       DO 303 K=1,2
       SEQ(I,3)=SEQ(I,3) + 0.5*NCLAS(I,3,K)/GUNIT
  303  CONTINUE
C      ADD SEM3 STUDENTS TAKING SEM1 UNITS
       DO 304 I=1,NDEP
```

```
      DO 304 K=1,2
      SEQ(I,1)=SEQ(I,1)+0.5*N3(1,K)/GUNIT
  304 CONTINUE
C     PART TWO
C     ALLOCATE NOT.CLASSES TO ARRAYS
      KX=5*NDEP
      DO 307 I=1,KX
      KZ(I,4)=KF4(I)
      KZ(I,5)=KF5(I)
      KZ(I,6)=KF6(I)
      KZ(I,7)=KF7(I)
      KZ(I,8)=KF8(I)
      KZ(I,9)=KF9(I)
  307 CONTINUE
C     CALCULATE STUDENT-COURSE WEIGHTING
       WRITE(2,402)
  402  FORMAT(' SEM  TOT COURSE UNITS')
      DO 308  J=4,9
       KTOT(J)=0
      DO 398  I=1,KX
      KTOT(J)=KTOT(J)+KZ(I,J)
  398  CONTINUE
       WRITE(2,403) J,KTOT(J)
  403   FORMAT(1X,I4,2X,I5)
  308 CONTINUE
       NSTUD(4)=NYR(2)
       NSTUD(5)=NYR(3)
       NSTUD(6)=NYR(3)
       NSTUD(7)=NYR(4)
       NSTUD(8)=NYR(4)
       NSTUD(9)=NYR(5)
```

```
C     CALCULATE EQUIVS
      DO 309 J=4,9
      DO 309 I=1,KX
      XKEQ(I,J)= NSTUD(J)/(2.0*KTOT(J))*KZ(I,J)
  309 CONTINUE
C     ALLOCATE STUD EQUIVS TO SUBS
      KA=3*NDEP
      DO 312 J=4,9
      DO 312 I=1,KA
      SEQ(I,J)=XKEQ(3*I,J)+XKEQ(3*I-1,J)+XKEQ(3*I-2,J)
  312 CONTINUE
C     ADD IN SEM5 STUDENTS TAKING SEM1 SUBS
      DO 313 I=1,NDEP
      LM=4*NDEP+I
      SEQ(I,1)=SEQ(I,1)+XKEQ(LM,5)
  313 CONTINUE
C     ADD IN SEM6 AND 4 STUDENTS TAKING SEM2 COURSES
      DO 314 I=1,NDEP
      LN=4*NDEP+I
      LR=3*NDEP+I
      SEQ(I,2)=SEQ(I,2)+XKEQ(LN,6)+XKEQ(LR,4)
  314 CONTINUE
C        SEM6 TAKING SEM2
       DO 330 I=1,NDEP
       LM=3*NDEP+I
      SEQ(I,4)=SEQ(I,4)+XKEQ(LM,4)
  330  CONTINUE
C     SUM UP STUDENTS EQUIVS FOR GIVEN SUBJECTS
```

```
      DO 315 I=1,NDEP
       XEQ(I)=0.0
      DO 315 J=1,9
      XEQ(I)=XEQ(I)+SEQ(I,J)
  315 CONTINUE
C     ADD IN POSTGRADS
      DO 316 I=1,NDEP
      SEQTOT(I)=XEQ(I)+NPGR1(I)+NPGR2(I)+NPGCR(I)
  316 CONTINUE
C     WRITE OUT STUDENTS EQUIVS
      WRITE(2,317)
  317 FORMAT(1H1,'STUDENT EQUIVS')
      WRITE(2,318)
  318 FORMAT(1H0,'SEMESTER TOTALS')
       WRITE(2,405) (I,I=1,9)
  405  FORMAT(1H0,'SEM  NO ', 9I6)
      DO 319 I=1,NDEP
      WRITE(2,320)(ADEP(I),(SEQ(I,J),J=1,9))
  320 FORMAT(1X,A10,9F6.2)
  319 CONTINUE
      WRITE(2,321)
  321 FORMAT(1H0,'STUDENT EQUIV TOTALS')
      WRITE(2,322)(ADEP(I),I=1,12)
  322 FORMAT(1H0,9X,12A10)
      WRITE(2,323)(XEQ(I),I=1,12)
  323 FORMAT(' UG EQUIV',12F10.2)
      WRITE(2,324)(SEQTOT(I),I=1,12)
  324 FORMAT(' TOT EQUIV',12F10.2)
      WRITE(2,322)(ADEP(I),I=13,NDEP)
      WRITE(2,323)(XEQ(I),I=13,NDEP)
      WRITE(2,324)(SEQTOT(I),I=13,NDEP)
      RETURN
      END
```

STUDENT EQUIV MODULE

SEM	TOT COURSE UNITS
4	1652
5	1216
6	1176
7	792
8	271
9	16

STUDENT EQUIVS

SEMESTER TOTALS

SEM NO	1	2	3	4	5	6	7	8	9
MATH	12.27	7.37	6.12	3.58	2.01	2.08	1.08	1.05	0.00
ECON	29.96	28.37	25.32	16.97	19.01	19.66	5.76	6.84	0.00
SOCIOL	51.04	50.74	36.71	34.32	31.99	31.92	15.65	15.25	0.00
ENGLISH	46.78	45.46	41.35	46.01	39.82	36.54	23.39	21.56	0.00
HISTORY	39.70	37.58	32.28	39.97	29.53	28.22	15.47	14.72	0.00
PHILOS	33.25	21.17	13.92	11.69	8.28	6.48	7.02	6.84	0.00
ACC&BL	22.37	14.16	10.34	16.40	9.62	12.03	8.64	12.62	0.00
REL ST	8.20	8.63	3.59	4.15	2.68	1.85	1.06	1.05	0.00
MAN SCI	9.68	8.04	3.59	1.70	3.58	1.62	1.80	1.58	0.00
COMP SC	10.55	9.03	3.80	4.90	2.46	2.54	1.08	1.05	0.00
FRENCH	20.02	16.08	14.14	16.22	11.63	14.11	8.28	7.89	0.00
GERMAN	8.46	9.76	6.33	7.73	8.05	7.86	4.68	4.21	0.00
SPANISH	5.81	5.88	2.53	4.90	2.24	2.78	1.08	1.58	0.00
BIOLOGY	24.08	21.11	14.35	28.47	26.62	25.67	13.49	12.62	0.00
PHYSICS	2.71	2.51	1.69	1.89	2.01	2.08	1.08	1.05	0.00
CHEM	13.95	11.56	6.33	6.41	7.61	6.94	5.22	4.73	0.00
PSYCHOL	54.39	38.55	32.07	46.57	32.66	31.22	18.89	18.40	0.00
INT SCI	1.70	1.51	0.00	0.74	1.34	0.69	0.00	0.00	0.00
F.ARTS	11.35	11.57	0.00	1.31	0.00	0.00	0.00	0.00	0.00
BIOCHEM	0.00	0.00	7.17	2.83	4.03	4.16	4.86	4.73	0.00
EDUCAT	0.00	37.65	15.61	14.33	14.76	15.50	3.96	4.73	8.00

STUDENT EQUIV TOTALS

	MATH	ECON	SOCIOL	ENGLISH	HISTORY	PHILOS	ACC&BL	REL ST	MAN SCI
UG EQUIV	35.57	151.88	267.61	300.90	237.48	108.64	106.17	31.23	31.57
TOT EQUIV	38.57	154.88	312.61	306.90	241.48	114.64	108.17	32.23	45.57

	SPANISH	BIOLOGY	PHYSICS	CHEM	PSYCHOL	INT SCI	F.ARTS	BIOCHEM	EDUCAT
UG EQUIV	26.80	166.41	15.03	62.75	272.75	6.18	24.43	27.78	114.54
TOT EQUIV	27.80	206.41	22.03	72.75	310.75	6.18	24.43	32.78	125.54

COMP SC	FRENCH	GERMAN
35.42	108.36	57.10
36.42	110.36	58.10

APPENDIX 6E

Staff allocation (workload module) module

6E1 Name of subroutine STAFF1

6E2 General description of module

A general description of the workload model is presented in Appendix 4. Notional class sizes projected by the notional class size module (see Appendix 6B) form the input to this module. Thus undergraduate workload for each subject can be estimated. Post-graduate workload is estimated on the basis of three hours per week for each single discipline postgraduate and six hours per week for interdisciplinary postgraduates. Individual staff allocations are made for postgraduate courses. Remaining staff are then allocated between subjects on the basis of workload.

APPENDIX 6

6E3 Detailed description of program

STAFF ALLOCATION MODULE (WORKLOAD) STAFF 1

454-60	COMMON statement
461-68	DIMENSION statement
473-77	Read in (and print out) number of subjects in CATs, A, B, C
478-84	Read in workload factors (constants)
485-95	Read in workload factors (variable) for semester J and option K
	Distribute notional class sizes unto categories
494-500	(1) Cat A notional class sizes assigned to array ACLAS(I,J,K)
501-06	(2) " " BCLAS(I,J,K)
507-12	(3) " " CCLAS(I,J,K)
514-18	Postgraduates - assign to appropriate arrays (Cat.A)
519-24	" " (Cat.B)
525-30	" " (Cat.C)
532-36	Read in statistical class factors Cat.A for subject I, semester J, option K
537-41	Read in statistical class factors Cat.C for subject I, semester J, option K
	<u>Workload calculation, Cat.A</u>
543-45	Zero arrays XDOA(I) and XDEA(I)
546-50	Calculation of subfactors D1, D2, D3
551-54	Allow for zero class size. If class size ≡ 0 put workload = 0
555-68	Calculate (and print out) workload for Cat 'A' classes
569-74	Sum up workload for odd semester in each subject
575-80	Sum up workload for even semester in each subject
581-84	Calculate average workload over odd and even semesters
585-95	Print out results
588-89	Subject names

590-01 Odd semester workload for each subject

592-93 Even semester workload for each subject

594-95 Average workload for each subject

596-644 As above for Cat 'B', appropriate modification to workload calculation for language subject

645-703 As above for Cat 'C', appropriate modifications to workload calculations for laboratory subjects. Including modification to allow for additional Education workload from teaching practice

704-08 Calculate postgraduate workload (research students) for subjects in Cat 'A'

709 Calculate total workload for a subject (UG + PG) Cat 'A'

710-22 Calculate total workload for a subject (UG + PG) Cat 'B'

723-30 Calculate total workload for a subject (UG + PG) Cat 'C'

731-37 Sum up total workload for Cat 'A' subjects

738-40 Sum up total workload for Cat 'B' subjects

741-43 Sum up total workload for Cat 'C' subjects

744-45 Calculate total University workload (add up workload in Cats 'A', 'B', and 'C')

746-47 Calculate total student numbers (add UG + PG)

748-50 Read in overall student:staff ratio

751-52 Calculate total University staff entitlement

753-54 Write out total University staff numbers

755-59 Read in staff allocated to PG courses (Cat A, B, C)

760-63 Zero variables NAPG, NBPG, NCPG

764-66 Sum staff allocated to PG courses (Cat 'A')

767-69 Sum staff allocated to PG courses (Cat 'B')

770-72 Sum staff allocated to PG courses (Cat 'C')

773-75 Calculate staff available for allocation on workload basis (total staff all - pg course allocation)

778-81 Calculate staff allocated for Departments (Cat A)

782-84 Calculate staff allocated for Departments (Cat B)

785-87 Calculate staff allocated for Departments (Cat C)

788-91 Write out hours of workload per staff member

792-97 Round off to nearest integer (Cat 'A')

798-803 Round off to nearest integer (Cat 'B')

804-09 Round off to nearest integer (Cat 'C')

810-13 Add staff allocation to PG course to staff allocated in workload basis (Cat 'A')

814-16 Add staff allocation to PG course to staff allocated in workload basis (Cat 'B')

817-19 Add staff allocation to PG course to staff allocated in workload basis (Cat 'C')

Write out staffing levels : Cat 'A'

823-24 Departmental name

825-26 Workload allocation

827-28 PG course allocation

829-30 Total allocation

831-36 As above for Cat 'B'

837-42 As above for Cat 'C'

APPENDIX 6

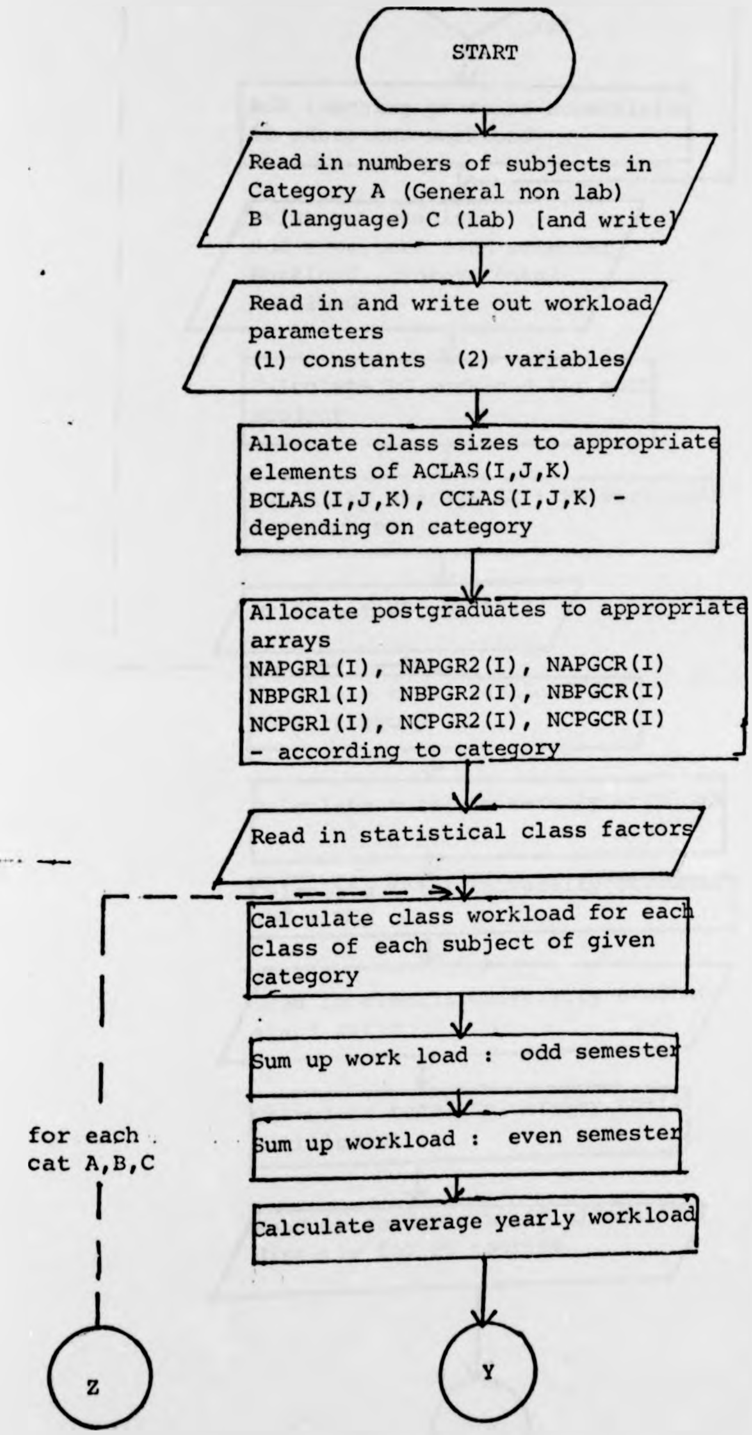
6E4 Definition of Variables

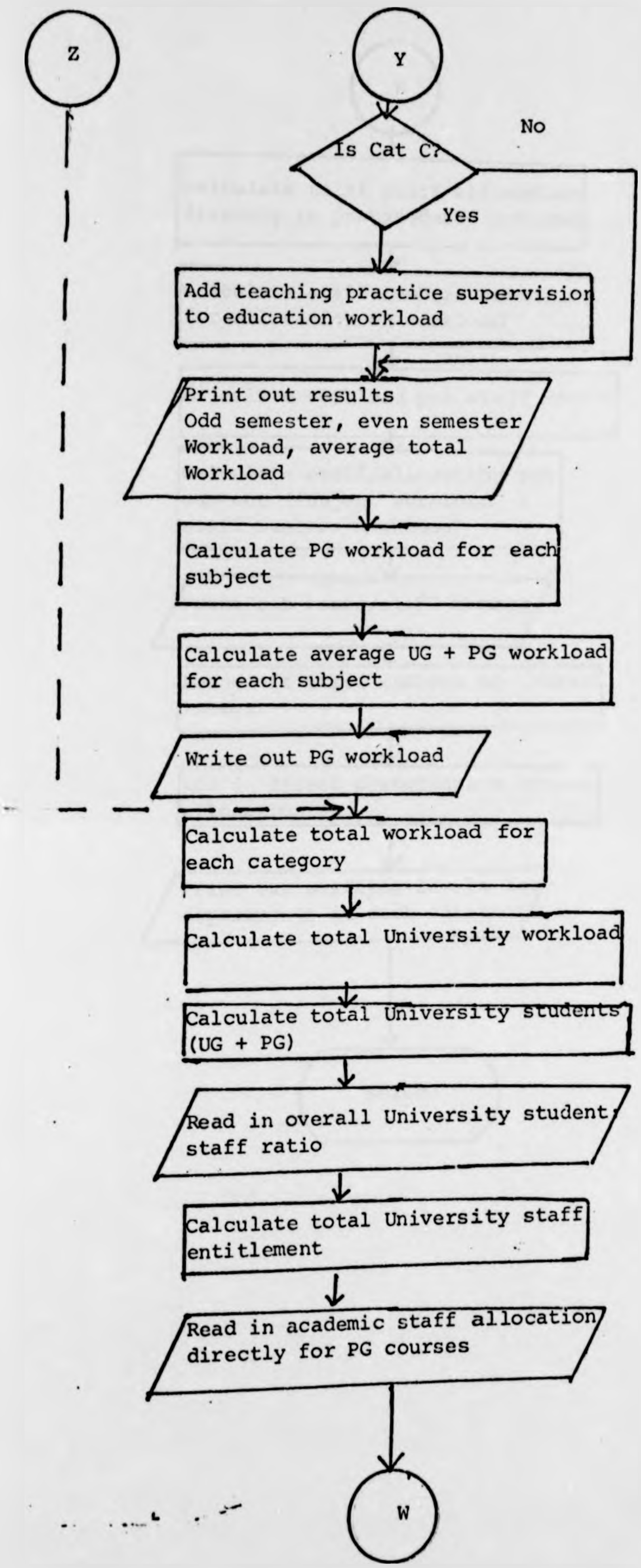
ACLAS(I,J,K) BCLAS(I,J,K) CCLAS(I,J,K)	Notional class sizes for (Cat. A, B, C) subject I, semester J, option K
BSB(JK)	Weekly frequency of language labs
FA, FB, FC	Tutorial frequency subject categories A, B, C
HRST	Average weekly workload per member of academic staff
LA(I,J,K) LC(I,J,K)	Frequency of statistical classes for subject I, semester J, option K (categories A, C)
MAST(I), MBST(I) MCST(I)	Total staff allocation for subject I (rounded off) for subject categories A, B, C
MSTUD	Total student population (UG + PG)
NA, NB, NC	Number of subjects in categories A, B, C
NAPG(I), NBPG(I) NCPG(I)	Total numbers of academic staff allocated directly for PG course work
NAPGCR)I) NBPGCR(I) NCPGCR(I)	Number of full time postgraduate students taking postgraduate course work in subject I (for categories A, B, C)
NAPGR1(I) NBPGR1(I) NCPGR1(I)	Number of full time research students taking single discipline subject (categories A, B, C)
NAPGR2(I) NBPGR2(I) NCPGR2(I)	Number of full time research students taking interdisciplinary subjects
NPG	Total academic staff allocated directly on basis of taught PG courses
NWK	Total academic staff available for allocation on workload basis
NAPGST(I) NBPGST(I) NCPGST(I)	Academic staff allocated directly to subject I for taught PG courses
QC(J, K)	Number of hours lab work/week semester J, option K
QOC(J,K)	Time to prepare experiment for standard 4 hours lab (semester J, option K)

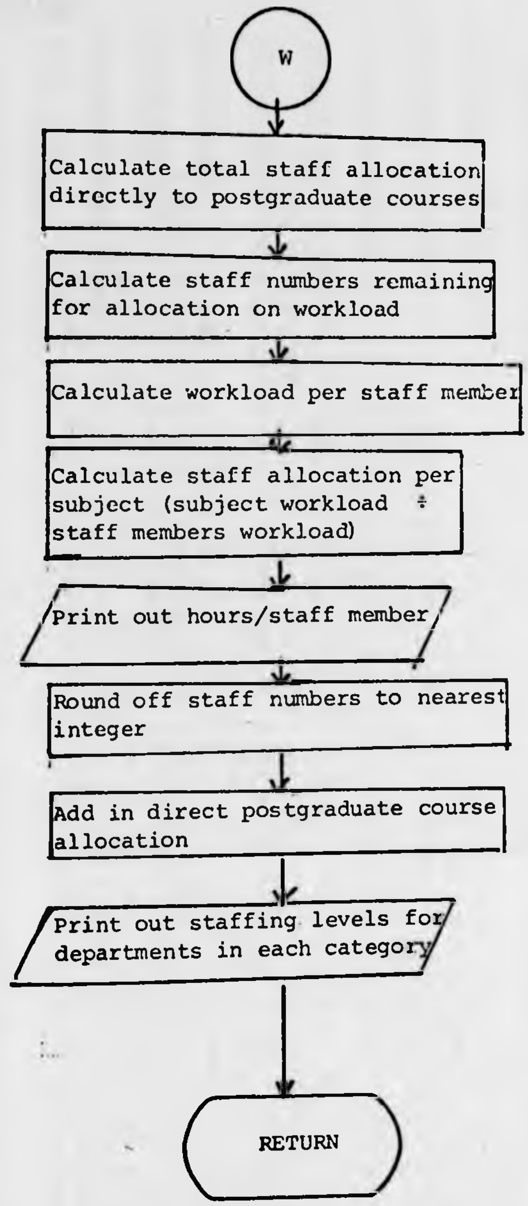
TG	Time to give tutorial
SSRAT	Overall University student:staff ratio
UATOT(I) UBTOT(I) UCTOT(I)	Total workload for category A, B, C, subjects
XATOT(I) XBTOT(I) XCTOT(I)	Average workload for subject I (categories A, B and C)
XCA(I,J,K) XCB(I,J,K) XCC(I,J,K)	Workload in class subject I, semester J, option K (category A, B, C subjects)
XDEA(I) XDEB(I) XDEC(I)	Total even (Spring) semester workload for subjects Cat A, B, C
XDOA(I) XDOB(I) XDOC(I)	Total odd (Autumn) semester workload for subjects Cat A, B, C
XL	Weekly lecture frequency
XM	Time to correct essay
XIN	Size of tutorial group
XNAST(I) XNBST(I) XNCST(I)	Staff allocation (unrounded) for subjects I (cat A, B, C)
XR	Size of language lab
XTP	Time to prepare tutorials
XW	Time to correct essays
XX	Time to correct exam paper
WA(J,K) WB(J,K)	Essay frequency, categories A, B
WATOT, WBTOT WCTOT	Total workload of categories A, B, C subjects
WEC(J,K)	Essay frequency - semesters J, option K
WKTOT	Total University workload
WTP	Time to mark translation
WKTP1	Workload involved in education teaching practice (1)
WKTP	Workload involved in education teaching practice (2)

APPENDIX 6

6E5 Staff allocation : Workload : Flow Diagram




Z
Y
Is Cat C?
No
Yes
Add teaching practice supervision to education workload
Print out results
Odd semester, even semester
Workload, average total
Workload
Calculate PG workload for each subject
Calculate average UG + PG workload for each subject
Write out PG workload
Calculate total workload for each category
Calculate total University workload
Calculate total University students (UG + PG)
Read in overall University student: staff ratio
Calculate total University staff entitlement
Read in academic staff allocation directly for PG courses
W


W
Calculate total staff allocation directly to postgraduate courses
Calculate staff numbers remaining for allocation on workload
Calculate workload per staff member
Calculate staff allocation per subject (subject workload ÷ staff members workload)
Print out hours/staff member
Round off staff numbers to nearest integer
Add in direct postgraduate course allocation
Print out staffing levels for departments in each category
RETURN

6E6 Program Listing

```
          SEGMENT

£ASSIGN;  1;DC;50;RB52,RBFILES;

          SUBROUTINE STAFF1
          COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
         1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150), KF9(150),NPGR1(30),
         2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
         3NBPGR1(15),NBPGR2(15), NBPGCR(15),NCPGR1(15),NCPGR2(15),
         4NCPGCR(15),MAST(15),MBST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
         5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),
         6 N3(30,2),MSTUD,SEQTOT(30),NPGTOT,NXCLAS(30,5,12)
          DIMENSION WA(9,3),WB(9,3),WTB(9,3),WEC(9,3),FA(9,3),FB(9,3),
         1SS(9,3),BSB(9,3),QC(9,3),QOC(9,3),QPOC(9,3),XP(9,3),ACLAS(15,9,3),
         4XDEA(15),XCA(15,9,3),XATOT(15),XDOB(6),XDEB(6),XBTOT(6),
         2BCLAS(12,9,3),CCLAS(12,9,3),LA(12,9,3),LC(12,9,3),XDOA(15),
         LUATOT(15),UBTOT(6),UCTOT(15),NAST(15),NBST(15),NCST(12),
         5XCB(6,9,3),XDOC(15),XDEC(15),AGWK(15),BGWK(15),CGWK(15),
         8XCC(12,9,3),XNAST(15),XNBST(6), XNCST(12),XCTOT(15),
         9NAPGST(15),NBPGST(15),NCPGST(15),FC(9,3)
C         STAFF ALLOCATION :VERSION 1
           WRITE (2,51)
   51     FORMAT(1H1,'STAFF ALL WKLOAD')
C         WORKLOAD MODULE
C         READ IN NO OF SUBJECTS IN CAT A,B,C
          READ(7,110) NA,NB,NC
  110     FORMAT(4I3)
           WRITE(2,601) NA,NB,NC
  601     FORMAT(1H0,'NO SUBS IN CATS A B C',3I3)
```

```
C     READ IN WORKLOAD FACTORS (1) CONSTANTS
      READ(7,113) XM,XL,XW,XX,XTP,XN,XR,XS,TG
  113 FORMAT(9F0.0)
       WRITE(2,52)
   52 FORMAT(1H0,'WORKLOAD FACTORS')
        WRITE(2,602) XM,XL,XW,XX,XTP,XN,XR,XS,TG
  602  FORMAT(1H0,9F9.3)
C       READ IN WORKLOAD FACTORS (2) VARIABLES
      DO 114 J=1,9
      DO 114 K=1,3
      READ(7,115) WA(J,K),WB(J,K),WTB(J,K),WEC(J,K),FA(J,K),FB(J,K),
     1FC(J,K),SS(J,K),BSB(J,K),QC(J,K),QOC(J,K),QPOC(J,K),XP(J,K)
  115 FORMAT(13F0.0)
       WRITE(2,602) WA(J,K),WB(J,K),WTB(J,K),WEC(J,K),FA(J,K),FB(J,K),
     1FC(J,K),SS(J,K),BSB(J,K),QC(J,K),QOC(J,K),QPOC(J,K),XP(J,K)
  114 CONTINUE
C     DISTRIBUTE SUBJS INTO  CATS
C     UNDERGRADS
      DO 117 I=1,NA
      DO 117 J=1,9
      DO 117 K=1,3
      ACLAS(I,J,K)=KCLAS(I,J,K)
  117 CONTINUE
      DO 118 I=1,NB
      DO 118 J=1,9
      DO 118 K=1,3
      NX=NA+I
      BCLAS(I,J,K)=KCLAS(NX,J,K)
```

```
C     READ IN WORKLOAD FACTORS (1) CONSTANTS
      READ(7,113) XM,XL,XW,XX,XTP,XN,XR,XS,TG
  113 FORMAT(9F0.0)
       WRITE(2,52)
   52 FORMAT(1H0,'WORKLOAD FACTORS')
        WRITE(2,602) XM,XL,XW,XX,XTP,XN,XR,XS,TG
  602  FORMAT(1H0,9F9.3)
C        READ IN WORKLOAD FACTORS (2) VARIABLES
      DO 114 J=1,9
      DO 114 K=1,3
      READ(7,115) WA(J,K),WB(J,K),WTB(J,K),WEC(J,K),FA(J,K),FB(J,K),
     1FC(J,K),SS(J,K),BSB(J,K),QC(J,K),QOC(J,K),QPOC(J,K),XP(J,K)
  115 FORMAT(13F0.0)
       WRITE(2,602) WA(J,K),WB(J,K),WTB(J,K),WEC(J,K),FA(J,K),FB(J,K),
     1FC(J,K),SS(J,K),BSB(J,K),QC(J,K),QOC(J,K),QPOC(J,K),XP(J,K)
  114 CONTINUE
C     DISTRIBUTE SUBJS INTO  CATS
C     UNDERGRADS
      DO 117 I=1,NA
      DO 117 J=1,9
      DO 117 K=1,3
      ACLAS(I,J,K)=KCLAS(I,J,K)
  117 CONTINUE
      DO 118 I=1,NH
      DO 118 J=1,9
      DO 118 K=1,3
      NX=NA+I
      BCLAS(I,J,K)=KCLAS(NX,J,K)
```

```
  118 CONTINUE
      DO 119 I=1,NC
      DO 119 J=1,9
      DO 119 K=1,3
      NY =NA+NB+I
      CCLAS(I,J,K)=KCLAS(NY,J,K)
  119 CONTINUE
C     POSTGRADUATES
      DO 120 I=1,NA
      NAPGR1(I)=NPGR1(I)
      NAPGR2(I)=NPGR2(I)
      NAPGCR(I)=NPGCR(I)
  120 CONTINUE
      DO 121 I=1,NB
      NX=NB+I
      NBPGR1(I)=NPGR1(NX)
      NBPGR2(I)=NPGR2(NX)
      NBPGCR(I)=NPGCR(NX)
  121 CONTINUE
      DO 122 I=1,NC
      NX=NA+NB+I
      NCPGR1(I)=NPGR1(NX)
      NCPGR2(I)=NPGR2(NX)
      NCPGCR(I)=NPGCR(NX)
  122 CONTINUE
C     READ IN STATISTICAL CLASS FACTORS 'DATA'
      DO 123 J=1,9
      DO 123 K=1,3
      READ(7,1124)(LA(I,J,K),I=1,NA)
 1124 FORMAT(30I2)
  123 CONTINUE
```

```
C     STATISTICAL CLASS FACTORS 'CATC'
      DO 1241 J=1,9
      DO 1241 K=1,3
      READ(7,1124)(LC(I,J,K),I=1,NC)
 1241 CONTINUE
C     CALCULATE WORKLOAD FOR CATA SUBS
      DO 1255  I=1,NA
      XDOA(I)=0.0
      XDEA(I)=0.0
      DO 1255 J=1,9
      DO 1255 K=1,3
      D1=AINT((ACLAS(I,J,K)-0.001)/(XN*4.0))
      D2=AINT((ACLAS(I,J,K)-0.001)/XN)
      D3=AINT((ACLAS(I,J,K)-0.001)/XS)
C     ALLOW FOR ZERO CLASS SIZE
      IF(ACLAS(I,J,K)-0.001)1220,1220,1230
 1220 XCA(I,J,K)=0.0
      GO TO 1255
C     CLASS WORKLOAD:CATA
 1230 XCA(I,J,K)=XM*XL/60.0+ACLAS(I,J,K)/60.0*(WA(J,K)*XW+XX/14.0)+
     1FA(J,K)*XTP/60.0*(D1+1.0) +FA(J,K)*(D2+1.0)*TS/60.0 +
     2ACLAS(I,J,K)/6+LA(I,J,K)*2*(D3+3)
 1255 CONTINUE
      WRITE(2,53)
   53 FORMAT(1H0,'COURSE WKLOAD CAT A')
      DO 620 I=1,NA
      WRITE(2,54) ADEP(I)
   54 FORMAT(1H0,A10)
      DO 620 J=1,9
```

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```
            WRITE(2,621) J,(XCA(I,J,K) ,K=1,3)
      621  FORMAT(1H0,'SEM NO', I2,2X,3F8.3)
      620  CONTINUE
C          SUM UP WORKLOAD:ODD SEM
           DO 124  I=1,NA
           DO 124  J=1,8,2
           DO 124  K 1,3
           XDOA(I)=XDOA(I)+XCA(I,J,K)
      124  CONTINUE
C          SUM UP WORKLOAD:EVEN SEMESTER
           DO 125 I=1,NA
           DO 125 J=2,8,2
           DO 125 K=1,3
           XDEA(I)=XDEA(I)+XCA(I,J,K)
      125  CONTINUE
C          CALCULATE AV  WORKLOAD
           DO 126 J=1,NA
           XATOT(J)=(XDOA(J)+XDEA(J))/2
      126  CONTINUE
C          PRINT RESULTS
           WRITE(2,1277)
     1277  FORMAT(1H0,'CATEGORY A- U G WKLD')
           WRITE(2,1288)(ADEP(I),I=1,NA)
     1288  FORMAT(8X,12A9)
           WRITE(2,129)(XDOA(I),I=1,NA)
      129   FORMAT(1X,'ODD SEM ',12F9.2)
           WRITE(2,130)(XDEA(I),I=1,NA)
      130   FORMAT(1X,'EVEN SEM',12F9.2)
           WRITE(2,131)(XATOT(I),I=1,NA)
      131   FORMAT(1X,'AV WKLD ',12F9.2)
```

```
C     CATEGORY B :LANG SUBS
      DO 132  I=1,NB
      XDOB(I)=0.0
      XDEB(I)=0.0
      DO 132  J=1,9
      DO 132  K=1,3
      D1=AINT((BCLAS(I,J,K)-0.001)/(XN*4.0))
      D2=AINT((BCLAS(I,J,K)-0.001)/XN)
      D3=AINT((BCLAS(I,J,K)-0.001)/XR)
C     ALLOW FOR ZERO  CLASS SIZE
      IF(BCLAS(I,J,K)-0.001) 127,127,128
  127 XCB(I,J,K)=0.0
      GO TO 132
  128 XCB(I,J,K)=XM*XL/60.0 +BCLAS(I,J,K)/60.0*(WB(J,K)*XW+WTB(J,K)+
     1XX/14.0)+FB(J,K)*XTP/60.0*(D1+1.0)+FB(J,K)*(D2+1.0)*TG/60.0+
     2SS(J,K)*BSB(J,K)/60*(D3+1.0)+BCLAS(I,J,K)/6.0
  132 CONTINUE
        WRITE(2,55)
   55 FORMAT(1H0,'COURSE WKLOAD :CAT B')
        DO 622 I=1,NB
        K=NA-I
          WRITE(2,54)  ADEP(K)
         DO 622 J=1,9
         WRITE(2,621) J,(XCB(I,J,K),K=1,3)
  622     CONTINUE
C       SUM UP WORKLOAD:ODD SEM
        DO 133 I=1,NB
        DO 133 J=1,9,2
        DO 133 K=1,3
        XDOB(I)=XDOB(I)+XCB(I,J,K)
```

```
  133 CONTINUE
C     SUM UP WORKLOAD:EVEN SEM
      DO 134 I=1,NB
      DO 134 J=2,8,2
      DO 134 K=1,3
      XDEB(I)=XDEB(I)+XCB(I,J,K)
  134 CONTINUE
C     AVERAGE WORKLOAD
      DO 135 I=1,NB
      XBTOT(I)=(XDOB(I)+XDEB(I))/2
  135 CONTINUE
      WRITE(2,136)
  136 FORMAT(1H0,'CATEGORY B')
      IX=NA+1
      IY=NA+NB
      WRITE(2,1288)(ADEP(I),I=IX,IY)
      WRITE(2,129)(XDOB(I),I=1,NB)
      WRITE(2,130)(XDEB(I),I=1,NB)
      WRITE(2,131)(XBTOT(I),I=1,NB)
C     CATEGORY C :SCIENCE SUBJECTS
      DO 138 I=1,NC
      XDOC(I)=0.0
      XDEC(I)=0.0
      DO 138 J=1,9
      DO 138 K=1,3
      D1=AINT((CCLAS(I,J,K)-0.001)/(XN*4.0))
      D2=AINT((CCLAS(I,J,K)-0.001)/XN)
      IF (XP(J,K)-0.01) 209,209,210
  209 D4=0.0
      GO TO 211
  210 D4=AINT((CCLAS(I,J,K)-0.001)/XP(J,K))
  211 D5=AINT((CCLAS(I,J,K)-0.001)/XS)
```

```
      IF(CCLAS(I,J,K)-0.001) 139,139,140
  139 XCC(I,J,K)=0.0
      GO TO 138
  140 XCC(I,J,K)=XM*XL/60.0+CCLAS(I,J,K)/60.0 *(WEC(J,K)+XX/14.0)+
     1FC(J,K)*XTP/60.0*(D1+1.0)+
     8FC(J,K)*(D2+1.0)*TG/60.0+QC(J,K)/60.0*(D4+1.0)+
     2QOC(J,K)*QC(J,K)/14400 +QPOC(J,K)*QC(J,K)*D4/14400+CCLAS(I,J,K)/6+
     3LA(I,J,K)*2*(D5+3)
  138 CONTINUE
      WRITE(2,56)
   56 FORMAT(1H0,'CRSE WKLOAD CAT C')
      DO 623 I=1,NC
      K=NA+NB+1
      WRITE(2,54) ADEP(K)
      DO 623 J=1,9
      WRITE(2,621) J,(XCC(I,J,K),K=1,3)
  623 CONTINUE
C     SUM UP WORKLOADS:ODD SEM
      DO 141 I=1,NC
      DO 141 J=1,9,2
      DO 141 K=1,3
      XDOC(I)=XDOC(I)+XCC(I,J,K)
  141 CONTINUE
C     SUM WORKLOADS :EVEN SEM
      DO 142 I=1,NC
      DO 142 J=2,8,2
      DO 142 K=1,3
      XDEC(I)=XDEC(I)+XCC(I,J,K)
```

```
  142 CONTINUE
C     ADDITION EDUC  WORKLOAD
C     TEACHING PRACTICE
      WKTP1=CCLAS(NC,4,1)-5*2.5/30.0
      WKTP2=CCLAS(NC,6,1)*4*2.5/30.0
      XDEC(NC)= XDEC(NC)+WKTP1+WKTP2
C     AVERAGE WORKLOAD
      DO 143 I=1,NC
      XCTOT(I)=(XDOC(I)+XDEC(I))/2
  143 CONTINUE
      WRITE(2,144)
  144 FORMAT(1H0,'CATEGORY C')
      IX=NA+NB+1
      IY=NA+NB+NC
      WRITE(2,1288)(ADEP(I),I=IX,IY)
       WRITE(2,129)(XDOC(I),I=1,NC)
      WRITE(2,130)(XDEC(I),I=1,NC)
      WRITE(2,131)(XCTOT(I),I=1,NC)
C     POSTGRADUATE WORKLOAD
       WRITE(2,57)
   57  FORMAT(1H0,'POSTGRAD WKLD')
      DO 145 I=1,NA
      AGWK(I)=3*NAPGR1(I)+6*NAPGR2(I)
      UATOT(I)=XATOT(I)+AGWK(I)
  145 CONTINUE
       WRITE(2,1288) (ADEP(I),I=1,NA)

       WRITE(2,242) (AGWK(I),I=1,NA)
  242  FORMAT(10X,12F9.2)
      DO 146 I=1,NB
      BGWK(I)=3*NBPGR1(I)+6*NBPGR2(I)
      UBTOT(I)=XBTOT(I)+BGWK(I)
  146 CONTINUE
```

```
      IX=NA+1
      IY=NA+NB
      WRITE(2,1288)(ADEP(I),I=IX,IY)
      WRITE(2,242)(BGWK(I),I=1,NB)
      DO 147 I=1,NC
      CGWK(I)=3*NCPGR1(I)+6*NCPGR2(I)
      UCTOT(I)=XCTOT(I)+CGWK(I)
  147 CONTINUE
      IX=NA+NB+1
      IY=NA+NB+NC
      WRITE(2,1288)(ADEP(I),I=IX,IY)
      WRITE(2,242)(CGWK(I),I=1,NC)
C     SUM UP TOTAL UNIVERSITY WORKLOAD
      WATOT=0.0
      WBTOT=0.0
      WCTOT=0.0
      DO 170 I=1,NA
      WATOT=WATOT+UATOT(I)
  170 CONTINUE
      DO 171 I=1,NB
      WBTOT=WBTOT+UBTOT(I)
  171 CONTINUE
      DO 172 I=1,NC
      WCTOT=WCTOT+UCTOT(I)
  172 CONTINUE
C     TOTAL WORKLOAD WKTOT
      WKTOT=WATOT+WBTOT+WCTOT
```

```
C      CALCULATE TOTAL STUDENTS
       MSTUD=NTOT+NPGTOT
C      READ IN OVERALL STUDENTS:STAFF RATIO
       READ(7,173) SSRAT
   173 FORMAT(F5.2)
C      CALCULATE  TOTAL UNIV STAFF ENTITLEMENT
       NSTAFF=MSTUD/SSRAT
       WRITE(2,1744)NSTAFF
  1744 FORMAT(1H0,'TOTAL UNIV  STAFF =',I4)
C      STAFF ALL TO PG COURSES
       READ(7,174)(NAPGST(I),I=1,NA)
       READ(7,174)(NBPGST(I),I=1,NB)
       READ(7,174)(NCPGST(I),I=1,NC)
   174 FORMAT(15I3)
C      SUM PG COURSE STAFF
       NAPG=0
       NBPG=0
       NCPG=0
       DO 175 I=1,NA
       NAPG=NAPG+NAPGST(I)
   175 CONTINUE
       DO 176 I=1,NB
       NBPG=NBPG+NBPGST(I)
   176 CONTINUE
       DO 177 I=1,NC
       NCPG=NCPG+NCPGST(I)
   177 CONTINUE
       NPG=NAPG+NBPG+NCPG
C      NO OF STAFF AVAIL FOR ALL ON WORKLOAD MODEL
       NWK=NSTAFF-NPG
C      CALCULATE WORKLOAD PER STAFF MEMBER
       HRST=WKTOT/NWK
```

```
C     CALCULATE TOTAL STUDENTS
      MSTUD=NTOT+NPGTOT
C     READ IN OVERALL STUDENTS:STAFF RATIO
      READ(7,173) SSRAT
  173 FORMAT(F5.2)
C     CALCULATE  TOTAL UNIV STAFF ENTITLEMENT
      NSTAFF=MSTUD/SSRAT
      WRITE(2,1744)NSTAFF
 1744 FORMAT(1H0,'TOTAL UNIV  STAFF =',I4)
C     STAFF ALL TO PG COURSES
      READ(7,174)(NAPGST(I),I=1,NA)
      READ(7,174)(NBPGST(I),I=1,NB)
      READ(7,174)(NCPGST(I),I=1,NC)
  174 FORMAT(15I3)
C     SUM PG COURSE STAFF
      NAPG=0
      NBPG=0
      NCPG=0
      DO 175 I=1,NA
      NAPG=NAPG+NAPGST(I)
  175 CONTINUE
      DO 176 I=1,NB
      NBPG=NBPG+NBPGST(I)
  176 CONTINUE
      DO 177 I=1,NC
      NCPG=NCPG+NCPGST(I)
  177 CONTINUE
      NPG=NAPG+NBPG+NCPG
C     NO OF STAFF AVAIL FOR ALL ON WORKLOAD MODEL
      NWK=NSTAFF-NPG
C     CALCULATE WORKLOAD PER STAFF MEMBER
      HRST=WKTOT/NWK
```

```
C     CALCULATE STAFF ALL PER  DEPT
      DO 178 I=1,NA
      XNAST(I)=UATOT(I)/HRST
  178 CONTINUE
      DO 179 I=1,NB
      XNBST(I)=UBTOT(I)/HRST
  179 CONTINUE
      DO 180 I=1,NC
      XNCST(I)=UCTOT(I)/HRST
  180 CONTINUE
C     WRITE HRS/STAFF MEMBER
      WRITE(2,181) HRST
  181 FORMAT(1X,'WORKLOAD PER STAFF MEMBER',F7.3)
C     ROUND OFF  TO  NEAREST INTEGER
      DO 184  I=1,NA
      IF ((XNAST(I)-INT(XNAST(I))).LE.0.5) GO TO 182
      NAST(I)=INT(XNAST(I))+1
      GO TO 184
  182 NAST(I)=INT(XNAST(I))
  184 CONTINUE
      DO 185 I=1,NB
      IF((XNBST(I)-INT(XNBST(I))).LE.0.5) GO TO 186
      NBST(I)=INT(XNBST(I))+1
      GO TO 185
  186 NBST(I)=INT(XNBST(I))
  185 CONTINUE
      DO 187 I=1,NC
      IF((XNCST(I)-INT(XNCST(I))).LE.0.5) GO TO 188
```

```
      NCST(I)=INT(XNCST(I))+1
      GO TO 187
  188 NCST(I)=INT(XNCST(I))
  187 CONTINUE
C     ADD IN PG ALLOCATION
      DO 189 I=1,NA
      MAST(I)=MAST(I)+NAPGST(I)
  189 CONTINUE
      DO 190 I=1,NB
      NBST(I)=NBST(I)+NBPGST(I)
  190 CONTINUE
      DO 192 I=1,NC
      NCST(I)=NCST(I)+NCPGST(I)
  192 CONTINUE
C     WRITE OUT STAFFING LEVELS
      WRITE(2,193)
  193 FORMAT(1HO,'ACADEMIC STAFF ALLOCATION')
      WRITE(2,194)(ADEP(I),I=1,NA)
  194 FORMAT(1HO,12X,12A10)
      WRITE(2,195)(NAST(I),I=1,NA)
  195 FORMAT(1X,'ALL ON WKLD',12I10)
      WRITE(2,196)(NAPGST(I),I=1,NA)
  196 FORMAT(1X,' PG ALLOCN ',12I10)
      WRITE(2,197)(MAST(I),I=1,NA)
  197 FORMAT(1X,' TOT ALLN  ',12I10)
      IX=NA+1
      IY=NA+NB
      WRITE(2,194)(ADEP(I),I=IX,IY)
      WRITE(2,195)(NBST(I),I=1,NB)
      WRITE(2,196)(NBPGST(I),I=1,NB)
      WRITE(2,197)(MBST(I),I=1,NB)
      IX=NA+NB+1
      IY=NA+NB+NC
      WRITE(2,194)(ADEP(I),I=IX,IY)
      WRITE(2,195)(NCST(I),I=1,NC)
      WRITE(2,196)(NCPGST(I),I=1,NC)
      WRITE(2,197)(MCST(I),I=1,NC)
      RETURN
      END
```

STAFF ALL WKLOAD

NO SUBS IN CATS A B C 10 3 8

WORKLOAD FACTORS

360.000	3.000	20.000	60.000	120.000	6.000	18.000	20.000	60.000
0.500	0.250	15.000	5.000	1.000	1.000	0.500	80.000	1.000
240.000	420.000	120.000	60.000					
0.500	0.250	15.000	5.000	1.000	1.000	0.500	80.000	1.000
240.000	420.000	120.000	60.000					
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000					
0.500	0.250	15.000	5.000	1.000	1.000	0.500	80.000	1.000
240.000	420.000	120.000	60.000					
0.500	0.250	15.000	5.000	1.000	1.000	0.500	80.000	1.000
240.000	420.000	120.000	60.000					
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000					
0.500	0.250	15.000	5.000	1.000	1.000	0.500	80.000	1.000
240.000	420.000	120.000	60.000					
0.500	0.250	15.000	5.000	1.000	1.000	0.500	80.000	1.000

COURSE WKLOAD CAT A

MATH

SEM NO 1	63.929	22.214	0.000
SEM NO 2	47.810	0.000	0.000
SEM NO 3	38.738	0.000	0.000
SEM NO 4	26.857	21.929	19.905
SEM NO 5	23.429	20.310	19.905
SEM NO 6	24.833	19.905	19.905
SEM NO 7	20.310	20.310	20.310
SEM NO 8	20.143	0.000	0.000
SEM NO 9	0.000	0.000	0.000

ECON

SEM NO 1	135.238	0.000	0.000
SEM NO 2	131.405	0.000	0.000
SEM NO 3	96.571	0.000	0.000
SEM NO 4	68.548	26.571	20.310
SEM NO 5	62.833	36.762	20.310
SEM NO 6	59.024	36.357	21.524
SEM NO 7	24.857	24.048	24.048
SEM NO 8	24.679	0.000	0.000
SEM NO 9	[illegible]	[illegible]	0.000

SOCIOL

SEM NO 1	213.405	0.000	0.000
SEM NO 2	215.429	0.000	0.000
SEM NO 3	135.643	0.000	0.000
SEM NO 4	107.119	54.929	20.310
SEM NO 5	75.810	38.881	26.690
SEM NO 6	68.548	42.214	29.095
SEM NO 7	34.238	34.238	34.238
SEM NO 8	31.821	0.000	0.000
SEM NO 9	0.000	0.000	0.000

ENGLISH

SEM NO 1	197.690	0.000	0.000
SEM NO 2	196.286	0.000	0.000
SEM NO 3	148.738	0.000	0.000
SEM NO 4	103.310	65.929	28.690
SEM NO 5	92.333	52.810	19.905
SEM NO 6	80.857	49.881	20.714
SEM NO 7	43.024	43.024	37.571
SEM NO 8	36.679	0.000	0.000
SEM NO 9	0.000	0.000	0.000

HISTORY

SEM NO 1	170.095	0.000	0.000
SEM NO 2	165.667	0.000	0.000
SEM NO 3	119.929	0.000	0.000
SEM NO 4	121.143	53.214	21.524
SEM NO 5	76.619	41.405	19.905
SEM NO 6	75.405	37.571	19.905
SEM NO 7	34.643	34.643	33.024
SEM NO 8	31.500	0.000	0.000
SEM NO 9	0.000	0.000	0.000

PHILOS

SEM NO 1	116.905	46.214	0.000
SEM NO 2	102.000	0.000	0.000
SEM NO 3	61.714	0.000	0.000
SEM NO 4	44.381	24.976	23.238
SEM NO 5	32.500	25.762	20.714
SEM NO 6	29.881	23.238	20.714
SEM NO 7	25.762	25.762	25.762
SEM NO 8	24.679	0.000	0.000
SEM NO 9	0.000	0.000	0.000

25SE84

ACC&BL

SEM NO 1	73.190	49.024	0.000
SEM NO 2	72.786	0.000	0.000
SEM NO 3	62.833	0.000	0.000
SEM NO 4	64.452	26.571	0.000
SEM NO 5	57.405	0.000	0.000
SEM NO 6	57.810	23.238	0.000
SEM NO 7	30.714	30.714	0.000
SEM NO 8	28.714	0.000	0.000
SEM NO 9	0.000	0.000	0.000

REL ST

SEM NO 1	48.619	0.000	0.000
SEM NO 2	53.238	0.000	0.000
SEM NO 3	29.881	0.000	0.000
SEM NO 4	28.262	21.310	19.905
SEM NO 5	25.643	20.310	19.905
SEM NO 6	24.333	19.905	0.000
SEM NO 7	20.310	20.310	20.310
SEM NO 8	20.143	0.000	0.000
SEM NO 9	0.000	0.000	0.000

SB

MAN SCI			
SEM NO 1	56.262	0.000	0.000
SEM NO 2	49.429	0.000	0.000
SEM NO 3	29.881	0.000	0.000
SEM NO 4	34.667	0.000	0.000
SEM NO 5	26.857	21.119	0.000
SEM NO 6	29.429	19.905	0.000
SEM NO 7	21.119	21.119	20.310
SEM NO 8	20.464	0.000	0.000
SEM NO 9	0.000	0.000	0.000
COMP SC			
SEM NO 1	56.667	0.000	0.000
SEM NO 2	54.452	0.000	0.000
SEM NO 3	30.286	0.000	0.000
SEM NO 4	30.286	22.833	0.000
SEM NO 5	24.833	20.714	19.905
SEM NO 6	24.833	20.714	19.905
SEM NO 7	20.310	20.310	20.310
SEM NO 8	20.143	0.000	0.000
SEM NO 9	0.000	0.000	0.000

Similar output for subjects in Cats B and C

CATEGORY A- U G WKLD

	MATH	ECON	SOCIOL	ENGLISH	HISTORY	PHILOS	ACC&BL	REL ST	MAN SCI	COMP SC
ODD SEM	249.45	424.67	595.14	635.10	530.26	383.10	303.88	205.29	196.67	213.33
EVEN SEM	201.29	388.42	569.46	582.85	526.93	295.11	273.57	186.60	153.89	193.17
AV WKLD	225.37	406.54	582.30	608.97	528.60	339.10	288.73	195.94	175.28	203.25

CATEGORY B

	FRENCH	GERMAN	SPANISH
ODD SEM	395.88	275.98	193.60
EVEN SEM	372.64	294.43	201.73
AV WKLD	384.26	285.20	197.66

CATEGORY C

	BIOLOGY	PHYSICS	CHEM	PSYCHOL	INT SCI	F.ARTS	BIOCHEM	EDUCAT
ODD SEM	481.96	260.29	347.71	620.57	72.14	86.79	227.14	224.56
EVEN SEM	435.39	247.82	300.61	555.36	108.46	88.89	145.25	336.83
AV WKLD	458.68	254.05	324.16	587.96	90.30	87.84	186.20	280.70

POSTGRAD WKLD

MATH	ECON	SOCIOL	ENGLISH	HISTORY	PHILOS	ACC&BL	REL ST	MAN SCI	COMP SC
9.00	45.00	24.00	18.00	12.00	18.00	6.00	3.00	45.00	3.00

FRENCH	GERMAN	SPANISH
16.00	12.00	18.00

BIOLOGY	PHYSICS	CHEM	PSYCHOL	INT SCI .	F.ARTS	BIOCHEM	EDUCAT
12[illegible].00	21.00	30.00	72.00	0.00	0.00	15.00	9.00

TOTAL UNIV STAFF = 260
WORKLOAD PER STAFF MEMBER 29.464

ACADEMIC STAFF ALLOCATION

	MATH	ECON	SOCIOL	ENGLISH	HISTORY	PHILOS	ACC&BL	REL ST	MAN SCI	COMP SC
ALL ON WKLD	8	15	21	21	18	12	10	7	7	7
PG ALLOCN	0	6	3	0	0	0	0	0	3	1
TOT ALLN	8	21	24	21	18	12	10	7	10	8

	FRENCH	GERMAN	SPANISH
ALL ON WKLD	14	10	7
PG ALLOCN	0	0	0
TOT ALLN	14	10	7

	BIOLOGY	PHYSICS	CHEM	PSYCHOL	INT SCI	. F.ARTS	BIOCHEM	EDUCAT
ALL ON WKLD	20	9	12	22	3	3	7	10
PG ALLOCN	0	0	0	3	0	0	0	0
TOT ALLN	20	9	12	25	3	3	7	10

** SEGMENT WANTED

APPENDIX 6

6F Staff Allocation Module (Student:Staff ratio) option

6F1 Name of subroutine STAFF 2

6F2 General description of module

This module provides an alternative policy for allocating academic staff to subjects to the workload policy module. In general this module divides total available academic staff between subjects on the basis of total student equivalents enrolled in each subject. It is possible to give additional weighting to postgraduate students of different types by varying the student:staff ratio applied to these groups. There is, however, a normalization routine to ensure total academic staff allocated to different subject equals total staff available.

APPENDIX 6

6F3 Detailed description of program

849-55	COMMON statement
856-57	DIMENSION statement
862-63	Read in student staff ratios for (1) undergraduates (2) postgraduate research (single discipline) (3) postgraduate research (interdisciplinary) (4) postgraduate courses
864-71	Calculate staff allocation per department for each of categories described above
873-75	Read in overall student:staff ratio
876-78	Calculate total staff entitlement {total student numbers divided by appropriate overall student:staff ratio}
879-80	Write out total staff entitlement
881-86	Calculate normalization factor (SNORM)
887-90	Adjust staff allocations by normalization factors (SO total staff allocations = total staff entitlement)
891-97	Round off staff allocation to nearest integer
899-901	Read in number of subjects in category 'A', 'B' and 'C'
902-04	Assign category 'A' staffing allocations to array MAST(I)
905-08	Assign category 'B' staffing allocations to array MBST(I)
909-12	Assign category 'C' staffing allocations to array MCST(I)
916-17	Write out department names (cat A)
918-19	Write out staffing levels (cat A)
922	Write out department names (cat B)
922-23	Write out staffing levels (cat B)
926	Write out department names (cat C)
927	Write out staffing levels (cat C)

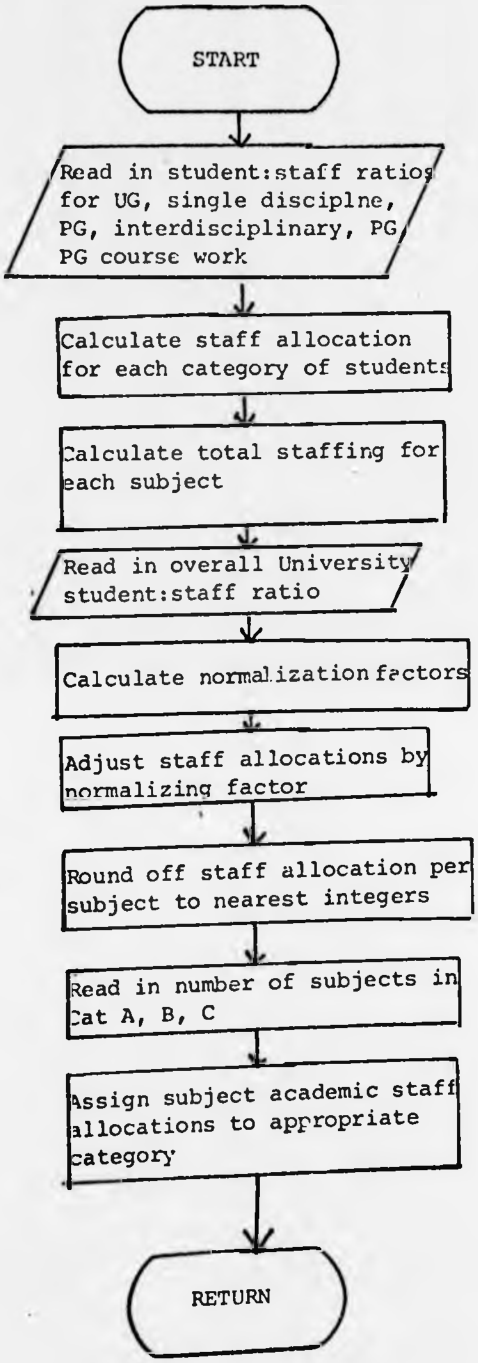
APPENDIX 6

6F4 Definition of Variables

MSTUD	Total student numbers
MAST(I) MBST(I) MCST(I)	Total staff allocated to subjects in Cat. A, B, C (A - general; B - language subject C - laboratory subject)
NA, NB, NC	Number of subjects in categories A, B, C
NSTAFF	Total university staff allocation
NST(I)	Total staff allocated to subject I
SSRAT	Overall student:staff ratio
SSCR	Student:staff ratio for postgraduate coursework students
SSR1	Student:staff ratio for single discipline postgraduates
SSR2	Student:staff ratio for interdisciplinary postgraduates
SSUG	Student:staff ratio for undergraduate students
STALL(I)	Academic staff (unrounded) allocated to subject I
STCR(I)	Staff allocated on basis of postgraduate course work
STR1(I)	Staff allocated on basis of (single discipline) postgraduate research
STR2(I)	Staff allocated on basis of (interdisciplinary) postgraduate research

APPENDIX 6

6F5 <u>Flow Chart : Staff Allocation 2</u>



6F6 Program Listing

```
&ASSIGN;     1;DC:50;RB53.RBFILES;

       SUBROUTINE STAFF2
       COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
     1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150), KF9(150),NPGR1(30),
     2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
     3NBPGR1(15),NBPGR2(15), NBPGCR(15),NCPGR1(15),NCPGR2(15),
     4NCPGCR(15),MAST(15),MBST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
     5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15), NCTEC(15),
     6 N3(30,2),MSTUD,SEQTOT(30),NPGTOT,NXCLAS(30,5,12)
       DIMENSION STALL(30),NST(30),
     1 STUG(30),STR1(30),STR2(30),STCR(30)
C      STAFF ALLOCATION :VERSION 2

C      STUDENT:STAFF RATIO  MODULE
C      READ IN STUDENT STAFF RATIOS FOR (1) UG (2)SINGLE DIS PG RES
C      (3) INTER-DISP RESEARCH (4) PG COURSES
       READ (7,902) SSUG,SSR1,SSR2,SSCR
  902  FORMAT(4F5.3)
C      CALCULATE  STAFF ALLOCATION
       DO 903 I=1,NDEP
       STUG(I)= XEQ(I)/SSUG
       STR1(I)= NPGR1(I)/SSR1
       STR2(I)= NPGR2(I)/SSR2
       STCR(I)= NPGCR(I)/SSCR
       STALL(I)= STUG(I)+STR1(I)+STR2(I)+STCR(I)
  903  CONTINUE
C      NORMALISE
C      READ IN OVERALL STUDENT STAFF RATIO
       READ(7,904) SSRAT
  904  FORMAT(F5.2)
C      CALCULATE UNIV STAFF ENTITLEMENT
         MSTUD=NTOT+NPGTOT
       NSTAFF =MSTUD/SSRAT
```

```
      WRITE(2,905) NSTAFF
  905 FORMAT(1H0,'TOTAL UNIV STAFF =  ',I4)
C     CALCULATE  CORRECTION  FACTOR
      STOT=0.0
      DO 906 I=1,NDEP
      STOT=STOT +STALL(I)
  906 CONTINUE
      SNORM=NSTAFF/STOT
C     MULT. BY NORMALIZING FACTOR
      DO 907 I=1,NDEP
      STALL(I)=STALL(I)*SNORM
  907 CONTINUE
C     ROUND OFF TO NEAREST INTEGER
      DO 909 I=1,NDEP
      IF ((STALL(I)-INT(STALL(I))).LE.0.5) GO TO 908
      NST(I)= INT(STALL(I))+1
      GO TO 909
  908 NST(I)=INT(STALL(I))
  909 CONTINUE
C     DIVIDE INTO CATEGORIES A,B,C
C       READ IN NOS OF SUBS IN EACH CATEGORY
      READ(7,910) NA,NB,NC
  910 FORMAT(3I3)
      DO 911 I=1,NA
      MAST(I)=NST(I)
  911 CONTINUE
      DO 912 I=1,NB
      NX=NA+I
      MBST(I)=NST(NX)
  912 CONTINUE
      DO 913 I=1,NC
      NX=NA+NB+I
      MCST(I)=NST(NX)
  913 CONTINUE
C     WRITE OUT STAFFING LEVELS
      WRITE(2,914)
  914 FORMAT(1H0,'ACADEMIC STAFF  ALLOCATION')
      WRITE(2,915)(ADEP(I),I=1,NA)
  915 FORMAT(1H0,10X,12A10)
      WRITE(2,916)(MAST(I),I=1,NA)
```

```
  916 FORMAT(1H0,'TOT AC ST',12I10)
      IX=NA+1
      IY=NA+NB
      WRITE(2,915)(ADEP(I),I=IX,IY)
      WRITE(2,916)(MBST(I),I=1,NB)
      IX=NA+NB+1
      IY=NA+NB+NC
      WRITE (2,915)(ADEP(I),I=IX,IY)
      WRITE (2,916)(MCST(I),I=1,NC)
      RETURN
      END
```

6F7 Sample Output

```
TOTAL UNIV STAFF -    264

ACADEMIC STAFF  ALLOCATION

                MATH    ECON     SOCIOL    ENGLISH   HISTORY   PHILOS  ACC&BL   REL ST    MAN SCI  COMP SC

TOT AC ST          4      21         35        33        26        12      12        3          5        4

              FRENCH    GERMAN   SPANISH

TOT AC ST         12        6          3

             BIOLOGY   PHYSICS      CHEM   PSYCHOL   INT SCI . F.ARTS  BIOCHEM  EDUCAT

TOT AC ST         23        2          8        34        1         3       4       14

** SEGMENT WANTED
```

APPENDIX 6

6G Non-academic staff module

6G1 Name of subroutine NACST

6G2 General description of module

The function of this module is the allocation of non-academic staff (secretarial and technical staff) to different subject areas. The policy is employed is that these grades of staff are related to academic staff in a given subject area by a constant factor (or norm). The numbers of staff thus allocated are rounded off to the nearest integer.

6G3 Detailed description of program

1220-26	COMMON statement
1227	DIMENSION statement
1232-33	Read in ratios of academic:secretaial staff and academic:technical staff
1234-37	Calculate numbers of secretarial staff for each subject in category A
1245-50	Round off to nearest integral number
1238-40) 1251-56)	Repeat above for category B
1241-43) 1257162)	Repeat above for category C
1263-65	Calculate numbers of technical staff for each (laboratory) subject
1266-70	Round off above numbers to nearest integer
1271-89	Print out results; subject names, number of secretarial staff, numbers of technical staff

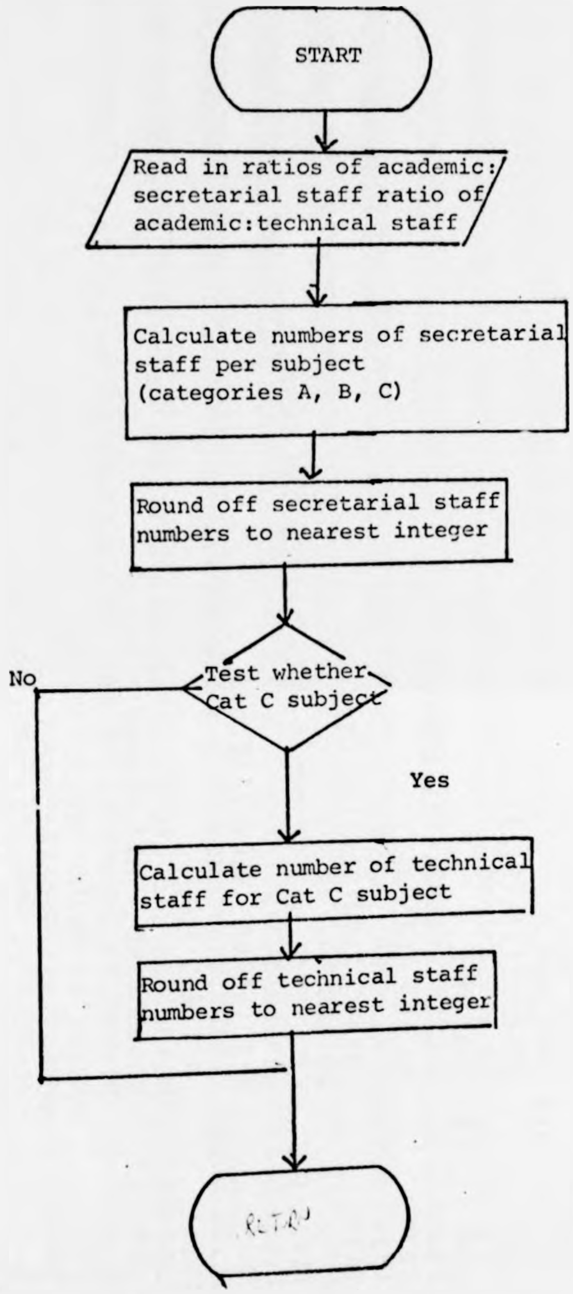
APPENDIX 6

6G4 Definition of variables

NASEC(I) NBSEC(I) NCSEC(I)	Number of secretarial staff allocated to subject I (subject categories A, B, C)
NCTEC(I)	Number of technicians allocated to subject I (category 'C' lab subject only)
SECRAT	Ratio of secretarial staff : academic staf
TECRAT	Ratio of technical staff : academic staff
XNC TEC(I)	Number of technicians allocated to subject I (unrounded)
ZNASEC(I) ZNBSEC(I) ZNCSEC(I)	Number of secretarial staff allocated to subject I (categories A, B, C)(unrounded)

APPENDIX 6

6G5 Flow diagram



```
&ASSIGN;    1;DC;50;RU64,NBFILES;

      SUBROUTINE  NACST
      COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
     1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150),KF9(150),NPGR1(30),
     2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
     3NBPGR1(15),NBPGR2(15),NBPGCR(15),NCPGR1(15),NCPGR2(15),
     4NCPGCR(15),MAST(15),MBST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
     5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),
     6N3(30,2),MSTUD,SENTOT(30),NPGTOT
      DIMENSION ZNASEC(15),ZNBSEC(10),ZNCSEC(15),XNCTEC(10)
C     SUBROUTINE : NON-ACADEMIC STAFF
C     READ IN RATIO  ACADEMIC :SECRETARIAL AND TECHNICAL STAFF
      WRITE(2,521)
  521 FORMAT(1H1,'NON AC STAFF MODULE')
      READ(7,501) SECRAT,TECRAT
  501 FORMAT(2F5.3)
C     CALCULATE NOS OF SECRETARIAL STAFF PER DEPT
      DO 580 I=1,NA
      ZNASEC(I)=MAST(I)/SECRAT
  580 CONTINUE
      DO 581 I=1,NB
      ZNBSEC(I)=MBST(I)/SECRAT
  581 CONTINUE
      DO 582 I=1,NC
      ZNCSEC(I)=MCST(I)/SECRAT
  582 CONTINUE
C     ROUND OFF SEC NOS
      DO 507 I=1,NA
      IF((ZNASEC(I)-INT(ZNASEC(I))).LE.0.5) GO TO 5021
      NASEC(I)= INT(ZNASEC(I))+1
      GO TO 507
 5021 NASEC(I)=INT(ZNASEC(I))
  507 CONTINUE
      DO 508 I=1,NB
      IF ((ZNBSEC(I)-INT(ZNBSEC(I))).LE.0.5) GO TO 5022
      NBSEC(I)=INT(ZNBSEC(I))+1
      GO TO 508
 5022 NBSEC(I)=INT(ZNBSEC(I))
  508 CONTINUE
      DO 509 I=1,NC
```

298-79

```
      IF ((ZNCSEC(I)-INT(ZNCSEC(I))).LE.0.5) GO TO 5023
      NCSEC(I)=INT(ZNCSEC(I))+1
      GO TO 509
 5023 NCSEC(I)=INT(ZNCSEC(I))
  509 CONTINUE
C     CALCULATION OF NOS OF TECHNICAL STAFF
      DO 514 I=1,NC
      XNCTEC(I)=MCST(I)/TECRAT
      IF((XNCTEC(I)-INT(XNCTEC(I))).LE.0.5) GO TO 515
      NCTEC(I)=INT(XNCTEC(I))+1
      GO TO  514
  515 NCTEC(I)=INT(XNCTEC(I))
  514 CONTINUE
C     WRITE OUT  RESULTS
      WRITE(2,599)
  599 FORMAT(1H0,   'SECRETARIAL  STAFF NOS')
      WRITE(2,518) (ADEP(I),I=1,NA)
  518 FORMAT(1H0,12A10)
      WRITE(2,519) (NASEC(I),I=1,NA)
  519 FORMAT(1X,I8,11I10)
      IX=NA+1
      IY=NA+NB
      WRITE(2,518)(ADEP(I),I=IY,IY)
      WRITE(2,519)(NBSEC(I),I=1,NB)
       IX=NA+NB 1
       IY=NA+NB+NC
      WRITE(2,518) (ADEP(I),I=IX,IY)
      WRITE(2,519) (NCSEC(I),I=1,NC)
       WRITE(2,520)
  520 FORMAT(1H0,'TECHNICAL STAFF NOS')
      WRITE 2,518) (ADEP(I),I=IX,IY)
      WRITE(2,519)(NCTEC(I),I=1,NC)
      RETURN
      END
```

```
SEGMENTS NOW IN STORE
 13   1   2   3   5   7  10                                                             CPU TIME =

NON AC STAFF MODULE

SECRETARIAL  STAFF NOS

    MATH     ECON      SOCIOL    ENGLISH   HISTORY   PHILOS   ACC&BL    REL ST    MAN  SCI   COMP SC
     1         3          4         3         3         2        2         1          2          1

   FRENCH    GERMAN    SPANISH
     2         2          1

   BIOLOGY   PHYSICS      CHEM    PSYCHOL  INT  SCI  . F.ARTS   BIOCHEM  EDUCAT
     3         1          2         4          0         0         1        2

 TECHNICAL STAFF NOS

   BIOLOGY   PHYSICS      CHEM    PSYCHOL  INT  SCI  . F.ARTS   BIOCHEM  EDUCAT
     20        9          12        25         3         3         7        10
```

APPENDIX 6

6H <u>Financial Module</u>

6H1 Name of subroutine FINMOD

6H2 Detailed Description of Module

This module gives information on financial implications of plans; in particular information on unit costs of producing students in different subject areas is provided. From a knowledge of the usual proportions of senior staff it is possible to calculate the numbers of staff in each subject in each grade and hence the total academic salary bill. By adding non-academic salaries the total salary expenditure for each subject can be determined. Departmental expenditure (i.e. expenditure for consumables, travel, hospitality etc.) is determined as a historically derived fraction of the total salary bill for a given subject area.

These calculations allow total direct expenditure in a given subject area to be calculated. Since numbers of full-time equivalent students that can be considered to be studying a particular subject area is known, unit costs in different subjects can be calculated.

APPENDIX 6

6H3 Detailed description of program

1068-74 COMMON block

1075-81 DIMENSION statement

1085-92 Read in salaries, professor, senior lecturer, lecturer, secretary, technician (and print out)

1093-95 Read in proportions of senior staff, professorial staff

1096-98 Calculate number of senior staff in category 'A' subjects

1099-1103 Round off to nearest integer

1104-09 Calculate numbers of professors, senior lecturers, lecturers in each category A subject

1110-12 Read in fraction of salary bill spent on departmental expenditure for each Cat A subject

1113-24 Student equivalent adjustment. Assign student equivalents (for categories A, B, C) to appropriate array SEQAT(I), SEQB(I), SEQCT(I)

1125-33 Calculate academic salaries, secretarial salaries, total salaries, departmental expenditure, total direct expenditure associated with a subject area and unit costs

1134-46 Print out results for category 'A', subject headings, academic salaries, total salaries, departmental expenditure, unit costs

1147-80 Repeat above sequence of operations for category 'B' subjects

1181-215 Repeat above sequence of operations for category 'C' subjects (except allowance is made for salary of technicians)

APPENDIX 6

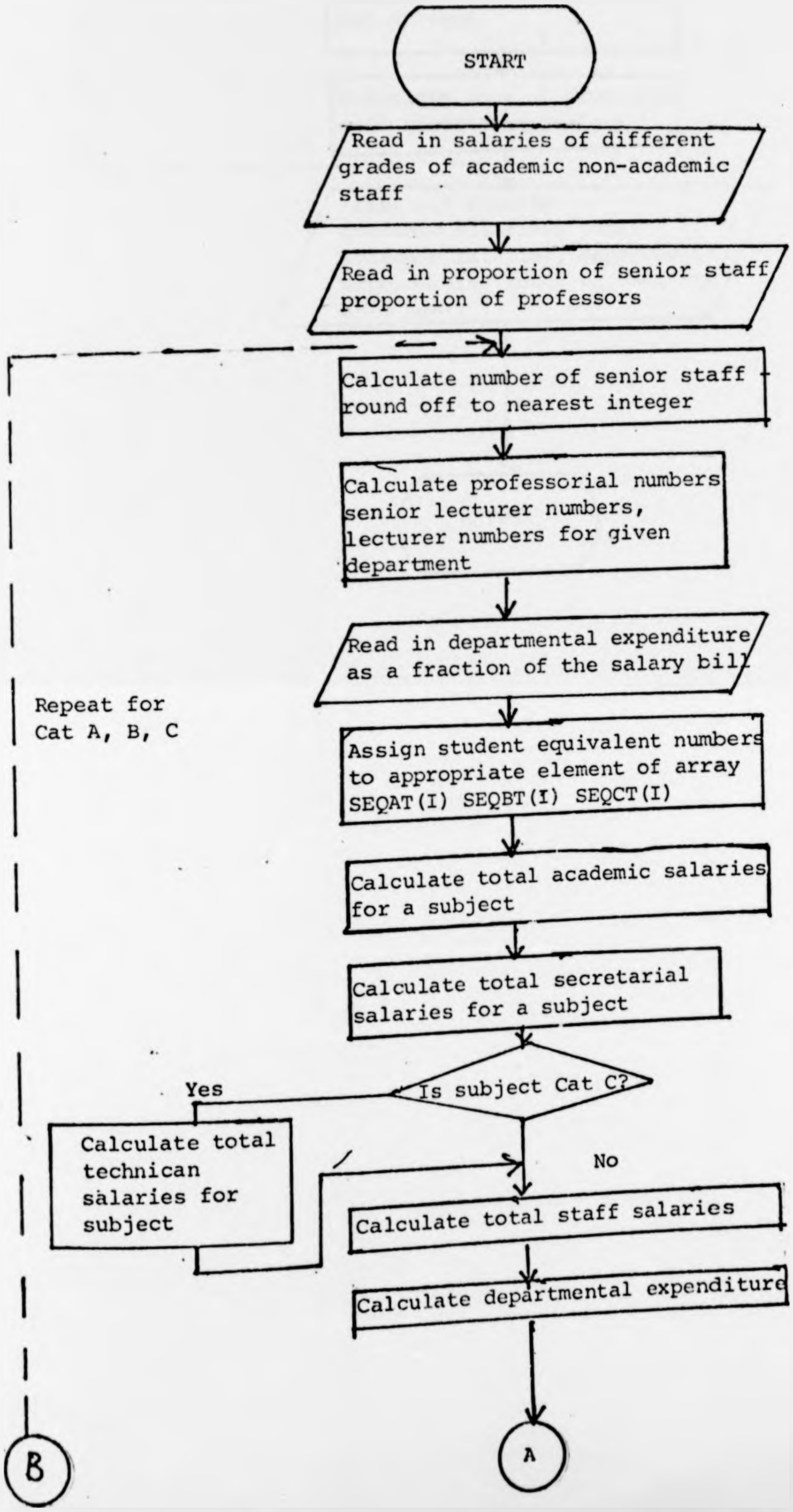
6H4 Definition of Variables

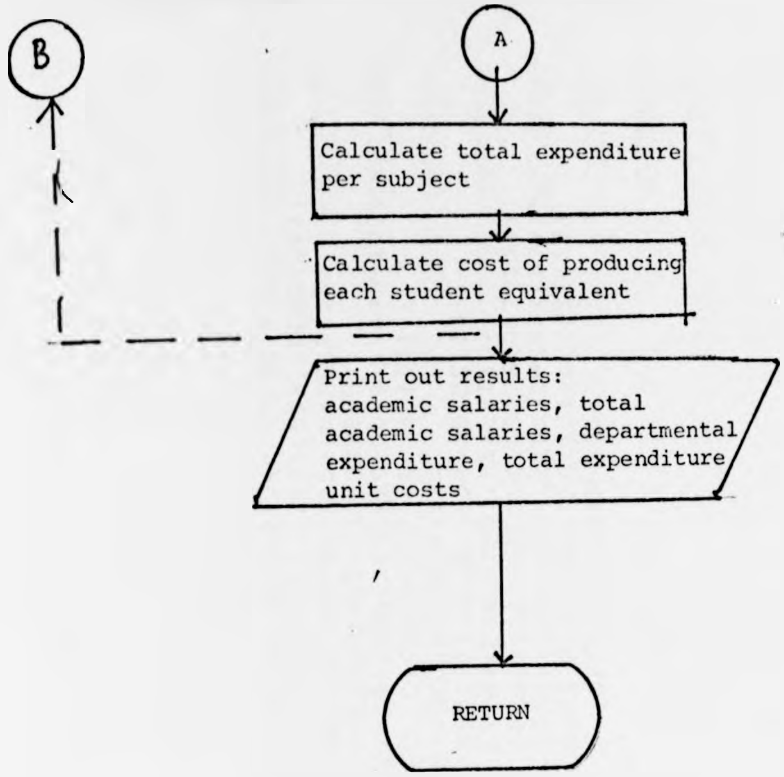
ASCALA(I) ACSALB(I) ACSALC(I)	Total academic salaries for subjects in categories A, B, C,
AuCOST(I) BuCOST(I) CuCOST(I)	Unit cost per full time equivalent students for subjects in categories A, B, C
DPEXA(I) DPEXB(I) DPEXC(I)	Departmental expenditure in subject I (categories A, B, C)
FSALA(I) FSALB(I) FSALC(I)	Departmental expenditure expressed as a fraction of total salary bill
MLSL	Average lecturer grade salary
MPRSL	Average professorial grade salary
MSECSL	Average secretarial grade salary
MSLSL	Average senior lecturer grade salary
MTECSL	Average technician grade salary
NALEC(I) NBLEC(I) NCLEC(I)	Number of lecturers in subject I (for categories A, B, C)
NAPR(I) NBPR(I) NCPR(I)	Number of professorial staff in subject I (categories A, B, C)
NASEN(I) NBSEN(I) NCSEN(I)	Number of senior staff in subject I (categories A, B, C)
NASL(I) NBSL(I) NCSL(I)	Number of senior lecturers staff in subject I (categories A, B, C)
PFRAT	Proportion of senior academic staff who are professors
SENRAT	Proportion of academic staff classified as senior (i.e. professorial and senior lecturer)
SECSLA(I) SECSLB(I) SECSLC(I)	Total secretarial salaries for subject I (categories A, B, C)

SEQAT(I) SEQBT(I) SEQCT(I)	Total student equivalents for subjects of categories A, B, C
TECSLC(I)	Total technician salaries for subject I (cat C only)
TOTSLA(I) TOTSLB(I) TOTSLC(I)	Total salary (academic plus non-academic) subject I (categories A, B, C)
XASEN(I) XBSEN(I) XCSEN(I)	Number of senior academic staff (unrounded) allocated to subject I (categories A, B, C)
XOTSLA(I) XOTSLB(I) XOTSLC(I)	Total expenditure for subject I (categories A, B, C)

APPENDIX 6

6H5 Finance Module : Flow Chart




B
A
Calculate total expenditure per subject
Calculate cost of producing each student equivalent
Print out results: academic salaries, total academic salaries, departmental expenditure, total expenditure unit costs
RETURN

```
        SEGMENT

&ASSIGN;  1;DC;50;R55,RBFILES:

      SUBROUTINE FINMOD
      COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
     1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150), KF9(150),NPGR1(30),
     2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
     3NBPGR1(15),NBPGR2(15), NBPGCR(15),NCPGR1(15),NCPGR2(15),
     4NCPGCR(15),MAST(15),MBST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
     5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),
     6 N3(30,2),MSTUD,SEQTOT(30),NPGTOT,NXCLAS(30,5,12)
      DIMENSION XASEN(15),XBSEN(10),XCSEN(10),NALEC(15),NBLEC(10),
     1 NCLEC(10),NASL(15),NBSL(10),NCSL(10),FSALA(15),FSALB(10),
     2FSALC(10),ACSALA(15),ACSALC(10),SECSLB(10),SECSLC(10),SEQAT(15),
     3SEQBT(10),SEQCT(10),TOTSLA(15),TOTSLB(10),TOTSLC(10),DPEXA(15),
     4 DPEXB(10),DPEXC(10),XOTSLA(15),XOTSLB(10),XOTSLC(10),AUCOST(15),
     5 BUCOST(10),CUCOST(10),NASEN(15),NBSEN(10),NCSEN(10),
     6 SECSLA(15),ACSALB(10),TECSLC(10)
C     FINANCIAL MODULE
      WRITE(2,9)
    9 FORMAT(1H1,'FINANCIAL MODULE')
```

```
C      READ IN SALS :PROF:SLECT:LECT:SEC :TEC
       READ(7,901) MPRSL,MSLSL,MLSL,MSECSL,MTECSL
  901  FORMAT(5I5)
        WRITE(2,10)
   10  FORMAT(1H0,'STAFF SALS')
        WRITE(2,11) MPRSL,MSLSL,MLSL,MSECSL,MTECSL
   11  FORMAT('PROF',I6,'  SEN LT',I6,'  LECT',I6,
     1 '  SEC',I6,'  TEC',I6)
C        READ IN PROP OF SENIOR STAFF
       READ(7,902) SENRAT,PFRAT
  902  FORMAT(2F5.3)
C      CALCULATE NOS PROF,SL,LECT FOR  CAT 'A'
       DO 903 I=1,NA
       XASEN(I)=MAST(I)*SENRAT
       IF((XASEN(I)-INT(XASEN(I))).LE.0.5) GO TO 904
       NASEN(I)=INT(XASEN(I))+1
       GO TO 903
  904  NASEN(I)=INT(XASEN(I))
  903  CONTINUE
C      CALCULATE  NOS  SEN LECT AND LECT
       DO 905 I=1,NA
        NAPR(I)=NASEN(I)*PFRAT
       NALEC(I)=MAST(I)-NASEN(I)
       NASL(I)=NASEN(I)-NAPR(I)
  905  CONTINUE
C      READ IN FRACTION OF SAL BILL SPENT ON DEPT EXP
       READ(7,906)(FSALA(I),I=1,NA)
  906  FORMAT(12F5.3)
C      STUDENT EQUIVALENT ADJUSTMENT
       DO 909 I=1,NA
       SEQAT(I)=SEQTOT(I)
  909  CONTINUE
```

```
      DO 910  I=1,NB
      NX=NA+I
      SEQBT(I)=SEQTOT(NX)
  910 CONTINUE
      DO 1911 I=1,NC
      NX=NA+NB+I
      SEQCT(I)=SEQTOT(NX)
 1911 CONTINUE
C       CALCULATE AC SALS, DEP EXP ,UNIT COSTS
       DO 907 I=1,NA
       ACSALA(I)=(NAPR(I)*NPRSL)+(NASL(I)*MSLSL)+(NALEC(I)*MLSL)
      SECSLA(I)=NASEC(I)*MSECSL
       TOTSLA(I)=ACSALA(I)+SECSLA(I)
       DPEXA(I)=TOTSLA(I)*FSALA(I)
       XOTSLA(I)=TOTSLA(I)-DPEXA(I)
       AUCOST(I)=XOTSLA(I)/SEQAT(I)
  907  CONTINUE
C     WRITE  RESULTS :CAT A
      WRITE(2,911) (ADEP(I),I=1,NA)
  911 FORMAT(1H0,10X,12A10)
      WRITE(2,912)(ACSALA(I),I=1,NA)
  912  FORMAT(1X,'AC  SALS     ',12F10.2)
      WRITE(2,913)(TOTSLA(I),I=1,NA)
  913  FORMAT(1X,' TOT SALS  ',12F10.2)
      WRITE(2,914)(DPEXA(I),I=1,NA)
  914  FORMAT(1X, ' DEP EXP  ',12F10.2)
      WRITE(2,915)(XOTSLA(I),I=1,NA)
  915  FORMAT(1X,'TOT DP EXP',12F10.2)
```

```
      WRITE(2,916)(AUCOST(I),I=1,NA)
  916 FORMAT(1X,' UNIT COST', 12F10.2)
C     CALCULATE  NOS PROF,SL,LECT FOR CAT 'B'
      DO 917 I=1,NB
      XBSEN(I)=NBST(I)*SENRAT
      IF((XBSEN(I)-INT(XBSEN(I))).LE.0.5) GO To 918
      NBSEN(I)=INT(XBSEN(I))+1
      GO TO 917
  918 NBSEN(I)=INT(XBSEN(I))
  917 CONTINUE
C     CALCULATE NOS OF SEN LECT AND LECT
      DO 9188 I=1,NB
       NBPR(I)=NBSEN(I)*PFRAT
      NBLEC(I)=NBST(I)-NBSEN(I)
      NBSL(I)=NBSEN(I)-NBPR(I)
 9188 CONTINUE
C     READ IN FRACTION OF SALARY BILL SPENT ON DEPT EXP
      READ(7,906) (FSALB(I),I=1,NB)
C     CALCULATE AC SALS DEPT EXP UNIT COSTS
      DO 919 I=1,NB
      ACSALB(I)=(NBPR(I)*MPRSL)+(NBSL(I)*MSLSL)+(NBLEC(I)*MLSL)
      SECSLB(I)= NBSEC(I)*MSECSL
      TOTSLB(I)= ACSALB(I)+SECSLB(I)
      DPEXB(I) =TOTSLB(I)*FSALB(I)
      XOTSLB(I)=TOTSLB(I)+DPEXB(I)
      BUCOST(I)=XOTSLB(I)/SEGBT(I)
  919 CONTINUE
C       WRITE RES B
       IX=NA+1
       IY=NA+NB
```

```
      WRITE(2,911)(ADEP(I),I=IX,IY)
      WRITE(2,912)(ACSALB(I),I=1,NB)
      WRITE(2,913)(TOTSLB(I),I=1,NB)
      WRITE(2,914)(DPEXB(I),I=1,NB)
      WRITE(2,915) (XOTSLB(I),I=1,NB)
      WRITE(2,916) (BUCOST(I),I=1,NB)
C     CALCULATE NOS PROFS, SL, LECT FOR CAT 'C'
      DO 920 I=1,NC
      XCSEN(I)=MCST(I)*SENRAT
      IF((XCSEN(I)-INT(XCSEN(I))).LE.0.5) GO TO 921
      NCSEN(I)=INT(XCSEN(I))+1
      GO TO 920
  921 NCSEN(I)=INT(XCSEN(I))
  920 CONTINUE
      DO 922 I=1,NC
       NCPR(I)=NCSEN(I)*PFRAT
      NCLEC(I)=NCST(I)-NCSEN(I)
      NCSL(I)=NCSEN(I)-NCPR(I)
  922 CONTINUE
C     FRACTION OF SAL BILL SPENT ON DEPT EXP
      READ(7,906)(FSALC(I),I=1,NC)
C     CALCULATE  AC SALS DEPT EXP UNIT COSTS
      DO 923 I=1,NC
      ACSALC(I)=(NCPR(I)*MPRSL)+(NCSL(I)*MSLSL)+(NCLEC(I)*MLSL)
      SECSLC(I)=NCSEC(I)*MSECSL
      TECSLC(I)=NCTEC(I)*MTECSL
      TOTSLC(I)=ACSALC(I)+SECSLC(I)+TECSLC(I)
      DPEXC(I)=TOTSLC(I)*FSALC(I)
      XOTSLC(I)=TOTSLC(I)+DPEXC(I)
      CUCOST(I)=XOTSLC(I)/SEQCT(I)
```

```
  923 CONTINUE
C       WRITE RESULTS : CAI C
      IX=NA-NB+1
      IY=NA-NB+NC
      WRITE(2,911)(ADEP(I),I=IX,IY)
      WRITE(2,912)(ACSALC(I),I=1,NC)
      WRITE(2,913)(TOTSLC(I),I=1,NC)
      WRITE(2,914)(UPEXC(I),I-1,NC)
      WRITE(2,915)(XOTSLC(I),I=1,NC)
      WRITE(2,916)(CUCOST(I),I=1,NC)
      RETURN
        END
```

```
FINANCIAL MODULE

STAFF SALS
PROF  8544   SEN LT  6445   LECT  4361   SEC  1802   TEC  2760
```

	MATH	ECON	SOCIOL	ENGLISH	HISTORY	PHILOS	ACC&BL	REL ST	MAN SCI	COMP SC
AC SALS	39056.00	104100.00	121366.00	104100.00	88933.00	60683.00	47778.00	34695.00	47778.00	39056.00
TOT SALS	40858.00	109506.00	128574.00	109506.00	94339.00	64287.00	51382.00	36497.00	51382.00	40858.00
DEP EXP	1184.68	6241.84	6943.00	2737.65	3113.19	1671.46	2158.04	948.92	5754.78	939.73
TOT DP EXP	42042.88	115747.84	135517.00	112243.65	97452.19	65958.46	53540.04	37445.92	57136.78	41797.73
UNIT COST	1090.12	626.06	433.50	365.73	403.57	575.33	494.95	1161.77	1253.73	1147.80

	FRENCH	GERMAN	SPANISH
AC SALS	69405.00	47778.00	34695.00
TOT SALS	73009.00	51382.00	36497.00
DEP EXP	3577.44	1746.99	1788.35
TOT DP EXP	76586.44	53128.99	38285.35
UNIT COST	693.99	914.41	1377.30

	BIOLOGY	PHYSICS	CHEM	PSYCHOL	INT SCI	F.ARTS	BIOCHEM	EDUCAT
AC SALS	99739.00	43417.00	60683.00	125727.00	15167.00	15167.00	34695.00	47778.00
TOT SALS	160345.00	70059.00	97407.00	201935.00	23447.00	23447.00	55817.00	78982.00
DEP EXP	33512.10	13311.21	16266.97	29078.64	2626.06	586.18	9767.97	11547.30
TOT DP EXP	193857.11	83370.21	113673.97	231013.64	26073.06	24033.18	65584.97	90829.30
UNIT COST	939.16	3784.97	1562.60	743.40	4216.88	983.85	2000.63	723.48

APPENDIX 6

6I Lecture and Seminar Room Space Module

6I1 Name of subroutine TSPACE

6I2 General description of module

The function of this module is the estimation of the likely utilization of lecture and seminar room space over a period of time.

A fairly detailed description of the method of approach to this problem has already been given in section 6.8(iv). Basically in order to estimate future room utilization it is necessary to attempt to forecast future course numbers (i.e. student numbers who actually enrol on each course option). The approach used is to note actual course numbers and total full time equivalents in a given subject and semester in a given base year. The plausible assumption is then made that future course numbers on each option will increase in line with projected full time equivalents in that subject and semester. There is provision allowed for assuming some increase in options available, the assumption being made that such options will have average enrolment and that numbers on existing options can be reduced pro-rata.

The amount of lecture room space can be calculated directly (since the number of lecture hours given on each course is provided as part of the input data). There is also provision for calculating the number of small group classes (seminar hours) provided. Although this approach is fairly crude it should nevertheless give some indication of likely future teaching space requirements.

APPENDIX 6

613 Detailed description of program

1294-1300 COMMON statement

1301-04 DIMENSION statement

1308-16 Read in and write out array SEQB(I,J); student equivalent in department I, semester J in base year.

1317-30 Read in actual class sizes and number of lecture hours per subject in base year; write out array

1331-34 Test for Autumn and Spring semesters

1335-41 If Autumn semester
Set array ZSEQ(I,J) - autumn semester equivalents equal number appropriate values of SEQ(I,J) - output from student equivalent module

1342-48 If Spring semester execute corresponding operation Spring semester equivalents

1349-52 Test for extra options

1353-62 If no extra options, calculate future class size on basis. If base year class size = 0, future year class size = 0 otherwise. Future class size = present class size × Future equivalents/subject/semester. Base year equivalents/subject/semester

1364-90 Deal with case where new options are introduced

1364-67 Read in number of base year, options in subject I and semester J NOPT(I,J). Read in total number of options in future years NEWOPT(I,J)

1368-70 Print out above arrays

1371-76 Calculate total number of student course units studied in a semester in a given subject area

1377-80 Calculate class size of new options = total student course units ÷ total number of options (NEWOPT(I,J))

1381 Put class sizes of new options - CLNEW

1383-84 Calculate total student courses taken in new options

1385 Calculate factor for reducing size of base year options (equals total number of student course units in future year - number of student course units on new options divided by total student courses)

1387-89	Modify class sizes of original options by factor F
1402-34	Allocation of classes to size categories
1402-03	Set array N(I) equal to zero
1407	Test to ascertain if class size is significantly different from zero (then room hour utilized will equal zero)
1408-16	Test range into which lecture class falls
1417-34	Add appropriate number of room hours to corresponding room size category
1435-37	Read in numbers of room hours available in each category
1438-40	Calculate teaching room utilization (i.e. fraction of available hours each size category is used)
1441-6	Read in number of seminar hours (NSEM(I,J,K) group size for seminar group in particular class (NGROUP(I,J,K)
1447-52	Calculate numbers of seminar hours required (number of classes required × number of hours in each class)
1453-48	Add up number of seminar hours required - add number to smallest room size category
1459	Calculate proportion of seminar room hours used for all teaching purposes
1460-64	Print out table headings
1465-67	Read in minimum and maximum sizes of the various size ranges
1468-72	Write out ranges in each size category; number of hours used, number of hours available, utilization

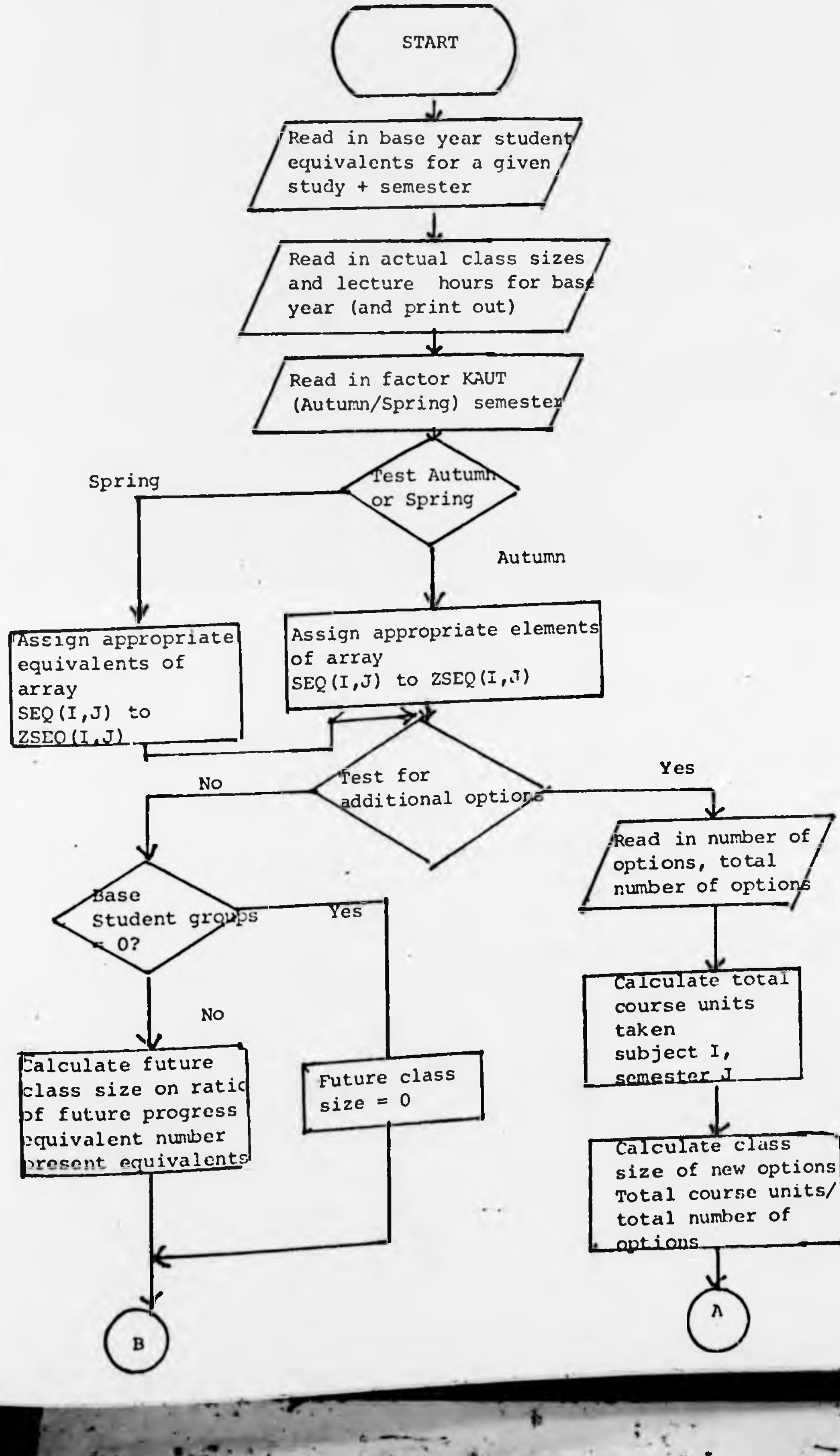
APPENDIX 6

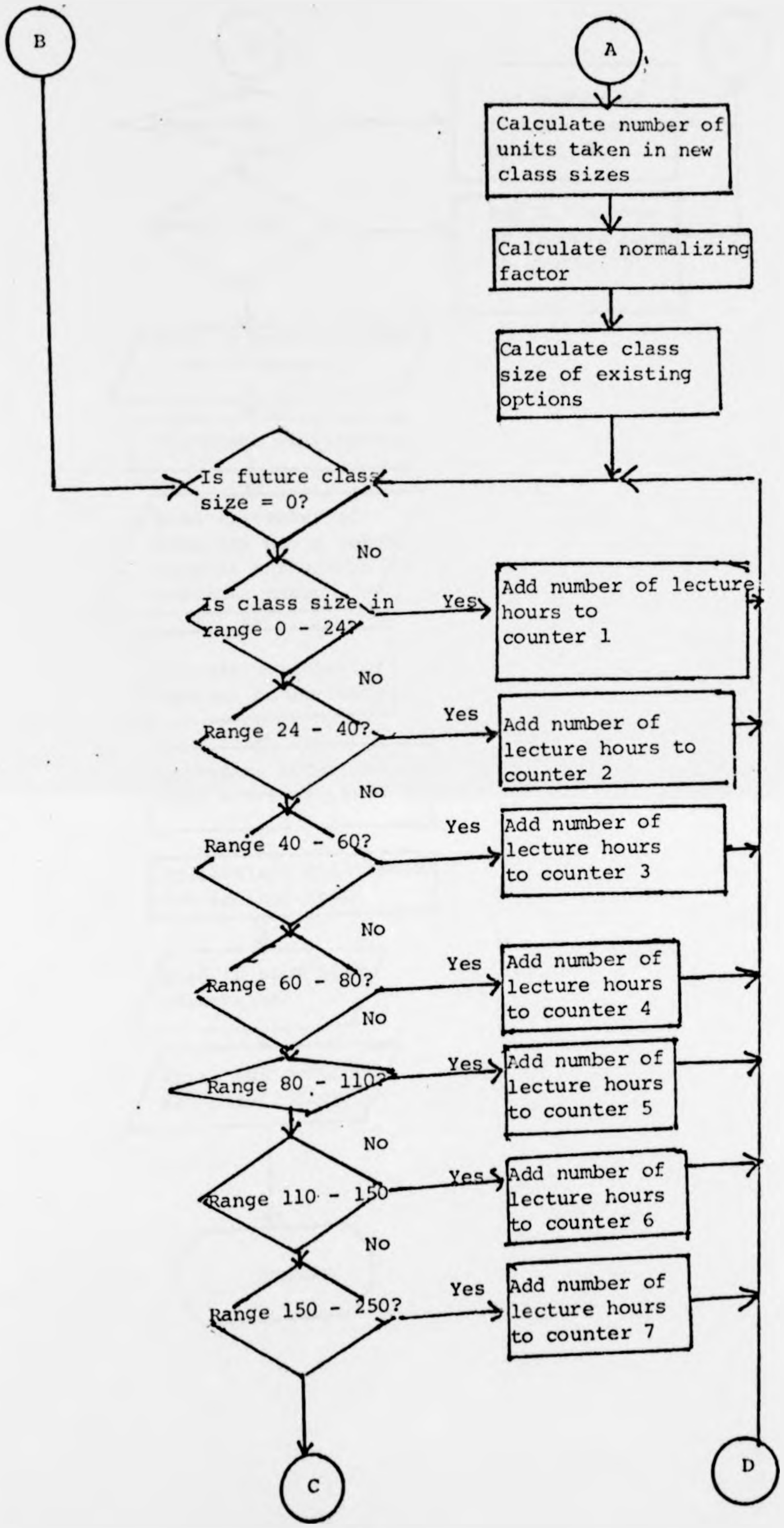
6I4 Definition of Variables

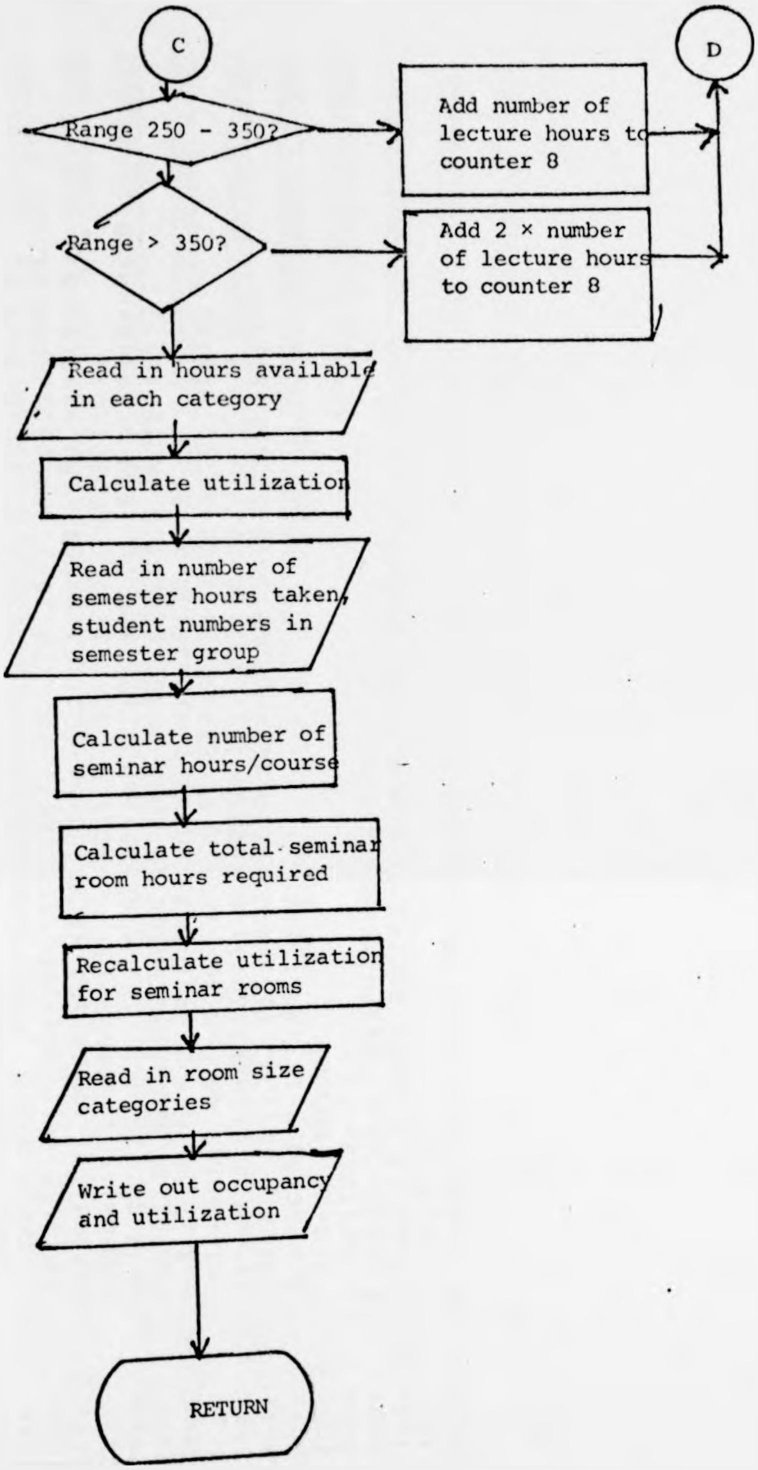
CLNEW	Number of enrolments on new subject options
F	Coefficient for adjusting student numbers on original options (allowing for new subject options)
KAUT	Index used for testing whether Autumn (K = 1) or Spring (K = 0) semester
LTOT(I,J)	Total number of student course units studied in subject I, semester J
MAVAIL(I)	Number of room hours available in category I
MOPT	Index used for indicating whether facility for including additional options is required
MQ	Total course units studied in new options
N(I)	Number of room hours used in size category I
NEWOPT(I,J)	Total number of optional courses in subject I, semester J including new options
NGROUP(I,J,K)	Size of seminar group subject I, semester J, option K
NHRS(I,J,K)	Number of seminar room hours required by subject I, semester J, option K
NLECT(I,J,K)	Number of lecture hours required by subject I, semester J, option K
NOPT(I,J)	Existing number of options in subject I, semester J
NPCLAS(I,J,K)	Size of base year class for subject I, semester J, option K
NSEM(I,J,K)	Number of seminar hours given by subject I, semester J, option K
NXCLAS(I,J,K)	Projected class size for future years subject I, semester J, option K
SEQB(I,J)	Full-time student equivalents in base year in subject I, semester J
ULIT(I)	Utilization of space category I
ZSEQ(I,J)	Student equivalents in subject I, semester J (For Autumn Semester 1, 3, 5, 7, 9 given by J = 1 - 5 For Spring Semester 2, 4, 6, 8 given by J = 2 - 4

APPENDIX 6

615 Module T-space Flow diagram




B
A
Calculate number of units taken in new class sizes
Calculate normalizing factor
Calculate class size of existing options
Is future class size = 0?
No
Is class size in range 0 - 24?
Yes
Add number of lecture hours to counter 1
No
Range 24 - 40?
Yes
Add number of lecture hours to counter 2
No
Range 40 - 60?
Yes
Add number of lecture hours to counter 3
No
Range 60 - 80?
Yes
Add number of lecture hours to counter 4
No
Range 80 - 110?
Yes
Add number of lecture hours to counter 5
No
Range 110 - 150
Yes
Add number of lecture hours to counter 6
No
Range 150 - 250?
Yes
Add number of lecture hours to counter 7
C
D


C
D
Range 250 - 350?
Add number of lecture hours to counter 8
Range > 350?
Add 2 × number of lecture hours to counter 8
Read in hours available in each category
Calculate utilization
Read in number of semester hours taken, student numbers in semester group
Calculate number of seminar hours/course
Calculate total seminar room hours required
Recalculate utilization for seminar rooms
Read in room size categories
Write out occupancy and utilization
RETURN

```
      SEGMENT

&ASSIGN;   1;DC;50;RB65,RBFILES:
      SUBROUTINE TSPACE
      COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
     1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150),KF9(150),NPGR1(30),
     2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
     3NBPGR1(15),NBPGR2(15),NBPGCR(15),NCPGR1(15),NCPGR2(15),
     4NCPGCR(15),MAST(15),MBST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
     5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),
     6U3(30,2),MSTUD,SEQTOT(30),NPGTOT,NXCLAS(30,5,12)
      DIMENSION NPCLAS(30,5,12),NLECT(30,5,12),ZSEQ(30,5),N(10),
     1SEQB(30,5),NOPT(30,5),NEWOPT(30,5),LTOT(30,5),
     2MAVAIL(10),UTIL(10),NSEM(30,5,12),NGROUP(30,5,12),MMIN(10),
     3 NHRS(30,5,12),MMAX(10)
C     TSPACE  MODULE
      WRITE(2,11)
   11 FORMAT(1H1,'TEACHING SPACE MODULE')
C     READ IN STUDENT EQUIVS BY SUBJECT AND SEMESTER
      WRITE(2,12)
   12 FORMAT(1H0,'BASE YR STUD EQUIV')
```

```
      DO 201 I=1,NDEP
      READ (7,202) (SEQH(I,J),J=1,5)
  202 FORMAT(5F8.1)
       WRITE(2,271) ADEP(I),(SEQH(I,J),J=1,5)
  271  FORMAT(1X,A10,5F8.1)
  201 CONTINUE
       WRITE(2,14)
   14  FORMAT(1H0, ACTUAL CLASS SIZES ,HRS BASE YR )
C     READ IN ACTUCLASS SIZES AND LECTURE HRS
      DO 203 I=1,NDEP
       WRITE(2,15)ADEP(I)
   15 FORMAT(1H0,A10)
      DO 203 J=1,5
       WRITE(2,16) J
   16 FORMAT(1X,'SEM NO',I3)
      READ(7,205) (NPCLAS(I,J,K),NLECT(I,J,K),K=1,12)
  205 FORMAT(24I3)
       WRITE(2,275) (NPCLAS(I,J,K),NLECT(I,J,K),K=1,12)
  275  FORMAT(1X,24I3)
  203 CONTINUE
      READ(7,2933) KAUT
 2933 FORMAT(I2)
       IF (KAUT.EQ.1) GO TO 251
       GO TO 252
C      AUTUMN  SEMESTER
  251 DO 253  I=1,NDEP
       DO 253 J=1,5
        K=2*J-1
        ZSEQ(I,J)=SEQ(I,K)
  253 CONTINUE
        GO TO 2988
```

```
C     SPRING SEMESTER
  252 DO 254 I=1,NDEP
      ZSEQ(I,1)=SEQ(I,2)
       DO 254 J=1,4
       K=2*J
       ZSEQ(I,J)=SEQ(I,J)
  254 CONTINUE
C     TEST FOR EXTRA OPTIONS
 2988  READ(7,206) MOPT
  206 FORMAT(I2)
       IF (MOPT.EQ.1) GO TO 207
C     NO EXTRA OPTIONS
C     CALCULATE FUTURE CLASS SIZES
      DO 299 I=1,NDEP
      DO 299 J=1,5
      DO 299 K=1,12
        IF(SEQB(I,J)- 0.001) 2998,2998,2999
 2999  NXCLAS(I,J,K)=NPCLAS(I,J,K)*ZSEQ(I,J)/SEQB(I,J)
       GO TO 299
 2998  NXCLAS(I,J,K)=0
  299 CONTINUE
       GO TO 298
C     DEAL WITH CASE WHERE WE HAVE MORE  OPTIONS
  207 DO 224 I=1,NDEP
      READ(7,225)(NOPT(I,J),NEWOPT(I,J),J=1,5)
  225 FORMAT(18I4)
       WRITE(2,60) (NOPT(I,J),NEWOPT(I,J), J=1,5)
   60    FORMAT(1H0,10I5)
  224 CONTINUE
```

298962

```
      C     CALCULATE STUDENT COURSES IN ANY SEMESTER
            DO 226 I=1,NDEP
            DO 226 J=1,5
            DO 290 K= 1,12
            LTOT(I,J)=LTOT(I,J)+NXCLAS(I,J,K)
        290 CONTINUE
            CLNEW=LTOT(I,J)/NEWOPT(I,J)
            M1=NOPT(I,J)+1
            NEWOPT(I,J)=M2
            DO 291 KA=M1,M2
            NXCLAS(I,J,KA)=CLNEW
        291 CONTINUE
      C     CALCULATE CLASS SIZE OF OLD OPTIONS
            MQ=CLNEW *(M2-M1+1)
             F=1.0*(LTOT(I,J)-MQ)/LTOT(I,J)
            M3=M1-1
            DO 227 KB =1,M3
            NXCLAS(I,J,KB)=NXCLAS(I,J,KB)*F
        227 CONTINUE
        226 CONTINUE
      C     FIND SIZE CAT INTO WHICH CLASSES FALL
             WRITE(2,17)
         17  FORMAT(1H1,'PROJECTED CLASS SIZES')
      C       WRITE OUT PROJ CLASS SIZES
             DO 50 I=1,NDEP
             WRITE(2,15) ADEP(I)
             DO 50 J=1,5
             WRITE(2,16) J
             WRITE(2,51) (NXCLAS(I,J,K),K=1,12)
         51  FORMAT(1X,12I10)
         50  CONTINUE
```

```
  298   DO 297 I=1,10
  297   N(I)=0
        DO 208  I=1,NDEP
        DO 208  J=1,5
        DO 208 K=1,12
        IF(NXCLAS(I,J,K).EQ.0) GO TO 208
        IF(NXCLAS(I,J,K).GT.0.AND.NXCLAS (I,J,K).LE.24) GO TO 209
        IF(NXCLAS(I,J,K).GT.24.AND.NXCLAS(I,J,K).LE.40) GO TO 210
        IF(NXCLAS(I,J,K).GT.40.AND.NXCLAS(I,J,K).LE.60) GO TO 211
        IF(NXCLAS(I,J,K).GT.60.AND.NXCLAS(I,J,K).LE.80) GO TO 212
        IF(NXCLAS(I,J,K).GE.80.AND.NXCLAS(I,J,K).LE.110)GO TO 213
        IF(NXCLAS(I,J,K).GE.110.AND.NXCLAS(I,J,K).LE.150) GO TO 214
        IF(NXCLAS(I,J,K).GE.150.AND.NXCLAS(I,J,K).LE.250) GO TO 215
        IF(NXCLAS(I,J,K).GE.250.AND.NXCLAS(I,J,K).LE.350) GO TO 216
        IF(NXCLAS(I,J,K).GE.350) GO TO 217
  209   N(1)=N(1)+NLECT(I,J,K)
        GO TO 208
  210   N(2)-N(2)+NLECT(I,J,K)
        GO TO 208
  211   N(3)=N(3)+NLECT(I,J,K)
        GO TO 208
  212   N(4)=N(4)+NLECT(I,J,K)
        GO TO 208
  213   N(5)=N(5)+NLECT(I,J,K)
        GO TO 208
  214   N(6)=N(6)+NLECT(I,J,K)
        GO TO 208
  215   N(7)=N(7)-NLECT(I,J,K)
        GO TO 208
```

```
 298      DO 297 I=1,10
 297  N(I)=0
      DO 208  I=1,NDEP
      DO 208  J=1,5
      DO 208 K=1,12
      IF(NXCLAS(I,J,K).EQ.0) GO TO 208
      IF(NXCLAS(I,J,K).GT.0.AND.NXCLAS (I,J,K).LE.24) GO TO 209
      IF(NXCLAS(I,J,K).GT.24.AND.NXCLAS(I,J,K).LE.40) GO TO 210
      IF(NXCLAS(I,J,K).GT.40.AND.NXCLAS(I,J,K).LE.60) GO TO 211
      IF(NXCLAS(I,J,K).GT.60.AND.NXCLAS(I,J,K).LE.80) GO TO 212
      IF(NXCLAS(I,J,K).GE.80.AND.NXCLAS(I,J,K).LE.110)GO TO 213
      IF(NXCLAS(I,J,K).GE.110.AND.NXCLAS(I,J,K).LE.150) GO TO 214
      IF(NXCLAS(I,J,K).GE.150.AND.NXCLAS(I,J,K).LE.250) GO TO 215
      IF(NXCLAS(I,J,K).GE.250.AND.NXCLAS(I,J,K).LE.350) GO TO 216
      IF(NXCLAS(I,J,K).GE.350) GO TO 217
 209  N(1)=N(1)+NLECT(I,J,K)
      GO TO 208
 210  N(2)=N(2)+NLECT(I,J,K)
      GO TO 208
 211  N(3)=N(3)+NLECT(I,J,K)
      GO TO 208
 212  N(4)=N(4)+NLECT(I,J,K)
      GO TO 208
 213  N(5)=N(5)+NLECT(I,J,K)
      GO TO 208
 214  N(6)=N(6)+NLECT(I,J,K)
      GO TO 208
 215  N(7)=N(7)+NLECT(I,J,K)
      GO TO 208
```

```
      216  N(8)=N(8)+NLECT(I,J,K)
           GO TO 208
      217  N(8)=N(8)+NLECT(I,J,K)*2
      208  CONTINUE
C          CALCULATE  TEACHING ROOM UTILIZATION
           READ(7,230)(MAVAIL(I),I=1,9)
      230  FORMAT(9I5)
           DO 2261 I=1,8
            UTIL(I) = 100.0*N(I)/MAVAIL(I)
     2261   CONTINUE
C          DEAL WITH SMALL ROOMS CLASSES
           DO 221 I=1,NDEP
           DO 221 J=1,5
           READ(7,222) (NSEM(I,J,K),NGROUP(I,J,K),K=1,12)
      222  FORMAT (24I3)
      221  CONTINUE
C          CALCULATE NO OF SEMINAR HRS
            DO 289 I=1,NDEP
           DO 289 J=1,5
             DO 289 K=1,12
           NHRS(I,J,K) =NSEM(I,J,K)*(INT(NXCLAS(I,J,K)/NGROUP(I,J,K))+1)
      289  CONTINUE
```

```
C     ADD UP TOTAL  HRS
      DO 223 I=1,NDEP
      DO 223 J=1,5
      DO 223 K=1,12
      N(I)= N(I)+NHRS(I,J,K)
  223 CONTINUE
      UTIL (I) =100.*N(I)/MAVAIL(I)
C     OUTPUT
       WRITE(2,235)
  235 FORMAT(1H0,20HTEACHING  ROOM OCC  )
      WRITE(2,228)
  228 FORMAT(1H0,'CLASS SIZES',4X,'HRS USED','HRS AVAIL',3X,'UTIL')
      READ(7,231)(MMIN(I),I=1,8)
      READ(7,231)(MMAX(I),I=1,8)
  231 FORMAT(9I5)
C     WRITE OUT OCCUPANCY
      DO 233 I=1,8
      WRITE(2,234) MMIN(I),MMAX(I),N(I),MAVAIL(I),UTIL(I)
  234 FORMAT(2X,2I4,6X,2I6,F8.2)
  233 CONTINUE
       RETURN
       END
```

TEACHING SPACE MODULE

BASE YR STUD EQUIV					
MATH	10.8	3.2	2.9	1.0	0.0
ECON	29.3	18.4	17.3	9.4	0.0
SOCIOL	41.0	24.8	22.2	5.6	0.0
ENGLISH	41.0	30.8	39.6	27.5	0.0
HISTORY	32.8	22.6	20.0	12.4	0.0
PHILOS	22.5	5.2	7.6	3.5	0.0
ACC&BL	29.2	4.8	4.4	1.3	0.0
REL ST	8.8	3.4	2.7	1.9	0.0
MAN SCI	7.2	2.4	2.0	4.0	0.0
COMP SC	8.8	0.0	3.9	0.8	0.0
FRENCH	16.7	10.8	5.1	4.8	0.0
GERMAN	6.5	4.4	6.9	5.4	0.0
SPANISH	5.8	3.2	1.3	0.4	0.0
BIOLOGY	19.8	9.6	14.2	3.3	0.0
PHYSICS	2.8	1.0	0.5	0.6	0.0
CHEM	8.5	5.2	6.4	1.7	0.0
PSYCHOL	39.3	26.2	24.9	3.3	0.0
INT SCI	1.2	0.0	0.2	1.0	0.0
F.ARTS	10.7	0.0	0.0	0.0	0.0
BIOCHEM	0.0	5.4	3.0	4.0	0.0
EDUCAT	0.0	15.0	11.3	12.5	18.0

```
ACTUAL CLASS SIZES ,HRS BASE YR

        MATH
SEM NO   1
 64   4  1  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   2
 16   3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   3
  5   2  4  2  1  2  1  2  1  3  5  4  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   4
  1   2  2  2  1  2  1  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   5
  0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

       ECON
 SEM NO   1
 176   3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 SEM NO   2
  92   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 SEM NO   3
  30   3 26  3 10  2 28  1 27  1  3  2  0  0  0  0  0  0  0  0  0  0  0  0
 SEM NO   4
  13   2  5  2 21  2  1  2  1  3  5  1  3  1  3  1  8  2  0  0  0  0  0  0
 SEM NO   5
   0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

       SOCIOL
  SEM NO   1
  246   3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  SEM NO   2
  124   2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  SEM NO   3
   33   2  6  2 10  2  4  2  8  2 11  1  7  2 14  1 17  3 12  1  0  0  0  0
  SEM NO   4
   16   2  7  2  2  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  SEM NO   5
    0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

25S(S?

```
    ENGLISH
SEM NO   1
247   2   0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   2
154   2   0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   3
127   2   8   0  2  0  6  0 10  0 14  0 12  0 14  0  3  0 11  0 11  0  0  0
SEM NO   4
 11   0   5   0 24  0 12  0  8  0 13  0 11  0 11  0 13  0  7  0 13  0 15  0
SEM NO   5
  0   0   0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

    HISTORY
SEM NO   1
197   2   0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   2
113   2   0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   3
 35   1  25   2 21  1 18  1 11  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   4
 10   0  10   0  4  0  5  0  1  0  4  0  4  0  5  0  0  0  0  0  0  0  0  0
SEM NO   5
  0   0   0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

```
    ENGLISH
SEM NO   1
247   2   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   2
154   2   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   3
127   2   8  0  2  0  6  0 10  0 14  0 12  0 14  0  3  0 11  0 11  0  0  0
SEM NO   4
 11   0   5  0 24  0 12  0  8  0 13  0 11  0 11  0 13  0  7  0 13  0 15  0
SEM NO   5
  0   0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

    HISTORY
SEM NO   1
197   2   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   2
113   2   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   3
 35   1  25  2 21  1 18  1 11  1  0  0  0  0  0  0  0  0  0  0  0  0  0
SEM NO   4
 10   0  10  0  4  0  5  0  1  0  4  0  4  0  5  0  0  0  0  0  0  0  0
SEM NO   5
  0   0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

TEACHING ROOM OCC

CLASS SIZES		HRS USED	HRS AVAIL	UTIL
0	24	550	920	59.00
25	40	38	80	47.50
41	60	35	40	87.50
61	80	32	80	40.00
81	110	11	40	27.50
111	150	7	40	17.50
151	250	14	120	11.67
251	350	8	40	20.00

6J Teaching Laboratory Space Module

6J1 Name of subroutine TLABSP

6J2 General description of subroutine

As mentioned in Chapter 6.8 (vii) this module is used for assessing teaching laboratory capacity for laboratory subjects.

Projected actual class sizes have already been calculated by the TSPACE module. Information is also available on the number of laboratories taken by each student per week in each course and the duration of each laboratory. Each subject also has a number of teaching laboratories of different sizes. Hence it is possible to assign each class to the appropriate laboratory size category and to calculate the number of laboratory hours that it will require. In this way the percentage utilizations of laboratories of different teaching subjects can be estimated.

APPENDIX 6

6J3 Detailed Description of program

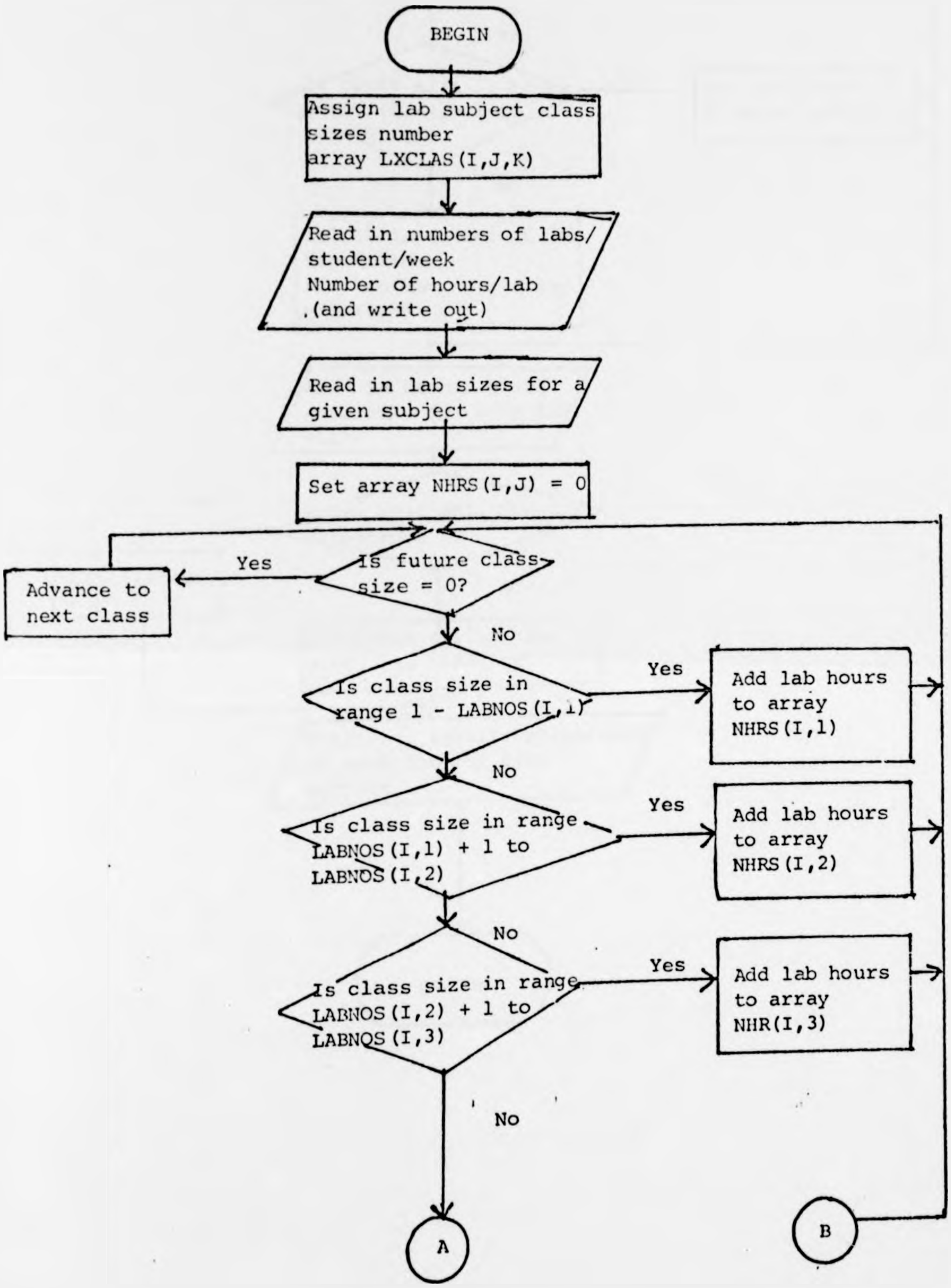
1478-84	COMMON statement
1485-86	DIMENSION statement
1490-96	Assign laboratory subject class sizes to array LXCLAS(I,J,K)
1497-1506	Write out above array
1509-16	Read in number of labs/student/week, duration (in hours per week)
1517-19	Write out above arrays
1520-23	Read in teaching lab sizes for each subject (LABNOS(I,J))
1527-30	Set array elements of array NHRS(I,J) equal to zero
1531-36	Assign class sizes to labs
1535	If class size = 0, lab hours required = 0
1537-56	For each course option add lab hours required to appropriate element of array NHRS(I,J)
1557-61	Read in number of hours available for each lab size category in each subject
1562-68	Calculate utilization of each teaching laboratory
1569-84	Print out results. For each laboratory subject: name, laboratory sizes; for each laboratory, hours used, hours available, utilization

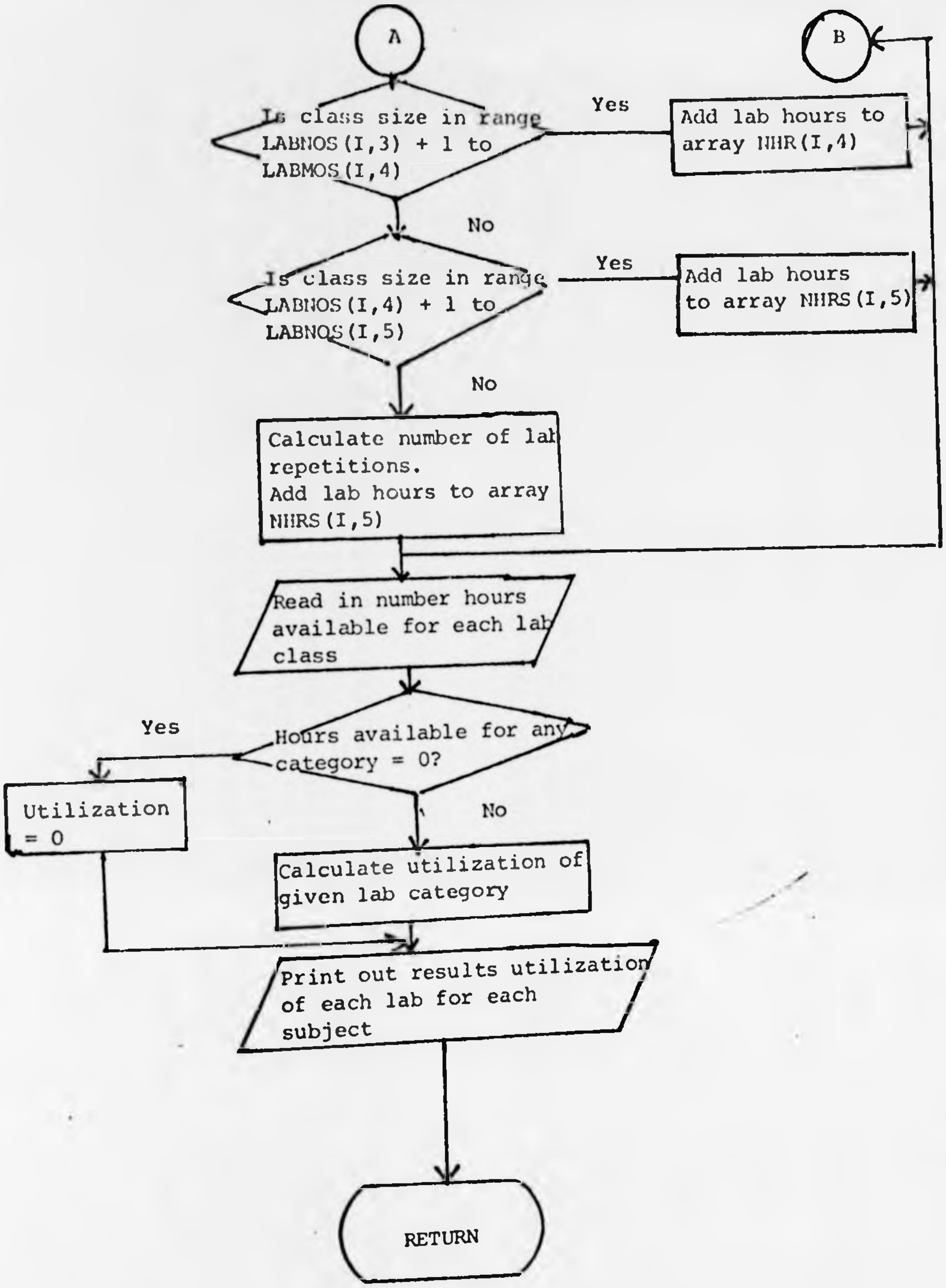
6J4 Definition of Variables

KAVAIL (I,J)	Number of hours available for subject I, lab size, category J
LABNOS(I,J)	Capacity of laboratory for subject I, category J
LXCLAS(I,J,K)	Student numbers in subject I, semester J, option K (laboratory subjects)
MTLAB(I,J,K)	Duration of laboratory (in hours for subject I, semester J
NHRS(I,J)	Number of laboratory hours used in subject I, laboratory category J
NLAB(I,J,K)	Number of laboratories per week for laboratory subject I, semester J, option K
UTIL(I,J)	Utilization of laboratory category J, subject I

APPENDIX 6

6J5 Flow Diagram TLABSPACE




A
B
Is class size in range LABNOS(I,3) + 1 to LABMOS(I,4)
Yes
Add lab hours to array NHR(I,4)
No
Is class size in range LABNOS(I,4) + 1 to LABNOS(I,5)
Yes
Add lab hours to array NHRS(I,5)
No
Calculate number of lab repetitions.
Add lab hours to array NHRS(I,5)
Read in number hours available for each lab class
Hours available for any category = 0?
Yes
Utilization = 0
No
Calculate utilization of given lab category
Print out results utilization of each lab for each subject
RETURN

```
          SEGMENT

&ASSIGN;  1;DC;50;R=61,RBFILES:
          SUBROUTINE  TLABSP
          COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
         1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150),KF9(150),NPGR1(30),
         2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
         3NBPGR1(15),NBPGR2(15),NBPGCR(15),NCPGR1(15),NCPGR2(15),
         4NCPGCR(15),MAST(15),MGST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
         5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),

         6N3(30,2),MSTUD,SEQTOT(30),NPGTOT,NXCLAS(30,5,12)
          DIMENSION  LXCLAS(30,5,12),NLAB(30,5,12),MTLAB(30,5,12),
         1NHRS(30,5),LABNOS(30,5),KAVAIL(10,5),UTIL(10,5)
C         TEACHING LAB SPACE SUBROUTINE
          WRITE(2,11)
     11   FORMAT(1H1,'TEACHING LAB MOD')
C         ASSIGN ARRAYS
          DO 241 I=1,NC
          L =NA+NB+I
          DO 241 J=1,5
          DO 241 K=1,12
          LXCLAS(I,J,K)=NXCLAS(L,J,K)
    241   CONTINUE
          DO 265 I=1,NC
          K=NA+NB+I
          WRITE(2,12) ADEP(K)
     12   FORMAT(1H0,A10)
```

29S"8?

```
      DO 265 J=1,5
      WRITE(2,13) J
   13 FORMAT(1X,'SEM NO',I3)
      WRITE(2,266) (LXCLAS(I,J,K),K=1,12)
  266 FORMAT(1X,12I10)
  265 CONTINUE
      WRITE(2,14)
   14 FORMAT(1H0,'NO LABS/STUD/WK & NO HRS/LAB')
C     READ IN NOS OF LABS/STUDENT/ WEEK,NO HRS/LAB
      DO 242 I=1,NC
      K=NA+NB+I
      WRITE(2,12) ADEP(K)
      DO 242 J=1,5
      WRITE(2,13) J
      READ(7,243)(NLAB(I,J,K),MTLAB(I,J,K),K=1,12)
  243 FORMAT(24I3)
      WRITE(2,290) (NLAB(I,J,K),MTLAB(I,J,K),K=1,12)
  290 FORMAT(1H0,24I3)
  242 CONTINUE
C       READ IN LAB SIZES
      DO 244  I=1,NC
      READ(7,245)(LABNOS(I,J),J=1,5)
  245 FORMAT (5I4)
      WRITE(2,291) (LABNOS(I,J),J=1,5)
  291 FORMAT(1H0,5I4)
  244 CONTINUE
      DO 261 I=1,NC
      DO 261 J=1,5
      NHRS(I,J)=0
  261 CONTINUE
C     ASSIGN CLASSES TO LABS
      DO 246  I=1,NC
      DO 246  J=1,5
      DO 246  K=1,12
        IF(LXCLAS(I,J,K).EQ.0) GO TO 246
```

```
      IF(LXCLAS(I,J,K).LE.LABNOS(I,1)) GO TO 247
      IF(LXCLAS(I,J,K).GT.LABNOS(I,1).AND.LXCLAS(I,J,K).LE.LABNOS(I,2))
     1GO TO 248
      IF(LXCLAS(I,J,K).GT.LABNOS(I,2).AND.LXCLAS(I,J,K).LE.LABNOS(I,3))
     1GO TO 249
      IF(LXCLAS(I,J,K).GT.LABNOS(I,3).AND.LXCLAS(I,J,K).LE.LABNOS(I,4))
     1GO TO 250
      IF(LXCLAS(I,J,K).GT.LABNOS(I,4).AND.LXCLAS(I,J,K).LE.LABNOS(I,5))


     1GO TO 251
      IF(LXCLAS(I,J,K).GT.LABNOS(I,5)) GO TO 251
  247 NHRS(I,1)=NHRS(I,1)+NLAB(I,J,K)*MTLAB(I,J,K)
      GO TO 246
  248 NHRS(I,2)=NHRS(I,2)+NLAB(I,J,K)*MTLAB(I,J,K)
      GO TO 246
  249 NHRS(I,3)=NHRS(I,3)+NLAB(I,J,K)*MTLAB(I,J,K)
      GO TO 246
  250 NHRS(I,4)=NHRS(I,4)+NLAB(I,J,K)*MTLAB(I,J,K)
      GO TO 246
  251 NHRS(I,5)=NHRS(I,5)+NLAB(I,J,K)*MTLAB(I,J,K)*(ABS(LXCLAS(I,J,K)/
     1LABNOS(I,5)+1))
  246 CONTINUE
C     READ IN NOS OF HRS AVAIL FOR EACH LAB CAT
      DO 2520 I=1,NC
      READ(7,253)(KAVAIL(I,J),J=1,5)
  253 FORMAT(5I5)
 2520 CONTINUE
```

```
      DO 254 I=1,NC
      DO 254 J=1,5
      IF (KAVAIL(I,J).EQ.0) GO  TO 2541
      UTIL(I,J)=100.0*NHRS(I,J)/KAVAIL(I,J)
      GO TO 254
 2541 UTIL(I,J)=0.0
  254 CONTINUE
C     PRINT OUT RESULTS
      WRITE(2,255)
  255 FORMAT(1H1,'LABORATORY SPACE')
      DO 259 I=1,NC
      IX=NA+NB+1
      WRITE(2,257) ADEP(IX)
  257 FORMAT(1H0,A10)
      WRITE(2,258) (LABNOS(I,J),J=1,5)
  258 FORMAT(1X,'LAB CAP   ',5I10)
      WRITE(2,359) (NHRS(I,J),J=1,5)
  359 FORMAT(1X,'HRS USED  ',5I10)
      WRITE(2,361) (KAVAIL(I,J),J=1,5)
  361 FORMAT(1X,'HRS AVAIL ',5I10)
      WRITE(2,260) (UTIL(I,J),J=1,5)
  260 FORMAT(1X,'UTILIZN  ',5F10.3)
  259 CONTINUE
      RETURN
      END
```

```
TEACHING LAB MOD

   BIOLOGY
SEM NO  1
       108     0     0     0     0     0     0     0     0     0     0
SEM NO  2
        71    44     0     0     0     0     0     0     0     0     0
SEM NO  3
        65    60    20     0     0     0     0     0     0     0     0
SEM NO  4
        70     0     0     0     0     0     0     0     0     0     0
SEM NO  5
         0     0     0     0     0     0     0     0     0     0     0

   PHYSICS
SEM NO  1
        16     0     0     0     0     0     0     0     0     0     0
SEM NO  2
         8     0     0     0     0     0     0     0     0     0     0
SEM NO  3
         3     3     3     0     0     0     0     0     0     0     0
SEM NO  4
         5     0     0     0     0     0     0     0     0     0     0
SEM NO  5
         0     0     0     0     0     0     0     0     0     0     0

    CHEM
SEM NO  1
        82     1     0     0     0     0     0     0     0     0     0
SEM NO  2
        31     0     0     0     0     0     0     0     0     0     0
SEM NO  3
        19    11    10     0     0     0     0     0     0     0     0
SEM NO  4
        27     0     0     0     0     0     0     0     0     0     0
SEM NO  5
         0     0     0     0     0     0     0     0     0     0     0
```

PSYCHOL											
SEM NO 1	326	0	0	0	0	0	0	0	0	0	0
SEM NO 2	160	0	0	0	0	0	0	0	0	0	0
SEM NO 3	49	34	49	45	0	0	0	0	0	0	0
SEM NO 4	34	63	0	0	0	0	0	0	0	0	0
SEM NO 5	0	0	0	0	0	0	0	0	0	0	0
INT SCI											
SEM NO 1	10	0	0	0	0	0	0	0	0	0	0
SEM NO 2	0	0	0	0	0	0	0	0	0	0	0
SEM NO 3	37	0	0	0	0	0	0	0	0	0	0
SEM NO 4	0	0	0	0	0	0	0	0	0	0	0
SEM NO 5	0	0	0	0	0	0	0	0	0	0	0
F.ARTS											
SEM NO 1	26	0	0	0	0	0	0	0	0	0	0
SEM NO 2	0	0	0	0	0	0	0	0	0	0	0
SEM NO 3	0	0	0	0	0	0	0	0	0	0	0
SEM NO 4	0	0	0	0	0	0	0	0	0	0	0
SEM NO 5	0	0	0	0	0	0	0	0	0	0	0

BIOCHEM

SEM NO 1	0	0	0	0	0	0	0	0	0	0	0
SEM NO 2	35	0	0	0	0	0	0	0	0	0	0
SEM NO 3	10	11	0	0	0	0	0	0	0	0	0
SEM NO 4	8	0	8	0	0	0	0	0	0	0	0
SEM NO 5	0	0	0	0	0	0	0	0	0	0	0

EDUCAT

SEM NO 1	0	0	0	0	0	0	0	0	0	0	0
SEM NO 2	76	0	0	0	0	0	0	0	0	0	0
SEM NO 3	81	0	0	0	0	0	0	0	0	0	0
SEM NO 4	17	3	0	0	0	0	0	0	0	0	0
SEM NO 5	8	0	0	0	0	0	0	0	0	0	0

NO LABS/STUD/WK & NO HRS/LAB

BIOLOGY

SEM NO 1

1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 2

1 4 1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 3

1 4 1 4 2 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 4

3 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 5

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

PHYSICS

SEM NO 1

1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 2

1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 3

1 4 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 4

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 5

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

CHEM

SEM NO 1

1 4 1 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 2

1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 3

1 4 1 4 1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 4

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 5

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

PSYCHOL

SEM NO 1

1 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 2

1 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 3

0 0 0 0 0 0 1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 4

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

SEM NO 5

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

LABORATORY SPACE

BIOLOGY

LAB CAP	0	12	30	40	70
HRS USED	0	0	8	0	52
HRS AVAIL	0	108	36	36	36
UTILIZN	0.000	0.000	22.222	0.000	144.444

PHYSICS

LAB CAP	5	8	12	21	25
HRS USED	12	4	0	4	0
HRS AVAIL	36	36	72	36	36
UTILIZN	33.333	11.111	0.000	11.111	0.000

CHEM

LAB CAP	0	18	26	43	45
HRS USED	0	11	4	4	8
HRS AVAIL	0	72	36	36	36
UTILIZN	0.000	15.278	11.111	11.111	22.222

PSYCHOL

LAB CAP	0	20	41	61	90
HRS USED	0	0	0	4	18
HRS AVAIL	0	36	36	36	36
UTILIZN	0.000	0.000	0.000	11.111	50.000

INT SCI

LAB CAP	0	0	0	2	24
HRS USED	0	0	0	0	12
HRS AVAIL	0	0	0	72	36
UTILIZN	0.000	0.000	0.000	0.000	33.333

```
 . F.ARTS
LAB CAP          0         0         0         0         0
HRS USED         0         0         0         0         0
HRS AVAIL         0         0         0         0         0
UTILIZN      0.000     0.000     0.000     0.000     0.000

  BIOCHEM
LAB CAP          0         0         0         0        12
HRS USED         0         0         0         0        36
HRS AVAIL         0         0         0         0        72
UTILIZN      0.000     0.000     0.000     0.000    50.000

  EDUCAT
LAB CAP          0         0         0         0         0
HRS USED         0         0         0         0         0
HRS AVAIL         0         0         0         0         0
UTILIZN      0.000     0.000     0.000     0.000     0.000

** SEGMENT WANTED

SEGMENTS NOW IN STORE
 13   1   2   3   5   6   7   8   9  10  11
```

APPENDIX 6K

6K Research Lab Space Module

6K1 Name of subroutine RLABSP

6K2 General description of module

The function of this module is to calculate the research laboratory space required in laboratory subjects. The policy on which this is based is that space is allocated on the bases of numbers of academic staff and research student in a subject area through 'norms' (i.e. so many square metres per academic staff member).

Thus if the appropriate norms are read in to the module, it is a fairly straightforward matter to calculate research laboratory space required by a particular subject. Total research space required is also calculated.

6K3 Detailed Description of Program

1621-27 COMMON statement

1628 DIMENSION statement

1629-32 Read in norms for academic staff and postgraduate research students

1633-41 Calculate research lab space required by each lab subject

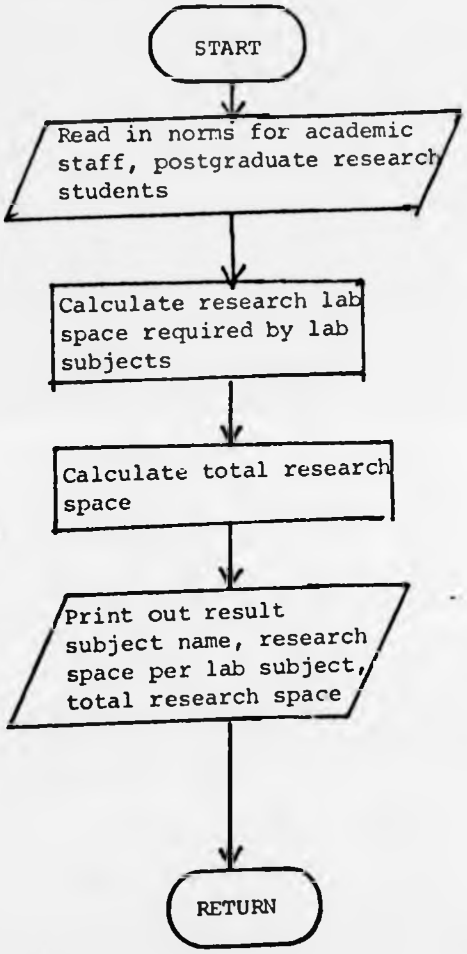
1642-46 Calculate total research space required

1647-57 Print out results: print out subject name, research space per subject, total research space required.

6K4 Definition of Variable

IRES(I)	Dummy indicating whether subject require res. lab. space
PDNORM	Research lab space norm for postgraduate students
RESP(I)	Research lab space assigned to subject I
STNORM	Research lab space norm for academic staff
TRESP	Total research lab space required

6K5 Flow Chart - Research Lab Module



```
?ASSIGN;     1;DC:50;R 62,RBFILES;

           SUBROUTINE  RLABSP
           COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
          1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150),KF9(150),NPGR1(30),
          2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
          3NBPGR1(15),NBPGR2(15),NBPGCR(15),NCPGR1(15),NCPGR2(15),
          4NCPGCR(15),MAST(15),MBST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
          5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),
          6N3(30,3),NSTUD,SEQTOT(30),NPGTOT,NXCLAS(30,5,12)
           DIMENSION RESP(15)
C          RESEARCH  LAB  SPACE  SUBROUTINE
C          READ IN RESEARCH  LAB SPACE NORMS
           READ(7,650)STNORM,PDNORM
      650  FORMAT(2F5.2)
C          CALCULATE RESEARCH SPACE
           DO 652  I=1,NC
            READ (7,646) IRES
      646  FORMAT(I2)
            IF(IRES.EQ.0) GO TO 647
           RESP(I)=MCST(I)*STNORM +(NCPGR1(I)+NCPGR2(I))*PDNORM
            GO TO 652
      647   RESP(I)=0
      652  CONTINUE
C          CALCULATE TOTAL RESEARCH SPACE
           TRESP=0.0
           DO 656 I=1,NC
           TRESP=TRESP + RESP(I)
      656  CONTINUE
C          PRINT OUT RESULTS
           WRITE(2,653)
      653  FORMAT(1H1,'RESEACH LAB SPACE ')
```

```
      IX=NA+NB+1
      IY=NA+NB+NC
      WRITE(2,654)(ADEP(I),I=IX,IY)
  654 FORMAT(1H0,12A10)
      WRITE(2,655)(RESP(I),I=1,NC)
  655 FORMAT(1X,12F10.2)
      WRITE 2,657) TRESP
  657 FORMA (1H0,'TOTAL  RESEARCH LAB SPACE=',F8.2)
      RETURN
      END
```

```
RESEACH LAB SPACE

   BIOLOGY    PHYSICS      CHEM   PSYCHOL  INT  SCI  . F.ARTS   BIOCHEM  EDUCAT
    660.00     176.00    242.00    539.00     33.00      0.00    132.00      0.00

TOTAL  RESEARCH LAB SPACE= 1782.00
```

APPENDIX 6

6L Office Space Module

6L1 Name of subroutine TOFFSP

6L2 General description of program

The function of this module is to carry out calculations of office space requirements of different subject areas. The policy on which this allocation is based is that there is a norm established for different grades of staff. Staff are divided into the following grades, professorial staff, non-professorial staff, non-academic staff. Each grade has an appropriate office space norm.

Thus if appropriate norms are read in, it is a relatively simple matter to calculate academic office space required.

6L3 Detailed description of program

1663-69 COMMON statement

1670-71 DIMENSION statement

1672-75 Read in office space norms for, professorial staff, non-professorial academic staff, non-academic staff

Calculate numbers of non-professorial staff for each subject area

1677-80 Calculate office area required for category 'A' subjects

1681-84 Repeat above for category 'B' subjects

1685-88 Repeat above for category 'C' subjects

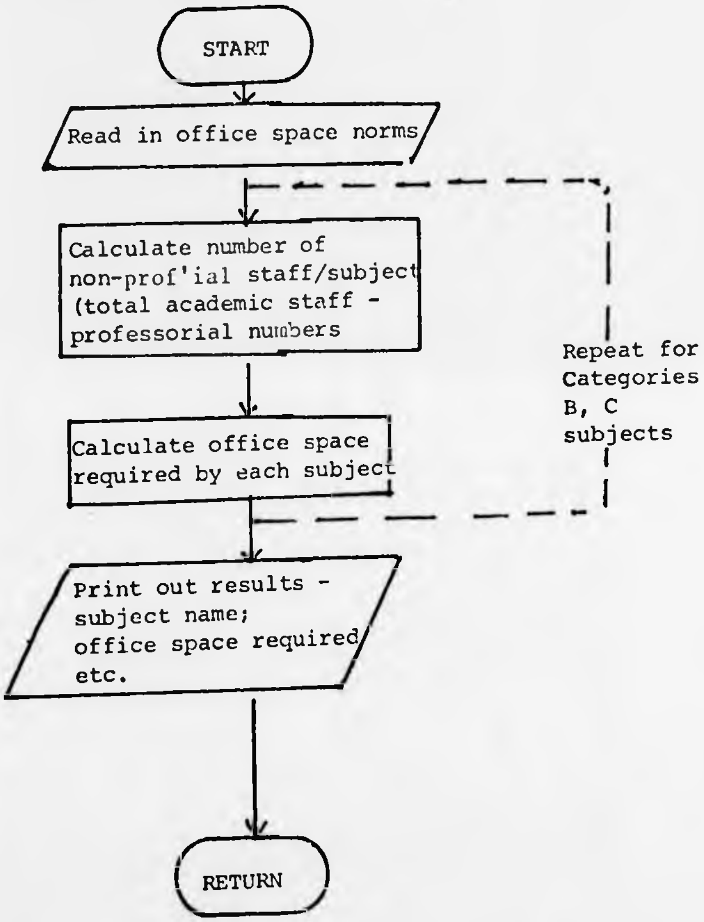
1689-95 Print out results; subject name, square metres of office space required (for category 'A')

1696-1703 Repeat above for categories 'B' and 'C'

6L4 Definition of Variables

ACNORM	Office space 'norm' for non-professorial academic staff
NANON(I), NBNON(I) NCNON	Number of non-professorial academic staff for subject I (categories A, B, C)
NAOFF(I), NBOFF(I) NCOFF(I)	Office space area required by subject I (categories A, B, C)
PFNORM	Office space 'norm' for professorial staff
XANORM	Office space 'norm' for non-academic staff

6L5 Flow Chart - Office space module



```
        SEGMENT

&ASSIGN;     1;DC;50;RB63,RBFILES;

        SUBROUTINE  TOFFSP
        COMMON NYR(5),NTOT,NDEP,ADEP(30),NCLAS(30,3,2),KCLAS(30,9,3),
       1KF4(150),KF5(150),KF6(150),KF7(150),KF8(150),KF9(150),NPGR1(30),
       2NPGR2(30),NPGCR(30),NA,NB,NC,NAPGR1(15),NAPGR2(15),NAPGCR(15),
       3NBPGR1(15),NBPGR2(15),NBPGCR(15),NCPGR1(15),NCPGR2(15),
       4NCPGCR(15),MAST(15),MBST(15),MCST(15),XEQ(30),SEQ(30,9),NAPR(15),
       5NBPR(15),NCPR(15),NASEC(15),NBSEC(15),NCSEC(15),NCTEC(15),
       6N3(30,2),MSTUD,SEQTOT(30),NPGTOT,NXCLAS(30,5,12)
        DIMENSION  OFFSPA(15),OFFSPB(10),OFFSPC(15),NANON(15),NBNON(10),
       1NCNON(15),NAOFF(15),NBOFF(15),NCOFF(15)
C       OFFICE SPACE SUBROUTINE
C       READ IN NORMS
        READ(7,604) PFNORM,ACNORM,XANORM
  604   FORMAT(3F5.2)
C       CALCULATE NOS OF NON PROF STAFF  PER DEPT AND OFFICE  SPACE
        DO 680  I=1,NA
        NANON(I)=MAST(I)-NAPR(I)
        NAOFF(I)=(NAPR(I)*PFNORM)+(NANON(I)*ACNORM) +(NASEC(I)*XANORM)
  680   CONTINUE
        DO 681 I=1,NB
         NBNON(I)=MBST(I)-NBPR(I)
        NBOFF(I)=(NBPR(I)*PFNORM)+(NBNON(I)*ACNORM) +(NBSEC(I)*XANORM)
  681   CONTINUE
```

```
      DO 682 I=1,NC
      NCNON(I)=HCST(I)-NCPR(I)
      NCOFF(I) =(NCPR(I)*PFNORM)+(NCNON(I)*ACNORM)+(NCSEC(I)*XANORM)
  682 CONTINUE
C     WRITE OUT RESULTS
      WRITE(2,611)
  611 FORMAT(1H1,'OFFICE  SPACE')
      WRITE(2,620)(ADEP(I),I=1,NA)
  620 FORMAT(1H0,12A10)
      WRITE(2,621)(NAOFF(I),I=1,NA)
  621 FORMAT(1X,12I10)
      IZ=NA+1
      IY=NA+NB
      WRITE(2,620)(ADEP(I),I=IZ,IY)
      WRITE(2,621)(NBOFF(I),I=1,NB)
      IZ=NA+NB+1
      IY=NA+NB+NC
      WRITE(2,620)(ADEP(I),I=IZ,IY)

      WRITE(2,621)(NCOFF(I),I=1,NC)
      RETURN
      END
```

OFFICE SPACE

MATH	ECON	SOCIOL	ENGLISH	HISTORY	PHILOS	ACC&BL	REL ST	MAN SCI	COMP SC
115	309	362	309	269	181	149	101	149	115
FRENCH	GERMAN	SPANISH							
206	149	101							
BIOLOGY	PHYSICS	CHEM	PSYCHOL	INT SCI	F.ARTS	BIOCHEM	EDUCAT		
295	128	181	375	40	40	101	149		

APPENDIX 7

Sensitivity Analysis I: Projected Space Utilization

(a) Lecture and Seminar Room Space

	1975/6		1981/2	
Room size	Hours used	% utilization	Hours used	% utilization
1-24 (places)	520	56.0	628	68.0
25-40 "	33	41.2	35	43.8
41-60 "	53	132.5	29	72.5
61-80 "	8	10.0	28	35.0
81-110 "	15	37.5	39	97.5
111-150 "	15	37.5	8	20.0
151-250 "	9	7.5	15	12.5
251-350 "	3	7.5	25	62.5

(b) Teaching Lab Space (1981/2)

BIOLOGY

Capacity (places)	12	30	40	70
Hours used	-	8	-	64
Hours available	108	36	36	36
% utilization	-	22.7	-	177.8

PHYSICS

Capacity (places)	5	8	12	21	25
Hours used	12	-	4	-	4
Hours available	36	36	72	36	36
% utilization	33.3	-	5.6	-	11.1

CHEMISTRY

Capacity (places)	18	26	43	45
Hours used	11	0	4	20
Hours available	72	36	36	36
% utilization	15.3	-	11.1	55.6

PSYCHOLOGY

Capacity (places)	20	41	61	90
Hours used	0	0	0	31
Hours available	36	36	36	36
% utilization	-	-	-	86.1

APPENDIX 7 cont

INTEGRATED SCIENCE

Capacity	2	24
Hours used	-	16
Hours available	72	36
% utilization	-	44.4

BIOCHEMISTRY

Capacity	12
Hours used	68
Hours available	72
% utilization	94.4

(c) Research Lab Space (1981/2)

	Area required (sq. m.)		
Subject	75/6	81/2	Capacity
Biology	594 sq.m.	946 sq.m.	724 sq.m.
Physics	165	231	438
Chemistry	220	341	617
Psychology	484	770	606
Integrated Science	33	33	33
Biochemistry	121	165	109
	1617	2486	2527

New Development

Earth & Environmental Science — 200-300 sq.m.

APPENDIX 7 cont

(d) Academic Office Space

Subject	Area Required 75/6	Area Required 81/2	Designated Area
Maths	101	149	416
Economics	282	402	460
Sociology	309	482	424
English	282	450	420
History	242	375	358
Philosophy	167	242	155
Accountacy & Bus. Law	128	194	140
Religious Studies	88	115	100
Management Science	149	181	380
Computing Science	115	128	80
French	181	269	368
German	128	194	235
Spanish	101	128	120
Biology	269	389	485
Physics	128	149	144
Chemistry	167	221	538
Psychology	348	516	545
Integrated Science	40	40	80
Fine Arts	40	61	40
Biochemistry	101	115	104
Education	128	194	395
New Developments	-	609	286
	3494	5603	6273

APPENDIX 8

Alternative Approaches to University Resource Allocation

1. Academic Staff Allocation

Any method of staff allocation chosen should fulfill the following requirements:

(1) Academic staff allocated to each department should be commensurate with its teaching commitments.

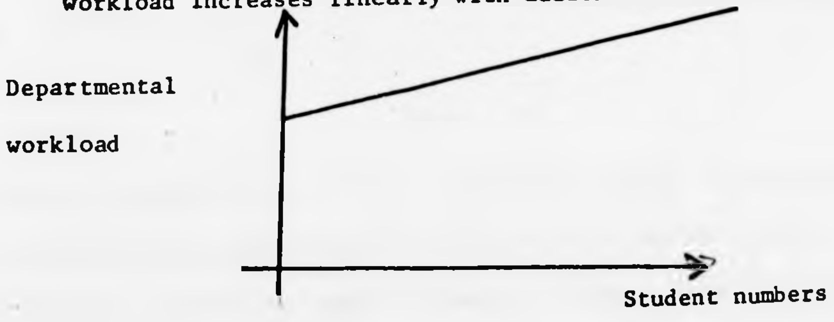
(2) Excessive detail should be avoided, the method should be robust but at least do "rough justice".

(3) Since many Stirling decision-makers are not numerate, any model should be kept as simple as possible.

Let us start by trying to make simple but hopefully realistic assumptions concerning the nature of teaching loads generated in a university. It might be sensible to assume

(1) a basic or fixed workload required to mount the degree programme offered by a department.

(2) owing to the small group teaching methods used at Stirling marginal workload increases linearly with additional student numbers.



This would correspond to a model of the form

$$\text{Academic staffing in a subject} = C_0 + C_1 \times \text{UG fte} + C_2 \times \text{PG fte}$$

It would be necessary to devise satisfactory values for the constants C_0, C_1, and C_2. (It would, of course, be possible to have, for example, different

APPENDIX 8 cont

values of C_1 and C_2 for Science subjects than for Arts subjects.)

(i) The Constant C_0

This corresponds to the minimum number of staff necessary to mount that department's degree programmes (minimum viable size). As before, we are not considering this question from the standpoint of academic viability but rather from the standpoint of the workload generated by its teaching commitments. To take a specific case, if a department has the responsibility of mounting a single Honours degree programme this involves (even if no options are provided) mounting a basic number of semester units as follows:

Semester	Minimum No. of units
1	1
2	1
3	1
4	2
5	3
6	3
7	3
8	2
Total	16

Thus, from this viewpoint, it appears that the minimum viable size of a department which has to mount its own single Honours degree is the number of staff required to mount 16 semester course units in a given academic year. This is a decision which would be in the hands of the university decision-makers and subject to debate. It might be decided that it should be in the neighbourhood of four.

APPENDIX 8 cont

(ii) The Constants C_1 and C_2

As explained in Chapter 5, total University academic staff numbers for a given year are generally determined. Since the constant C_0 will have been already decided it is necessary only to decide on the relationship between C_1 and C_2 to derive their value.

It is possible to have different values of C_1 and C_2 for different groups of subjects providing the relative weighting is known.

2 Advantages of this method

(i) This method is simple to understand and apply.

(ii) While ensuring a minimum level of academic staffing for small departments, it allocates additional staffing purely in relation to student numbers.

(iii) The costs of setting up new developments are clearly indicated.

Relationship between above model, work load and student:staff rates.

In general there is a fairly close relationship between the model proposed above and the workload model. Both models propose a basic element of staffing (or workload) and then the additional staffing (or workload) increases more or less linearly with student numbers, (although there are step functions in the workload model, workload generally increases approximately linearly with student numbers if considered over a reasonably wide range of student numbers). In fact if the parameters of the models are adjusted accordingly, results achieved by the two models can be virtually identical. The workload model has the advantage that the elements of workload considered are easily identifiable. Its application, however, generally requires the use of a computer and it has the disadvantage that it requires agreement on a large number of parameters. The proposed model only requires agreement on one or two parameters, and it is easy to apply and to check its results. Hence it might well be more acceptable.

Both the proposed model and workload model would correspond to the staff:student ratio technique in the limiting case when their constant term is given a value equal to zero.