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ABSTRACT

This study was undertaken to investigate new techniques of costing and resource allocation in higher education. A preliminary study was made of current costs of producing graduates in different disciplines broken down by major items of expenditure (capital and maintenance costs, salaries, administrative costs, etc.). Then, alternative models were constructed corresponding to different sets of assumptions regarding the University of Bradford's: future enrollment policy for new course combinations, staff/student ratios, use of buildings, building costs economics, etc. Data were collected to assess the variation of costs per unit in relation to increased enrollments, and conclusions were tested. Part 1 looks at the nature of university costs from an economist's view. Part 2 treats cost as an allocation of past expenditures. Part 3 describes a method of building academic staff requirements for a course on the basis of the amount of teaching involved. Part 4 studies the utilization of teaching accommodations. Part 5 is concerned with factors affecting the demand for technical staff. Part 6 examines cost in relation to specific academic development proposals. Reproduction of text on several pages of this study may be of poor quality as the original is marginal in legibility. (JS)

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UNIVERSITY OF BRADFORD

COST-EFFECTIVENESS IN HIGHER EDUCATION

PROJECT PLANNING CENTRE

COST-EFFECTIVENESS IN HIGHER EDUCATION

A report of research work carried out in the Project Planning Centre of the University of Bradford, sponsored jointly by the Organisation for Economic Co-operation and Development's Centre for Educational Research and Innovation and by the United Kingdom Department of Education and Science.

JULY 1971.

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FOREWORD

The research work at the University of Bradford forms one part of the Centre for Educational Research and Innovation's Programme in Institutional Management in Higher Education. Other universities participating in this project are Chalmers University of Technology, Gothenburg, Sweden; the Catholic University of Nijmegen, Netherlands; the University of Lancaster, U.K.; the Technical University of Denmark at Lyngby; Universite de Paris-Ouest, Nanterre, France; the Free University of Berlin, West Germany; and the University of Novi Sad, Yugoslavia.

The terms of reference of the Bradford project are as follows:

"Study of potential economies per student year.

The study shall comprise:

(i) a preliminary study of the current costs of producing graduates in different disciplines broken down by major items of expenditure (capital and maintenance costs, salaries, administrative costs, etc.);

(ii) the construction of alternative models corresponding to different sets of assumptions regarding the University's future enrolment policy for new course combinations, staff/student ratios, use of the building, building cost economies, etc.;

(iii) the collection of data in order to assess the variation of costs per unit in relation to increased enrolments;

(iv) the pilot testing of conclusions emerging from the research work referred in sub-paragraphs (i), (ii) and (iii) above."

The work is directed towards identifying potential economies in the teaching of students under alternative sets of assumptions, in order that action may be taken by national educational authorities, and by universities themselves, to secure a more economic use of resources in the higher education sector.

The Bradford project has confined itself to collecting data from within the University of Bradford; its results consequently relate to economies that might be realised in that university. The methods used, however, are of wider applicability, and the object of the research work has been as much to develop methods of identifying economies and allocating resources, as to produce specific results in the University of Bradford.

The timing of the project has coincided with the preliminary stages of the University's planning for the quinquennium 1972-77. This had the advantage that the university as a whole was considering its future plans and it was realistic to talk in terms of changes to the present pattern of activities. On the other hand it had the disadvantage that the research team was still investigating new techniques of costing and resource allocation at the same time that the university might wish to apply them. We have as far as possible used specific academic development proposals made within the university as data for our study, but we have also found it necessary to postulate changes ourselves in order to search for potential economies.

During the course of our research, the University received from the U.K. University Grants Committee preliminary guidance on the formulation of their quinquennial estimates, including a provisional figure for the total student population of the university at the end of the quinquennium, and a statement of suggested building priorities up to 1974-75. We have borne these constraints in mind, but have not limited our "alternative assumptions" to those within the bounds of these constraints.

Nevertheless, the general discussion of potential economies in this report takes place against the background of these national constraints, notably that there will be a substantial increase in the number of students over the next quinquennium, and that the government is seeking to obtain this expansion without a pro rata increase in cost, whilst expecting universities to maintain the quality of their output.

Part 1 of the report looks generally at the nature of university costs from an economist's viewpoint. In particular the concept of cost as an intrinsic attribute of a particular output is rejected. A distinction is made between cost at the point of decision-making (when it is avoidable), and cost as an allocation of past expenditure (when it is sunk). The need to define cost in terms of the particular problem in hand is considered. Financial and economic (social opportunity) costs are distinguished. Some general problems of pricing factors of production are considered.

In Part 2 cost is treated as an allocation of past expenditures. The concept of output budgeting within an individual institution is introduced and the problems of allocating joint-costs discussed. A method of calculating unit costs of undergraduate courses is described and assessed. The unit and total costs of undergraduate courses in 1969/70 are presented and analysed by items of expenditure. These figures include only costs strictly attributable to the courses in question; costs attributable to other outputs (such as that part of the time of staff which is spent on research) are excluded.

Part 3 of the report describes a method of building up the academic staff requirements for a course on the basis of the amount of teaching involved in it. A number of courses are analysed in terms of the amount of each type of teaching (lecture, class, tutorial, laboratory session, etc.) given and the standard group sizes used. From this can be calculated the number of teaching meetings of different types and sizes that must be provided, and consequently the number of academic staff and teaching rooms required. This is used to calculate cost per student, and the effects on cost of changing the level of enrolment, the structure of the course (the total number of contact hours, the number of optional subjects, the size of teaching groups, and the relative numbers of lectures, tutorials, etc.), and the teaching load of staff, is observed. The policy implications of the relative sizes of economies obtainable by varying these parameters are considered.

In Part 4 the utilisation of teaching accommodation is studied. The existing level of utilisation is analysed by type and size of room. The effect on room utilisation of expansion of student numbers is investigated, and the points at which particular types or sizes of room cease to be available are identified. The effect on costs of increasing the degree of utilisation, and of extending the period over which buildings are used (longer days, weeks and academic years) are investigated and compared with the alternative of providing new buildings. Possible economies in the provision of new buildings are considered.

Part 5 is concerned with a third major item of expense after teaching and space costs - the factors affecting the demand for technical staff. In particular the absence of any relation between the numbers of technical staff and the number of students is noted, and an alternative relationship to laboratory area is postulated.

In Part 6 cost is studied in relation to specific academic development proposals. The concepts of marginal and incremental costs are defined and the reasons for expecting them to differ from existing average costs are discussed; these include economies of scale, the reallocation of resources between outputs, and the bringing into use of under-utilised resources. A method of calculating the incremental cost of specific academic proposals is described, and some actual proposals for new courses and for expanding existing courses during the 1972-77 quinquennium are costed on the basis of professors' estimates of resource requirements. In the light of the findings of Parts 3, 4 and 5, certain economies in resource requirements are postulated in this section, alternative costings are produced, and some policy implications deduced. Incremental costs of expansion are compared with existing unit costs, and comparisons are made between different development proposals.

Part 7 deals with the role of computerised models in university planning. The scope of existing models is surveyed and two models designed for use at Bradford are described. These computer programs accept as data a number of planning norms, such as staff:student ratios, technical staff ratios, accommodation limits, etc., and enable these parameters to be varied. Details of courses are fed into the program which calculates the necessary resource requirements either over a single year, or over a five year period, relating these to the level of the recurrent grants. The effects on resource requirements of altering various norms are analysed and their policy implications presented.

Part 8 investigates existing courses in an attempt to discover whether economies of scale already exist in practice. Existing elements of cost are correlated with course size and a significant degree of correlation of staff cost with size of course is found, providing useful independent evidence of the economies propounded in Chapter 5.

In Part 9 the major potential economies identified in the report are summarised, and the manner in which these might be implemented is discussed. Certain key areas for further investigation are suggested.

Working Papers

During the course of the project, the following papers, prepared by members at the University of Bradford, have been issued by the Centre for Educational Research and Innovation:

CERI/IM/70.05 : J.A. Bottomley : "The Installation of Output Budgeting or Planning-Programming-Budgeting Systems at the University of Bradford", June 1970.
CERI/IM/70.09 : J.E. Dunworth : "Cost-Effectiveness at the University of Bradford", June 1970.
CERI/IM/70.27 : J.E. Dunworth : "Cost-Effectiveness in Higher Education", October 1970.
CERI/IM/70.34 : M. Pickford : "Cost-Effectiveness at the University of Bradford - Interim Report on the Costing of Proposals for the Expansion of Student Numbers", December, 1970.
CERI/IM/70.35 : R.K. Khanna : "Model for a Cost Analysis of Undergraduate Education", December, 1970.
CERI/IM/71.03 : J.A. Bottomley : "Potential Clients for Studies in University Cost-Effectiveness", January, 1971.
CERI/IM/71.08 : R. Dasey : "Expansion of Student Numbers in Specific Courses: The Effects on Staff Hours Required and Course Structure at the University of Bradford", January, 1971.
CERI/IM/71.10 : J.E. Dunworth : "Statement of Objectives and Method of Approach", April, 1971.
CERI/IM/71.11 : M. Pickford : "Interim Report on the Costing of Proposals for Expansion of Student Numbers", February, 1971. (with Annex.).
CERI/IM/71.12 : M.Pickford : "Marginal Costs, Step-Functions of Expansion, and Economies of Scale in the University - A Preliminary Survey", April, 1971.
CERI/IM/71.13 : J.E. Dunworth : "Some Implications of Reducing the Staff:Student Ratio", March, 1971.
CERI/IM/71.14 : R.E. Cooley : "Progress Report", April, 1971.
CERI/IM/71.15 : R.K. Khanna : "Total Cost per Student Year by Course, University of Bradford, 1969-70", February, 1971.
CERI/IM/71.16 : C.A. Barton : "Progress Report", April, 1971.

PART 1

INTRODUCTION

CHAPTER 1

THE NATURE OF UNIVERSITY COSTS

In this chapter we discuss the uses to which student cost figures may be put, distinguishing what we call "accounting" purposes from "planning" purposes. We then consider three alternative definitions of cost, "financial", "economic", and "opportunity" costs, and see how these differ.

Before making any attempt to measure university costs, either as they are or as they might be in alternative situations, it is essential to be clear exactly what is meant by the term "cost". It is a word which has so many meanings to the layman as well as to the economist or accountant, that its use can be highly misleading if not carefully defined. It is tempting to suppose that there exists a single definition of cost that could be applied in all circumstances. Such a definition would be of much value in comparing different situations with the present, and in assessing alternative possible lines of action.

However, far from there being a single definitive concept of cost, there are a number of concepts each equally valid in its own particular context. This means that before attempting to define cost one must define the purpose for which the concept is to be used. This involves a number of major problems -- cost of what? cost to whom? cost when? The cost "per student" for instance will differ according to whether one allocates the whole expense of university activity to teaching students, or whether one extracts costs attributable to other activities such as the personal research of members of staff. The cost to the student is very different from the cost to the U.K. University Grants Committee (U.G.C.), which in turn is different from the cost to the public sector as a whole, and from the cost to the national economy. The current cost is different from the total cost (including capital expenditures of previous years), and the average cost obtained by spreading past outlays over existing students is different from the marginal cost that would have been incurred if one extra student had been enrolled. It is the purpose of this chapter to consider these basic problems of the nature of "cost", and in so doing it will become clear that "cost" is not an intrinsic attribute of a product in the same sense as "weight" or "colour".

The Uses of Costs

The most critical question to be answered is the purpose for which the cost figures are required. On first sight it might appear disreputable to adjust the definition of cost in the light of the purpose to which the figures will be put, but this is not so, for in fact two very different concepts of cost are required for two distinct purposes. The uses of cost figures are, very broadly, twofold -- "accounting" uses, and "planning" uses. In the category of "accounting" uses are included any ex post exercises in allocating costs that have already been incurred to outputs that have already been produced. The category of "planning" uses includes any exercise involving the estimation of costs that will in future be incurred in order to produce output. Thus an exercise which involved dividing recurrent expenditure in a past year by student load to produce a figure of recurrent expenditure per unit of student load would fall into the "accounting" category, as would an exercise to calculate the cost per student to the national economy in a past year. On the other hand, an attempt to estimate the cost of producing graduates in the future, whether concerned with recurrent or capital cost to the university, or cost to the national economy, falls into the "planning" category.

There is thus a distinction between two broad concepts of cost. On the one hand there is the ex post concept of cost as an allocation of past expenditures, when cost is sunk and resources can no longer be reallocated. On the other hand there is the concept of cost as an element in the decision-making process; such a cost arises only at the point in time at which a decision relating to production is made. It is at this stage avoidable. For "planning" purposes one is concerned with avoidable costs only, as sunk costs have already been incurred and should not therefore affect decisions about the future.

A simple example will clarify this important distinction. Let us suppose that course X was taught last year and the resources used consisted solely of academic staff costing £10,000 altogether and building space-hours owned by the university, the interest and amortisation of which amounts to £50,000 annually. The total cost of mounting the course during the year was therefore £60,000. This figure represents cost in the ex post sense of an allocation of past expenditure (real and imputed). Now suppose that it is proposed to double enrolment to the course in the following year and that this requires an exact doubling of staff and space-hours. Suppose further that these space-hours currently lie idle in the university. In order to decide whether to expand the course the university needs to know the costs that will be incurred in so doing. The figure of £60,000 is not relevant to the decision that must be taken, for £50,000 of it has already been sunk; the space-hours are there already. The cost of expanding the course is the £10,000 required for academic staff, and this represents cost in the "planning" sense. This is the figure of avoidable cost which is a factor influencing decision-making.

<u>It would be quite wrong to use ex post calculations of cost in order to influence decision-making.</u> <u>The university would not save in any real sense £60,000 by discontinuing the course considered above.</u> <u>It would also be wrong to use the figure of avoidable cost to represent the amount of resources used to provide the the course in the past.</u> <u>This fundamental distinction must be kept in mind throughout this report.</u> In Part 2, where the object is to measure the costs already incurred and allocate them to various outputs, cost is used in the ex post sense. In Parts 3 and 6, cost figures are required to aid decision-making, and consequently figures of additional avoidable costs are presented. However in order to enable comparisons to be made with the existing situation it is useful also to calculate ex post costs as they would be in the changed situation. <u>It is important however to remember that the difference between the ex post cost in the original situation and that in the changed situation should not be used to justify making (or not making) the change.</u> This is due to the existence of a substantial body of sunk costs in the form of capital invested in land, buildings and equipment, and of current expenditure committed to the maintenance of existing buildings. <u>Costs that have already been incurred are no longer avoidable and so should not be allowed to influence future decisions.</u>

FINANCIAL AND ECONOMIC COST

We consider now the distinction between the financial and economic costs of a particular line of action. Whilst individual universities will be practice be concerned with financial costs, since these are the costs that must be met from their recurrent and capital grants, national educational authorities will be concerned with both financial costs, since these determine the level of grants to institutions, and with economic costs, since these reflect the demands of higher education on the national economy.

In the context of an individual university the distinction between financial and economic cost is as follows:

(a) financial costing is concerned with actual cash outflows from the university on maintaining, operating, and expanding the university.

(b) economic costing is concerned with the derived demand of the university for the services of factors of production. If these factors provide services over several years, then their services are costed on an annual basis, even though the financial outlay to obtain the factors was made in a single year in the past.

Financial costing after the initial year produces lower annual cost figures than economic costing. To show why this is so, we examine in turn the major cost items from each costing viewpoint.

1. Accommodation

The construction of university buildings in Britain is usually financed by means of a capital grant from the University Grants Committee for the construction of a specified new building. Thereafter the university is responsible for maintaining the building from its recurrent grant; it is not responsible for paying any depreciation charges on the building, except for the heavy capital equipment such as boilers and lifts which have a shorter working life than the buildings in which they are housed, nor for setting aside reserves for the eventual replacement of the building.

(a) Financial Costing

Hence in financial costing terms, the annual cost of a building to the university comprises the following elements:

(i) the purchase price of the land on which the building stands, attributed solely to the year in which the land was bought (or the annual rent if the land is rented).

(ii) the initial construction costs (less the cost of heavy capital equipment) attributed solely to the year(s) during which the building was constructed.

(iii) the annual insurance payments

(iv) the annual maintenance costs

(v) the cost of adaptations to the building attributed wholly to the year in which they were made

(vi) the annual depreciation charges on heavy capital equipment.

Because of item (ii) the annual financial cost of the building in the first year(s) will be very high, but then drops steeply to the normal level determined largely be items (iii), (iv) and (vi).

Alternatively, if a building or part of a building is rented, the annual rental will constitute the annual financial cost of that accommodation.

(b) Economic Costing

Since economic costing is concerned with pricing the services rendered to the university by its resources over their period of use, we must find a basis on which to cost the services of university accommodation.

To arrive at an economic cost, a university should amortise its capital together with interest payments. These repayments would be made in equal annual installments over the estimated life of the buildings, and their value would be calculated by multiplying the capital (insured) value of the building by the appropriate discount and amortisation factor.

If the land upon which the buildings stand is owned by the university, then it should be imputed the opportunity cost interest rate on the capital supposedly invested in the land. This imputed interest should be included whether the university bought the land or whether it was donated to it. Because such land does not depreciate, no amortisation is required.

Hence the annual economic cost to the university of its accommodation comprises the following:

(i) the annual interest charges on the capital invested in the land, but no amortisation since such land never depreciates.

(ii) the annual amortisation and interest payments on the capital invested in the building, less the capital invested in the heavy capital equipment.

(iii) the annual insurance payments.

(iv) annual maintenance costs.

(v) cost of adaptations to the building, expressed in annual terms as in (ii).

(vi) annual amortisation and interest on the capital invested in the heavy capital equipment.

These elements comprise the imputed rental of a university building throughout its life.

As far as rented accommodation is concerned, we may assume that the annual rental comprises all five above-mentioned elements. In other words, the annual economic cost equals the annual financial cost for rented accommodation.

2. Equipment

The costing of equipment is similar to that of accommodation.

The purchase of equipment by the university is done on a once-for-all basis; a machine is paid for in a particular year and thereafter maintenance charges, but no depreciation, are paid. Hence, under the financial costing system, the purchase cost of a new machine should be attributed to the course in the year in which it was purchased, although it has a life of several years. This is justified in financial costing, since all cash outflows from the university in a particular year must be attributed to the relevant outputs.

In addition, the annual maintenance charges on the machine must also be included in the financial cost, in subsequent years.

In economic costing, we are concerned with costing the services rendered by the equipment over its lifetime. Since the university can be looked upon as borrowing the capital required to purchase an item of equipment, it must implicitly amortise and pay interest on that capital. The annual installments are computed by multiplying the capital value of the equipment by the appropriate factor, and these, along with the annual maintenance charges on the equipment, comprise the economic cost.

In the case of a new machine, its economic cost will be higher over time than its financial cost because of the interest payments associated with the former. However, the incremental financial cost will be considerably higher in the year of purchase because a large proportion of the financial cost arises at that time.

3. Staff: Academic and Technical

The cost of staff amounts to their annual salaries, superannuation and national insurance payments. As far as the university is concerned the economic cost of employing staff is the same as the financial cost.

4. Materials

Materials are simply "consumables" and therefore attributable to the year in which they were purchased. Economic cost is the same as financial cost.

5. General Expenditures

These comprise the following main elements:

(i) expenditure on administration both centrally and by departments

(ii) library expenditures

(iii) expenditure on study facilities and student facilities.

They may be broken down into the first four categories of resources and treated in the same way.

OPPORTUNITY COST

The concept of economic cost so far developed is valid only in the "accounting" context of cost. It is a satisfactory method of calculating the ex post cost to the university of its activities in a past period. In particular it provides a way of spreading the already-incurred costs of capital assets over the useful life of those assets; it costs the services provided by the assets rather than the provision of the asset itself. However the concept is not sufficient for 'planning' purposes, neither from the university's point of view nor from that of the economy as a whole. In the 'planning' context the concepts of Opportunity Cost to the university and Social Opportunity Cost (to the nation) must be used.

The Committee on Higher Education in 1963 recognised that the cost of the higher education system to the public sector did not represent the full cost of the system to the national economy, and commented:

> "In the last analysis, the real cost of anything is what has to be foregone in order to have it. Hence the real cost of higher education is what could have been produced or enjoyed had the means involved -- the use of buildings and materials, the services of staff and students -- been available for other purposes .....The ultimate cost of higher education is what is foregone by devoting resources, including the potential earnings of students, to this purpose rather than to something else....."[1]

1. U.K. Committee on Higher Education, Cmnd 2154, (The Robbins Report), H.M.S.O., 1963.

This accurately describes Social Opportunity Cost. If the body incurring the cost is narrowed down from the nation to the University then we can speak of the Opportunity Cost to the university.

There are however major problems in measuring opportunity costs as the alternative uses of resources are manifold, and there is no way of ensuring that the most profitable has been identified. We now look at the opportunity costs of the principal university resources.

1. Buildings

The conventional method of imputing a rent to a building is to measure the value of the capital invested in it (purchase of land, construction of buildings, adaptations made to it, and fixed equipment embodied in it), write off all except the land over the estimated life of the building, and then to calculate the productivity of this capital in alternative uses by assuming that the capital could be invested at the ruling rate of interest. This is a valid method of calculating ex post costs and is used in the calculations of costs in Part 2 of the report. It represents the opportunity cost of the building at the time at which the decision to construct it was being made. At that time the alternative of investing the capital elsewhere was theoretically open, and consequently the foregone opportunities of such alternative investment represented the cost of constructing the building. However once the building has been constructed and equipped the possibility of realising the capital invested in it for some alternative use no longer exists. An asset of a highly specific nature has been created, and its scope of its potential use is much narrower than when the capital was still in the form of money. The original capital cannot be recovered; the only way it can be put to an alternative use is by leasing or selling the building to some other user outside the university. In other words the free-market rent or sale price represents the opportunity cost of the building to the university. Now this varies from place to place. A general-purpose teaching building belonging to a central London college is likely to be able to earn a much higher rent or sale price in the market, than an identical building in Bradford where the commercial demand for office space is relatively low. Specialised scientific buildings, though more expensive to construct, are likely to be faced with a smaller alternative market than general-purpose teaching buildings.

For the purpose of opportunity costing, therefore, the imputed rent for the building should be based on its potential free-market rent rather than on the expenditures sunk in providing the building initially.

In the case of rented buildings, the rent which the university actually pays for these buildings in the free market represents their opportunity cost. The university would actually have the amount of the rent in hand if it ceased to lease the accommodation, and the buildings would be available to alternative users who valued their contribution to their own output at least as greatly as the amount of rent to be paid.

2. Equipment

Like buildings, equipment is conventionally inputed a rent, based on the capital invested in it being alternatively invested elsewhere, at the ruling rate of interest. Again, as with buildings, the objection must be made that this represents the opportunity cost only at the moment of decision. Once the equipment has been purchased its opportunity cost to the university is its realisable value, either for sale or leasing, and this realisable value is likely to be less than the ex post cost to the university of obtaining it.

3. Staff

The opportunity cost to the university of the staff it employs is the goods or services forgone as a result of not spending the money used for the employment of staff on the most productive alternative factors of production. Conventional economic theory assumes that in a free market the price paid represents the productive value of the factor to the user, and that the user will seek to maximise the productivity of the resources he uses. Consequently the price paid for staff (salary, superannuation, insurance, etc) reflects their opportunity cost to the university, otherwise the university would not have employed the staff member but spent the money on something else.

The social opportunity cost of staff employed by the university is the flow of goods and services foregone by the national economy as a result of the staff not being employed in the most productive alternative. Conventional economic theory assumes that the individual's contribution to the flow of goods or services in any employment is measured by the price paid by the employer for his work. It further assumes that rational individuals in a free market seek to maximise their incomes. Consequently the continuing employment of an individual in the university indicates that there is no alternative employment in which he could make a greater productive contribution than he already does. Thus the price paid by the university may be taken to reflect his social opportunity cost.

It is sometimes asserted that university academic staff could earn considerably more outside the university world, and consequently their cost to the university is less than their social opportunity cost. If in fact they could earn more outside then their social opportunity cost is greater than their cost to the university, and one should strictly include in their cost an element representing the extra earnings they forego in order to obtain the non-pecuniary benefits of the academic life.

4. Materials

In a free market economy the price paid by the university for materials may be assumed to equal both their opportunity cost to the university and their social opportunity cost.

5. Students

Although the university does not pay anything, in either a financial or an economic sense, to secure the services of students, this does not mean that they represent a free input. The costs are borne by society in the form of the loss of production incurred as a result of students not taking productive employment immediately upon leaving school. This loss of production can be measured by the earnings foregone by the student, less any part-time or vacation earnings he may make. Any calculation of social opportunity cost should therefore contain an element measuring the net earnings foregone by students. Student maintenance awards, being a form of transfer payment, do not represent a cost to the national economy and should not be included in social opportunity cost; they do however represent expenditure by the public sector, and so should be included in public sector financial cost.

Cost in a Subjective Sense

It is apparent that the concept of opportunity cost, whether to the individual university or to the national economy, is difficult to quantify. Only in the case of materials can actual expenditures be used without qualification. For the other major elements of cost -- the imputed rents of buildings and equipment, staff salaries and wages, and the foregone earnings of students -- approximations to probable market prices are required.

Indeed one can take the view that not only are opportunity costs difficult to quantify, but that they are, in their very nature, subjective and incapable of measurement. In assessing the alternative courses of action different individuals will place different values on them. The cost of any line of action, therefore, is the valuation placed on its most preferred alternative by the person responsible for taking the decision. Cost, consequently, is not an attribute of the product which is predetermined as far as the would-be consumer is concerned, but a judgement made by the decision-maker or consumer and likely therefore to differ between different decision-makers and consumers.

Specifically in the context of expenditure on higher education, the cost is not to be measured objectively in money terms, but subjectively in terms of the foregone benefits of alternative expenditure on other levels of education, on other government services, or on private investment and consumption. Valuation of such benefits is determined by political rather than economic factors. It is important to remember that one million pounds sterling saved in one field does not necessarily mean one million pounds sterling available for another purpose because the resources it represents may not be interchangeable.

Similarly, within an individual university, the cost of introducing a new course, or expanding an existing one, is to be measured in terms not of expenditure, real or imputed, but of the subjective valuations placed by the university's planning authorities on the alternative development proposals that will be excluded if the proposal in question is adopted.

Furthermore there is no way of checking after the decision has been taken (and the opportunity cost, therefore, incurred, even though much of the outlay has yet to be made) that the decision-maker's estimate of cost was correct, because the alternative line of action never happened, and its benefits consequently could not be measured.

For the purposes of this report, which is concerned with identifying possible economies in the execution of the university's activities, this subjective concept of cost is not particularly useful. Of more importance, are the financial and economic outlays that will occur as a result of taking various lines of action. Consequently throughout this report the term "cost", whether used in the ex post "accounting" sense, or in the "planning" sense, in fact measures outlays of resources, not the foregone benefits of alternative policies.

Cost Pre-determined by Revenue

A further complication in university costing arises from the fact that the system of grants to universities in the United Kingdom means that costs are determined in advance of the process of production. A university's recurrent grant for a particular year is known in advance and whatever changes in the method of production or the level of operation may be made, the total amount of the grant will be spent. Any economies made in one sphere of activity will be taken up by additional expenditure in another; consequently, the total cost of the university's activities will be unchanged. Savings in cost per student can be realised simply by increasing the number of students. Indeed it is impossible for the university to control exactly the number of students enrolled in any one year; numbers may vary by about 5% of the target figure due to year to year changes in failure rates and to the flexibiltiy of the undergraduate admissions system. Since the recurrent grants, and therefore recurrent expenditure, is already known, recurrent cost-per-student is subject to a similar variation. In the short-run therefore the university seems to have no way of reducing total costs, but an increase in numbers will perforce reduce the cost-per-student, since total expenditure is fixed in advance and will not normally be increased as a result of accepting additional students.

PART 2

UNIT COSTS IN UNIVERSITIES

CHAPTER 2

OUTPUT-BUDGETING AND THE CALCULATION OF UNIT COSTS

The technique of output-budgeting is becoming increasingly popular in several sections of the public sector. Since its introduction in the United States Department of Defence, its use has spread to most branches of U.S. federal and state government activities, including education, and to some individual institutions. Thus, since 1969, the University of California has presented its budgets to the state government in this form. The concept has gained less ground in the United Kingdom, but has been investigated by, amongst several others, the Department of Education and Science.[1]

In this chapter its relevance within an individual institution is considered. The term "output-budgeting" is a misleading abbreviation for the original terminology of "planning-programming-budgeting system", or "PPBS" as it is generally referred to. The original terminology emphasizes the threefold process of the system, whereas the shorter form magnifies the importance of the budgeting process at the expense of the earlier and higher level processes of planning and programming. The essence of PPBS is the close relationship created between the fundamentally routine process of budgeting and the policy decisions made in order to fulfil an institution's objectives.

The first vital step of introducing a planning-programming-budgeting system is to define the objectives for which the institution exists. The second step is to define the various programmes of activities that are being carried out, or might be carried out, in order to fulfil these objectives. The third step is to estimate the cost of these programmes. In operation, PPBS involves the continuous monitoring of activities to see how the costs work out and how well the various programmes in fact fulfil the objectives. It further involves the constant review of all programmes in the light of possible alternatives to see whether an alternative programme might not better or more economically meet the institution's objectives.

It is beyond the scope of this report to consider how PPBS could be integrated into the planning systems of existing institutions, and we are aware that this question is being studied as part of an OECD-associated project at Chalmers University of Technology, Gothenburg, Sweden. In this report our aim is modest: to consider whether it is possible to define and cost programmes of activity within an individual university, and if so, whether such costings would be useful.

The objectives of a university are notoriously difficult to define. In its budget submitted in April 1968 and covering the period up to 1973-74, the University of California sidesteps the issue by saying:

> "The primary goal of the University is ..... to contribute to the public good by providing higher education services.[2]"

1. United Kingdom, Department of Education and Science, Education Planning Paper No. 1 Output Budgeting for the Department of Education and Science (London: HMSO, 1970)
2. University of California, A Program Budget: FY 1970-71 - FY 1973-74, April 1969

It then immediately switches attention to the means of doing this, and defines three major programmes of activity -- instruction, research and public service. It recognizes, however, that there are substantial groups of activities that contribute to more than one of these programmes simultaneously, and cannot realistically be divided. Consequently three more programmes are defined -- libraries, university administration, and supporting services -- and these programmes are given equal status to the three original ones.

In the context of a British university, one would wish to distinguish teaching and research as separate objectives. "Public service" has never been of the same importance in British as in American universities, but nevertheless the number of contracts made with industrial concerns for research and other purposes is growing and might rate as an objective in its own right. To these two basic objectives a number of subsidiary ones may be added, such as the social welfare of the members of the university (through the services of the Student's Union, Health Service, Physical Recreation, counselling, residential accommodation, catering, etc.), and the placing of its graduates in employment.

There can be no one "right" definition of objectives. The provision of student residential services may, to some, be an objective in its own right, whilst to others it is merely one part of the objective of teaching students.

It is a mistake to regard output-budgeting as a concept totally distinct from existing methods, for the traditional methods of presenting university accounts and budgets already contain elements of it, as certain projects and activities are already costed separately. One can tell at a glance the (current) cost of, for instance, the Students' Health Service.

Basically, however, university budgets and accounts are "object-orientated"; that is, expenditures are expressed in terms of the resources on which they are spent. Thus quinquennial submissions to the U.G.C., annual budgets, and annual accounts show how much will be, or was, spent on, for instance, academic salaries, maintenance of premises, or municipal taxes and rates. They do not however enable one to see the cost of producing graduates in particular subjects, or of pursuing research in a particular field. Yet it is the cost of programmes that is relevant to planners, both in universities and in government, in making decisions to expand existing courses or to start new ones. The purpose of output-budgeting is to make available to planners cost data relating to alternative programmes of activities, so that the planners, in making their decisions, are better able to assess the demands they are placing on the finite amount of resources at their disposal.

University planning is about matters such as establishing a new department, introducing a new course, increasing enrolment to an existing course, and building residential accommodation. Output-budgeting seeks to make available the cost of activities such as these. Consequently the programmes must be defined in terms of specific courses, and of specific research projects. In this part of the report, we define each undergraduate course as a programme, although no attempt is made to distinguish Honours and Ordinary students in the same discipline. We confine our attention to undergraduate programmes only.

It is apparent that a coherent set of programmes can be defined for a university. The approach adopted here takes the narrow view of what constitutes a programme -- thus activities such as physical recreation are not regarded as programmes in their own right but are treated as contributory activities to the main programmes of teaching and research.

In Part 2 of this report, nineteen programmes, each corresponding to an undergraduate course, are defined, and their cost to the university in 1969-70 is calculated.

In Part 6 individual proposals for expanding courses or introducing new ones are defined as programmes and their costs are calculated.

The major difficulty that has been found in costing the undergraduate programmes is the treatment of joint-costs -- the costs, that is, of resources that contribute to more than one programme and help to produce more than one type of output. One member of staff both teaches students and pursues his own research, and in the present climate, it is fundamental to his successful operation in either of these fields that he also operates in the other. Even if the distribution of his time between these two activities could be accurately measured (and there are reasons for doubting that any such measurement can be accurate) there would still be strong objections to attributing his cost in the same proportion. The objection is based on the assertion that even though part of his time is spent on research, that expenditure of time (and therefore its cost) must unavoidably be incurred if the university is to secure his teaching services; since this research expenditure must be incurred then it should be regarded as part of the cost of undergraduate teaching.

We have attempted to resolve this problem by presenting in Part 2 only costs directly attributable to undergraduate courses -- the cost of staff time (and teaching, accommodation, equipment and materials) devoted to other activities (including research) has been extracted from the cost figures presented. In Part 6, however, where the purpose is to calculate the costs that will be incurred if certain proposals relating to undergraduate courses are adopted, alternative sets of costs are produced. One set (which we call "full cost") includes the full cost of the extra staff required, including the cost of the time devoted to other activities. The other set of costs ("part cost") contains only the cost of that part of staff time actually devoted to the undergraduate proposal under consideration.

It has been found in the process of costing existing undergraduate courses that virtually every resource used by the university contributes to the output of more than one programme -- nearly all costs are, in one way or another, joint-costs. Academic staff teach and pursue research; technical staff service teaching and research laboratories; classrooms, laboratories and items of equipment are used by students on different courses; materials are purchased on behalf of schools of study and it is difficult to find which course they are ultimately used by; library, central administrative and student facilities are used to differing degrees by staff and students from different schools of study. Although in Part 2 an equitable distribution of costs over different outputs is achieved, it is important to remember that the figure consequently quoted as the "cost" of a particular course reflects, not only the resources devoted to that course, but also the joint use of those same resources for other programmes of activity, and the cost of the time during which they were not used at all. The use of output-budgeting techniques to measure ex post costs, as is done in this part of the report, must be treated with caution; in budgeting for the cost of proposed changes to the pattern of activity, as is done in Part 6, it is much more meaningful.

Method of Calculating Unit Costs

We describe now the method used to calculate the unit costs of teaching undergraduate students in each separate discipline at the University of Bradford in 1969-70. The costs calculated are ex post economic costs to the University Grants Committee. They do not represent social opportunity cost because the foregone earnings of students are not included, nor do they represent the full public sector cost as no allowance is made for students' maintenance grants. They are ex post costs as opposed to true opportunity costs, because the capital invested in buildings and equipment has been valued in terms of what the capital could have earned if it had been invested elsewhere, rather than in terms of what the physical assets could now earn outside the university.

Costs are calculated on an annual per student basis. These are subdivided under the following headings:

(1) Capital and maintenance costs

(2) Teaching Costs (Salaries of teaching and technical staff and expenditure on teaching equipment and materials)

(3) Administrative expenditures

(4) Library expenditures

(5) Student facility, general educational and miscellaneous expenditures

The University of Bradford runs "sandwich courses" in which either a part of some academic years or one whole year is spent outside the university for the purpose of industrial training. Those courses that require a part of several academic years to be spent in industrial training are known as "thin" sandwich courses; courses in which one whole year is spent in industry are known as "thick" sandwich courses. The total duration of a sandwich course is four years. Other courses have no industrial training and last for three years only.

1. Capital and Maintenance Costs

These costs comprise annual interest and amortisation on buildings, non-teaching equipment and furniture, and their maintenance costs. The capital sums represent the insured value in 1969 of the items concerned. The insured value was multiplied by the appropriate discount and amortisation factor at 7% over a period of fifty years.[3]

For example, the "Main Building" of the University of Bradford has an insured capital value (including non-teaching equipment such as furniture) of £3,675,174. With an interest rate of 7% and amortisation of fifty years, the discount and amortisation factor for annual repayments is .072460. Thus, the annual capital value of the building and non-teaching equipment is £3,675,174 x .072460 = £266,303. To this is added the value of the site upon which the building stands -- £23,000 multiplied by 7% only, since land never depreciates and need not be amortised. This amounts to £1,610. (In the case of rented buildings the actual annual rental is used instead of the amortised capital amount.)

Annual maintenance expenditure[4] and municipal rates attributable to the Main Building of £221,318 are also added, summing to a grand total of £489,231. This is then divided by the 336,717 total weighted square feet of usable area in the Main Building. The result was a figure of £1.45 for the annual capital and maintenance cost per weighted square foot of usable area.

"Usable" area is defined as space used for some identifiable purpose in connection with teaching, research, administration or facilities. It excludes what the U.G.C. call " balance" area, such as corridors, cloakrooms, etc.

The concept of weighted square footage is used to allow for the fact that laboratory space is more expensive to construct and maintain than general teaching and office space. In the case of general purpose space, rooms are costed by multiplying the actual square footage by the cost per weighted square foot (£1.45); laboratories are costed by multiplying the actual square footage by the weighting factor[5] and then by the cost per weighted square foot.

The total usable space is analysed into different types of rooms as shown in Table 2.1 and the annual cost of each type of accommodation computed incorporating the laboratory weighting factor.

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3. A rate of 7% is used as representing the current long-term rate of interest of around 10%, less its estimated inflation element. A period of fifty years is used since it is the figure employed in the U.S.A. by the National Committee on Standard Reports for Institutions of Higher Education.
4. Maintenance expenditures here comprise annual insurance premiums on the buildings, expenditure on materials (i.e. cleaning requisites), water charges, heating, wages and salaries of porters, cleaners and superintending staff, etc. and miscellaneous expenditures such as window cleaning.
5. The weights used are derived from U.G.C. norms of permitted capital cost published in "Non-Recurrent Grants: Notes on Procedure, 1969", and are as follows: Physics 1.38; Chemistry 1.65; Biology 1.57; Pharmacy 1.65; Engineering 1.67; Textiles 1.67.

Table 2.1 Area and Annual Cost of Different Types of Accommodation: Main Building 1969/70

	Actual Area (sq.ft.)	Allocated Cost (£)
Classrooms	41,486	60,156
Laboratories	134,947	307,857
Academic Staff Offices	25,852	37,485
Administrative Staff Offices	13,450	19,502
Study Facility Space	11,315	16,407
Student Facility Space	27,982	40,574
Staff Facility Space	5,000	7,250
TOTAL	260,032	489,231

Study facility space consists of libraries and reading rooms; student facility space consists of refectories, students' union offices, gymnasia, lodgings office, etc.; staff facility space consists of staff common rooms and dining rooms.

A similar analysis has been carried out for each building in the university, including halls of residence and student flats owned by the university. Interest, at the rate of 7%, on the current value of the sites of playing fields is included in the figure for student facilities.

The method of distributing space costs between different categories of students is as follows:

(a) Classrooms and Laboratories

Timetables for all classrooms and laboratories have been analysed and their costs are allocated to different disciplines in proportion to the time they are used by each discipline. Thus a room used 8 hours a week for postgraduate work, 8 hours for the undergraduate course in Mathematics, 8 hours for the undergraduate course in Chemistry and empty for the remaining time, would have its costs allocated in three equal parts to the three categories of user. The cost of unused room-hours consequently is spread over the users in proportion to the amount of their use. The breakdown of use takes account of service teaching given by one school to students of another discipline.

(b) Academic Staff Offices

The cost of academic staff offices attributable to undergraduate work as a whole (as distinct from postgraduate and other activities) is taken as being directly proportionate to the time that academic staff devoted to undergraduate work out of their total working time. This proportion is derived from a survey of the use of academic staff time in the University of Bradford in 1968.[6] The survey found that the proportion of total term-time working time devoted to undergraduate work varied between 47% in Physical Sciences and 61% in Social Sciences, the average for the whole university being 52%.

Concerning undergraduate work during vacations, the Robbins Report quotes 20% as the proportion of vacation time that is devoted to undergraduate work. This figure is used in association with the term-time proportions found in the Bradford survey, to give overall annual distributions of staff time in each of the four Boards of Study.

That proportion of the cost of academic staff offices that was attributable to undergraduate work as a whole, was then allocated to individual disciplines in proportion to the actual amount of timetabled teaching.

(c) Administrative Staff Offices

The cost of offices of School (departmental) administrations and clerical staff was equally divided over all students registered in the School. The cost of offices of central administrative and clerical staff was equally divided over all students in the university.

(d) Study Facility Space

The cost of libraries and readings rooms was divided over all students in the university with postgraduates weighted as 2, to reflect their greater use of library facilities.

(e) Student and Staff Facility Space

The costs of this accommodation was divided over all students in the university with students on "thin sandwich" courses weighted as ½ because these courses comprise two intakes per year, the students of only one of which are present in the university at any one time, the other receiving training in industry.

2. Teaching Costs

These comprise the annual salaries, superannuation and insurance of academic and technical staff, the annual value of teaching equipment, and expenditure on materials used in teaching.

The cost of academic staff is split firstly between undergraduate and other work, and secondly between undergraduate disciplines, in the same way as the cost of academic staff offices. Thus, on average, 43% (52% of 33 term weeks plus 20% of 13 non-holiday vacation weeks) of academic staff costs are attributable to undergraduate work. This cost is spread over disciplines in proportion to the amount of timetabled teaching carried out, making due allowance for "service teaching" between departments.

6. R. K. Khanna and M. Shattock: Analysis of University Staff Time (unpublished paper of the University of Bradford, 1968)

The costs of technical staff are treated differently. Since the raison d'etre of technical staff is the servicing of laboratories, their cost has been attributed to undergraduate or other work in proportion to the ratio of undergraduate teaching to research laboratories. Thus if 25% of a department's laboratory space consists of undergraduate teaching laboratories, as opposed to post-graduate and research laboratories, then 25% of the cost of technical staff is attributed to undergraduate work. Chapter 12 of this report contains a fuller justification for this method of allocating technical staff costs. The costs attributable to undergraduate work are then distributed between courses in proportion to the use made of each laboratory by each course.

The total accumulated purchases of teaching equipment by each department over the five years since Bradford became a university, is taken to represent the capital value of this equipment. Annual capital value is calculated at 7% over 15 years.[7] To this is added expenditure on teaching materials by each department during 1969-70. A proportion of this sum is then attributed to undergraduate work on the basis of the university's Form 3 returns to the U.G.C.

3. Administrative Expenditures

Central administrative expenditures comprise salaries and fringe benefits of all central university administrative and clerical staff, and expenditures on office equipment and materials. The total expenditures are equally distributed over all students in the university.

School administrative expenditures include salaries and expenditures on school office equipment and materials. The total administrative expenditure in each school is divided among the students in that school on the basis of full-time undergraduate equivalent students, weighting postgraduates as 2.

4. Library Expenditures

The annual value of the library's stock of books and periodicals is assumed to equal one year's expenditure. To this is added the salaries, etc. of library staff. The total expenditure of the library was distributed between undergraduate, postgraduates and academic staff and between undergraduate disciplines, on the basis of a points system used by the university in allocating library expenditures between disciplines. The points system is designed to reflect the demands made on the library by different types of students and by staff in different subject fields.

5. Student Facility, General and Miscellaneous Expenditures

This includes the operating deficits on refectories and halls of residence, etc., revenue contributions to the Student's Union, and to sports, medical and welfare

7. National Committee on Standard Reports for Institutions of Higher Education

activities. Also included are a variety of miscellaneous expenditures such as external examiner's fees, hospitality, expenses payments, etc. These are distributed equally over all students.

The costs produced for undergraduates in each discipline are presented and analysed in Chapter 3.

CRITIQUE OF METHOD ADOPTED

It is useful at this stage to evaluate the meaning of the figures produced, and to pose the question: "How far do they represent the costs incurred by the university during 1969-70 in teaching undergraduates on various courses?" The question is of two parts: "How far is the total right?" and "How accurate is the distribution?"

The first part of the question has been considered in Part 1 of this report. The figures quoted in Chapter 3 measure costs in an ex post sense; they put a value on resources used, but do not distinguish between costs that had already been incurred, and those which were actually incurred during the year in question. Insofar as the figures put a value on resources used by the university one must express reservations about the imputed costs of the services provided by buildings, equipment and library books.

The capital value of buildings and non-teaching equipment is based on their insured value in 1969-70. The use of this figure is open to criticism on two grounds: that it is an estimated value, and that it represents the cost of replacing the building at current prices. Although the estimate is made by professionally qualified people, it is nevertheless an estimate and consequently not proven in an open market. The second criticism is more serious -- if the object is to put a value on resources used, then it might be more relevant to use the actual construction cost of the building and the purchase price of its fittings and furniture. Current value has been used since the intention of cost figures is to measure the opportunity costs of continuing to use the buildings and equipment, but one must bear in mind the fact that, in practice, the possibility of disposing of them at that price is not open. In the light of this, historical cost might have more meaning. On the other hand, one could validly argue that the occupation of accommodation by a particular School of Study contributes towards the complete usage of existing accommodation, thus pushing some future School of Study into newly constructed buildings. Since such buildings would be built to the U.G.C.'s cost norms, it is tenable that the cost of existing accommodation should be regarded as equal to the cost of new accommodation. It would follow from this that the value, historic or current, of existing actual buildings should be totally ignored and all existing space costed at the rate necessary to obtain new accommodation, either purpose built to U.G.C. norms, or rented on the open market.

The figures quoted for the annual cost of buildings and non-teaching equipment are open to the further criticism that they are dependent on the rate of interest and the period of amortisation chosen. These together have a significant effect on capital cost per student. For example in an exercise relating to the academic year 1966-67 the cost per student for the four years of the undergraduate course in

Mechanical Engineering was calculated at £3,410 of which £1,548 was capital and maintenance costs based on an interest rate of 7% and an amortisation period of 50 years. To show the effect of changing either of these factors, costs have been recalculated on alternative bases and the results are shown in Table 2.2.

It is clear that the choice of interest rate and amortisation period has considerable effect on cost per student. In the case of Mechanical Engineering the difference between 7% over 50 years (as used in this report) and 10% over 60 years (as used by the D.E.S. in Planning Paper No. 2) amounts to £388 per student over the four years of the course.

Table 2.2 Cost per Student in Relation to Interest Rate and Period of Amortisation

(Mechanical Engineering, 1966-67)

	Interest Rate and Amortisation Period			
	7%/50yrs	10%/60yrs	5%/100yrs	15%/20yrs
(1) Capital & Maintenance Costs	£1548	£1936	£1287	£2619
(2) Other Costs	1862	1862	1862	1862
(3) Total Cost per Student	3410	3798	3149	4481
(4) Capital & Maintenance Costs as a proportion of Total Costs (1) x 100 / (3)	45%	51%	41%	58%

The rate of interest and period of amortisation seem to us reasonable, but nevertheless to some extent they are arbitrary, and other, equally reasonable, values might have been chosen.

In summary, the capital element of the costs quoted in Chapter 3 must be treated with caution, since they are imputed costs not market-determined costs, and are based on a number of arbitrary and partly subjective estimates.

The annual costs of the services of teaching equipment and library books are also somewhat arbitrary, based on the assumption that the average new purchases in a year represent the annual value of the accumulated stock. In the absence of any valuation of the stock of teaching equipment and books, there is no alternative to a figure based on annual additions to the stock. Nevertheless, it means that these figures also must be treated with caution.

When one considers the distribution of costs between different disciplines further reservations must be expressed. The distribution of academic staff time between undergraduate work and other activities, which is crucial to the distribution of many items of cost, is based entirely on a diary covering a two-week period in 1968, and on estimates of vacation activities made by the Robbins and Hale committee in 1963.

However accurate these figures may have been at the time, they are always liable to change over time. Our quoted cost figures assume the continued validity of distribution of staff time. Furthermore the distribution of academic staff time between different undergraduate disciplines is based on the relative amounts of timetabled teaching. It is assumed that time spent in preparation and marking is proportional to actual teaching time as between different courses, but we have no conclusive proof that this is so. Similarly technical staff time is distributed in proportion to timetabled laboratory periods, although it may be the case that the technical staff back-up varies between different laboratory meetings.

The division of teaching equipment and materials costs between undergraduate and other activities is based on proportions derived from the Form 3 returns to the U.G.C. These are themselves based on partly-subjective estimates made by professors.

The allocation of many central costs, both actual expenditures and the imputed costs of accommodation, equally over all students (with some limited weighting of postgraduates and students on sandwich courses) is also arbitrary to some extent.

The cost figures quoted in Chapter 3 represent the best attempt that could at the present be made to evaluate the resources used by different undergraduate courses. It has been necessary to make certain assumptions and some relatively arbitrary allocations. These do not invalidate the figures but imply caution in the use to which they are put.

CHAPTER 3

UNIT COSTS OF UNDERGRADUATE COURSES AND THEIR PRINCIPAL COMPONENTS

In this chapter we look at the items making up the cost of students on different courses, and consider the principal variations between courses.

Detailed cost figures are given in Appendix 2, where for each undergraduate course the total cost and the cost per student are shown. These are broken down by year of course and by item of expenditure. Appendix 2 also shows, for each course, the proportion of total cost-per-student that each item constitutes.

Table 3.1 below shows the cost per student for each course. The costs cover all years of the course, and so represent the cost of teaching one student for the full three, or four, years of the course. They are broken down to show the relative proportions of:

a) capital and maintenance costs,
b) teaching costs,
c) administrative, library, student facility, general and miscellaneous expenditures.

Only the proportion of capital, teaching and administrative costs directly applicable to undergraduate instruction is included. Academic staff time and building space attributable to other objectives are excluded as described in Chapter 2.

Courses are arranged in two groups: those with substantial laboratory teaching, and those without.

Table 3.1 Total Cost per Student (1969-70)

Course	Capital and Maintenance Costs		Teaching Costs		Administrative, Library, Student Facility, General & Misc. Expendit.		Total Cost Per Student
	£	% of Total	£	% of Total	£	% of Total	£
Laboratory Based Courses							
Chemical Engineering	908	35	1089	43	560	22	2557
Civil Engineering	1030	41	956	38	523	21	2509
Electrical Engineering	1278	36	1769	49	556	15	3603
Industrial Technology*							
Mechanical Engineering	1768	44	1679	42	544	14	3991
Applied Biology	849	27	1639	53	622	20	3110

.....continued

Course	Capital and Maintenance Costs		Teaching Costs		Administrative, Library, Student Facility, General & Misc. Expendit.		Total Cost Per Student
	£	% of Total	£	% of Total	£	% of Total	£
Pharmacy	1446	44	1329	40	519	16	3294
Chemistry	1915	49	1332	34	627	17	3874
Colour Chemistry	1888	48	1517	39	513	13	3918
Materials Science	1134	31	1874	51	672	18	3680
Opthalmic Optics	1011	34	1484	49	504	17	2999
Applied Physics	1375	36	1635	46	672	18	3682
Textile Science	1245	40	1290	41	621	19	3156
Classroom Based Courses							
Business Studies	710	34	693	32	711	34	2114
Modern Languages	818	34	748	32	820	34	2386
Social Sciences	548	34	475	30	609	36	1632
Applied Soc. Studies	676	36	419	22	812	42	1907
Mathematics	907	39	744	33	656	28	2307
Statistics	563	31	613	35	599	34	1775

* Excluded because by 1969-70 students only enrolled in the first 2 years of the course.

One would expect there to be differences in cost between courses due to the nature of the subjects taught, and especially to the amount of laboratory space and equipment required. Thus classroom based courses are considerably cheaper (£1632 - £2386 per student over all years of the course) than laboratory based courses (£2509 - £3991). The comparison is even more marked than appears from the ranges alone. If one excludes Chemical Engineering (whose undergraduate course in fact includes little laboratory work as this is mostly done during the industrial training period) and Civil Engineering (who have subsequently moved into a new building with more laboratory space) the range of costs for laboratory based courses narrows to £2999 - £3991. Within the category of laboratory based courses there is no difference in cost between engineering and pure science courses as such, which is perhaps surprising.

Of the three elements of cost distinguished in Table 3.1, capital and maintenance costs vary between £849 and £1915 in laboratory based courses and £548 and £907 in classroom based courses; in general capital and maintenance costs in laboratory based courses are approximately double those in classroom based courses.

Teaching costs range between £956 and £1874 in laboratory based courses and between £419 and £748 in classroom based courses; again costs in laboratory based courses are approximately double those in classroom based courses.

Administrative, library, student facility and general expenditures range from £504 to £672 in laboratory based courses, and from £599 to £820 in classroom based courses.

Table 3.2 correlates each of the three cost-heads with total cost per student, analysing laboratory based and classroom based courses separately. As one might expect, there are significant correlations between total cost per student on the one hand, and both capital and maintenance costs and teaching costs on the other.

Table 3.2 Correlation of Cost-heads with Total Cost-per-Student

Cost Head	Laboratory-based Courses		Classroom-based Courses		All Courses	
	Correlation Coefficient	Significance P	Correlation Coefficient	Significance P	Correlation Coefficient	Significance P
Capital and Maintenance Costs	0.8029	<0.01	0.9424	<0.02	0.9013	<0.01
Teaching Costs	0.7046	<0.02	0.8082	<0.10	0.9187	<0.01
Administrative, Library Facility, etc Expendit.	0.2735	----	0.5463	----	-0.3875	----

Despite these high correlations, there are differences between courses in the proportion that each cost-head constitutes of total cost per student. Capital and maintenance costs vary between 27% and 49% in the case of laboratory-based courses, although two-thirds of the courses are in the range 34% to 44%; for classroom-based courses the range is only 31% to 39%.

Teaching costs vary between 34% and 53% in laboratory based courses and 22% and 35% in classroom based courses.

Administrative, library, etc. expenditures vary between 13% and 42%, giving insignificant correlations. One would expect poor correlations for this group of costs as in absolute terms it varies less between courses; indeed one can conclude that the wide range in the proportion of this category to total costs reflects changes in the absolute size of capital and teaching costs.

It is instructive to note the differences in cost between apparently similar courses, especially the capital and maintenance item. Chemistry's capital and maintenance cost is £1915 per student whereas Applied Biology's is only £849, less than half as much. Mechanical Engineering (operating a thin sandwich course with two student entries a year and a 42-week total teaching year) has capital and maintenance costs of £1768 whereas, perhaps surprisingly, in Civil Engineering (operating a thick sandwich single entry course for only 30 weeks of the year) it is only £908. Similarly there are substantial differences in teaching costs between courses, Materials Science (£1874) being twice as expensive as Civil Engineering (£956) in this respect.

Direct Cost Components

We now concentrate attention on the direct costs of each course; that is, those items of cost that can be directly attributed to particular courses, as opposed to central costs which must be allocated as overheads.

These direct costs are shown in Table 3.3 and consist of:

(1) Capital and maintenance costs of classrooms and teaching laboratories (Col. 1)

(2) Academic staff expenditures (Col. 2)

(3) Technical staff expenditures (Col. 3)

(4) School secretarial staff expenditures, plus capital and maintenance costs of offices for academic and school secretarial staff (Col. 4)

(5) Teaching equipment costs and expenditures on materials (Col. 5)

Total direct cost per student is shown in Col. 6, and the proportion that this comprises of total cost per student is shown in Col. 7. The proportions that the respective items constitute of total direct cost per student are also shown.

Table 3.3 Direct Cost Components

Course	Teaching Space (1)		Academic Staff (2)		Technical Staff (3)		Secretarial Staff plus Offices (4)		Equipment and Materials (5)		Total Direct Costs (6)	% of Total Cost (7)
Laboratory Based Courses	£	%	£	%	£	%	£	%	£	%	£	%
Chem. Eng.	580	32	617	34	204	11	128	7	268	15	1797	70
Civil Eng.	613	37	458	28	240	14	93	6	258	15	1662	66
Elec. Eng.	882	32	1073	38	352	14	144	4	344	12	2795	77
Mech. Eng.	1388	44	981	31	452	14	120	3	240	8	3187	79

.....continued

Course	Teaching Space (1)		Academic Staff (2)		Technical Staff (3)		Secretarial Staff plus Offices (4)		Equipment and Materials (5)		Total Direct Costs (6)	% of Total Cost (7)
	£	%	£	%	£	%	£	%	£	%	£	%
App. Biology	416	19	946	43	339	15	145	7	354	16	2200	70
Pharmacy	1026	42	549	22	474	19	114	5	306	12	2469	75
Chemistry	1482	49	600	20	432	14	187	6	300	10	3001	77
Colour Chem.	1465	47	785	25	432	14	156	5	300	9	3138	80
Mat. Sci.	618	23	982	37	472	18	164	6	420	16	2656	70
Opthalmic Optics	624	28	815	37	354	16	123	5	315	14	2231	74
App. Physics	859	32	743	28	472	18	164	6	420	16	2658	72
Textile Sci.	777	34	696	30	468	20	224	11	126	5	2291	73
Classroom <u>Based Courses</u>												
Business Studies	284	24	486	41	42	4	204	17	165	14	1181	56
Mod. Lang.	258	22	624	53	64	5	176	15	60	5	1182	50
Soc. Sci.	188	24	406	52	18	2	114	15	51	6	777	47
App. Soc. Studies	116	17	327	49	24	4	136	20	68	10	671	35
Maths.	339	27	652	52	–	–	172	14	92	7	1255	55
Stats.	126	14	544	62	–	–	144	16	69	8	883	50

It may be seen from Table 3.3 that direct costs form 66% to 80% of total cost per student in laboratory-based courses and 35% to 56% in classroom-based courses. Overhead costs thus represent a high proportion of total cost per student. In absolute terms the relative costliness of laboratory based courses is more marked in terms of direct costs than in terms of total costs; thus direct costs in classroom based courses range from £671 to £1255 per student, whereas those of laboratory based courses vary between £1662 and £3187, approximately two and a half times as much.

Table 3.4 presents averages, weighted by the number of students on each course, of the components of direct cost for laboratory based and classroom based courses.

With the exception of secretarial staff and academic and secretarial offices (Col. 4) each item of direct cost is greater for laboratory based than for classroom based courses; teaching space cost per student is four times greater, academic staff expenditure 50% greater, technical staff expenditure twelve times greater, and equipment and materials costs twice as great.

Table 3.4 Direct Cost Components - Weighted Averages of Cost-per-Student

	Teaching Space (1)	Academic Staff (2)	Technical Staff (3)	Secretarial Staff plus Offices (4)	Equipment and Materials (5)	Total Direct Costs (6)
Laboratory Based Courses:						
Cost per Student	£885	£741	£368	£135	£295	£2424
% of total direct cost	37	31	15	5	12	
Classroom Based Courses:						
Cost per Student	£226	£496	£ 29	£149	£130	£1030
% of total direct cost	22	48	3	14	13	

Within the two groups, however, there are considerable differences between individual courses, as can be seen in Table 3.3. The cost of teaching space varies between £416 per head in Applied Biology and £1482 in Chemistry; Academic Staff Cost per student varies between £458 in Civil Engineering and £1073 in Electrical Engineering; Technical Staff Cost varies between £204 in Chemical Engineering and £474 in Pharmacy; and Equipment and Materials Cost varies between £240 and £420. (In the latter case, Textile Science may be discounted as it shares its laboratories and equipment with the local authority technical college.) There is less variation from the average amongst the classroom based courses.

Table 3.5 correlates each of the items of direct cost with total direct cost per student, analysing laboratory based and classroom based courses separately. It can be seen that teaching space cost and technical staff cost are both strongly correlated with total direct cost, and that, to a lesser extent, academic staff cost is significantly correlated with total direct cost, particularly for classroom based courses. The high correlation of equipment and materials cost with total direct cost over all courses must be treated with caution in the light of the insignificance of the correlation for laboratory based courses.

Table 3.5 Correlation of Individual Items of Cost With Total Direct Cost per Student

Item of Cost	Laboratory-based Courses		Classroom-based Courses		All Courses	
	Correlation Coefficient	Significance P	Correlation Coefficient	Significance P	Correlation Coefficient	Significance P
Teaching Space	0.8169	<0.01	0.9156	<0.05	0.9133	<0.01
Academic Staff	0.4902	--	0.8528	<0.10	0.7344	<0.01
Technical Staff	0.7235	<0.02	0.8628	<0.10	0.9275	<0.01
Secretarial Staff plus Offices	0.3228	--	0.8496	<0.10	0.0619	--
Equipment & Materials	0.1924	--	0.5190	--	0.7927	<0.01

In Appendix 2 the costs of teaching accommodation for each course are shown for classrooms and laboratories separately. On average laboratory cost per student is six times greater than classroom costs in laboratory based courses; in non-laboratory based courses, classroom costs are five times greater than laboratory costs.

As one would expect, laboratory cost per student is closely related to the area of teaching laboratories in the school running the course. For undergraduate courses the coefficient of correlation is 0.8639 which is significant at the 1% level. Similarly there is a close relationship between the classroom and laboratory area per student in different schools of study, and classroom and laboratory cost per student. A coefficient of 0.8562 (significant to 1%) was found for laboratory based courses. Variations in the capital and maintenance cost per square foot of different buildings, and differences in the level of utilisation of laboratories in different schools of study, prevent perfect correlations. The problem of improving the level of utilisation and its effect on cost per student is considered in Part 5 of this report.

It is clear from the figures quoted so far that laboratory costs are a highly significant element of cost per student, and that economies in laboratory cost per student will have a substantial proportionate effect on total cost per student.

SUMMARY -- The Structure of Costs

The structure of the unit cost figures may be summarised in broad terms as follows:

(a) Laboratory based courses

Teaching accommodation	- almost 40% of direct cost
Academic staff	- about 30% of direct cost
Technical staff	- about 15% of direct cost
Equipment and Materials	- about 10% of direct cost
Secretarial staff, and offices	- about 5% of direct cost

To the direct cost must be added an "overhead" of £750 to £1000 (approximately 20% to 30% of direct cost) representing the cost of the library, central administration, student facilities, etc. The absolute amount of the overhead cost varies according to the length of course and whether there are one or two intakes of students each year.

(b) Classroom based courses

Academic staff	- about 50% of direct cost
Teaching accommodation	- about 20% of direct cost
Equipment & Materials	- about 15% of direct cost
Secretarial staff, and offices	- about 15% of direct cost

To the direct cost must be added an "overhead" of £850 to £1000 (approximately 50% to 65% of direct cost.) The reason for the absolute size of the overhead cost being so much greater for classroom based courses, is that library expenditure per student is approximately 3 times greater for students on these courses than for laboratory based students.

Organisation of the Course

So far we have distinguished between courses on whether they were laboratory based or not. A further useful distinction is by the length and broad structure of the course, and to this end five categories can be distinguished:

(1) Conventional 3-year courses:

Pharmacy
Mathematics and Statistics (B.Sc. Ordinary)
Opthalmic Optics
Business and Administrative Studies
Social Sciences

Students on these courses spend the whole of their time (9 full terms) in the university.

(2) Conventional 4-year courses:

Applied Social Studies

Students are university-based for 4 full years (12 terms) although in their 3rd and 4th years there are short interspersed periods of practical training outside the university.

(3) Thick-Sandwich courses:

Civil Engineering
Applied Biology
Mathematics (Honours)
Statistics (Honours)
Textile Science and Technology

Students spend years 1, 2 and 4 in the university (9 terms) and year 3 in industry.

(4) Thin-Sandwich single-entry courses:

Colour Chemistry and Colour Technology
Chemistry
Industrial Technology
Materials Science and Technology
Applied Physics
Modern Languages

Students spend a total of 9 terms spread over 4 years in the university, interspersed with continuous periods in industry or abroad. The actual timing of the terms spent away from the university varies between courses.

(5) Thin-Sandwich Double-Entry courses:

Chemical Engineering
Electrical Engineering
Mechanical Engineering

Students spend a total of 8 or 9 terms spread over 4 years in the university, interspersed with continuous periods in industry. There are two annual intakes of students and industrial training and university teaching is so organised that the students from one intake are in industry whilst the others are in the university, thus increasing the annual throughput of students compared with a single entry course. University buildings and equipment are in use for 42 weeks of the year instead of 33.

In Table 3.6 total cost per student and direct cost per student for each course are grouped by type of course, and averages, weighted by the number of students, are shown for each group.

Table 3.6 Total Cost per Student and Direct Cost per Student for Different Types of Courses

Type of Course	Laboratory-based Courses		Non-Laboratory-based Courses	
	Total Cost per Student	Direct Cost per Student	Total Cost per Student	Direct Cost per Student
CONVENTIONAL 3-YEAR COURSE	£	£	£	£
Pharmacy	3294	2469		
Opthalmic Optics	2999	2231		
Business Studies			2114	1181
Social Sciences			1632	777
AVERAGE	3228	2416	1743	870
CONVENTIONAL 4-YEAR COURSE				
Applied Social Studies			1907	671
THICK-SANDWICH COURSE				
Civil Engineering	2509	1662		
Applied Biology	3110	2200		
Textile Science	3156	2291		
Statistics			1775	883
AVERAGE	2791	1923	1775	883

.....continued

Type of Course	Laboratory-based Courses		Non-Laboratory-based Courses	
	Total Cost per Student	Direct Cost per Student	Total Cost per Student	Direct Cost per Student
THIN-SANDWICH, SINGLE-ENTRY	£	£	£	£
Chemistry	3874	3001		
Colour Chemistry	3918	3138		
Materials Science	3680	2656		
Applied Physics	3682	2658		
Modern Languages			2386	1182
AVERAGE	3806	2891	2386	1182
THIN-SANDWICH, DOUBLE-ENTRY				
Chemical Engineering	2557	1797		
Electrical Engineering	3603	2795		
Mechanical Engineering	3991	3187		
AVERAGE	3265	2471		

(Industrial Technology, Mathematics, and Mathematics & Statistics are excluded because of limitations on the data.)

One must be cautious in drawing conclusions from the figures in Table 3.6 about the difference in costs between the groups of courses, because of the small number of courses in each group and the wide range of values within some of them. Cost differences between the groups may be the result of the type of course, but it is possible that the thin-sandwich, single-entry courses (the costliest group) are inherently the most expensive due to other factors.

Since, if we disregard Applied Social Studies, all the courses involve the equivalent of 8 or 9 terms in the university spread over 3 or 4 years, one would not expect the cost of academic and technical staff per student to differ between groups, nor expenditure on materials. One would however expect that the cost per student of classrooms and teaching laboratories would be less in those courses where accommodation and equipment was used for more than the traditional 33 weeks per year; that is, in the thin-sandwich, double-entry courses. We see from Tables 3.3 and 3.4 that the average cost of teaching space per student in laboratory based courses is £885 whereas for the 3 double-entry courses it is £580 in Chemical Engineering, £882 in Electrical Engineering and £1388 in Mechanical Engineering. One cannot conclude from the observed costs of different courses that thin-sandwich, double-entry courses are, in themselves, cheaper than other types of courses. However in Part 5 we shall consider the extent to which certain courses might become cheaper if their structures were switched from single to double entry.

Table 3.7 <u>Relationship of Cost to Teaching Load</u>

Course	Total annual hours teaching given to course	Teaching hours given per student	Academic Staff Cost-per-student	Teaching Accommodation Cost-per-student	Academic Staff plus Teaching Accommodation Cost-per-student	Total Direct Cost-per Student	Teaching Area per Student (sq.ft.)
Chemical Engineering	5896	16.9	617	580	1197	1797	43
Civil Engineering	4927	19.1	458	613	1071	1662	n.a.
Electrical Engineering	10819	43.8	1073	882	1955	2795	100
Mechanical Engineering	9972	40.9	987	1388	2375	3187	146
Applied Biology	2546	24.7	946	416	1362	2200	61
Pharmacy	6201	27.0	549	1026	1575	2469	143
Chemistry	2870	17.7	600	1484	2084	3001	134
Colour Chemistry	1987	30.6	785	1465	2250	3138	137
Materials Science	3083	44.0	982	618	1600	2656	75
Opthalmic Optics	4307	74.3	815	624	1439	2231	103
Applied Physics	3686	45.0	743	859	1602	2658	113
Textile Science	3608	42.4	696	777	1473	2291	94
Correlation with Teaching hours per Student	----	----	0.4056	-0.2479	-0.0555	0.0032	0.0869

Costs and the Volume of Teaching

In an ideal situation, where the allocation of resources was perfectly related to the demands made by courses for staff and teaching accommodation, one would expect various items of cost per student to be related to the amount of teaching hours given.

In Part 4 of this report we consider a method analysing the teaching structure of courses in order to calculate the amount of staff and teaching accommodation required. In the present chapter we simply observe the present situation to see whether there is any relationship. We have calculated from timetables the total number of teaching hours given to students on all years of each laboratory based course 1969-70. This teaching load, divided by the number of students on the course is shown in Table 3.7, together with the academic staff cost per student, the teaching accommodation cost per student, the total direct cost per student and the area of teaching accommodation per student.

There appears to be no systematic relation between any of these items of cost and the teaching load imposed by different courses. Not only does the total teaching load per registered student vary widely between courses (from 16.9 to 74.3 hours per year) reflecting differences in the contact hours each student receives and the size of teaching meeting, but the allocation of staff and teaching accommodation to schools of study to meet these teaching loads also varies greatly, implying differences in the average teaching load per member of staff and in the degree of utilisation of teaching accommodation between schools of study.

A Broad Division of Costs

It is interesting to note the distribution of costs between academic, administrative, and what might be termed "welfare" functions.

Administrative costs include both current expenditure on administration and the annual capital and maintenance costs attributable to administrative offices. "Welfare" costs include the capital and maintenance costs attributable to student and staff

Table 3.8 Academic, Administrative and Welfare Costs

Cost-head	Laboratory-based Courses		Classroom-based Courses	
	£ per student year	%	£ per student year	%
Academic Costs	657	75	316	57
Administrative Costs	109	13	111	19
Welfare Costs	103	12	138	24
TOTAL	869	100	565	100

Note: The lower welfare cost for laboratory based courses reflects the greater number of sandwich courses in this group. Students on thin sandwich courses use facilities for only half the year, and costs have been attributed accordingly.

facility space such as the Student's Union, common rooms, refectories, residential accommodation, health services, etc. (after allowing for the revenue raised by them) and net current expenditure on these items. All other costs are treated as academic.

It is clear that welfare costs constitute a significant proportion of total cost per student, and the possibility of charging staff and students a more nearly economic price for them, would merit further investigation.

PART 3

THE GENERATION OF ACADEMIC STAFF REQUIREMENTS FOR INDIVIDUAL COURSES

In Part 3 we describe a method of calculating the number and cost of academic staff required to teach a single course, and study how these vary at different levels of enrolment and with different teaching methods. Several individual courses are studied in detail, and the teaching processes involved in them are defined in such a way that the number and cost of academic staff required can be calculated. The method enables valid comparisons to be made of the relative costs of teaching a course with various enrolments and teaching methods. The results are compared with the 1969-70 unit economic costs presented in Part 2.

Chapter 4 describes the way in which the teaching structure of a course is defined, how the number of teaching meetings and academic staff requirements and costs are calculated, and how the potential economies of changing enrolments and teaching methods are measured and expressed.

In Chapter 5, the level of enrolment on each course is increased by steps of one student up to at least double the present intake, and in the case of very small courses to four or five times the present intake. In each case it is found that expansion is associated with a less than pro rata growth in academic staff requirements, based on teaching-hours commitments.

In Chapter 6, the method of teaching each course is varied, through changes in total contact hours received by each student, relative balance of lectures, tutorials and seminars, the number of optional subjects, and the size of teaching group. Alternative costings are produced for each course as these parameters vary, in order to identify potential economies.

In Chapter 7, the average teaching load of staff is increased, and the effects of various increases on staff costs is measured. It is found that scope exists for increasing teaching load at a time of expansion, and that substantial economies would accrue.

CHAPTER 4

THEORETICAL BASIS FOR MEASURING AND COSTING ACADEMIC STAFF REQUIREMENTS

The teaching function of the university requires academic staff commitment to formal classroom hours, preparation, correction of student submissions, interview outside the classrooms, and examination of students, as well as sundry administrative work. Of this commitment, the major portion is concerned with formal teaching meetings. In this study attention is confined to academic staff related directly to this formal contact.

In this chapter a method of building up total teaching-meetings hours, by type of meeting is developed. Then we describe how this is translated into staff numbers and costs.

1) Notation

Sj = Number of students enrolled on year j of a course

$S = \sum Sj$ (total enrolment on all years of the course)

Tij = full-time equivalent academic staff required for each type of teaching meeting, i, in the jth year of the course

$T = \sum Tij$ (total full-time equivalent academic staff required for the course)

r = staff:student ratio (S/T)

t = average teaching load per staff member (in hours per year)

Cij = contact hours per student per term-time week, of each type of teaching meeting i in the jth year of the course

Wj = number of teaching weeks per year in year j of the course

gi = maximum size of each type of meeting i

Gij = number of groups into which students are divided for each type of meeting i, in the jth year of the course

Mij = total number of meetings, in hours, of each type of meeting i, in the jth year of the course

$M = \sum Mij$ (total number of meetings of all types for all years of the course)

X = average annual expense (salary, superannuation and insurance, per academic staff member

Z = Full academic staff cost of the course, per year (no deduction is made in respect of that proportion of time devoted to research)

2) Basic Relationship

On the one hand the number of meetings must equal the number of staff multiplied by the average annual teaching load:

$$M = T.t \tag{1}$$

On the other hand, the number of meetings must equal the annual number of contact hours per student multiplied by the number of groups into which students are divided. For each type of meeting (lectures, classes, tutorials and laboratories) in each year of the course:

$$Mij = Cij \;.\; Wj \;.\; Gij \tag{2}$$

The number of groups equals the number of students divided by the maximum group size:

$$Gij = \frac{Sj}{gij} + 1 \tag{3}$$

such that if Sj/gij is not an integer its value is increased to the nearest integer above.

Combining equations (2) and (3):

$$Mij = Cij \times Wj \times (\frac{Sj}{gij} + 1) \tag{4}$$

These are summed for all types of meeting and all years of the course to obtain the total number of meetings required for the course:

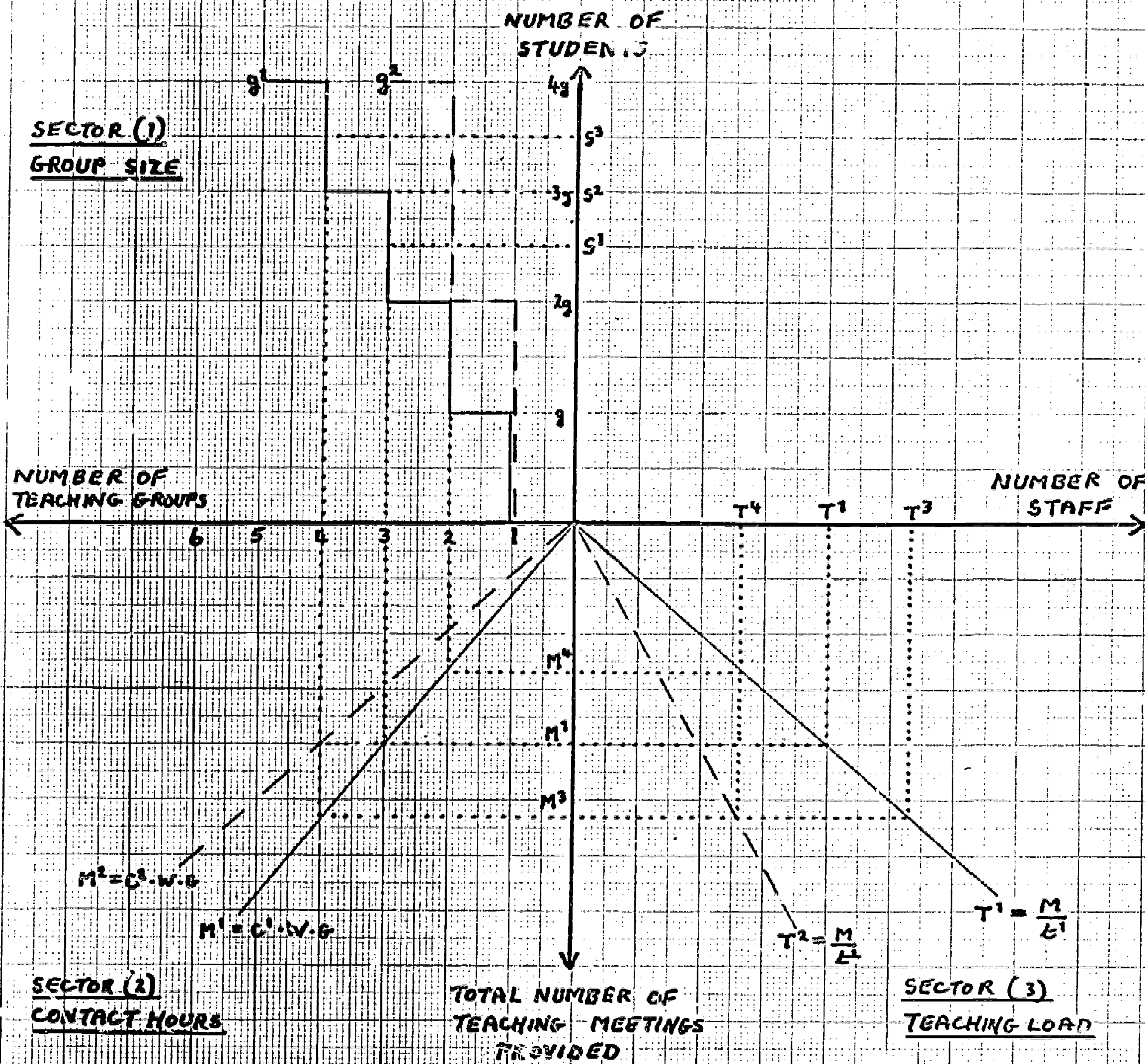
$$M = \quad (Cij \;.\; Wj \;.\; (\frac{Sj}{gij} + 1) \tag{5}$$

For any given permutation of student enrolment, group size, contact hours and staff teaching load, the number of academic staff required is defined by combining equations (1) and (5):

$$T = \frac{\Sigma\,(Cij \;.\; Wj \;.\; ((Sj/gij) + 1))}{t} \tag{6}$$

Figure 4.1 illustrates the relationship between student numbers and staff numbers, and how this is affected by group size, number of contact hours, and staff teaching load. In order to simplify the graph it is assumed that the course is a one-year course only and consists of one type of meeting.

FIGURE 4.1 : RELATIONSHIP BETWEEN STUDENT ENROLMENT AND ACADEMIC STAFF REQUIREMENTS.



Sector (i) describes the relationship between student enrolment in a year of a course and the subsequent number of groups necessary. This operates via the maximum group size, here called g. The student enrolment is expressed in units of this group maximum.

Sector (ii) relates the number of groups to the total number of meetings to be provided, via the contact hours received per student. This latter element is represented by the function $M = C.W.G.$ (In order to generalise the equation, it should strictly be of the form $Mij = Cij.Wj.Gij.$)

Sector (iii) relates the number of meetings to be provided to the number of full-time equivalent academic staff, via the average teaching load of staff, represented by the function $T = M/t$ (Strictly $Tij = Mij/t$).

Via this graphical representation we can trace the effects on the staff requirements of changes in student enrolment, the maximum size of the group, contact hours per student, and teaching load of staff.

In Figure 4.1 student enrolment is initially S^1. With a class size of g three groups must be formed. With contact hours per student of C^1, this necessitates M^1 total meetings. With teaching load = t^1, the full-time equivalent staff requirement is T^1. An expansion of student enrolment to S^2 within this situation can be catered for with the existing number of meetings and so leaves other variables unchanged. The additional students are incorporated into the existing groups. However when student numbers increase to S^3, a fourth group must be formed and this leads to M^3 total meetings and T^3 full-time equivalent staff.

The maximum size of a group determines the relationship between student enrolment and the number of groups. In sector (i) the solid line g^1 is valid only when the maximum group size is g. If the maximum group size is raised to 2g, then the relationship is expressed by the broken line g^2. If contact hours per student remain C^1, student enrolment of S^1, S^2 and S^3 now generate only M^4 meetings and require only T^4 full-time equivalent staff. One extreme of group size is the individual tutorial, where $g = 1$, in which case, the number of groups is in direct proportion to the student enrolment. The other extreme is the lecture where no class maximum operates over the feasible range of student intake, and hence g in sector (i) will be a horizontal straight line, with student enrolment having no influence on the number of groups.

Variation in contact hours per student has a direct proportional effect on total meetings. With S^3 students and g group size, a fall from C^1 to C^2 in contact hours per student causes the number of meetings to fall from M^3 to M^1, and the number of staff to fall from T^3 to T^1.

Variation in the average teaching load inversely affects the number of staff required. If M^3 meetings are given, then an increase in teaching load from t^1 to t^2 causes the staff requirement to fall from T^3 to T^4.

Staff/Student Ratio

From equations (4) and (5), the staff commitment in formal teaching hours per student is:

$$\frac{M}{S} = \frac{Mij}{S} = \frac{(Cij.Wj.(Sj/gij + 1)}{S} \qquad (7)$$

Using equations (6) and (7) derivation of a staff/student ratio in terms of the variables determining staff resources required is now possible:

$$r = \frac{S}{T} = \frac{S.t}{M} = \frac{S.t}{(Cij.Wj.(Sj/gij + 1))} \qquad (8)$$

3) Classification of Teaching Methods

Schools of Study in the University of Bradford have been asked in respect of a number of courses, to provide basic information on course structure. Each course is broken down into individual series of teaching meetings, including personal tutorials. The types and sizes of meetings identified are listed in Table 4.1.

Table 4.1 Classification of Teaching Methods

i classification	Description	Maximum group size gi
1	Lecture	No maximum
2 3 4	Exercise classes with discussion of problems; sometimes including a lecture	50 40 30
5 6 7	Discussion classes, or Lecture / Discussion	25 20 15
8 9 10	Seminars, or Small group discussion	12 8 6
11 12	Tutorials	4 1

.....continued

i classification	Description	Maximum group size gi
13 14 15 16 17 18 19 20	Practical classes in laboratories. Although asked for an "educational" opinion on the maximum number allowable in a class, maximum quoted seems often to be determined by the size of laboratories in existence. Since no new laboratories are likely to be built in 1971/77 these estimates are for all practical purposes equivalent.	60 50 40 30 20 18 12 6

Data was also obtained from Schools on weekly and annual contact hours for each series of meeting. Each course was described in the manner examplified for the first year of the undergraduate course in Civil Engineering in Table 4.2.

Table 4.2 Civil Engineering First-Year Course Structure

No. of weeks in year Wj	No. of students 1970-71 Sj	Teaching Method		Maximum Group Size Gij	Contact-Hours per week Cij
		i	Description		
33	66	1	Lecture	No.max.	10
		3	Exercise Class	40	1
		4	Exercise Class	30	2
		6	Discussion Class	20	2.5
		15	Laboratory	40	6.5

This description of a course is henceforth referred to as the "course structure".

4) Method of Calculating Academic Staff Requirements and Cost for a Course

From the data in Table 4.2 we calculate for each component of the course the number of groups necessary (Gij) and the total number of meetings per year (Mij). The number of meetings can then be summed for all components and all years of the course, to obtain the total academic staff commitment to the course, in terms of teaching hours per year. The results for Civil Engineering are shown in Table 4.3.

Table 4.3 Civil Engineering First-Year Teaching Commitment

Teaching Method i	Description	Number of Groups Necessary $G_{ij} = (\frac{S_i}{g_{ij}})$	Total Number of Teaching Meetings per year $M_{ij}=G_{ij}.C_{ij}.W_j$
1	Lecture	1	330
3	Exercise Class	2	66
4	Exercise Class	3	198
6	Discussion Class	4	330
15	Laboratory	2	429
TOTAL			1353

Since this set of simple calculations must be repeated many times for each level of enrolment, and for all the variable parameters relating to teaching methods, a computer program has been prepared to do this.[1] A statement of the course structure as defined in Table 4.2 forms the data for this program, which then computes the number of meetings required at successive levels of enrolment. By varying the data to represent alternative course structures, it is possible to analyse the effect of altering each of the variables, on the total number of meetings.

Figure 4.2 illustrates the way in which the results will be presented in Chapters 5, 6 and 7. The number of teaching meetings required is plotted against:

i) alternative levels of enrolment, with the existing course structure (Figure 4.2a)

ii) alternative total number of contact hours, with the existing enrolment (Figure 4.2b)

iii) alternative combinations of teaching method, with the existing enrolment and total of contact hours (Figure 4.2c)

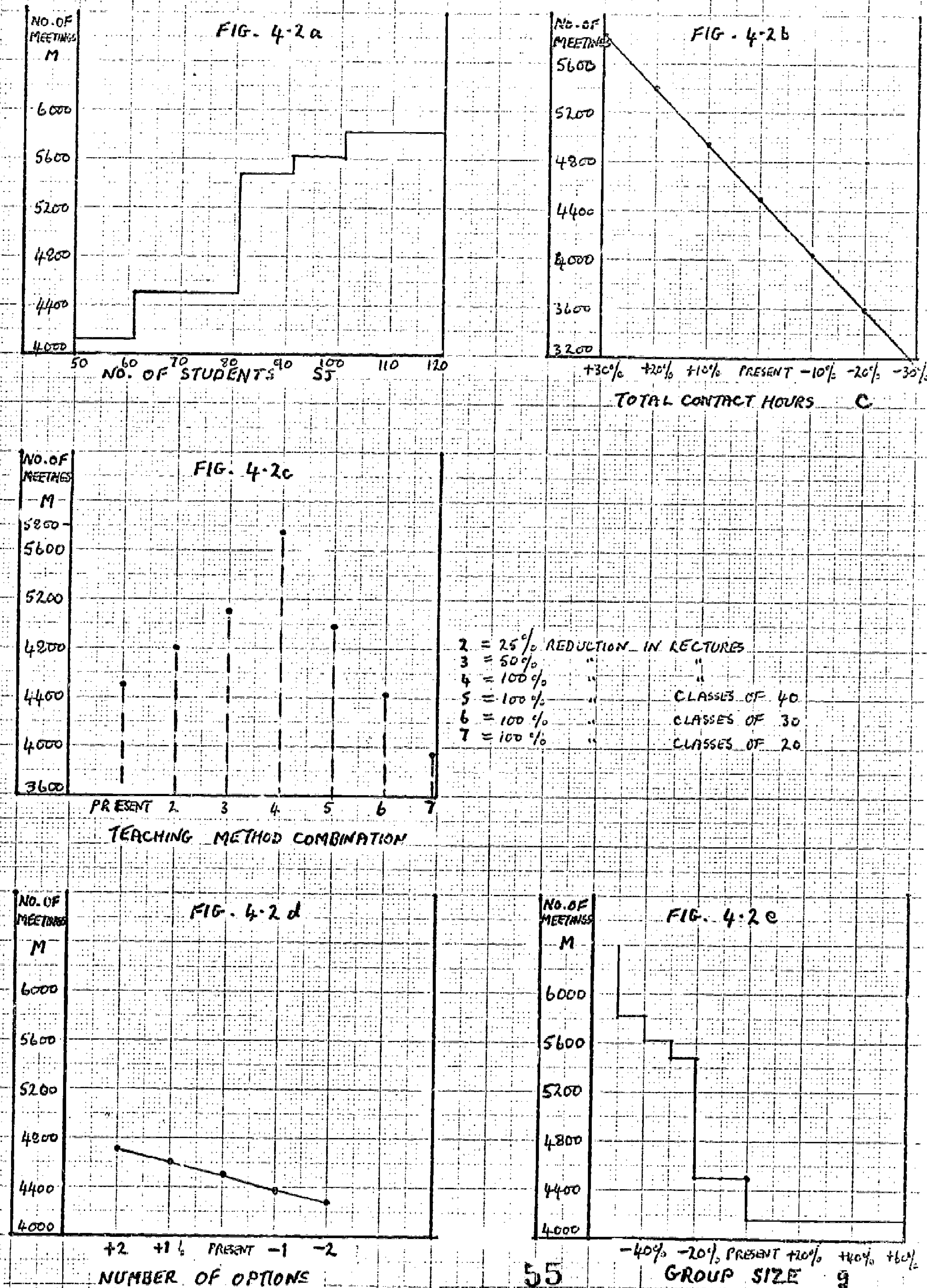
iv) alternative number of optional subjects, with the existing enrolment and combination of teaching methods (Figure 4.2d)

v) alternative sizes of teaching group, with the existing enrolment and combination of teaching methods (Figure 4.2e)

The measure of the number of teaching meetings can be used in two ways: as an intermediate step towards calculating the number of academic staff required, and as an index of the cost of academic staff for the course.

1. Program VA54DASEYAC, see Appendix 1

FIGURE 4.2 : NUMBER OF TEACHING MEETINGS REQUIRED (CIVIL ENGINEERING)



It is apparent from Figure 4.1, sector (iii) that if a standard teaching load (t) can be evaluated, then the number of staff required can be derived from the number of meetings given. Re-arranging equation (1) in the form:

$$T = \frac{M}{t} \tag{9}$$

we see that the number of staff is obtained by dividing the number of meetings by the standard teaching load. Although there are problems in fixing a value to t, this method is adopted in preference to the alternative of measuring the time devoted to preparation and other work related to undergraduate teaching, because of the great variability of ancilliary to teaching time between different subjects, different individuals, different grades of staff, and according to the number of times meetings are repeated for different groups of students.[2]

Before indicating how a value is set upon t, it will be useful to describe the concept of the number of meetings (M) as an index of academic staff cost.

The total annual cost of academic staff for the course (Z) may be represented:

$$Zp = X \cdot T \tag{10}$$

where subscript p indicates any particular level of enrolment and structure of course, and X the average annual expense of employing a member of staff, in terms of salary, superannuation and national insurance. Combining equations (9) and (10):

$$Zp = \frac{X \cdot Mp}{t} \tag{11}$$

In order to measure the change in staff cost as a result of moving to any situation p, where either the level of enrolment or the course structure is different, it is useful to express the staff cost in situation p as a proportion of that in the original situation, which we designate q. This provides a simple index (I) of the change in the total staff cost of the course. Thus:

$$Ip = \frac{Zp \cdot 100}{Zq} \tag{12}$$

In the light of the definition of Zp used in equation (11) we may now expand equation (12):

$$Ip = \frac{\left(\frac{X \cdot Mp \cdot 100}{t}\right)}{\left(\frac{X \cdot Mq}{t}\right)} \tag{13}$$

---

2. Work on the relation of ancilliary to teaching time is being carried out in the associated project at the University of Lancaster.

X and t can now be eliminated from both numerator and denominator and the index can be redefined more simply as:

$$Ip = \frac{Mp \cdot 100}{Mq} \qquad (14)$$

The change in cost can be measured simply in terms of the number of meetings. Given constant teaching loads (t) and cost per staff member (X), then the academic staff cost of a course at different enrolments or with different teaching structures is directly proportional to the number of meetings given.

Figure 4.2 may now be re-scaled on the vertical axis to express the number of meetings in the new situation as a proportion of the number originally given, and this is done in Figure 4.3 (scale 2).

In order to obtain absolute figures of academic staff cost, values must be set to t and X. It is particularly difficult to set a value to t as it differs so much between individuals, departments, and universities. (Indeed one of the merits of using the Index is that it enables changes in enrolment and teaching method to be analysed without the complications of varying values of t). The University Teachers Survey carried out for the Robbins and Hale committees in 1962 quotes 6.1 hours per term-time week (201 hours per 33-week year) as an average load of undergraduate teaching covering all faculties and all grades of staff. A survey carried out in the University of Bradford[3] in 1968 found an overall average of 6 - 8 hours per term-time week (198 - 264 p.a.) of undergraduate teaching in different Boards of Study. In calculating staff allowances for interdepartmental service teaching, the Allocations Committee of the University of Bradford works on a national 400 hours per year (12.1 hour per week). This latter figure however relates solely to service teaching, the burden of which is less than that of more specialised teaching. The Committee of Vice-Chancellors in its 1969 survey did not ask for information on actual teaching hours.

For the purpose of this study the teaching load measured in the University of Bradford in 1968 has been used. Table 4.4 summarises the findings:

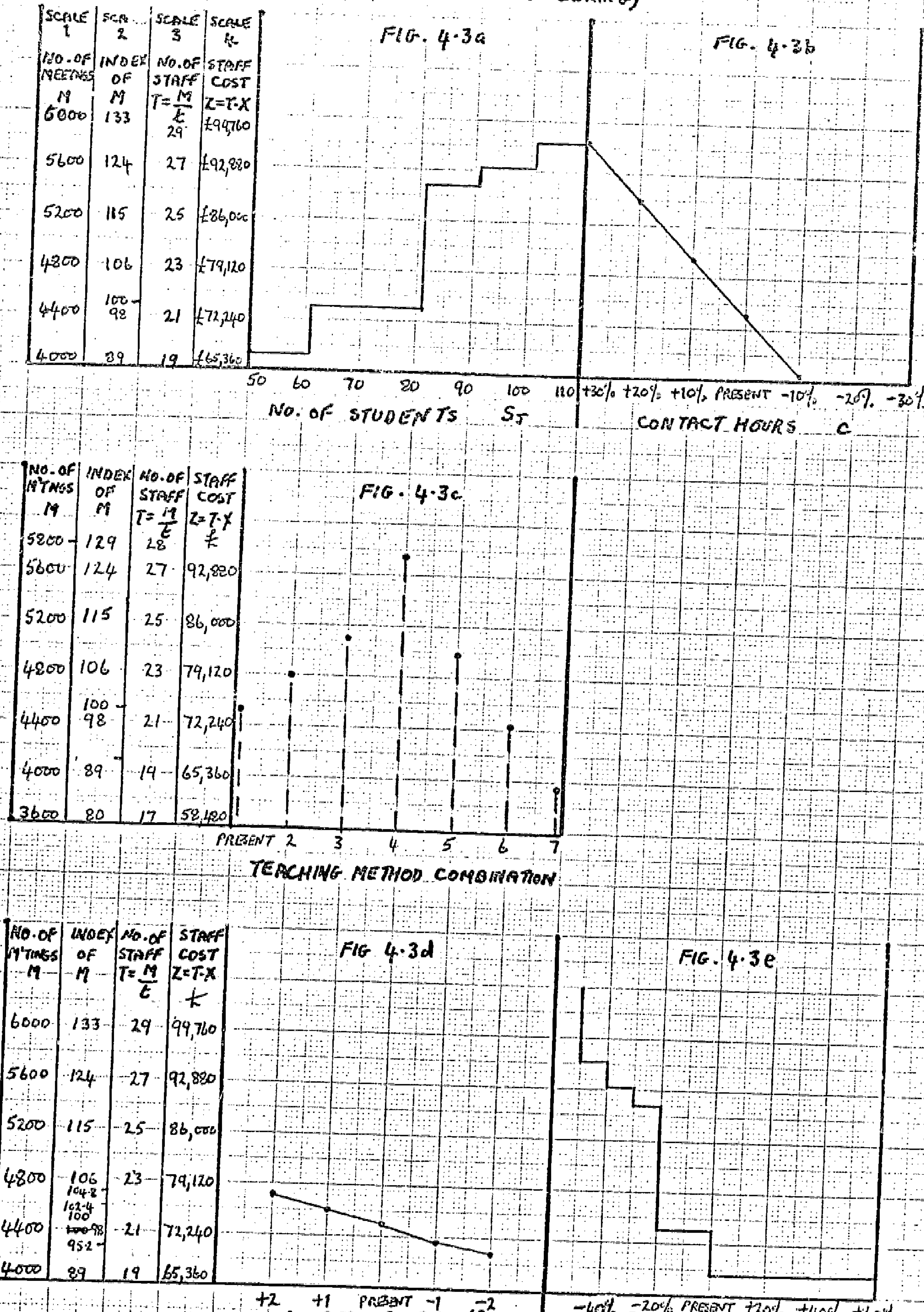
Table 4.4 Weekly Teaching Load of Staff at University of Bradford 1967/68

Board of Study	Undergrad. Teaching		Postgrad. Teaching	
	Hours per week	Hours per 33-week year	Hours per week	Hours per 33-week year
Engineering	6	198	1	33
Life Sciences	6	198	-	-
Physical Sciences	6	198	2	66
Social Sciences	8	264	1	33

3. R. K. Khanna & M. Shattock, "Analysis of University Staff Time" (Bradford University unpublished paper), 1968

FIGURE 4.3 : ACADEMIC STAFF REQUIREMENTS AND COST

(CIVIL ENGINEERING)



In order to allow for the effects of the worsening in the staff:student ratio since 1967/68 it is necessary to make some increase in the teaching load. The ratio of teaching staff to undergraduates has worsened by 8.7% over the period 1967/68-1970/71 (from 1:6-9 to 1:7-5), and to compensate for this the undergraduate teaching loads have been increased by approximately 6%. The ratio of teaching staff to postgraduates on advanced courses has worsened by 150% over the same period (from 1:0.2 to 1:0.5), and to compensate for this the postgraduate teaching loads have been increased by approximately 100%. The reason for increasing the load by less than the worsening of the ratio is that, as will be demonstrated in Chapter 5 of this report, an expansion of enrolment does not cause a pro rata increase in the total amount of teaching to be given. Table 4.5 contains the revised teaching loads which are subsequently used as a basis of calculating staff numbers and cost.

Table 4.5 Revised Weekly Teaching Loads

Board of Study	Undergrad. Teaching		Postgrad. Teaching	
	Hours per week	Hours per 33-week year	Hours per week	Hours per 33-week year
Engineering	$6\frac{1}{2}$	210	2	66
Life Sciences	$6\frac{1}{2}$	210	-	-
Physical Sciences	$6\frac{1}{2}$	210	4	132
Social Sciences	$8\frac{1}{2}$	280	2	66

By dividing the number of meetings by the standard teaching load for the course, it is possible to re-scale Figure 4.3 to show the number of full-time equivalent academic staff required at each level of enrolment and for each course structure. Scale 3 of Figure 4.3 measures this. It should be noted that the figure obtained is of full-time equivalent staff, possibly containing fractional units of staff from several service departments.

In estimating the cost of employing a single member of staff (X) it is assumed that staff are distributed between grades in the ratio of 10% professors to 25% readers/senior lecturers to 65% lecturers, in line with U.G.C. requirements that the number of professors and readers/senior lecturers shall not exceed 35% of the total teaching staff. (Actual proportions in the University of Bradford in 1970-71 are 9% professors to 22% readers/senior lecturers to 69% lecturers.) Professors are costed at the 1970-71 negotiated average of £5610, readers/senior lecturers at the mid-point of their scale (£3800), and lecturers at the midpoint of their scale (£2454). 10% is added to all salaries in respect of the university's contribution to superannuation, and £100 per head in respect of national insurance payments. The resultant average annual expense per staff member if £3440.

It is now possible to rescale Figure 4.3 once more. By multiplying the number of staff (T) by the average annual expense (X), the academic staff cost of the course is obtained; this is indicated on scale 4. It should be noted that no allowance has been made, as it was in Part 2, for the fact that part of the time of staff is devoted to other activities. In Part 3, the whole cost of employing academic staff is attributed to the course in question.

We have thus devised a single measure of:

a) the number of teaching meetings provided for a course

b) the number of full-time equivalent academic staff required for that course

c) the cost of academic staff for that course.

<u>In the absence of known values of teaching load (t) and average expense of staff (X), the measure serves as an index of these three values, measuring how each may change as a result of changes in enrolment and course structure.</u>

5) <u>Method of Calculating Staff Numbers and Cost per Student</u>

The next step is to relate this measure of cost to the number of students enrolled, in order to calculate a cost per student, and to study how this varies with changes in enrolment or course structure.

In equation (11) the academic staff cost of a course with any particular enrolment and course structure (p) is defined as:

$$Zp = \frac{X \cdot Mp}{t} \qquad (11)$$

The academic staff cost <u>per student enrolled</u> is therefore:

$$\frac{Zp}{Sp} = \frac{X \cdot Mp}{t \cdot Sp} \qquad (15)$$

It is convenient to be able to express changes in staff cost per student when moving to any situation p, as proportional to the cost in the original situation q. To do this, the concept of the <u>Staff Cost Index (SCI)</u> is defined:

$$SCIp = \frac{\left(\frac{Zp}{Sp} \cdot 100\right)}{\left(\frac{Zq}{Sq}\right)} \qquad (16)$$

In the light of the definition of Zp/Sp used in equation (15), equation (16) may now be expanded thus:

$$SCIp = \frac{\left(\frac{X \cdot Mp \cdot 100}{t \cdot Sp}\right)}{\left(\frac{X \cdot Mq}{t \cdot Sq}\right)} \qquad (17)$$

Again X and t may be eliminated, and the Staff Cost Index redefined more simply as:

$$SCIp = \frac{Mp \cdot Sq \cdot 100}{Mq \cdot Sp} \tag{18}$$

where q relates to the original enrolment and course structure, and p to the changed situation.

An example will clarify the concept. In the original situation 9 students are enrolled (Sq) and 1560 meetings are held (Mq). After expansion 20 students are enrolled (Sp) and 2280 meetings must be given (Mp). Consequently,

$$SCIp = \frac{2280 \cdot 9 \cdot 100}{1560 \cdot 20} = 65.8$$

This can be checked as follows:

a) Number of meetings per student originally provided:

$$\frac{Mq}{Sq} = \frac{1560}{9} = 173$$

b) Number of meetings per student after expansion:

$$\frac{Mp}{Sp} = \frac{2280}{20} = 114$$

c) 114 = 65.8% of 173.

<u>The Staff Cost Index thus measures the change in the number of meetings provided per enrolled student as a proportion of the original value, resulting from a change in enrolment or course structure</u>. This concept of the Staff Cost Index is of crucial importance for the analysis carried out in relation to expanding enrolment.

In considering the effect of changing enrolment it is useful to plot the Staff Cost Index and in Figure 4.4 it is superimposed on the "Number of Meetings" line from Figure 4.2(a). Scale 1 of Figure 4.4 measures the Staff Cost Index or number of meetings per student, and scale 4 the total number of meetings.

Just as it was possible to re-scale Figure 4.2(a) to translate the number of meetings into the number of academic staff and into the academic staff cost of the course, so Figure 4.4 can be re-scaled to measure the number of academic staff per enrolled student (scale 2), and the academic staff cost per student (scale 3). Scale 2 represents the staff:student ratio, and is calculated using the formula

$$1 : \frac{t.Sj.y}{M}$$

where y is the number of years on the course and Sj the number of students in a single year. <u>Regardless of the actual values imputed to the teaching load of staff (t) and</u>

to the annual cost per staff member (X), the Staff Cost Index measures the proportionate change in the staff:student ratio and in the academic cost per student.

We have thus devised a single measure of:

a) the number of teaching meetings provided per enrolled student

b) the staff:student ratio

c) the academic staff cost per student.

In the absence of known values for t and X, the Staff Cost Index serves as an index of these three values.

In considering the effects of changing course structure, the Staff Cost Index is less relevant, as enrolment is held constant in order to isolate the effects on cost of the change in structure. Figures 4.3(b) to 4.3(e) do not need re-drawing; they may simply be re-scaled by dividing the number of meetings (M), number of staff (T) and staff cost (T.X) by the (constant) number of students (S).

6) Method of Expressing Results

The results of the analysis of the courses may be presented in three ways and these are described below. Not all of these ways will be relevant to any single variable parameter.

1. In terms of absolute savings in academic staff cost-per-student

The figures as developed so far are sufficient to show the results in this manner. Figure 4.4 shows for any chosen expansion:

a) the change in staff-cost per student (absolutely and proportionately)

b) the change in staff:student ratio (absolutely and proportionately)

Figures 4.3(b) to 4.3(e) show for any chosen change in teaching methods:

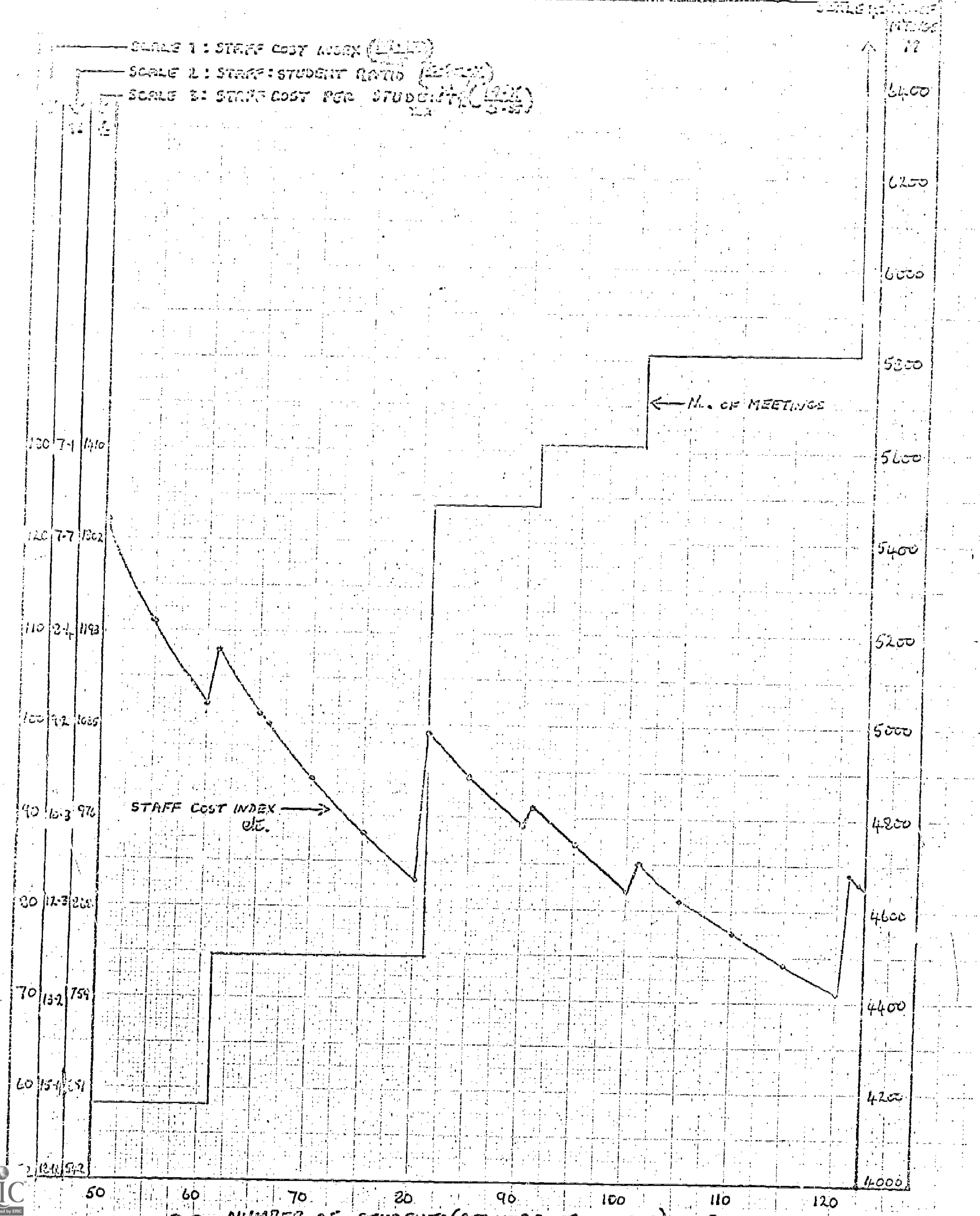
a) the change in staff-cost of the course (absolutely and proportionately)

b) the change in staff cost-per-student (absolutely and proportionately).

2. In terms of applying a constant staff:student ratio

In considering changes of enrolment it is useful to compare the cost of expansion if additional staff requirements are based on the increased teaching commit-

FIGURE 4.4 : STAFF COST PER STUDENT (CIVIL ENGINEERING)



ment, with the cost that would be incurred if sufficient extra staff were recruited to hold the staff:student ratio constant.

In Figure 4.5(a) the number of staff required at different enrolments is measured on scale 1 and the total staff cost on scale 2.

The line r = 12.38 represents staff requirements and cost when applying a constant staff:student ratio of 1:12.38. This is the weighted staff:student ratio observed in all U.K. universities for the U.G.C. subject group "Engineering", in 1968-69.[4]

The line t = 281 represents staff requirements and cost calculated on the basis of the total number of teaching meetings provided at different enrolments, and an annual teaching load of 281 hours per member of staff. The value of 281 is obtained by dividing the number of meetings provided at the current enrolment by the notional staff entitlement at that enrolment, if the U.K. average staff:student ratio were adhered to. Thus with the current intake of 66 students, 4496 meetings are provided and the national staff entitlement is 15.99, giving a nominal teaching load of 281 hours per year. Details of the calculation of nominal teaching loads are given in Appendix 4.

The two lines consequently intersect at the point (I) whose y co-ordinate represents the current enrolment, and whose x co-ordinate represents the current notional staff entitlement. The ratio used is unlikely to be the same as that empirically observed in the department, for it represents <u>full-time equivalent staff involved with the course</u>, not the actual number of staff employed in the department. These two figures will differ to the extent that the department's staff teach other courses, and staff of other departments teach students on the course under consideration. Non-integral numbers are thus valid, implying that a proportion of time is devoted to service teaching for other courses.

The vertical distance between the two lines in Figure 4.5(a) measures the difference in the number of staff required using teaching commitment and constant ratio bases. These differences at each level of enrolment (as distinct from the absolute values) are plotted with greater clarity in Figure 4.5(b). The staff saving obtained by using the teaching commitment basis is measured by the extent to which the broken line is below the horizontal line at any given enrolment. Thus, for example, if the enrolment in Figure 4.5 were increased from 66 to 110, the number of staff required would be 20.69 if calculated from the number of meetings, whilst, by contrast, preserving the staff:student ratio would give entitlement to 26.64 staff. A saving of 6 staff appears feasible without altering the structure of the course or the teaching load of staff.

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4. Weighted staff:student ratios have been calculated for the U.G.C. subject groups that are relevant to the University of Bradford (see Appendix 4). Figures for staff and weighted student numbers for all U.K. universities are taken from D.E.S.: Statistics of Education, Volume 6, 1969.

Translation of staff numbers into staff costs is achieved by multiplying each line by the average cost of a member of staff (X), redefining them as

$$T = \frac{S.X}{r} \quad \text{and} \quad T = \frac{M.X}{t} \quad \text{respectively.}$$

The staff cost of the course is indicated in scale 2, using X = £3440 as calculated above.

3. In terms of Unit Economic Costs

The Staff Cost Index may be used to estimate the change in unit economic cost, as measured in Part 2, that might come about as a result of the postulated expansions. It would not be valid to substitute the absolute values of staff costs calculated in this chapter into the unit costs calculated in Part 3 as the latter have been reduced in proportion to research and other activities. However, it is possible to multiply the "academic staff cost" element of unit economic cost, by the Staff Cost Index at different enrolments, and to recalculate the total economic cost-per-student. Furthermore, since academic staff require offices pro rata, it is possible also to multiply the "academic staff offices" element by the Staff Cost Index.

Table 4.6 shows the estimated costs for Civil Engineering with annual intakes of 80, 90, 100 and 120.

Table 4.6 Civil Engineering: Economic Cost-per-Student at various enrolments

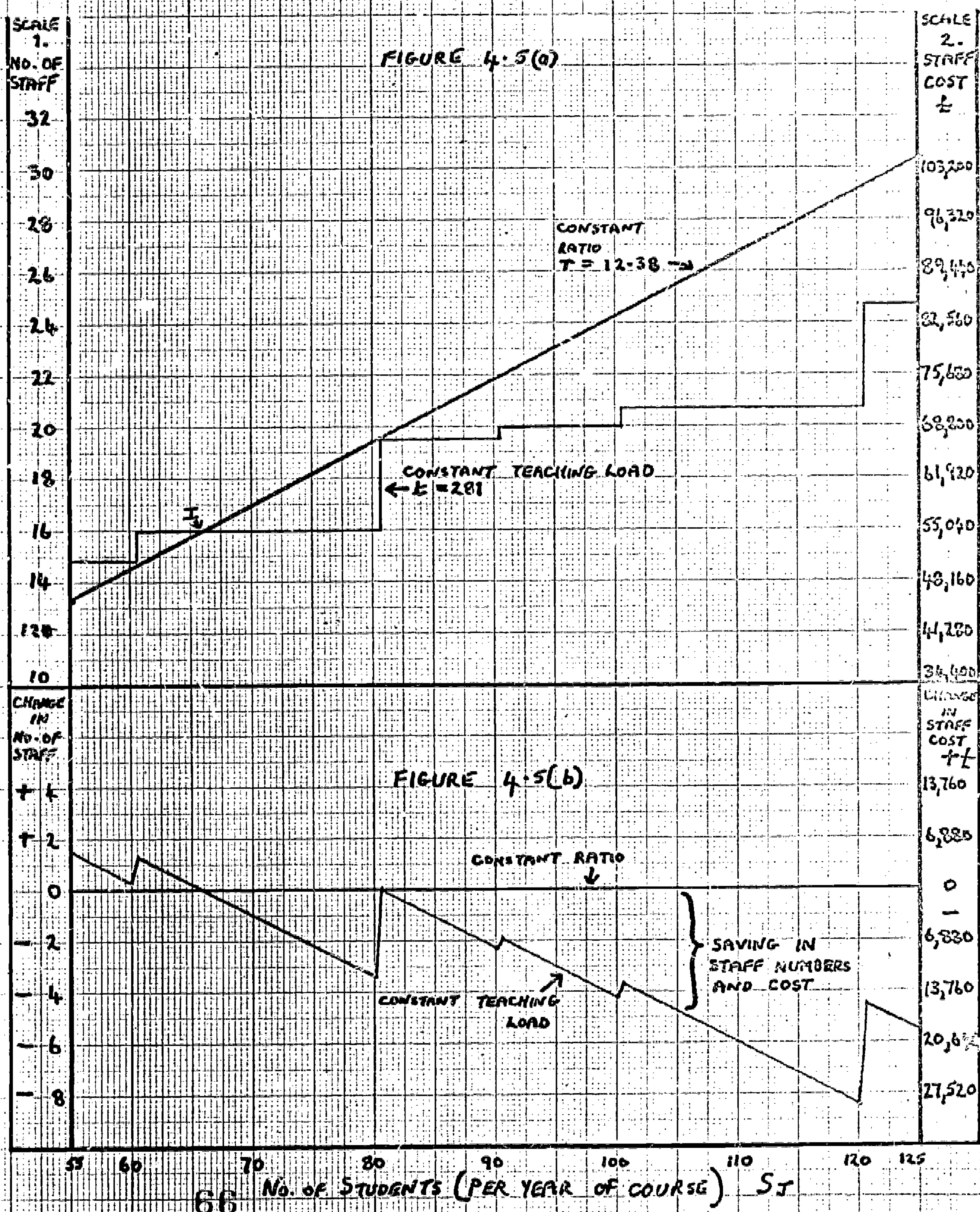
	Annual Enrolment				
	(Current) 66	80	90	100	120
Staff Cost Index	100	83	89	82	71
Academic Staff Cost (£)	458	380	408	375	325
Academic Staff Offices (£)	57	47	51	46	40
Total Cost per Student (£)	2509	2421	2453	2415	2359
% Saving in Cost per Student	---	3.5%	2.2%	3.7%	6.0%

It is assumed in the calculations for Table 4.6 that the balance of activity of staff between teaching and research remains the same as at present, and that the amount of preparation, marking, etc. generated by the additional teaching meetings is in the same proportion to actual teaching as with the existing meetings.

We now proceed in Chapters 5, 6 and 7 to alter various parameters in a search for potential economies.

FIGURE 4·5: STAFF REQUIREMENTS AND COST BASED ON a) CONSTANT RATIOS AND b) NUMBER OF MEETINGS

(CIVIL ENGINEERING)



CHAPTER 5

ECONOMIES ARISING FROM THE EXPANSION OF ENROLMENT

In this chapter we apply the method described in Chapter 4 to a number of courses in order to consider the effect of increasing enrolment on academic staff costs and total cost-per-student.

The course structure is held constant. Consequently there is no increase in the size of teaching groups (except for straight lectures) beyond what is at present the standard size that the professor deems is desirable on educational grounds. The total number of teaching contact hours received by any one student, and the number of each type of meetings (lectures, classes, tutorials and laboratory sessions), are also constant. The student, therefore, receives the same amount of teaching in the same types and sizes of meeting as at present, although the straight lectures he attends will be larger. From an educational viewpoint the quality of service is unimpaired; there is no change in the quality of education.

Similarly the teaching load of staff is unchanged. Staff are not required to teach any more hours, nor, apart from lectures, do they face larger groups. The increase in the number of teaching meetings that must be mounted, is met by a pro rata increase in staff numbers. It is assumed that work ancilliary to the actual teaching, such as preparation and marking, increases in direct proportion to the number of teaching meetings, although in practice it is unlikely that preparatory work will increase to anything like the same proportion. To this extent the results underestimate the potential economies, as maintaining a constant teaching load will cause a reduction in the total undergraduate work-load of an individual staff member, because the extra teaching consists in repeating existing teaching meetings.

1. General Nature of the Results

The results presented in this chapter show substantial economies in staff costs associated with expansion of enrolment.

These economies arise primarily from the increase in the number of students attending each lecture. In each course examined the lecture group size has been described by the School of Study as having no maximum. Although we have come across a few contrary opinions, Schools of Study, when providing data, have generally agreed that an increase in the size of lecture audiences, where there is no *active* participation by students, does not result in any deterioration in the quality of education. An increase in lecture group size, therefore, represents an improvement in efficiency.

A second contributory factor to these economies of scale is the "filling up" process which takes place as enrolment increases. At any level of enrolment not all meetings will be "full", in the sense that the number of students registered may be less than the standard group size. For example, if a particular course contains a class which meets in groups of maximum size 30, and enrolment is currently 50, then the class must be duplicated and there is an effective wastage of ten places; 1/6 of the capacity of the two series of meetings is wasted. If enrolment increases to 60, then no extra meetings are required and the waste is removed; the capacity "fills up".

Even if meetings are not "full" at higher enrolments the significance of the waste is less. With an enrolment of 110 there must be four series of meetings; there are still ten wasted places, but this represents only 1/12 of capacity.

Although the results differ in detail between courses, there is an important similarity common to all. This is illustrated in two ways: firstly by the behaviour of the Staff Cost Index; and secondly by the divergence between staff costs when calculated on the teaching commitment basis, and when based on a constant staff:student ratio.

The Staff Cost Index exhibits the same basic form in all the courses studied, and three characteristics should be noted:

1) it falls as enrolment increases, indicating economies of scale. An increase in enrolment generates a less than proportionate increase in the total number of teaching meetings required to maintain the course structure unchanged. With a constant teaching load per member of staff, the increase in staff numbers is less than proportionate to the increase in student numbers, so that the staff:student ratio deteriorates, and staff cost per student declines.

2) it falls at a decreasing rate. The economies to be achieved from successive equal increases in student numbers get smaller and smaller.

3) the fall is punctuated by sharp rises at regular intervals. These periodic jumps give the Index its characteristic "sawedge" shape, and the enrolment levels at which they occur correspond to the points at which particular series of meetings must be repeated. Thus if a class of 40 meets 120 times per year, there will be an increase of 120 in the number of meetings every time enrolment passes a multiple of 40. In many courses several different elements of the course have the same maximum group size, causing very big increases in the number of meetings at intervals. Very often enrolment must be expanded a considerable way beyond one of these jump-points, before the Index falls back to its value immediately before the jump.

The second aspect of the similarity between courses is the divergence between staff costs when calculated on the teaching commitment basis, and when based on a constant staff:student ratio. In all the courses studied the former fell below the latter as enrolment increased.

The general pattern to emerge from the study is that an expansion of enrolment may be accompanied by a deterioration in the staff:student ratio, which results in economics in cost-per-student, without either impairing the quality of education by altering the course structure, or increasing the average teaching load of staff.

Before attempting to generalise as to the extent to which the staff:student ratio may deteriorate, or the level of savings that might be expected, it is necessary to present the results of the courses individually.

2. Individual Courses

The results for each course are presented in the form of:

a) a brief commentary noting the principal findings

b) a table showing savings in total economic cost per student as defined in Part 2, i.e. after deducting staff costs attributable to research (corresponding to Table 4.6)

c) a graph showing the Staff Cost Indix, the staff:student ratio and staff cost per student, based on the estimated teaching load at Bradford. (This corresponds to Figure 4.4 in Chapter 4.) This includes the full cost of staff.

d) a graph showing total staff requirements and cost compared with expansion based on national average staff:student ratio (corresponding to Figure 4.5). This includes the full cost of staff.

PHARMACOLOGY

Current Enrolment: 9

Jump-points: Multiples of 12 students

Staff Cost Index: Falls to 75% at enrolment of 12, then jumps to 99%. Expansion to 24 students causes the index to fall to 55%.

Effects of Expansion to 24 students per year:

1) In terms of the estimated Bradford teaching load of 210 hours per year:

   a) staff:student ratio may deteriorate from 1:3.3 with 9 students, to 1:6.0 with 24 students

   b) full academic staff cost per student falls from £3123 to £1715, a saving of £1408

2) In terms of the national average weighted staff:student ratio of 1:7.04:

   If the ratio is held constant, total equivalent staff numbers rise from 3.7 to 10.2, compared with only 5.4 if calculated on a teaching commitment basis. This represents a total saving of £16,500 per annum.

3) In terms of unit costs defined in Part 2, total economic cost per student falls 8.3%.

Table 5.1 Pharmacology: Economic Cost-per-Student at Various Enrolments (after excluding costs attributable to other activities)

	Annual Enrolment			
	9 (current)	12	18	24
Staff Cost Index	100	75	72	55
Academic Staff Cost (£)	549	411	395	302
Academic Staff Offices (£)	57	43	41	30
Total Cost per Student (£)	3294	3142	3124	3020
% Saving in Cost-per-Student	-	4.6%	5.1%	8.3%

FIGURE 5·1 : STAFF COST PER STUDENT

(PHARMACOLOGY)

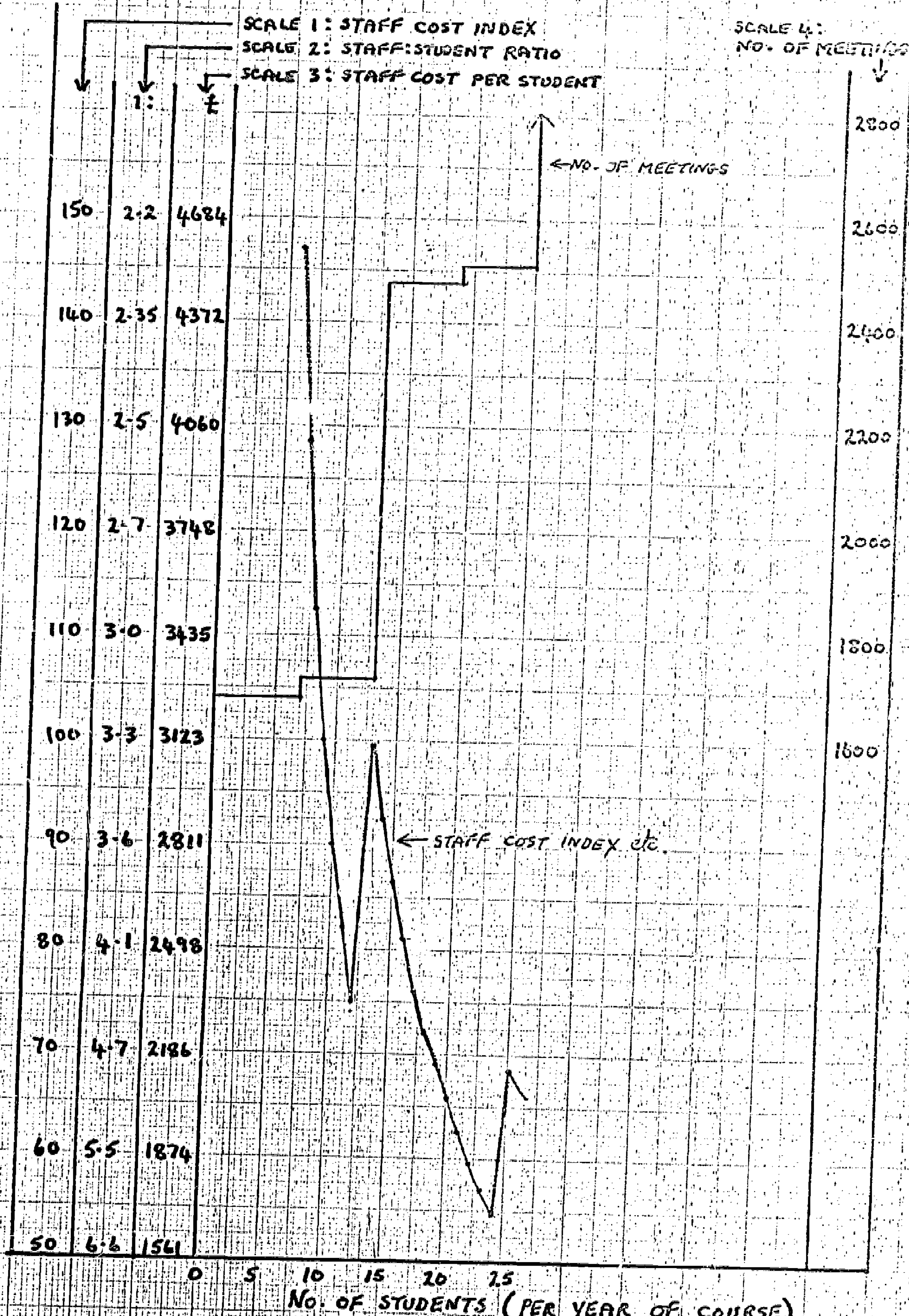
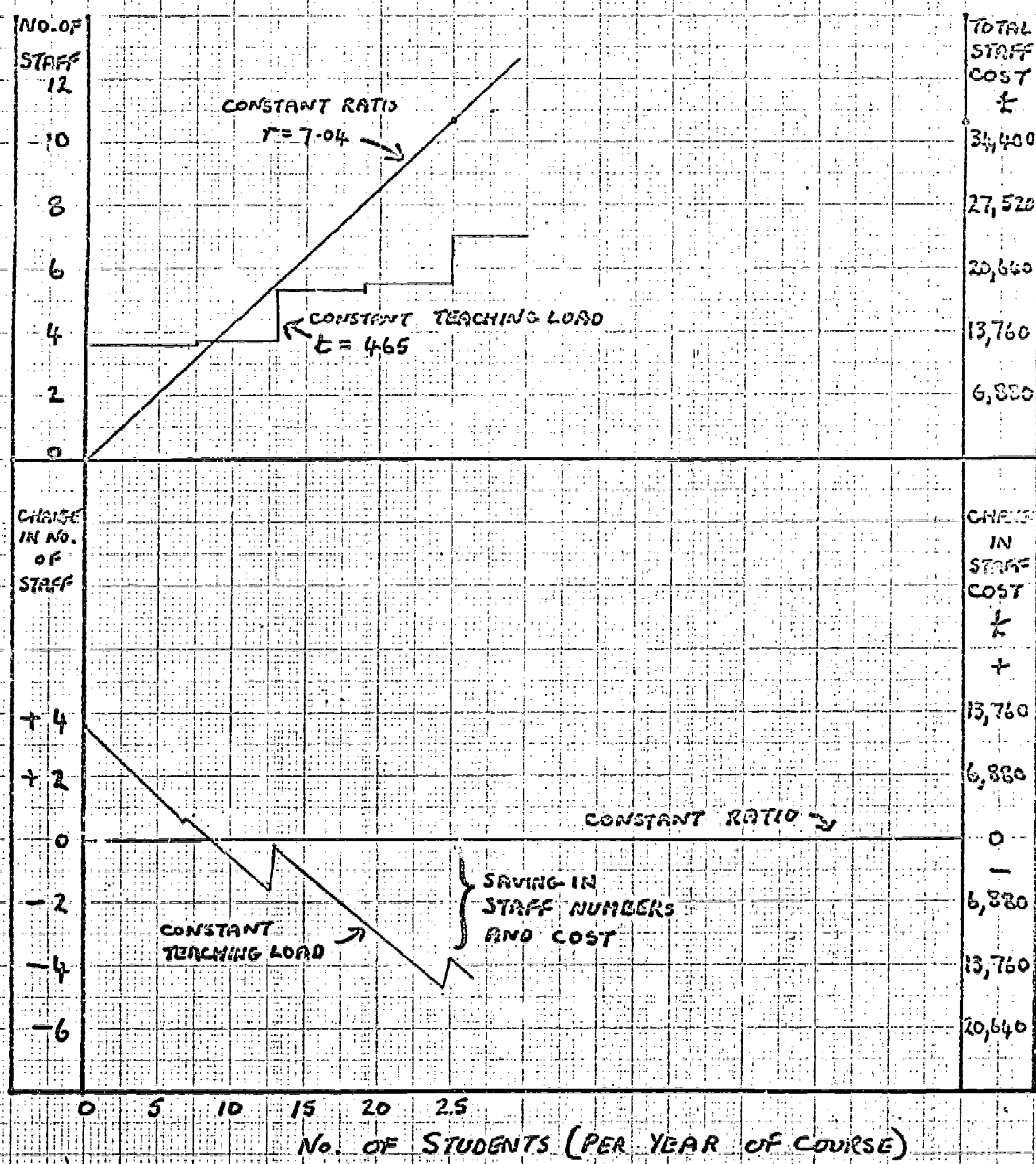


FIGURE 5·2 : STAFF REQUIREMENTS AND COST

(PHARMACOLOGY)



CHEMICAL ENGINEERING

(Two intakes of students annually. Quoted figures of numbers of students and numbers of meetings relate to a single intake only.)

Current, Half-yearly, enrolment: 40

Jump-points: Multiples of 50 students

Staff Cost Indix: Falls to 84% at enrolment of 50, then jumps to 107%. Student numbers must increase to beyond 67 before the Index falls below 84% again.

Effect of Expansion to 100 students per half-yearly intake:

1) In terms of the estimated Bradford Teaching load of 210 hours per year:

   a) staff:student ratio may deteriorate from 1:19.4 with 40 students to 1:31.4 with 100 students

   b) full academic staff cost per student falls from £530 to £328, a saving of £202.

2) In terms of the national average weighted staff: student ratio of 1:12.38:

   If the ratio is held constant, total equivalent staff numbers rise from 25.8 to 64.6, compared with only 40.0 if calculated on a teaching commitment basis. This represents a total saving of £42,300 per half-year.

3) In terms of the unit costs defined in Part 2, total economic cost per student falls by 9.9%

Table 5.2 Chemical Engineering: Economic Cost-per-Student at Various Enrolments
(after excluding costs attributable to other activities)

	Half-Yearly Enrolment			
	40(current)	50	80	100
Staff Cost Index	100	84	73	62
Academic Staff Cost (£)	617	518	450	383
Academic Staff Offices (£)	52	44	38	32
Total Cost-per-Student (£)	2557	2450	2376	2303
% Saving in Cost-per-Student	-	4.2%	7.1%	9.9%

FIGURE 5.3 STAFF COST PER STUDENT (CHEMICAL ENGINEERING)

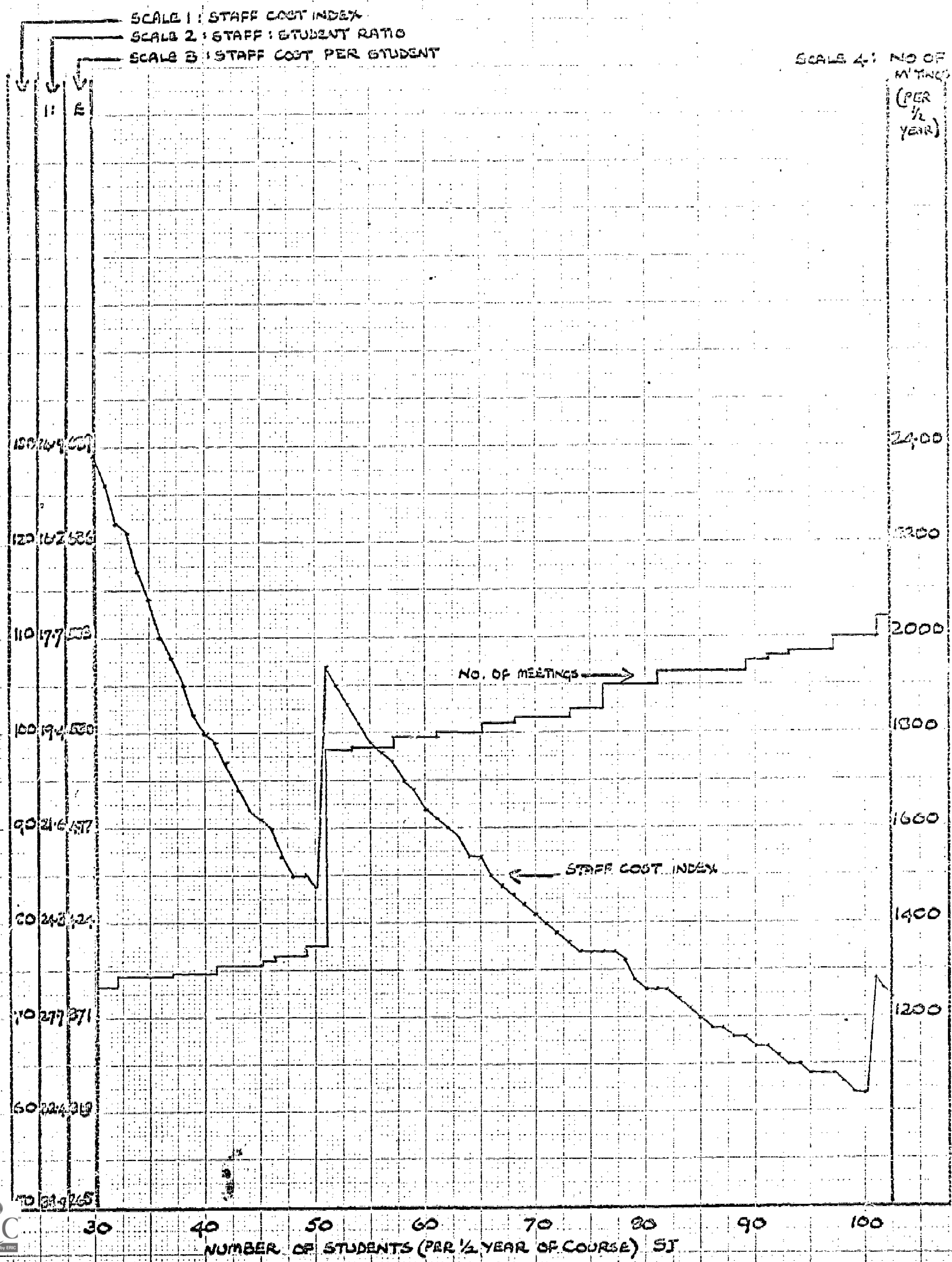
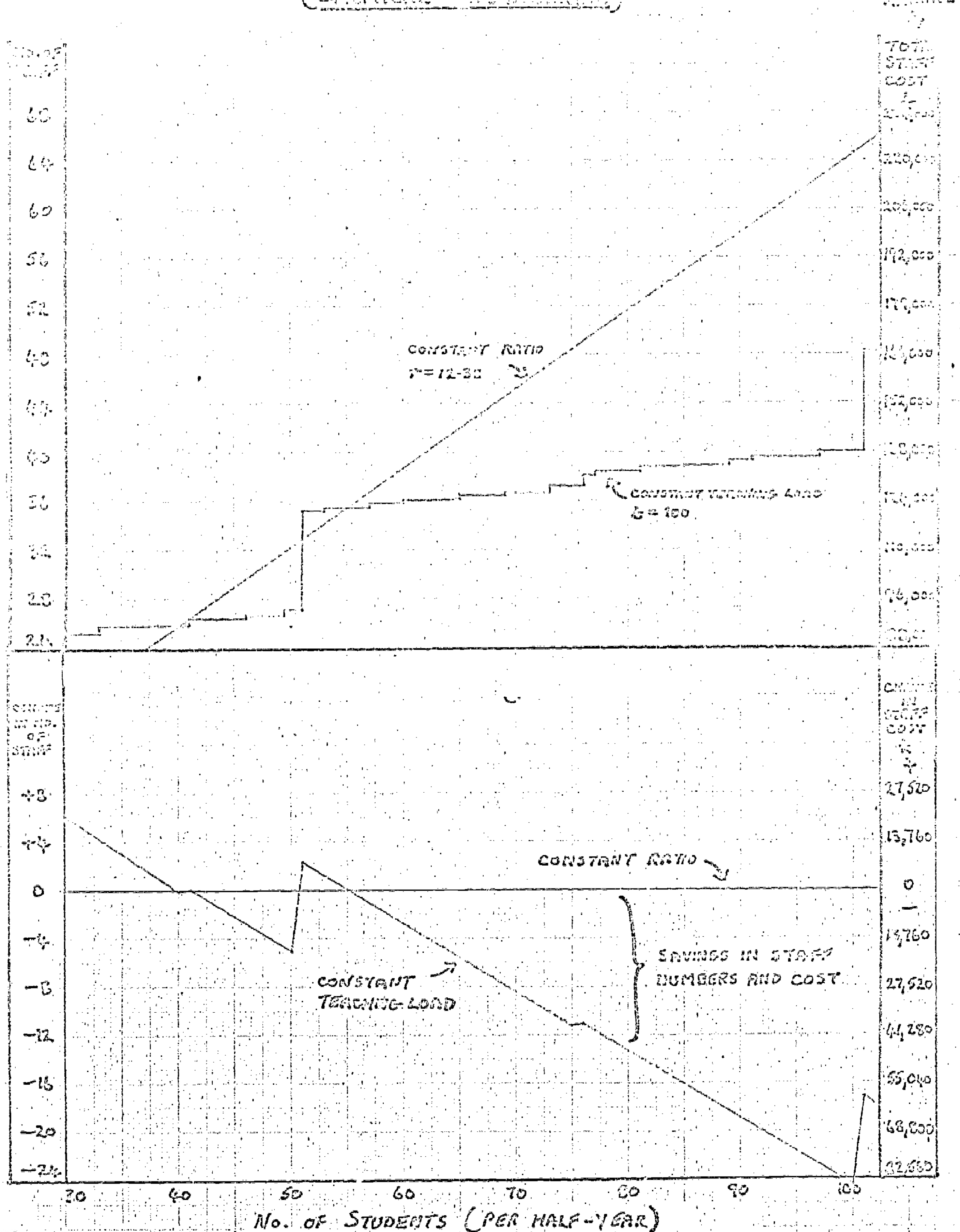


FIGURE 5-A : STAFF REQUIREMENTS AND COST

(CHEMICAL ENGINEERING)



COLOUR CHEMISTRY

Current Enrolment: 21

Jump-points: Multiples of 30 students. Individual tutorials cause the total number of meetings to increase with every single increase of intake.

Staff Cost Index: Falls to 74% at enrolment of 30, then jumps to 91%. Students must increase to beyond 40 before Index falls below 70% again.

Effect of Expansion to 60 students per year:

1) In terms of the estimated Bradford Teaching load of 210 hours per year:

   a) staff:student ratio may deteriorate from 1:5.0 with 21 students to 1:9.6 with 60 students

   b) full academic staff cost per student falls from £2058 to £1060, a saving of £998

2) In terms of the national average weighted staff: student ratio of 1:11.09:

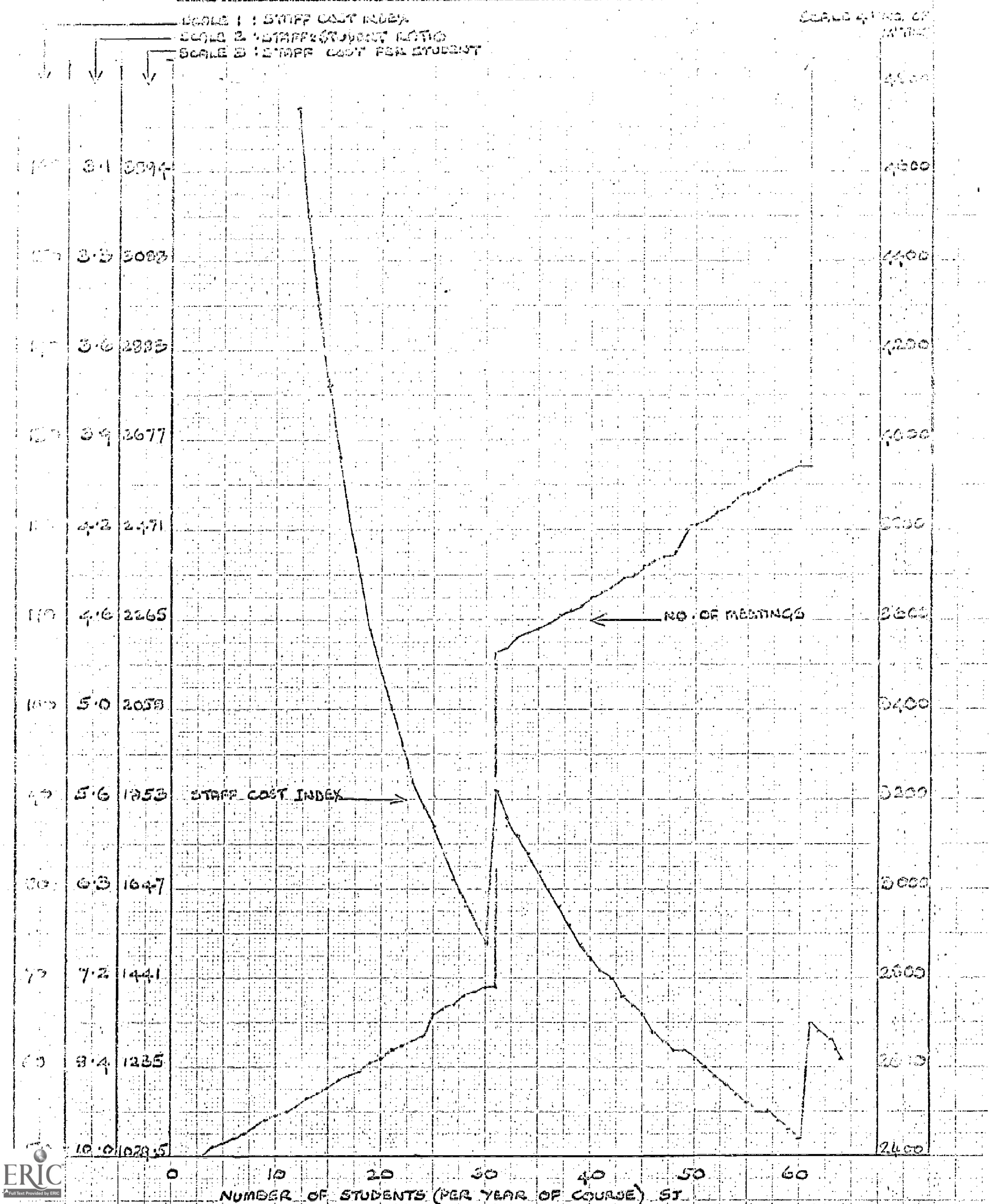
   If the ratio is held constant, total equivalent staff numbers rise from 5.6 to 16.2, compared with only 8.3 if calculated on a teaching commitment basis. This represents a saving of £27,200 per year.

3) In terms of the unit costs defined in Part 2, total economic cost per student falls by 10.4%.

Table 5.3 Colour Chemistry: Economic Cost-per-Student at Various Enrolments
(after excluding costs attributable to other activities)

	Annual Enrolment			
	21(current)	30	45	60
Staff Cost Index	100	74	66	52
Academic Staff Cost (£)	785	581	518	408
Academic Staff Offices(£)	63	47	42	33
Total Cost-per-Student(£)	3918	3698	3630	3511
% Saving in Cost-per-Student	–	5.6%	7.3%	10.4%

FIGURE 5·5 STAFF COST PER STUDENT



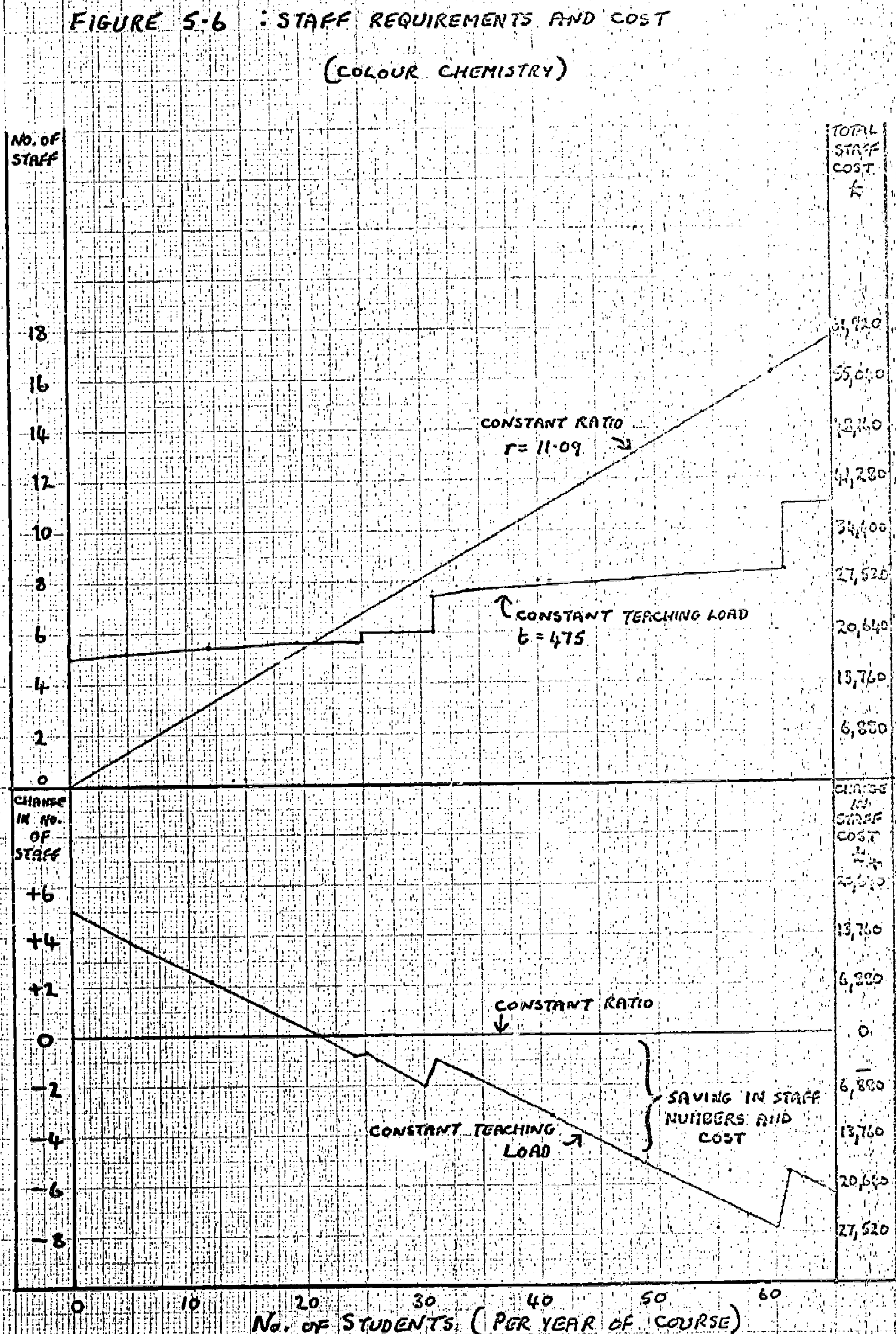


FIGURE 5-6 : STAFF REQUIREMENTS AND COST
(COLOUR CHEMISTRY)
NO. OF STAFF
TOTAL STAFF COST £
18
16
14
12
10
8
6
4
2
0
CONSTANT RATIO
r = 11·09
CONSTANT TEACHING LOAD
t = 475
20,640
13,760
6,880
27,520
CHANGE IN NO. OF STAFF
CHANGE IN STAFF COST £
+6
+4
+2
0
-2
-4
-6
-8
CONSTANT RATIO
SAVING IN STAFF NUMBERS AND COST
CONSTANT TEACHING LOAD
0
10
20
30
40
50
60
No. OF STUDENTS (PER YEAR OF COURSE)

CIVIL ENGINEERING

Current Annual Enrolment: 66

Jump-points: Major jumps at multiples of 40 students; smaller jumps at multiples of 20 and 30

Staff Cost Index: Falls to 83% at enrolment of 80, then jumps to 99%. Students must increase to beyond 105 before the index falls below 83% again.

Effects of Expansion to 120 students per year:

1) In terms of the estimated Bradford teaching load of 210 hours per year:

   a) staff:student ratio may deteriorate from 1:9.24 with 66 students, to 1:13.0 with 120 students

   b) full academic staff cost per student falls from £1085 to £774, a saving of £311

2) In terms of the national average weighted staff:student ratio of 1:12.38:

   If the ratio is held constant, total equivalent staff numbers rise from 16.0 to 29.1 compared with only 20.7 if calculated on a teaching commitment basis. This represents a total saving of £28,900 per annum.

3) In terms of the unit costs defined in Part 2, total economic cost per student falls 6%.

Table 5.4 Civil Engineering: Economic Cost-per-Student at Various Enrolments
(after excluding costs attributable to other activities)

	Annual Enrolment				
	66(Current)	80	90	100	120
Staff Cost Index	100	83	89	82	71
Academic Staff Cost (£)	458	380	408	375	325
Academic Staff Offices(£)	57	47	51	46	40
Total Cost-per-Student(£)	2509	2421	2453	2415	2359
% Saving in Cost-per-Student	-	3.5%	2.2%	3.7%	6.0%

(The graphs have already been presented - see Chapter 4 Figures 4.4 and 4.5)

COMPUTER SCIENCE

(1 year postgraduate course; students weighted '3')

Current Annual Enrolment: 12

Jump-points: Multiples of 6 students

Staff Cost Index: Is in a trough with the current enrolment of 12. Jumps to 103% immediately and falls to 74% with 18 students. Expansion to 24 students causes the index to fall to 63%, and continued expansion shows further falls.

Effect of expansion to 24 students per year:

1) In terms of the estimated Bradford teaching load of 132 hours per year:

a) weighted staff:student ratio may deteriorate from 1:5.6 with 12 students, to 1:8.9 with 24 students

b) full academic staff cost per student falls from £1850 to £1165, a saving of £685.

2) In terms of the national average weighted staff: student ratio of 1:12.07:

If the ratio is held constant, total equivalent staff numbers rise from 3.0 to 6.0 compared with only 3.8 if calculated on a teaching commitment basis. This represents a total saving of £7,600 per year.

3) The present unit economic cost of the course is not available.

FIGURE 5·7 : STAFF COST PER STUDENT

(COMPUTER SCIENCE)

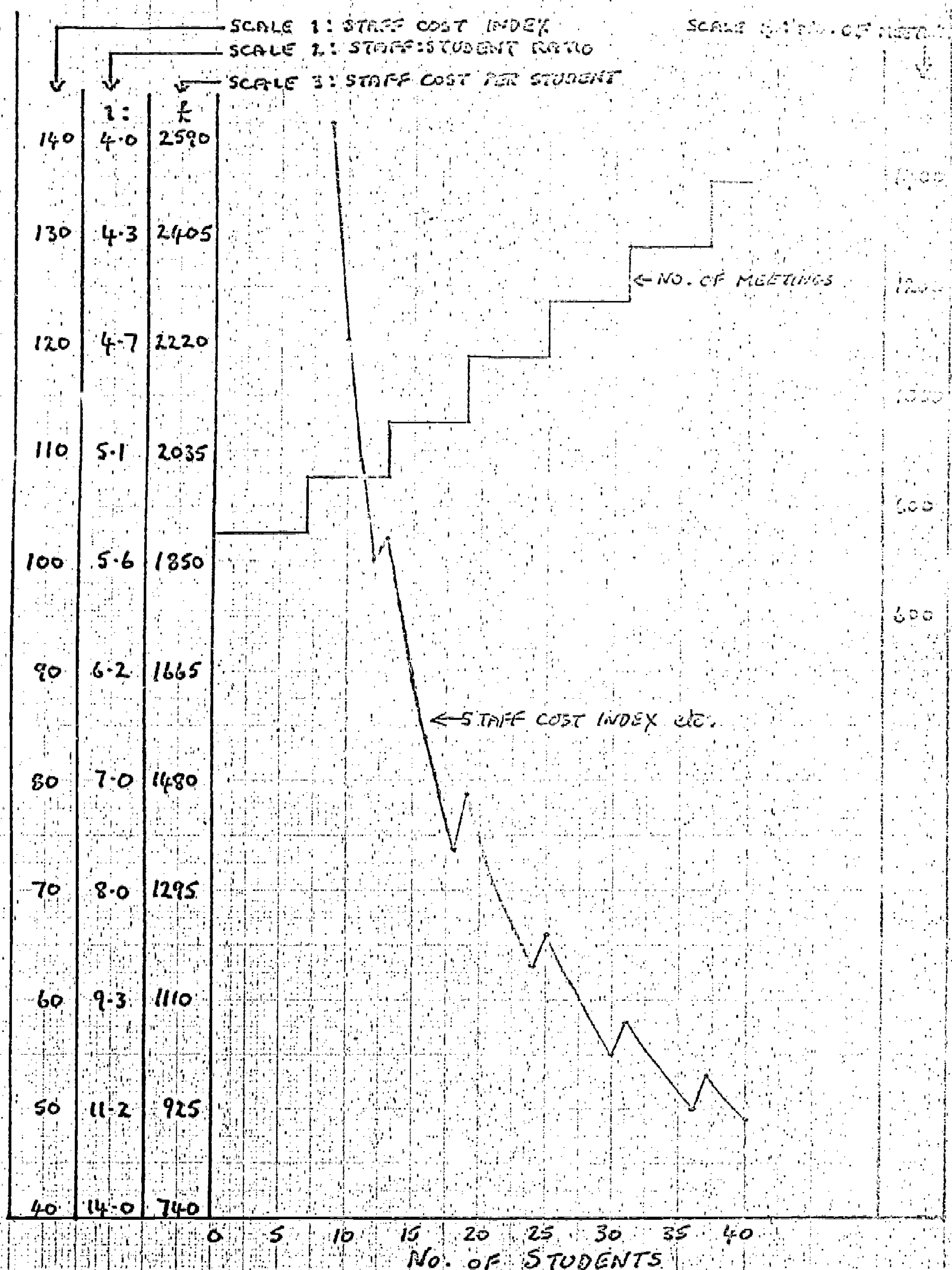
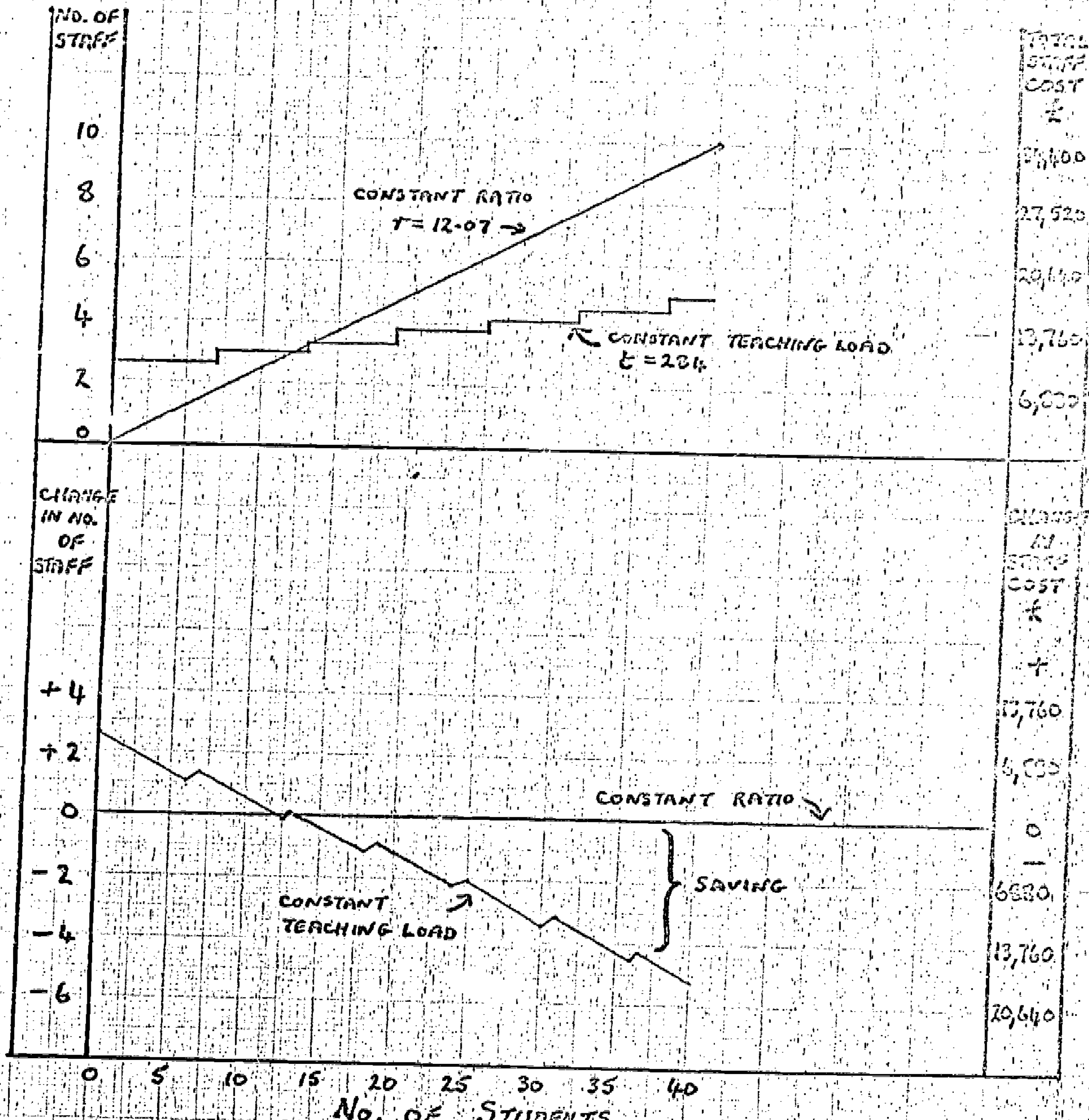


FIGURE 5·8 : STAFF REQUIREMENTS AND COST

(COMPUTER SCIENCE)



SOCIAL SCIENCES

Current Enrolment: 120

Jump-points: Irregular, due to the range of optional subjects

Staff Cost Index: Falls at the general rate of approximately 5% for every additional 30 students, but punctuated with frequent, irregular and small jumps.

Effect of Expansion to 240 students per year:

1) In terms of the estimated Bradford teaching load of 280 hours per year:

   a) staff:student ratio may deteriorate from 1:16.8 with 120 students to 1:21.5 with 240 students

   b) full academic staff cost per student falls from £615 to £480, a saving of £135.

2) In terms of the national average weighted staff: student ratio of 1:13.47:

   If the ratio is held constant, total equivalent staff numbers rise from 26.7 to 53.4 compared with only 41.7 if calculated on a teaching commitment basis. This represents a total saving of £40,200 per year.

3) In terms of the unit costs defined in Part 2, total economic cost per student falls 6.2%.

Table 5.5 Social Sciences: Economic Cost-per-Student at Various Enrolments
(after excluding costs attributable to other activities)

	Annual Enrolment			
	120(current)	160	200	240
Staff Cost Index	100	92	82	78
Academic Staff Cost (£)	406	375	334	318
Academic Staff Offices (£)	60	55	49	47
Total Cost-per-Student (£)	1632	1596	1549	1531
% Saving in Cost-per-Student	-	2.2%	5.1%	6.2%

FIGURE 5·9 STAFF COST PER STUDENT (SOCIAL SCIENCES)

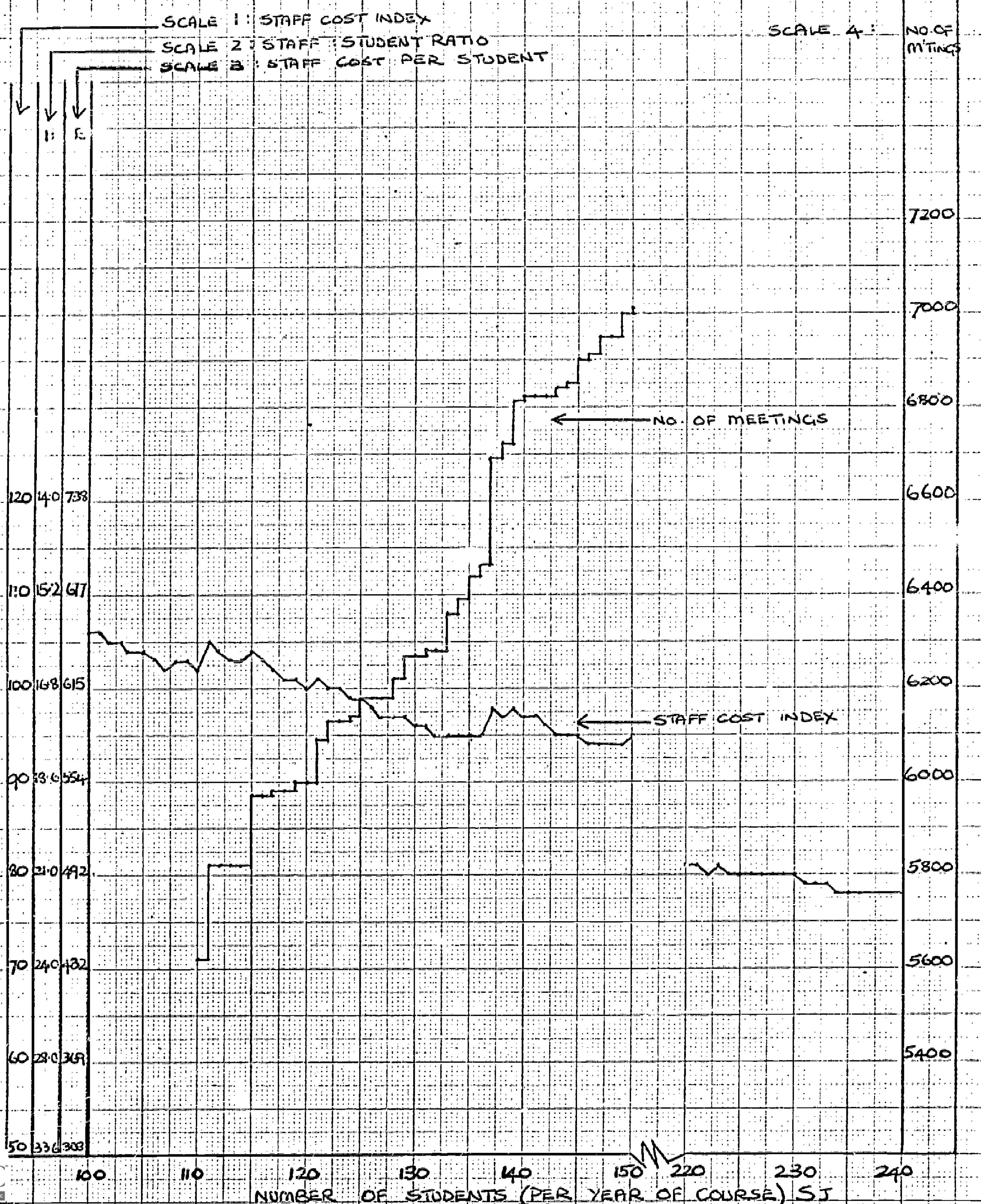
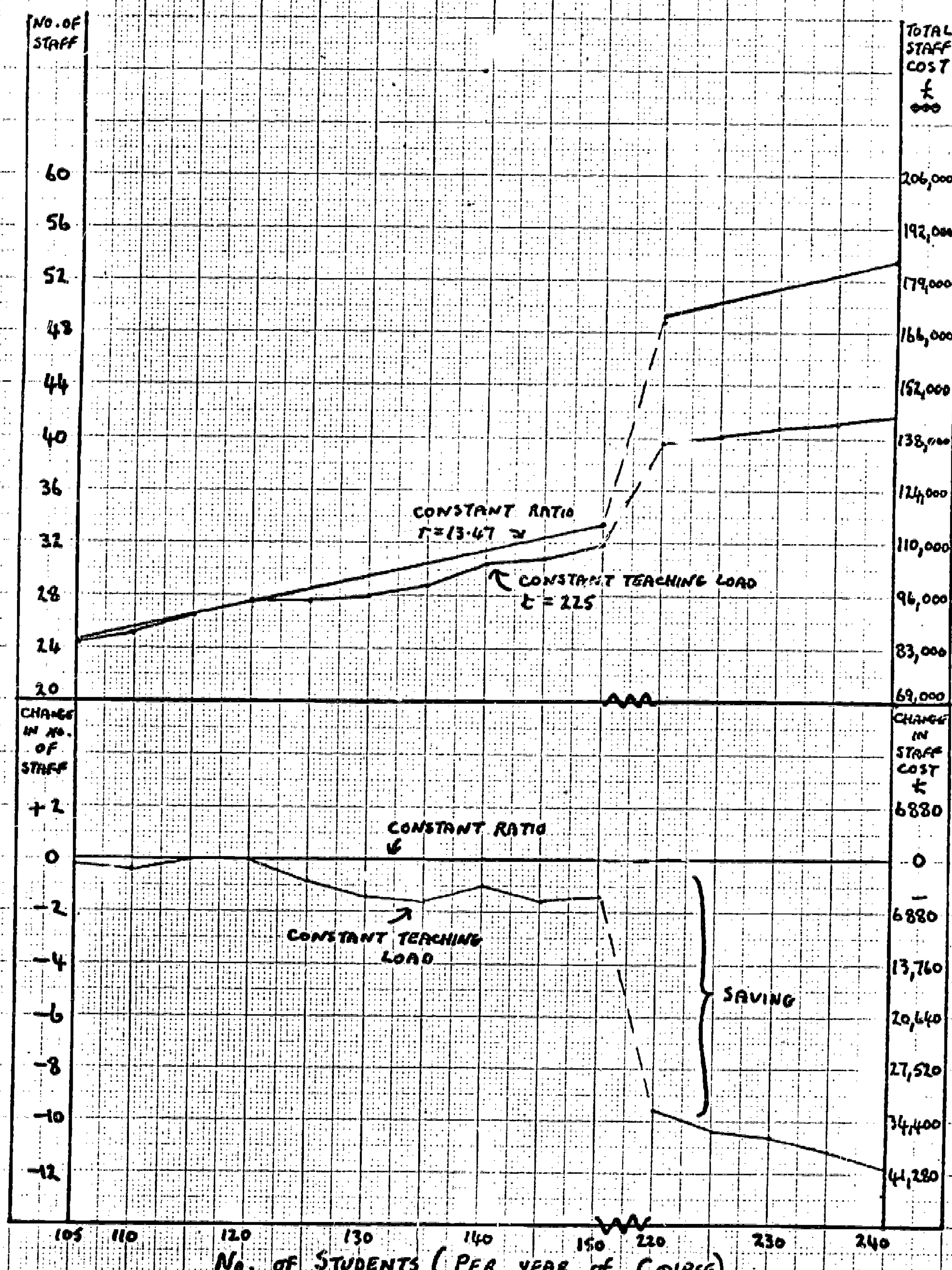


FIGURE 5-10 : STAFF REQUIREMENTS AND COST

(SOCIAL SCIENCES)



APPLIED PHYSICS

Current Enrolment: 22

Jump-points: Multiples of 16 students. Also at 40.

Staff Cost Index: Falls to 85% at enrolment of 32, then small jump to 88%. Expansion to 48 students causes the index to fall to 78%.

Effect of Expansion to 48 students per year:

1) In terms of the estimated Bradford teaching load of 210 hours per year:

   a) staff:student ratio may deteriorate from 1:4.1 with 22 students, to 1:5.2 with 48 students.

   b) full academic staff cost per student falls from £3346 to £2610, a saving of £736.

2) In terms of the national average weighted staff: student ratio of 1:11.09:

   If the ratio is held constant, total equivalent staff numbers rise from 7.9 to 17.5, compared with only 13.4 if calculated on a teaching commitment basis. This represents a total saving of £14,100 per annum.

3) In terms of unit costs defined in Part 2, total economic cost per student falls 4.6%.

Table 5.6 Applied Physics: Economic Cost-per-Student at Various Enrolments
(after excluding costs attributable to other activities)

	Annual Enrolment		
	22(current)	32	48
Staff Cost Index	100	85	78
Academic Staff Cost (£)	743	632	580
Academic Staff Offices (£)	40	35	32
Total Cost-per-Student (£)	3682	3566	3511
% Saving in Cost-per-Student	-	3.2%	4.6%

FIGURE 5.11 : STAFF COST PER STUDENT

(APPLIED PHYSICS)

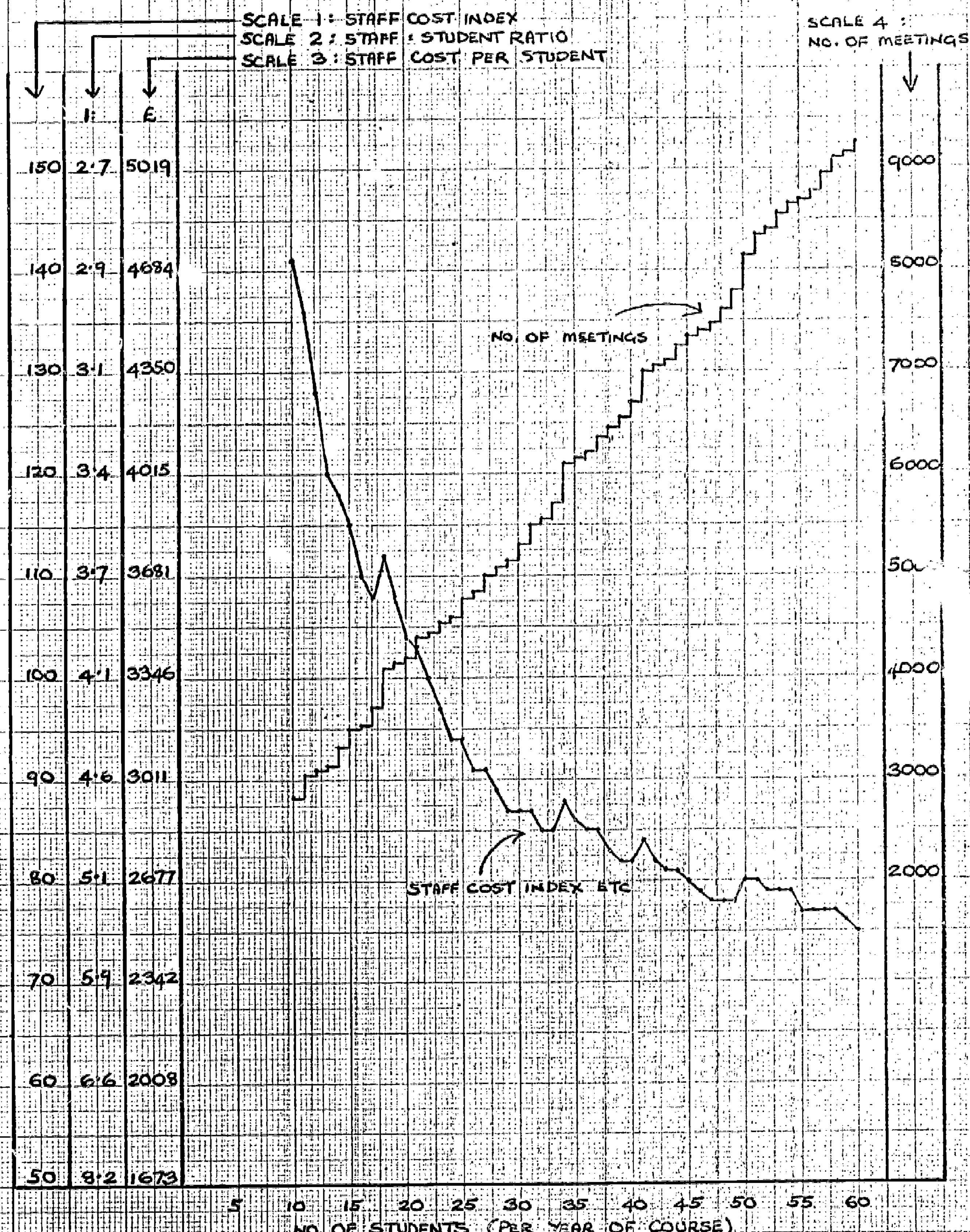
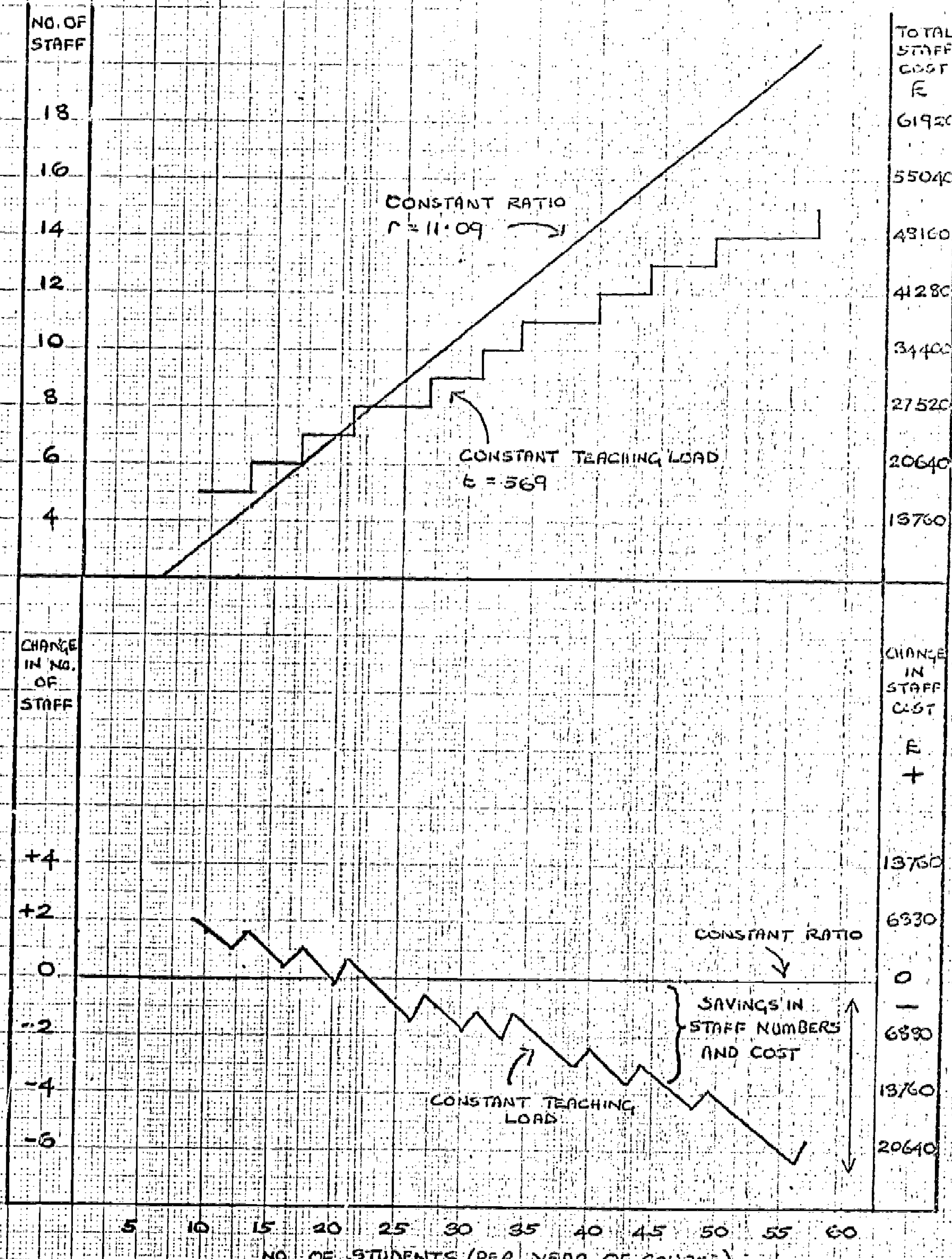


FIGURE 5.12 : STAFF REQU[illegible]EMENTS AND COST

(APPLIED PHYSICS)



APPLIED BIOLOGY

Current Enrolment: 33

Jump-points: Multiples of 30, with smaller jumps every 20 students.

Staff Cost Index: Falls to 83% at enrolment of 40 and 59% at enrolment of 60 students. Then jumps to 76% and enrolment must expand to 86 students before index falls to 59% again.

Effect of Expansion to 60 Students per year:

1) In terms of the estimated Bradford teaching load of 210 hours per year:

   a) staff:student ratio may deteriorate from 1:4.1 with 33 students to 1:6.7 with 60 students.

   b) full academic staff cost per student falls from £2455 to £1447, a saving of £1008.

2) In terms of the national average weighted staff:student ratio of 1:10.71:

   If the ratio is held constant, total equivalent staff numbers rise from 8.4 to 16.8, compared with only 12.5 if calculated on a teaching commitment basis. This represents a total saving of £14,800 per annum.

3) In terms of the unit costs defined in Part 2, total economic cost per student falls by 13.1%.

Table 5.7 Applied Biology: Economic Cost-per-Student at Various Enrolments
(after excluding costs attributable to other activities)

	Annual Enrolment		
	33(current)	45	60
Staff Cost Index	100	78	59
Academic Staff Cost (£)	946	738	558
Academic Staff Offices (£)	57	45	35
Total Cost-per-Student (£)	3110	2890	2700
% Saving in Cost-per-Student	-	7.1%	13.1%

FIGURE 5.13 : STAFF COST PER STUDENT (APPLIED BIOLOGY)

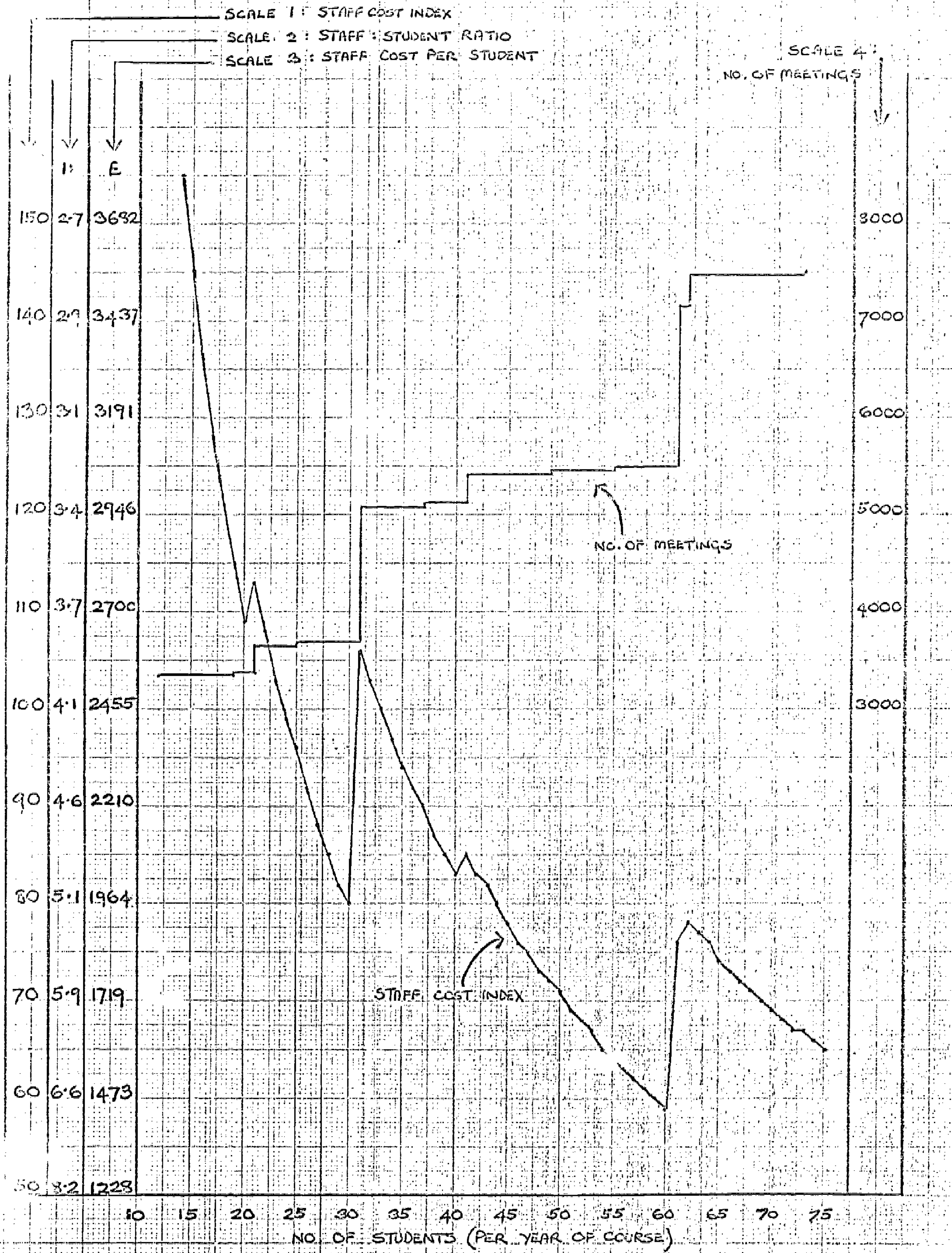
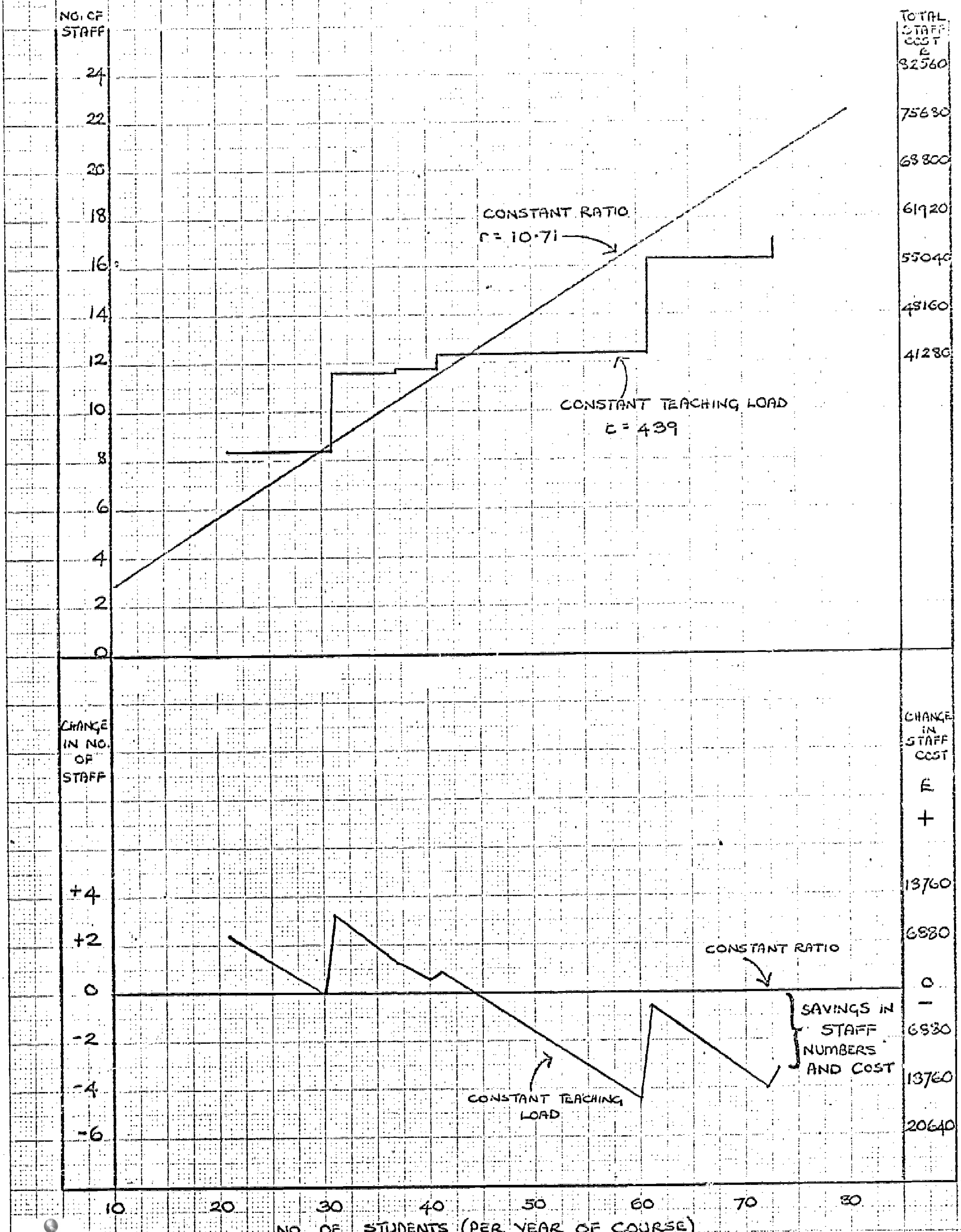


FIGURE 5.14: STAFF REQUIREMENTS AND COST

(APPLIED BIOLOGY)



MATERIALS SCIENCE

Current Enrolment: 21

Jump-points: Multiples of 20 students, with smaller jumps every 2 students.

Staff Cost Index: Falls to 82% at enrolment of 40, then jumps to 87%. Falls to 78% at enrolment of 60.

Effect of Expansion to 40 students per year:

1) In terms of the estimated Bradford teaching load of 210 hours per year:

   a) staff:student ratio may deteriorate from 1:4.2 with 21 students to 1:5.1 with 40 students.

   b) full academic staff cost per student falls from £3292 to £2700, a saving of £592.

2) In terms of the national average weighted staff: student ratio of 1:11.09:

   If the ratio is held constant, total equivalent staff numbers rise from 7.2 to 14.4, compared with only 13.1 if calculated on a teaching commitment basis. This represents a saving of £4,400 per annum.

3) In terms of the unit costs defined in Part 2, total economic cost per student falls 5.0%.

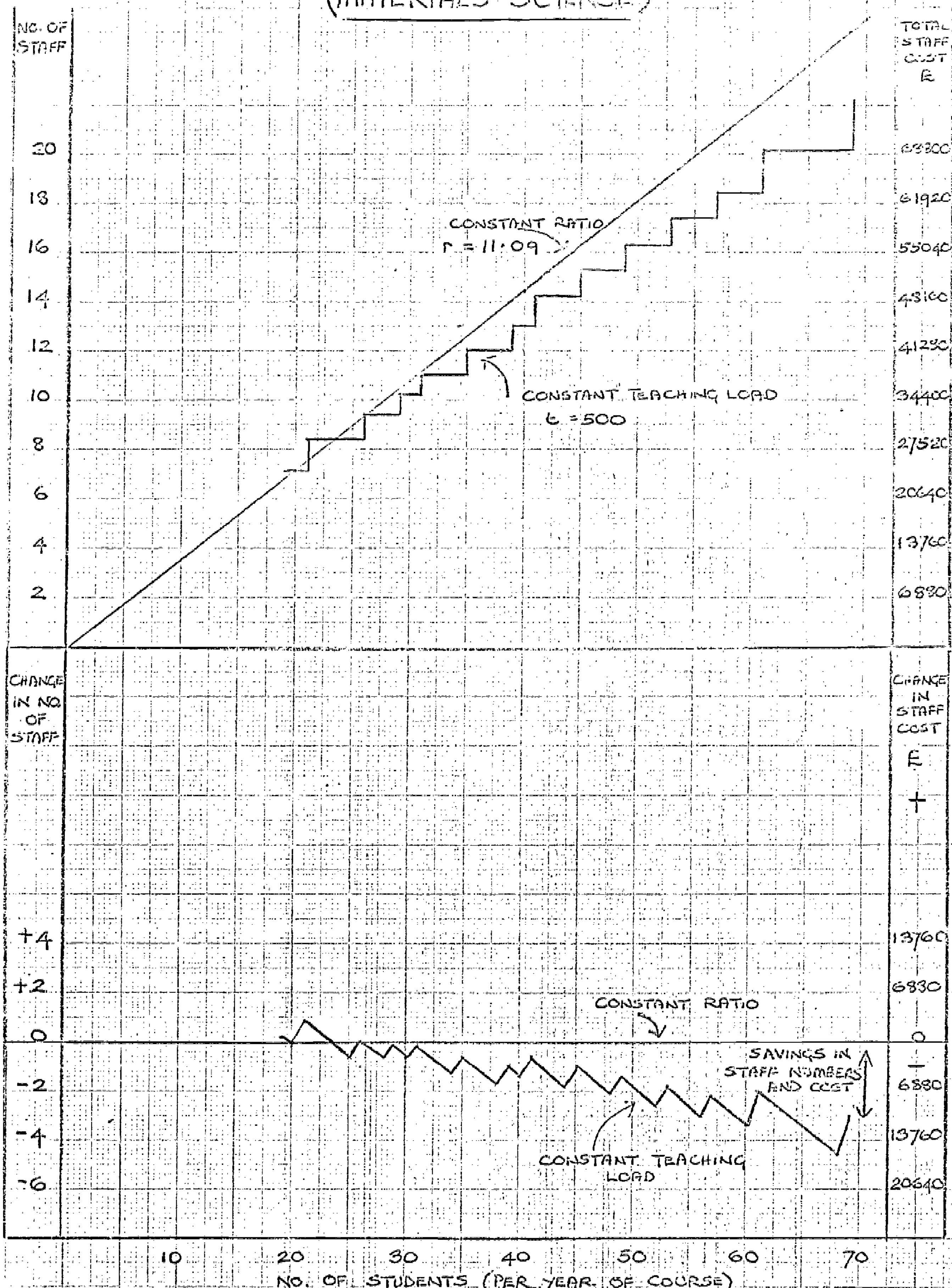
Table 5.7 Materials Science: Economic Cost-per-Student at Various Enrolments
(after excluding costs attributable to other activities)

	Annual Enrolment		
	21(current)	30	40
Staff Cost Index	100	87	82
Academic Staff Cost (£)	982	854	805
Academic Staff Offices (£)	40	35	33
Total Cost-per-Student (£)	3680	3547	3496
% Saving in Cost-per-Student	-	3.6%	5.0%

FIGURE 5.15 : STAFF COST PER STUDENT (MATERIALS SCIENCE)

FIGURE 5.16 : STAFF REQUIREMENTS AND COST

(MATERIALS SCIENCE)



Conclusions

1) Major Jump-points

The points at which upward jumps in staff costs per student occur, differ between courses:

Chemical Engineering	multiples of 50 students
Civil Engineering	multiples of 40 students
Applied Biology	multiples of 30 students
Colour Chemistry	multiples of 30 students
Materials Science	multiples of 20 students
Applied Physics	multiples of 16 students
Pharmacology	multiples of 12 students
Computer Science	multiples of 6 students
Social Sciences	irregular

Since the increases in cost-per-student that occur at these points are substantial, it is important that enrolment should be at a level which coincides with a trough in the Staff Cost Index, i.e. at a level immediately below one of these jump-points.

As these points differ between courses, it is vital, when considering expansion of student numbers, that courses should be studied individually, and the appropriate target enrolment set for each course. The application of blanket proportionate increases to whole groups of courses could be most uneconomic.

2) Scale of Likely Economies

Table 5.6 summarises the potential economies to be obtained from exp^nsion of student numbers. The expansion applied to each of the courses is an approximate doubling. The new levels of enrolment have been carefully chosen to coincide with a "trough" in the Staff Cost Index.

Table 5.6 Effects of an Approximate Doubling of Student Numbers

Course	Staff Cost Index %	Saving in Total Economic Cost per Student %	Total Annual Savings compared with expansion holding staff: student ratio constant £
Pharmacology	55	8.3	16,500
Chemical Engineering	62	9.9	84,600
Colour Chemistry	52	10.4	27,200
Civil Engineering	71	6.0	28,900
Computer Science	63	n.a.	7,600
Social Sciences	78	6.2	40,200
Applied Physics	78	4.6	14,100
Applied Biology	59	13.1	14,800
Materials Science	82	5.0	4,400

The Staff Cost Index may be expected to fall to between 52% and 82%, with an approximate doubling of enrolment, provided a suitable point is chosen. This implies equal proportionate deterioration in the staff: student ratio and in staff-cost per student. It must again be emphasised that the "deterioration" in the staff:student ratio represents improved efficiency, as there is no adverse change in course structure, nor any increase in average staff teaching load.

When weighted by the number of students on each course, the average value of the Staff Cost Index on the nine courses falls to 69% with an approximate doubling of enrolment to an optimum point. If this sample of courses is typical of all U.K. University courses, then the overall weighted[1] staff:student ratio for all U.K. Universities and all subject groups, which in 1968/69 was 1:11.57, could "deteriorate" to 1:16.71 with an approximate doubling of student numbers provided an optimum point were chosen for each course.

In terms of the unit economic costs defined in Part 2 (excluding costs attributable to research, but including annual costs of buildings and equipment), these economies imply reductions of between 5.0% and 13.1%. Savings of this order are substantial and represent reductions in current expenditures. When weighted by the number of students on each course, the average saving in economic cost per student is 7.7%.

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1 Using conventional U.G.C. weights for postgraduates.

The final column of Table 5.6 shows the total annual financial savings obtained by expanding the courses on the basis of holding the average teaching load constant (and consequently allowing the staff: student ratio to "deteriorate"), compared with expanding them maintaining a constant staff:student ratio. The ratio used is the national average weighted staff:student ratio for the appropriate subject group in 1968/69[2]. These savings are calculated by first costing the extra staff that would be required if the relevant national average ratio were maintained, and then subtracting from this figure, the cost of the (fewer) extra staff required to hold average teaching load constant. The very high savings in Chemical Engineering reflect the double-entry of students each year, and the fact that "doubling" of intake to an optimum point in fact involves an increase to two and a half times the present intake.

The total annual financial savings for the nine courses amount to £238,300. At the increased level of enrolment the saving would be £520 for each fo the 384 students enrolled each year.

3) Recommendation

The use of the Staff Cost Index to assess staff requirements is especially useful at a time of expansion. It is sometimes objected that the use of teaching commitment to measure staff requirements would encourage professors to intensify the teaching of their courses by increasing contact hours and diminishing the size of teaching groups, in order to obtain more staff for other activities such as research. In the context of expanding existing courses this objection does not apply. In the calculations in this chapter, course structure has been held constant, and staff requirements increase less than student numbers. The U.G.C., in considering universities' requests for additional staff to back the expansion, and universities, in allocating staff to departments, could similarly assume that the existing course structure be maintained, and make their allocations on that basis. Universities, and departments, would not be entitled to claim extra staff simply in order to intensify the teaching content of their courses.

Such a system enables the relative requirements of different sorts of courses (conventional 3-year courses, thick sandwich courses, thin sandwich courses, part-time courses, etc.) to be measured more accurately than by the present system of norms with essentially arbitrary weightings for different types of course.

<u>The economies identified above indicate that supporting expansion with a constant staff:student ratio results in more staff being allocated than are necessary to maintain the existing average teaching load of staff. In view of this it is strongly recommended that consideration be given to using a teaching commitment basis rather than a staff:student ratio basis in calculating the extra staff necessary to support expansion of student numbers.</u>

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2 See Appendix 4 for details.

CHAPTER 6

Economies Arising from Changing the Structure of Courses

In this chapter, four methods of changing the course structure are combined, and applied to some individual courses. Student enrolment on each course is held constant as each parameter is varied separately. The four parameters are:-

1) the total number of contact hours per student embodied in the course, i.e. the number of hours teaching a student receives each week.

2) the number of optimal subjects taught within the course.

3) the size of teaching groups, in terms of the maximum number of students that may attend a meeting before it must be repeated.

4) the relative balance of different types of teaching meeting (lectures, classes, tutorials and laboratories) embodied within a fixed total contact hours.

As each of the parameters is varied, the number of teaching meetings that must be provided is calculated. (Reference back to Chapter 4, particular figures 4.2 and 4.3 would be useful at this point)

An Index of the number of meetings is then calculated, which expresses the number of meetings generated by different course structures as a percentage of the number required with the existing structure. This Index may be used as a measure of the proportionate changes in the number and cost of academic staff with different course structures. Subsequently, absolute values are calculated for the full annual financial cost, by using the average teaching loads found in the 1968 survey at Bradford[1], and the average cost figure of £3440 per member of staff. Finally, the economic costs-per-student, as defined in Part 2, are recalculated by altering the academic staff cost element in proportion to the value of the Index.

1) CHANGING THE TOTAL NUMBER OF CONTACT-HOURS PER STUDENT

In this section we investigate the effects of varying the total number of contact-hours per student embodied in the course. By "contact-hours per student" is meant the number of hours teaching of all kinds (lectures, classes, tutorials, laboratories, etc.) received by an individual student on the course during one academic year. Group size maxima are held constant.

The method adopted is to start from the present number of contact hours and make successive 10% additions to and deductions from this figure, covering a range from 10% of the present figure up to 200% of it. Thus if the present number of contact hours received by each student is 600 per year, then successive values from 60 by steps of 60 to 1,200 are used. For each successive figure of contact-hours, the total number of teaching meetings that must be provided is calculated[2], and the effect on cost investigated.

1. See Appendix 4, Table 2, for the loads used for each course.

2. Program VA54DASEYAD. See Appendix 1.

In making the 10% changes in total contact-hours, on the course, the hours of <u>each</u> type of meeting composing the course have been altered by 10%, thus maintaining the same relative balance of types of teaching within the course. The method thus isolates the effects on staff requirements of varying the total contact-hours per student.

Tables 6.1 to 6.9 show for each course at each level of contact-hours, the number of meetings that must be provided, the proportion that this is of the present load, the full staff cost-per-student, and the total annual savings in staff costs compared with the present situation. Figure 6.1 shows the results graphically for two courses. Identical straight line graphs could be drawn for the other courses.

The Tables also show the effect on the economic cost-per-student of these changes in academic staff costs. In these calculations no change in the per-student cost of classroom and laboratory space has been made. This is because, in strict output-budgeting terms, unused resources are allocated to various outputs in proportion to their share of used resources. In-so-far as the extra contact hours are under-utilised teaching accommodation there is no net addition to the university's teaching space, and in-so-far as the accommodation freed with fewer contact hours becomes unused, there is no reduction in the university's teaching space.

Table 6.1 : <u>[illegible] - Effect of Changing Total Contact Hours</u>

	% Change in Total Contact Hours					
	+40%	+20%	Present Number	-20%	-40%	-60%
No. of Meetings Provided	2,402	2,059	1,716	1,372	1,029	686
% of present No. of Meetings	140	120	100	80	60	40
Full Staff Cost-per-Student (£)	4,372	3,748	3,123	2,498	1,874	1,249
Total Annual Financial Saving (£) (+ = saving)	-11,250	-5,625	0	+5,625	+11,250	+16,875
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	769	659	549	439	329	220
Academic Staff Offices(£)	80	68	57	46	34	23
Total Economic Cost-per-Student (£)	3,536	3,415	3,294	3,173	3,052	2,931
% Saving in Cost-per-Student (+ = saving)	-7.4%	-3.7%	0	+3.7%	+7.4%	+11.0%

Table 6.2: Chemical Engineering - Effect of Changing Total Contact Hours

	% Change in Total Contact Hours					
	+40%	+20%	Present Number	-20%	-40%	-60%
No. of Meetings Provided*	1,812	1,553	1,294	1,036	777	518
% of present No. of Meetings	140	120	100	80	60	40
Full Staff Cost-per-Student (£)	742	636	530	424	318	212
Total Annual Financial Savings (£) (+ = saving)	-16,960	-8,480	0	+8,480	+16,960	+25,440
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	844	740	617	494	370	247
Academic Staff Offices (£)	73	62	52	42	31	21
Total Economic Cost-per-Student (£)	2,825	2,691	2,557	2,423	2,289	2,155
% Saving in Cost-per-Student (+ = saving)	-10.4%	-5.2%	0	+5.2%	+10.4%	+15.7%

* per half-year, i.e. for each of the two intakes.

Table 6.3 : Colour Chemistry - Effect of Changing Total Contact Hours

	% Change in Total Contact Hours					
	+40%	+20%	Present Number	-20%	-40%	-60%
No. of Meetings Provided	3,695	3,167	2,639	2,111	1,583	1,056
% of Present No. of Meetings	140	120	100	80	60	40
Full Staff Cost-per Student (£)	2,881	2,469	2,058	1,646	1,235	823
Total Annual Financial Saving (£) (+ = saving)	-17,288	-8,644	0	+8,644	+17,288	+25,932
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	1,099	942	785	628	471	314
Academic Staff Offices (£)	88	76	63	50	38	25
Total Economic Cost-per-Student (£)	4,257	4,088	3,918	3,748	3,579	3,409
% Saving in Cost-per-Student (+ = saving)	-8.6%	-4.3%	0	+4.3%	+8.6%	+12.9%

Table 6.4 : Civil Engineering - Effect of Changing Total Contact Hours

	% Change in Total Contact Hours					
	+40%	+20%	Present Number	-20%	-40%	-60%
No. of Meetings Provided	6,294	5,395	4,496	3,597	2,698	1,798
% of Present No. of Meetings	140	120	100	80	60	40
Full Staff Cost-per Student (£)	1,519	1,302	1,085	868	651	434
Total Annual Financial Savings (£) (+ = saving)	-28,600	-14,300	0	+14,300	+28,600	+42,900
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	641	550	458	366	275	183
Academic Staff Offices (£)	80	68	57	46	34	23
Total Economic Cost-per-Student (£)	2,715	2,612	2,509	2,406	2,303	2,200
% Saving in Cost-per-Student (+ = saving)	-8.2%	-4.1%	0	+4.1%	+8.2%	+12.3%

Table 6.5 : Computer Science - Effect of Changing Total Contact Hours

	% Change in Total Contact Hours					
	+40%	+20%	Present Number	-20%	-40%	-60%
No. of Meetings Provided	1,192	1,022	851	681	511	341
% of Present No. of Meetings	140	120	100	80	60	40
Full Staff Cost-per-Student (£)	2,590	2,220	1,850	1,480	1,110	740
Total Annual Financial Saving (£) (+ = saving)	-8,800	-4,400	0	+4,400	+8,800	+13,200
ECONOMIC COST PER STUDENT	Not Available					

Table 6.6 : Social Sciences - Effect of Changing Total Contact Hours

	% Change in Total Contact Hours					
	+40%	+20%	Present Number	-20%	-40%	-60%
No. of Meetings Provided	8,413	7,211	6,009	4,807	3,605	2,403
% of Present No. of Meetings	140	120	100	80	60	40
Full Staff Cost-per-Student (£)	861	738	615	492	369	246
Total Annual Financial Saving (£) (+ = saving)	-29,520	-14,760	0	+14,760	+29,520	+44,280
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	569	487	406	325	244	162
Academic Staff Offices (£)	84	72	60	48	36	24
Total Economic Cost-per-Student (£)	1,818	1,725	1,632	1,539	1,446	1,353
% Saving in Cost-per-Student (+ = saving)	-11.4%	-5.7%	0	+5.7%	+11.4%	+17.0%

Table 6.7 : Applied Physics - Effect of Changing Total Contact Hours

	% Change in Total Contact Hours					
	+40%	+20%	Present Number	-20%	-40%	-60%
No. of Meetings Provided	6,293	5,394	4,495	3,596	2,697	1,797
% of Present No. of Meetings	140	120	100	80	60	40
Full Staff Cost-per Student (£)	4,684	4,015	3,346	2,677	2,008	1,339
Total Annual Financial Saving (£) (+ = saving)	-29,460	-14,730	0	+14,730	+29,460	+44,190
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	1,040	892	743	594	446	297
Academic Staff Offices (£)	56	48	40	32	24	16
Total Economic Cost-per-Student (£)	3,995	3,839	3,682	3,525	3,369	3,212
% Saving in Cost-per-Student (+ = saving)	-8.6%	-4.3%	0	+4.3%	+8.6%	+12.9%

Table 6.8 Applied Biology - Effect of Changing Total Contact Hours

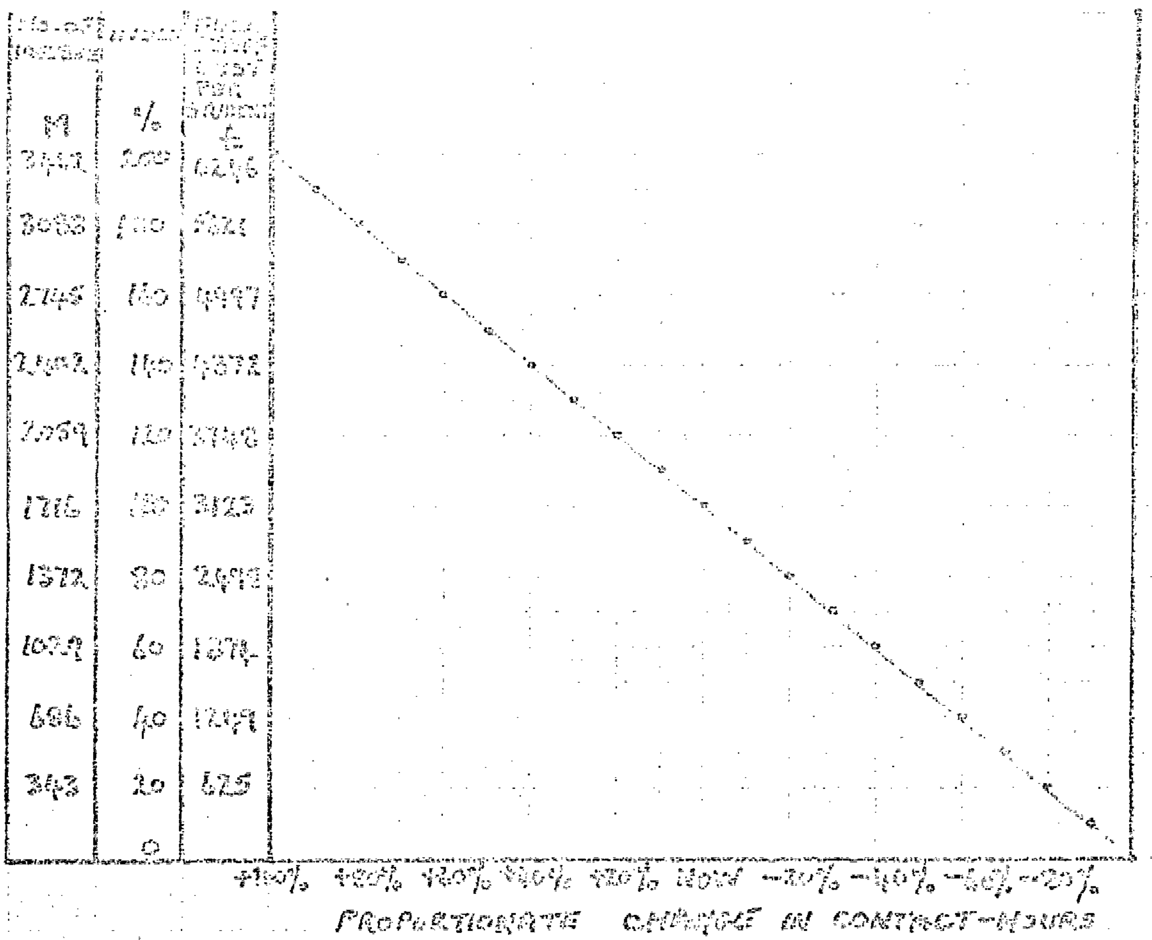
	% Change in Total Contact Hours					
	+40%	+20%	Present Number	-20%	-40%	-60%
No. of Meetings Provided	5,165	4,427	3,689	2,951	2,213	1,475
% of Present No. of Meetings	140	120	100	80	60	40
Full Staff Cost-per-Student (£)	3,437	2,945	2,455	1,964	1,473	982
Total Annual Financial Saving (£) (+ = saving)	-32,340	-16,170	0	+16,170	+32,340	+48,510
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	1,324	1,135	946	757	568	378
Academic Staff Offices (£)	80	68	57	46	34	23
Total Economic Cost-per-Student (£)	3,493	3,302	3,110	2,918	2,727	2,535
% Saving in Cost-per-Student (+ = saving)	-12.4%	-6.2%	0	+6.2%	+12.4%	+18.6%

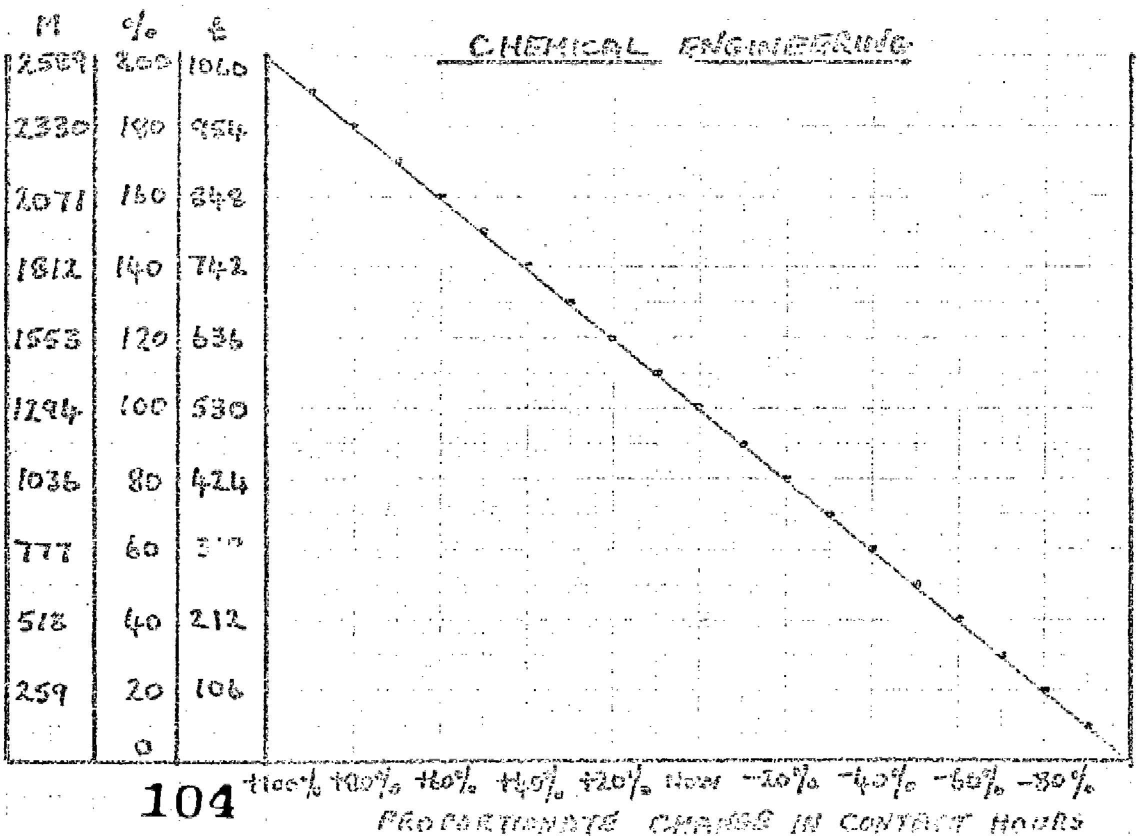
Table 6.9 : Materials Science - Effect of Changing Total Contact Hours

	% Change in Total Contact Hours					
	+40%	+20%	Present Number	-20%	-40%	-60%
No. of Meetings Provided	5,025	4,307	3,589	2,871	2,153	1,435
% of Present No. of Meetings	140	120	100	80	60	40
Full Staff Cost-per-Student (£)	4,609	3,950	3,292	2,634	1,975	1,317
Total Annual Financial Saving (£) (+ = saving)	-27,640	-13,820	0	+13,820	+27,640	+41,460
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	1,375	1,178	982	786	589	393
Academic Staff Offices (£)	56	48	40	32	24	16
Total Economic Cost-per-Student (£)	4,089	3,884	3,680	3,476	3,271	3,067
% Saving in Cost-per-Student (+ = saving)	-11.2%	-5.6%	0	+5.6%	+11.2%	+16.8%

FIGURE 6.1 : EFFECT OF CHANGING TOTAL CONTACT HOURS

(PHARMACOLOGY)





It is clear from figure 6.1, and from the tables, that the number of meetings provided, and therefore the full staff cost per student changes in direct proportion to the change in the total number of contact hours incorporated in the course. Thus a doubling of contact hours doubles academic staff cost per student and a halving of contact hours halves this cost. The annual financial savings of a reduction in contact hours are substantial, and Table 6.10 shows the total savings over the nine courses together of various proportionate changes in the total contact hours.

Table 6.10 : Total Savings on 9 Courses in Relation to Total Contact Hours

	% Change in Total Contact Hours					
	+40%	+20%	Present Number	-20%	-40%	-60%
Total Annual Saving in Staff Cost (£) (+ = saving)	-219,000	-109,000	0	+109,000	+219,000	+328,000

In terms of the economic cost per student, the reduction in cost associated with a 20% reduction in contact hours varies between 3.7% and 6.2%. The average for all the courses, weighted by the number of students on each course is 5.1%.

2. CHANGING THE NUMBER OF OPTIONAL SUBJECTS

In this section we consider the effects of altering the number of optional subjects that are available to students. A subject is "optional" if it is one of a series of alternatives from which a student must select at least one: it is not optional in the sense that he can avoid altogether this part of the course. The course structure, in terms of contact hours of each type of meeting and groups sizes, remains unchanged, but smaller or larger numbers of optional subjects are offered to students, from which they must choose the same number of subjects as at present. The number of compulsory subjects and their hours of teaching are held constant.

Not all courses contain optional subjects, and in those that do, not all years of the course contain them. Furthermore, the present situation with regard to number of options varies considerably. The first year of the Social Sciences course currently offers eight options of which students must choose five. Other courses require simply a choice of one out of two subjects. The pattern is further complicated in that in some courses, the options cover a very large proportion of the total contact hours, whereas in others only a single lecture a week may be involved.

It is therefore difficult to generalise about the effect on costs of changes in the number of optional subjects offered. The method adopted here is to start with the present situation on each course, and then alter the number offered by one and two in each direction. The proportional change in the number of options thus differs between courses, and care must be taken not to over-generalise from highly specific data.

In estimating the number of students who will select a particular option from the new range available, the method differs according to whether the range is being increased or decreased.

In reducing the number of options, that one which currently enrols the smallest proportion of the students on the course, is discontinued. The students taking it are re-distributed over the remaining options in proportion to the present size of those remaining options. The resultant total number of meetings is calculated. This process is successively repeated with the smallest remaining option.

In increasing the number of options, it is arbitrarily assumed that each additional option attracts the same proportion of students as it represents of the number of options available, i.e. if a fifth option is is added to four existing ones it will attract one-fifth of the students. It is further assumed that these will be drawn from the existing options in proportion to their present size, i.e. each of the four original options loses one-fifth of its enrolment.

As far as the teaching of the additional options is concerned, it is assumed that they involve the same number of lectures, classes, etc., and the same group sizes as the original options. The situation pertaining at the University of Bradford suggests that this assumption is realistic.

Tables 6.11 to 6.14 show the results for courses that at present contain optional subjects, and figure 6.2 expresses the results graphically.

Table 6.11 : Colour Chemistry - Effect of Changing the Number of Optional Subjects

	Number of Optional Subjects				
	+2	+1	Present Number	-1	-2 *
No. of Meetings Provided	3,168	2,904	2,639	2,309	2,309
% of Present No. of Meetings	120.0	110.0	100	87.5	87.5
Full Staff cost-per-Student (£)	2,470	2,264	2,058	1,801	1,801
Total Annual Financial Saving (£) (+ = saving)	-8,650	-4,330	0	+5,400	+5,400
ECONOMIC COST PER STUDENT					
Academic Staff Cost (£)	942	864	785	687	687
Academic Staff Offices (£)	76	69	63	55	55
Total Economic Cost-per-Student (£)	4,088	4,003	3,918	3,802	3,802
% Saving in Cost-per-Student (+ = saving)	-4.3%	-2.2%	0	+3.0%	+3.0%

* Only 2 options currently available, thus results for -7 and -2 are the same.

Table 6.12 : Civil Engineering - Effect of Changing the Number of Optional Subjects

	Number of Optional Subjects				
	+2	+1	Present Number	-1	-2
No. of Meetings Provided	4,712	4,604	4,496	4,388	4,280
% of Present No. of Meetings	104.8	102.4	100	97.6	95.2
Full Staff Cost-per-Student (£)	1,135	1,110	1,085	1,060	1,035
Total Annual Financial Saving (£) (+ = saving)	-3,300	-1,650	0	+1,650	+3,300
ECONOMIC COST PER STUDENT					
Academic Staff Cost (£)	480	469	458	447	436
Academic Staff Offices (£)	60	58	57	56	54
Total Economic Cost-per-Student (£)	2,534	2,521	2,509	2,497	2,484
% Saving in Cost-per-Student (+ = saving)	-1.0%	-0.5%	0	+0.5%	+1.0%

Table 6.13 : Computer Science - Effect of Changing the Number of Optional Subjects

	Number of Optional Subjects				
	+2	+1	Present Number	-1	-2
No. of Meetings Provided	891	871	851	832	812
% of Present No. of Meetings	104.7	102.4	100	97.7	95.4
Full Staff Cost-per-Student (£)	1,937	1,894	1,850	1,807	1,765
Total Annual Financial Saving (£) (+ = saving)	-1,044	-528	0	+516	+1,020
ECONOMIC COST PER STUDENT	Not Available				

Table 6.14 : Social Sciences - Effect of Changing the Number of Optional Subjects

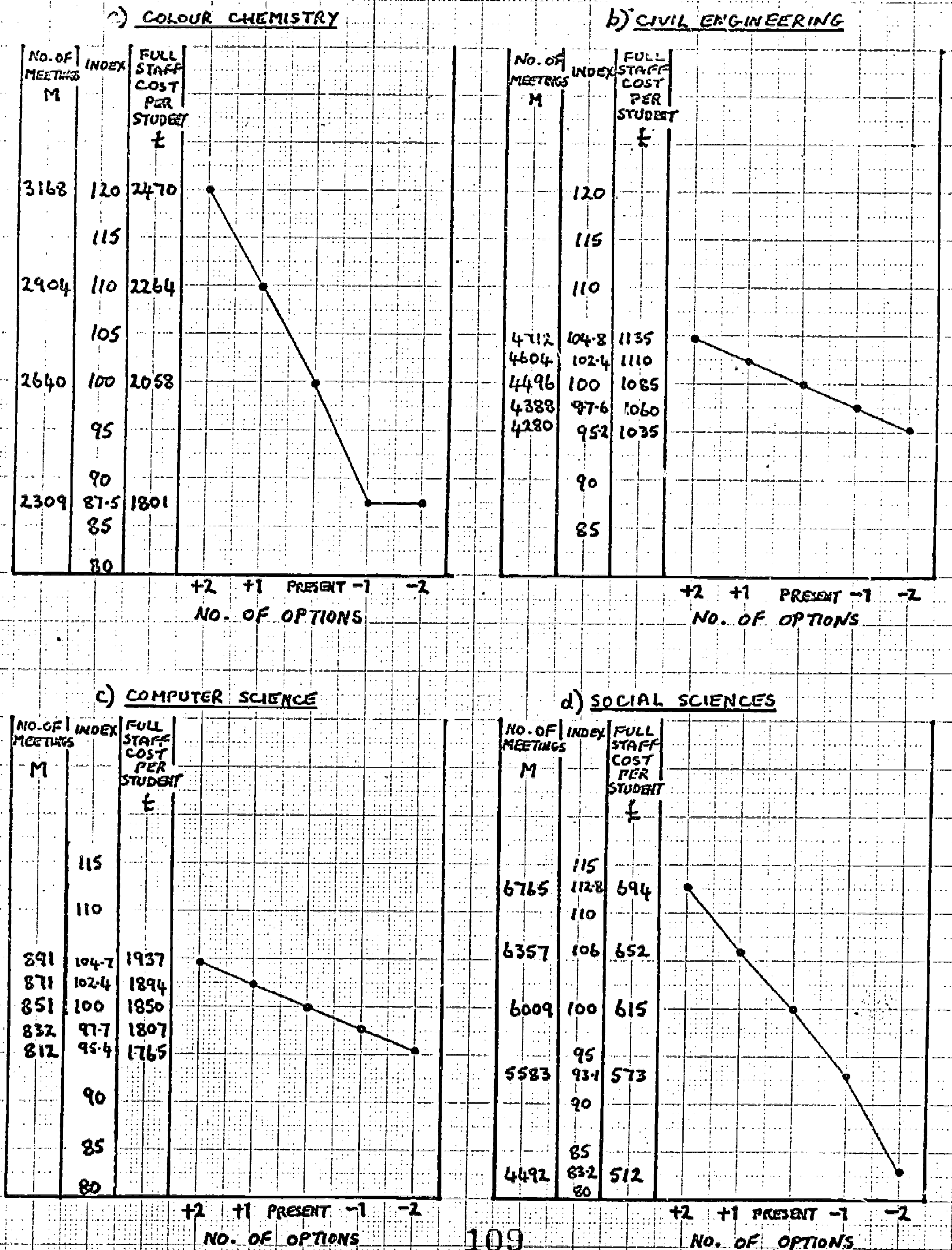
	Number of Optional Subjects				
	+2	+1	Present Number	-1	-2
No. of Meetings Provided	6,765	6,357	6,009	5,583	4,992
% of Present No. of Meetings	112.8	106.0	100	93.1	83.2
Full Staff Cost-per-Student (£)	694	652	615	573	512
Total Annual Financial Saving (£) (+ = saving)	-9,480	-4,440	0	+5,040	+12,360
ECONOMIC COST PER STUDENT					
Academic Staff Cost (£)	458	430	406	378	337
Academic Staff Offices (£)	68	64	60	56	50
Total Economic Cost-per-Student (£)	1,692	1,660	1,632	1,600	1,553
% Saving in Cost-per-Student (+ = saving)	-3.7%	-1.7%	0	+2.0%	+4.8%

It can be seen from the tables that an increase in the choice of options available causes an increase in the number of teaching meetings provided and therefore in staff cost per student. Conversely a reduction in the available number of options enables staff economies to be made. Thus a reduction of two in the number of options is calculated to save £5,400 annually in Colour Chemistry (the equivalent of 1½ staff members), £3,300 in Civil Engineering (1 staff member), £1,020 in Computer Science (½ staff member), and £12,360 in Social Sciences (almost 3 staff members). The effect on the economic cost per student is quite significant - a 4.8% reduction in Social Sciences. Even the 1.0% saving in Civil Engineering is important, from such a relative minor change in the pattern of teaching. Whilst it might be difficult, and indeed academically undesirable, to persuade universities to reduce the range of optional subjects available, <u>it is important that they should not proliferate the number of options further as this significantly increases cost per student</u> - in Colour Chemistry we calculate that two extra options would increase the economic cost per student by 4.3%

3. CHANGING THE MAXIMUM SIZE OF TEACHING GROUPS

Here we investigate the effects of changing the sizes of teaching groups. For each component of existing courses, professors have specified the maximum number of students that may attend a meeting. These maxima are classified in Chapter 4, table 4.1. If student enrolment on a course exceeds this maximum then the meeting will be repeated. This does not apply to lectures where professors have specified that there is no maximum to the size of group.

FIGURE 6.2: EFFECT OF CHANGING THE NUMBER OF OPTIONAL SUBJECTS



In this section, the course structure is altered by varying group size maxima, whilst holding constant the total contact hours per student and the relative balance of different teaching methods. The method adopted is to increase and decrease the group size maxima for all the meeting types together by steps of 10% from 50% of present size to 200% of present size, except in the case of lectures where the "no maximum" condition is retained. Thus if a course consists of lectures, classes of 30 students and classes of 50 students, the group sizes considered will range from 15 and 25 by steps of 3 and 5 respectively up to 60 and 100.

Results are presented in tables 6.15 to 6.20, and in figures 6.3 to 6.8.

Table 6.15 : Pharmacology - Effect of Changing Size of Teaching Groups

	% Change in Maximum Group Size					
	-40%	-20%	Present Size	+20%	+40%	+60%
No. of Meetings Provided	2,475	1,716	1,716	1,716	1,716	1,683
% of Present No. of Meetings	144	100	100	100	100	98
Full Staff Cost-per-Student (£)	4,503	3,123	3,123	3,123	3,123	3,061
Total Annual Financial Saving (£) (+ = saving)	-12,400	0	0	0	0	+560
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	791	549	549	549	549	538
Academic Staff Offices (£)	80	57	57	57	57	56
Total Economic Cost-per-Student (£)	3,558	3,294	3,294	3,294	3,294	3,282
% saving in Cost-per-Student (+ = saving)	-8%	0	0	0	0	+0.3%

Table 6.16 : Computer Science - Effect of Changing Size of Teaching Groups

	% Change in Maximum Group Size					
	- 40%	-20%	Present Size	+20%	+40%	+60%
No. of Meetings Provided	1,072	950	851	851	851	851
% of Present No. of Meetings	127	112	100	100	100	100
Full Staff Cost-per-Student (£)	2,350	2,072	1,850	1,850	1,850	1,850
Total Annual Financial Saving (£) (+ = saving)	-6,000	-2,700	0	0	0	0
ECONOMIC COST PER STUDENT	Not Available					

Table 6.17 : Chemical Engineering - Effect of Changing Size of Teaching Groups

	% Change in Maximum Group Size					
	-40%	-20%	Present Size	+20%	+40%	+60%
No. of Meetings Provided*	1,829	1,355	1,294	1,289	1,257	1,216
% of Present No. of Meetings	141	104	100	99	96	93
Full Staff Cost-per-Student (£)	747	551	530	525	509	493
Total Annual Financial Savings (£) (+ = saving)	-17,400	-1,700	0	+400	+1,700	+3,000
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	870	642	617	611	586	574
Academic Staff Offices (£)	73	54	52	51	50	49
Total Economic Cost-per-Student (£)	2,831	2,584	2,557	2,550	2,523	2,511
% Saving in Cost-per-Student (+ = saving)	-10.7%	-1.1%	0	0	+1.1%	+1.7%

* Per half-year, i.e. for each of the two intakes.

Table 6.18 : Colour Chemistry - Effect of Changing Group Size

	% Change in Maximum Group Size					
	-40%	-20%	Present Size	+20%	+40%	+60%
No. of Meetings Provided	3,642	2,749	2,639	2,598	2,558	2,546
% of Present No. of Meetings	138	104	100	98	97	96
Full Staff Cost-per-Student (£)	2,840	2,140	2,058	2,017	1,997	1,976
Total Annual Financial Savings (£) (+ = saving)	-16,400	-1,720	0	+880	+1,320	+1,720
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	1,083	816	785	769	761	754
Academic Staff Offices (£)	90	66	63	62	61	60
Total Economic Cost-per-Student (£)	4,240	3,952	3,918	3,901	3,892	3,884
% Saving in Cost-per-Student (£) (+ = saving)	-8.3%	-0.9%	0	+0.5%	+0.7%	+0.9%

Table 6.19 : Civil Engineering - Effect of Changing Group Size

	% Change in Maximum Group Size					
	-40%	-20%	Present Size	+20%	+40%	+60%
No. of Meetings Provided	5,813	5,481	4,496	4,164	4,164	4,164
% of Present No. of Meetings	129	122	100	93	93	93
Full Staff Cost-per-Student (£)	1,400	1,324	1,085	1,009	1,009	1,009
Total Annual Financial Savings (£) (+ = saving)	-20,800	-15,700	0	+5,000	+5,000	+5,000
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	591	559	458	426	426	426
Academic Staff Offices (£)	74	70	57	53	53	53
Total Economic Cost-per-Student (£)	2,659	2,623	2,509	2,473	2,473	2,473
% Saving in Cost-per-Student (+ = saving)	-12.0%	-4.5%	0	+1.6%	+1.6%	+1.6%

Table 6.20 : Social Sciences - Effect of Changing Group Size

	% Change in Maximum Group Size					
	-40%	-20%	Present Size	+20%	+40%	+60%
No. of Meetings Provided	8,242	7,129	6,009	5,281	4,983	4,798
% of Present No. of Meetings	137	118	100	87	84	80
Full Staff Cost-per-Student (£)	843	726	615	535	517	492
Total Annual Financial Saving (£) (+ = saving)	-27,400	-13,320	0	+9,600	+11,800	+14,800
ECONOMIC COST PER STUDENT						
Academic Staff Cost (£)	556	479	406	353	341	325
Academic Staff Offices (£)	82	71	60	52	50	48
Total Economic Cost-per-Student (£)	1,804	1,716	1,632	1,571	1,557	1,539
% Saving in Cost-per-Student (+ = saving)	-10.5%	-5.0%	0	+3.7%	+4.5%	+5.7%

It can be seen that economic cost-per-student is very insensitive to increases in the maximum sizes of teaching groups. Apart from Social Sciences, a 60% increase in group size never reduces economic cost-per-student by more than 1.7% Only in Social Sciences does the size of group significantly affect economic cost, and here a 60% increase in group size causes economic cost to fall by 5.7%

The annual financial savings in the cost of academic staff are correspondingly small. A 60% increase in group size on all six courses saves only £25,000.

On the other hand a reduction in group size maxima is much more significant. A cut of 40% causes increases in economic cost of between 8.0% and 12.0%.

FIGURE 6.3: EFFECT OF CHANGING THE MAXIMUM SIZE OF TEACHING GROUPS

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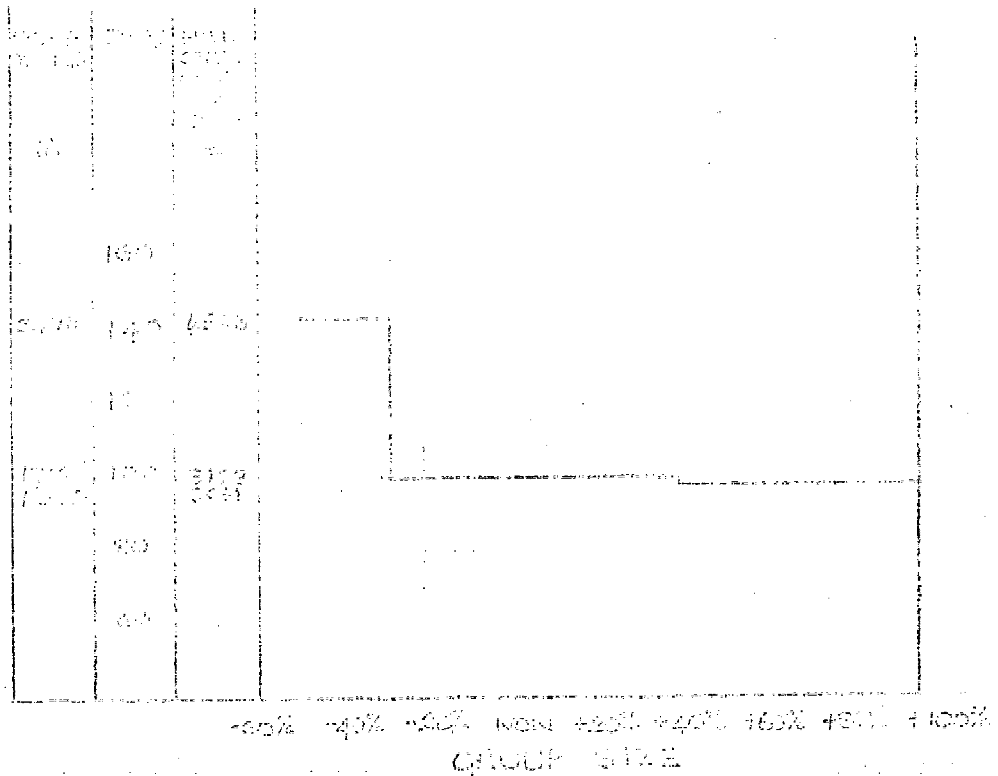
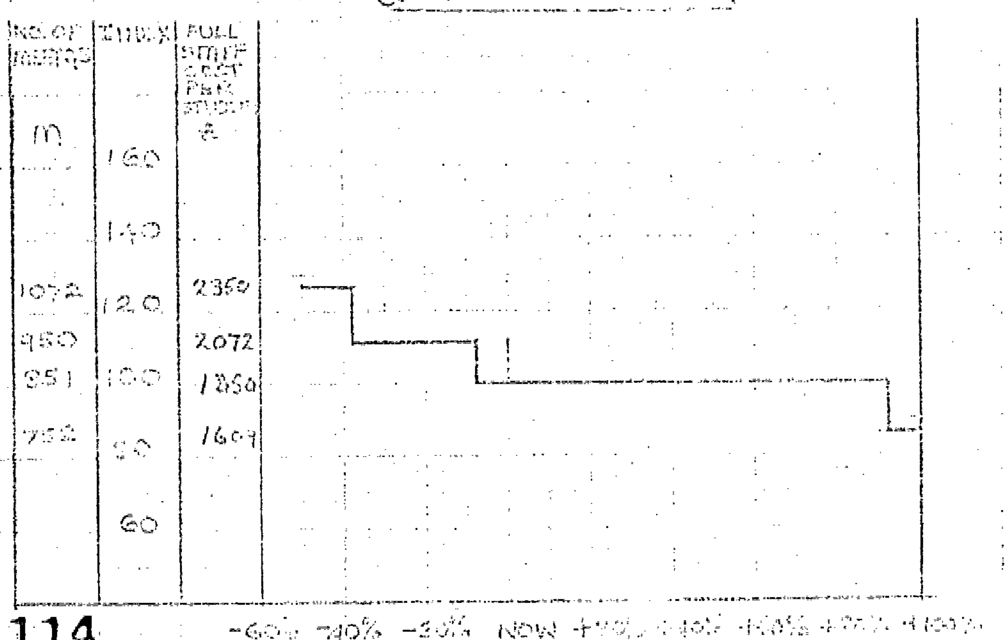


FIGURE 6.4: EFFECT OF CHANGING THE MAXIMUM SIZE OF TEACHING GROUPS

(COMPUTER SCIENCE)



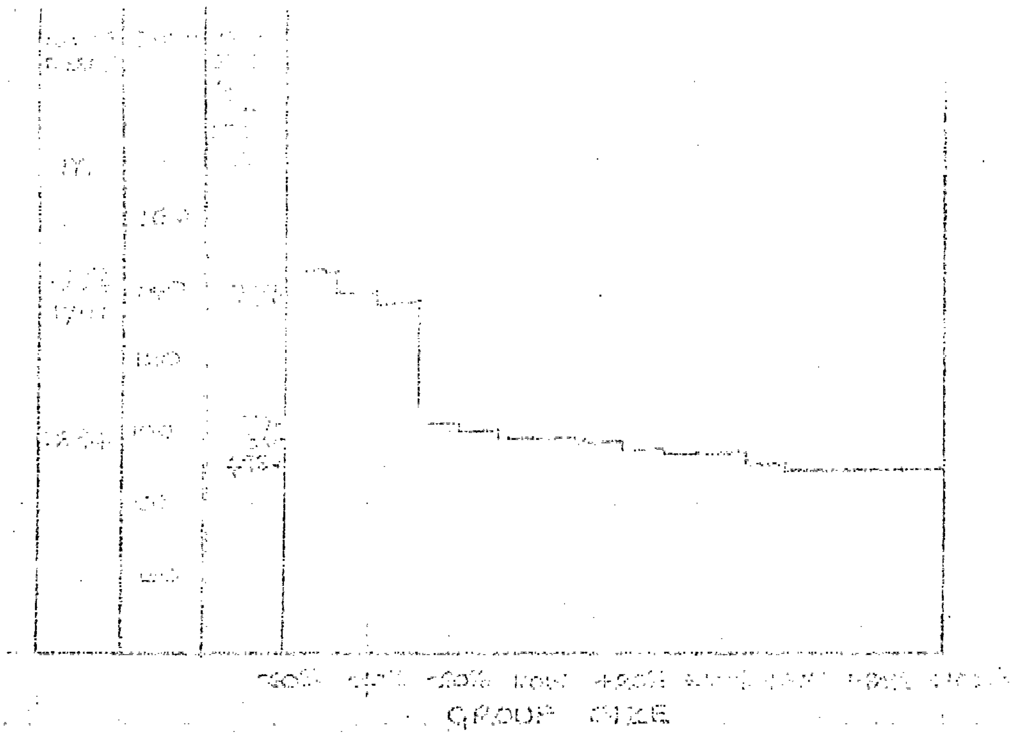
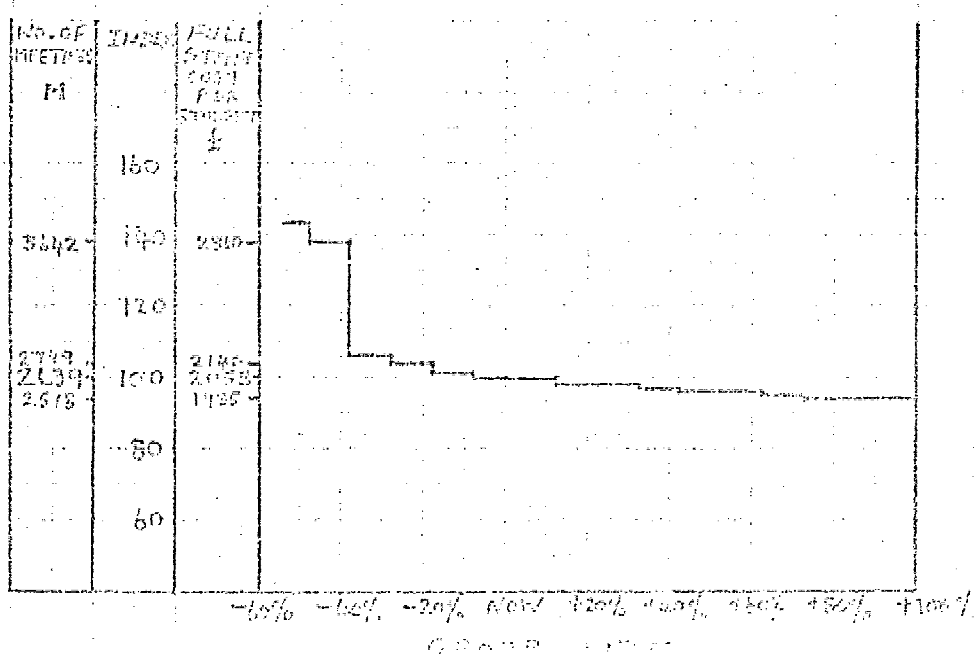


FIGURE 6.6 : COLOUR CHEMISTRY



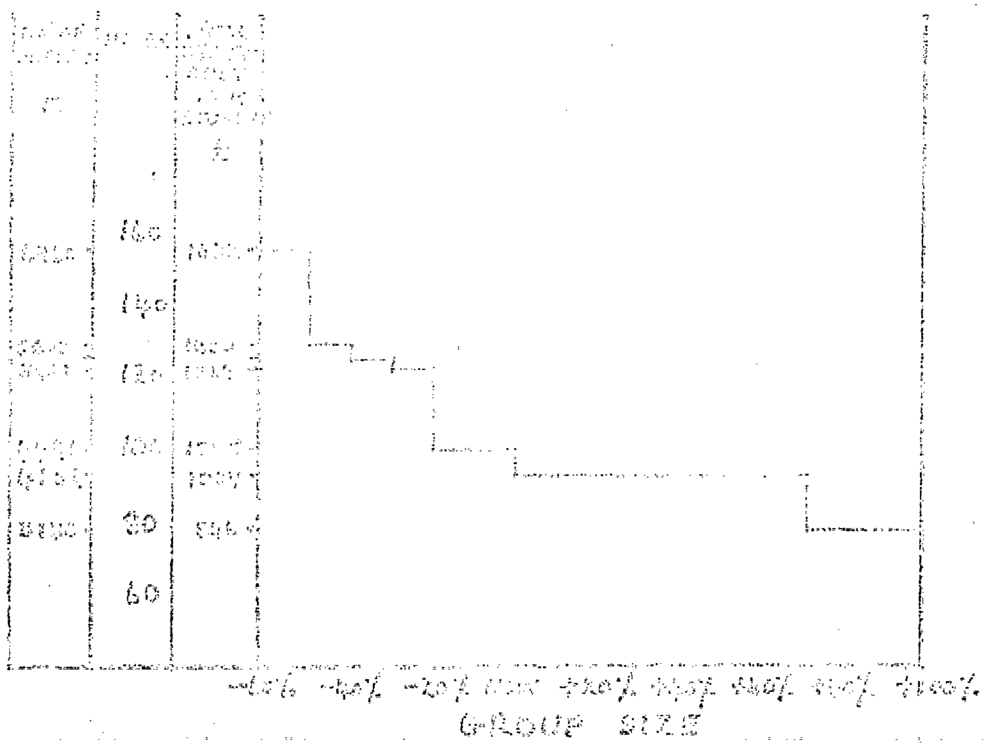
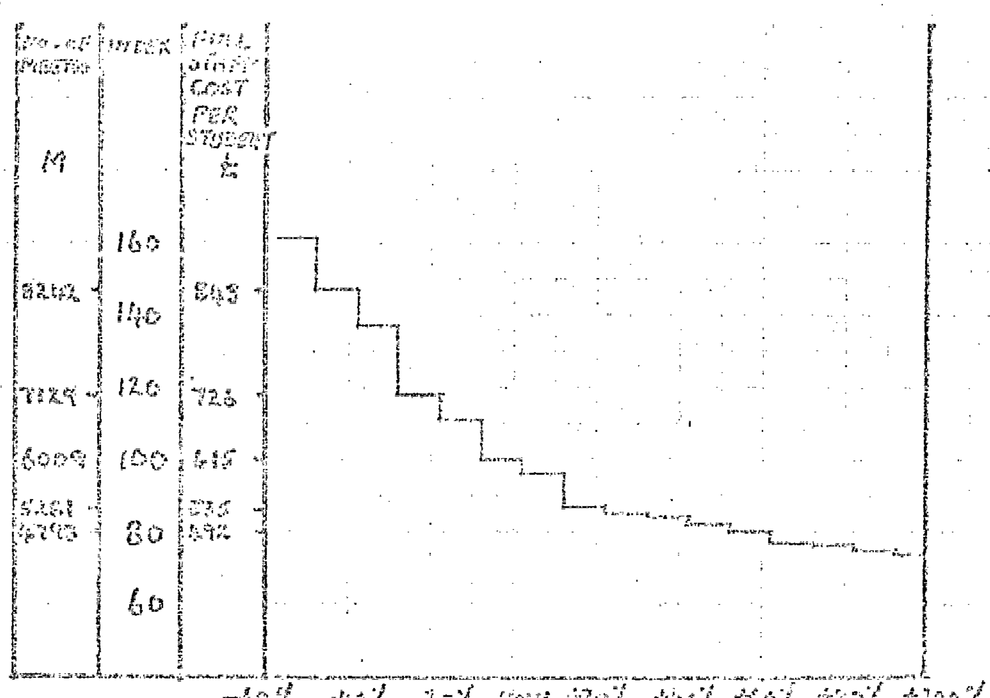


FIGURE 1.8 : SOCIAL SCIENCES



4) CHANGING THE RELATIVE BALANCE OF DIFFERENT TYPES OF TEACHING MEETING

Assessment of the relative costs of different methods of teaching is closely related to the relative effectiveness of the different methods in terms of the quality and impact of the education imparted. It strikes too at professorial sovereignty in the teaching of his subject. We do not, in this report, comment upon the educational effectiveness of different teaching methods. Rather, we attempt to measure the cost, in terms of total teaching load, of alternative methods of teaching existing courses.

The total number of contact hours per student is held constant but the relative balance of lectures, classes and tutorials constituting the course is altered. Because of the great variety of combinations of teaching methods currently in use at the University of Bradford, it is difficult to be wholly systematic in the manner of changing the combinations. The method generally adopted is to reduce the number of lectures per week by 25%, 50% and 100% and increase other forms of teaching to maintain the same total contact hours per student. Then the weekly number of classes and seminars is reduced by the same proportion. For courses where individual tutorials are given, one of the combinations postulated is to replace them by lectures.

Throughout this section group size maxima are held constant.

Results are presented in tables 6.21 to 6.25 and in figures 6.9 to 6.12

Table 6.21 : Pharmacology.- Different combinations of teaching methods.

	Present method	% reduction in No. of lectures			% reduction in No. of classes		Abolition of Tutorials
		-25%	-50%	-100%	-50%	-100%	
No. of Meetings Provided	1716	1740	1766	1815	1733	1749	1679
% of present No. of Meetings	100	101	103	106	101	102	98
Full Staff Cost per Student	3123	3154	3217	3310	3154	3185	3061
Total annual Financial Savings (+ = saving) (£)	0	-280	-640	-1680	-280	-560	+560
ECONOMIC COST PER STUDENT.							
Academic Staff Cost (£)	549	554	565	583	554	560	538
Academic Staff Offices (£)	57	58	59	61	58	58	56
Total economic cost per student (£)	3294	3300	3312	3332	3300	3306	3282
% Saving in cost per student (+ = saving)	0	-0.2%	-0.6%	-1.2%	-0.2%	-0.4%	+0.4%

Table 6.22 : Computer Science - Different combinations of teaching methods.

	Present Method	% reduction in No. of lectures -25%	-50%	-100%	Abolition of Classes	Abolition of Tutorials
No. of Meetings Provided	851	947	1048	1208	865	673
% of Present No. of Meetings	100	111	123	142	102	79
Full Staff Cost per Student(£)	1850	2054	2276	2627	1889	1461
Total Annual Financial Saving (£) (+ = saving)	0	-2450	-5100	-9300	-450	+4700
ECONOMIC COST PER STUDENT	NOT AVAILABLE					

Table 6.23 : Chemical Engineering - Different combinations of teaching methods.

	Present Method	% reduction in No. of lectures. -25%	-50%	-100%	% reduction in No. of classes -50%	-100%	Abolition of Tutorials
No. of Meetings Provided *	1294	1434	1583	1840	1381	1811	1119
% of Present No.of Meetings	100	111	122	142	107	140	87
Full Staff Cost per Student(£)	530	586	647	753	567	742	461
Total Annual Financial Saving (£) (+ = saving)	0	-4650	-9350	-17800	-3000	-17000	+5500
ECONOMIC COST PER STUDENT.							
Academic Staff Cost (£)	617	685	753	876	660	864	537
Academic Staff Offices (£)	52	58	64	74	56	73	45
Total Economic Cost per Student (£)	2557	2633	2699	2836	2604	2825	2470
% Saving in Cost per Student(£) (+ = saving)	0	-2.9%	-5.6%	-11.0%	-1.8%	-10.5%	+3.5%

* per half-year, i.e. for each of two intakes.

Table 6.24 : Civil Engineering - Different combinations of teaching methods.

	Present Method	% reduction in No. of lectures -25%	-50%	-100%	Abolition of Classes of 40	Classes of 30	Classes of 20
No. of Meetings Provided	4496	4813	5111	5744	4979	4424	3936
% of Present No. of Meetings	100	107	114	128	111	98	87
Full Staff Cost per Student (£)	1085	1161	1237	1389	1204	1063	943
Total Annual Financial Saving (£) (+ = saving)	0	-5000	-10000	-20000	-7500	+1400	+9400
ECONOMIC COST PER STUDENT.							
Academic Staff Cost (£)	458	490	522	586	508	449	398
Academic Staff Offices (£)	57	61	65	73	63	56	50
Total Economic Cost per Student (£)	2509	2545	2583	2653	2565	2499	2442
% Saving in Cost per Student (+ = savings)	0	-1.4%	-2.8%	-5.7%	-2.2%	+0.4%	+2.7%

Table 6.25: Colour Chemistry - Different combinations of teaching methods

	Present Method	% reduction in No. of lectures -25%	-50%	-100%	% reduction in No. of classes -50%	-100.	Abolition of Tutorials
No. of Meetings Provided	2639	4077	5622	8563	4787	6830	2477
% of Present No. of Meetings	100	154	213	324	181	259	94
Full Staff Cost per Student (£)	2058	3169	4383	6668	3724	5331	1935
Total Annual Financial Saving (£) (+ = saving)	0	-23300	-48800	-96800	-35000	-68700	+2600
ECONOMIC COST PER STUDENT							
Academic Staff Cost (£)	785	1209	1672	2542	1421	2034	738
Academic Staff Offices (£)	63	97	134	205	114	163	59
Total Economic Cost per Student (£)	3918	4376	4876	5817	4605	5330	3867
% Saving in Cost per Student (+ = saving)	0	-11.7	-24.9	-48.5	-17.5	-36.1	+1.3

The effect of altoring the balance of different types of teaching meeting within the existing total ontact hours varies considerably between courses. The replacement of lectures by more classes and tutorials of the same size and in the same proportion as with the existing course structure causes economic cost per student to rise between 1.2% and 48.5%, or on average by 13.0%. Replacement of classes by lectures and tutorials causes economic cost to increase by between 0.4% and 36.1%, or on average by 9.9%. Replacement of tutorials by lectures and classes shows savings in economic cost of between 0.4% and 3.5%, an average saving of 2.7%

The alternative combinations of teaching methods stulated above are only a few of an almost limitless range. Further research will be undertaken into the possibilities, and discussions on these will be held with the schools of study involved.

FIGURE 6·9 : EFFECT OF DIFFERENT COMBINATIONS OF TEACHING METHODS ON STAFF REQUIREMENTS (PHARMACOLOGY)

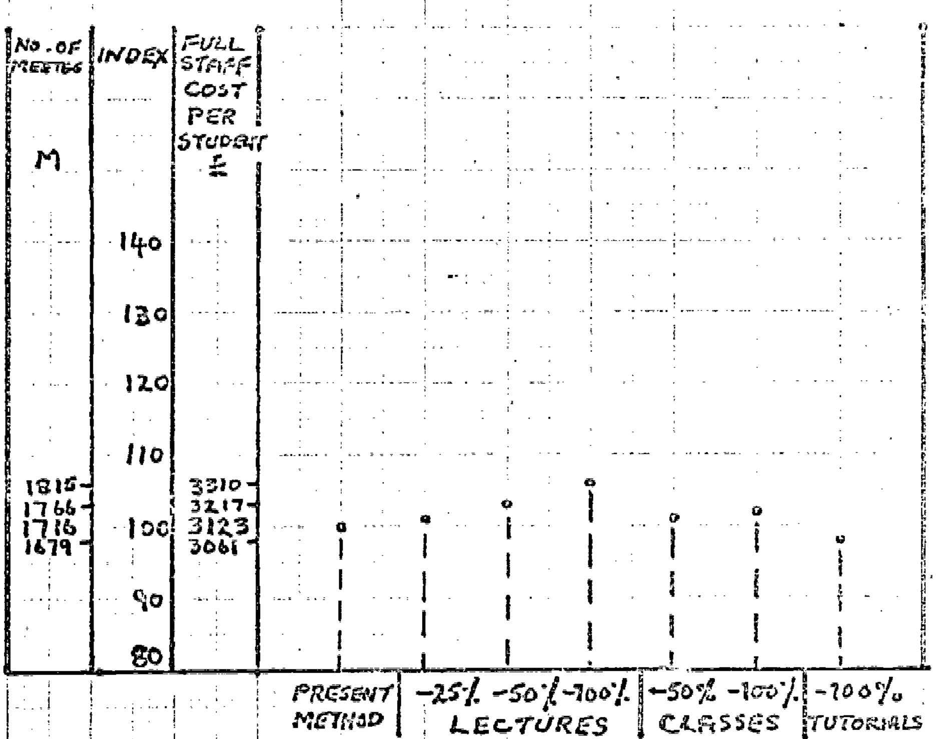


FIGURE 6·10 : COMPUTER SCIENCE

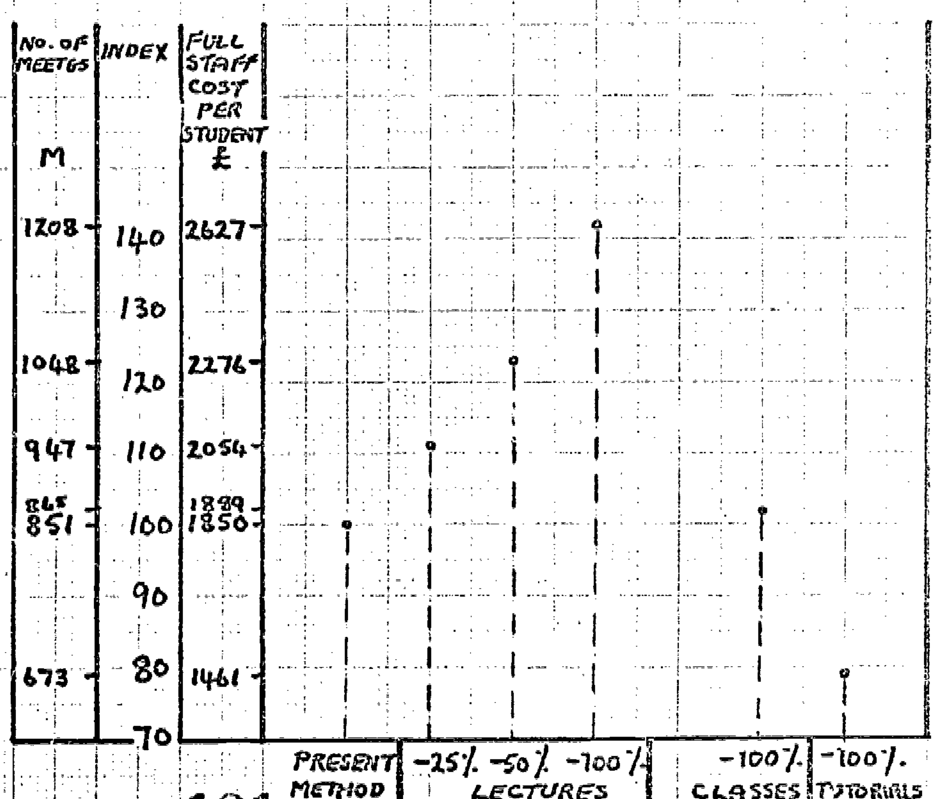


FIGURE 6·11 : EFFECT OF DIFFERENT COMBINATIONS OF TEACHING METHODS ON STAFF REQUIREMENTS

(CHEMICAL ENGINEERING)

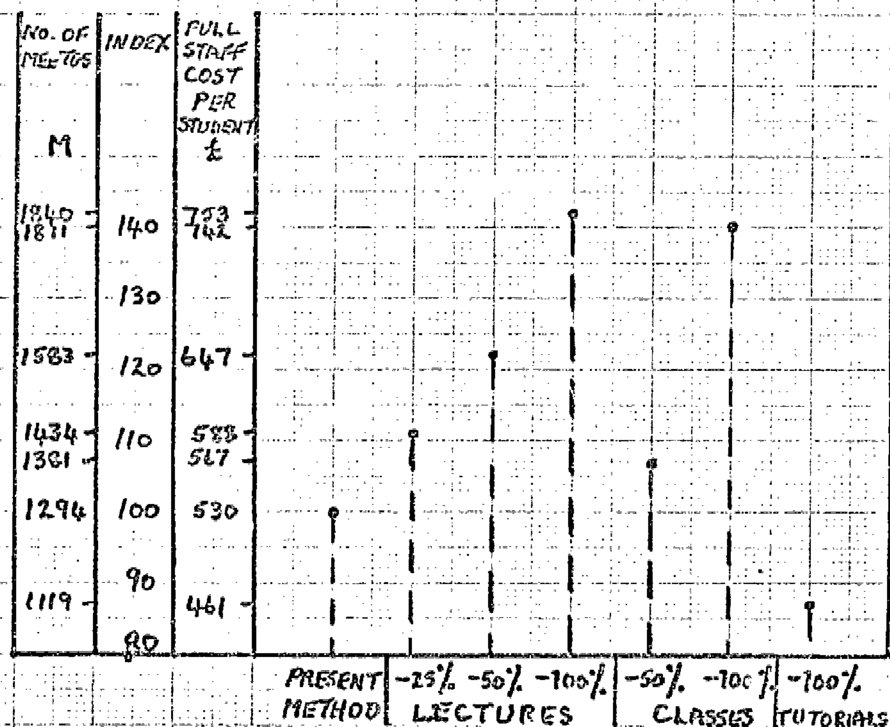
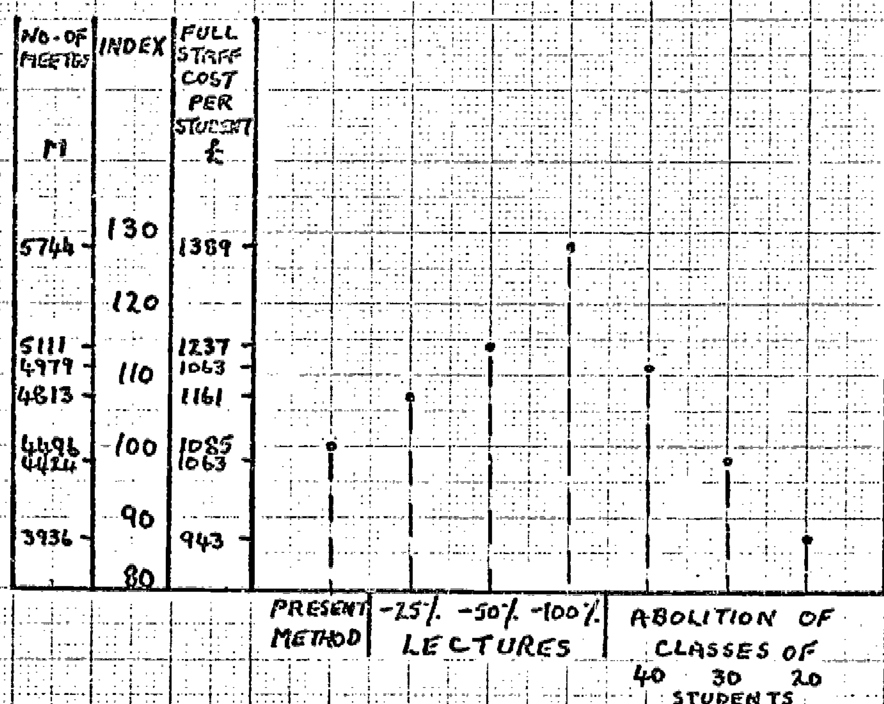


FIGURE 6·13 : CIVIL ENGINEERING



CHAPTER 7

Economies Arising from Increasing The Teaching Load Of Staff

In Chapters 5 and 6 it was assumed that the average annual teaching load of staff remained constant. Now, in Chapter 7, we investigate the potential savings from increasing teaching load.

After briefly commenting on the relationship of teaching and research, we look at a number of individual courses and see how the number of staff required, and consequently the annual financial cost, would vary in different teaching loads. Savings are calculated in terms of the full cost of the staff concerned, i.e. no allowance is made for time devoted to research, etc. Substantial potential economies are identified.

Finally, we consider the effect of changing teaching load on the economic cost-per-student defined in Part 2. We conclude that this is not a particularly helpful way of expressing the savings, but has important implications in identifying the "savings" as largely reflecting a transfer of resources from research activities.

1) RELATIONSHIP OF TEACHING AND RESEARCH

It has often been suggested that teaching loads might be increased in order more economically to cope with additional students, even to the extent of employing some staff whose sole function would be to teach, and who would not be expected to engage in research. This proposal is normally countered by the assertion that teaching and research are mutually dependent - that research enables a lecturer to teach his subject in a stimulating and up-to-date manner, and that the discipline of ordering thoughts for the purpose of teaching is invaluable in giving shape to otherwise amorphous research activities.

Acceptance of the need to combine teaching and research activities does not however preclude the possibility of altering the actual distribution of time between the two. Whilst there is abundant material to support the case for engaging in both, there has been no justification of any particular pattern of distribution.

The survey of academic staff time carried out in the University of Bradford in 1968 found that the proportion of staff time during term, devoted to work directly related to undergraduate students varied between 45% and 61% in different Boards of Studies. Actual teaching time per week averaged between 6 and 8 hours in different boards.

These averages, however, conceal considerable differences between departments and between individuals. Indeed the very nature of the academic post requires flexibility. Insofar as universities engage in the two activities of teaching and research, one would expect that the dominant talents of different members of staff would be in one or other of these directions.

It appears, however, from the figures quoted above, that there is scope for increasing average teaching loads, at the expense of other activities, without completely removing opportunities for research, and in this chapter we make selective additions to teaching loads in order to see what effect this has on costs.

2) EFFECT OF INCREASING TEACHING LOAD ON THE TOTAL STAFF COST OF COURSES.

In this section we take each of the courses studied in Chapters 5 and 6 and recalculate the number of academic staff required, and the total academic staff cost of the course, with several different average teaching loads. The present course structure, in terms of contact hours and group sizes, is held constant, and enrolment is progressively increased up to an approximate doubling of the present intake. The costs quoted represent the full cost of the academic staff required to teach the course - no deduction is made in respect of the proportion of time devoted to other activities such as research.

Five alternative values are attributed to the average teaching load;

a) the current average load for the appropriate Board of Studies within the University of Bradford. These are the values found by the 1968 survey, and modified to allow for the subsequent deterioration in the staff:student ratio[1] The load is 210 hours per year for all courses except Social Sciences, which is 280, and Computer Science which is 132.

b) a 25% increase in the current average load (260, 350 and 165 hours per year).

c) a 50% increase in the current average load (315, 420 and 198 hours per year).

d) a 75% increase in the current average load (365, 470 and 231 hours per year).

e) the load obtained by assuming that the U.K. average weighted staff:student ratio for the appropriate U.G.C. subject group was actually in force in the University of Bradford, calculating the notional staff entitlement at the current level of enrolment, and dividing this into the number of meetings provided.[2] The U.K. average ratios applicable to each course are shown in Table 7.1, together with the nominal annual teaching load per member of staff. It will be seen that these vary considerably.

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1. See Chapter 4, Tables 4.4 and 4.5 for details.

2. See Appendix 4, for a full description of the method of calculating this load.

Table 7.1 : U.K. Average Weighted Staff:Student Ratios, and Nominal Teaching Loads at the University of Bradford

Course	U.K. Average Weighted Staff:Student Ratio	Nominal Teaching Load (hours per year)
Pharmacology	1: 7.04	465
Chemical Engineering	1:12.38	100
Colour Chemistry	1:11.09	475
Civil Engineering	1:12.38	281
Computer Science	1:12.07	284
Social Sciences	1:13.47	225
Applied Physics	1:11.09	569
Applied Biology	1:10.71	439
Materials Science	1:11.09	500

Figures 7.1 to 7.9 show the number of academic staff required, and their total cost at different levels of enrolment, with each of the alternative teaching loads. Scale 1 measures the number of academic staff required, and Scale 2 the total academic staff cost of the course, attributing the full cost of staff to the course. Each line on the graphs represents a different teaching load, the dotted lines being the nominal load obtained by applying the U.K. average staff:student ratio.

The detailed results presented in figures 7.1 to 7.6 are summarised below.

Tables 7.2 and 7.3 respectively show, at the current level of student enrolment, the number of academic staff required, and the academic staff cost of the course, for each teaching load.

Table 7.2: Academic Staff Numbers in relation to Teaching Load with the Current Enrolment

Course	Teaching Load				
	Current Average for Board of Studies	25% increase	50% increase	75% increase	Obtained from U.K. Staff: Student Ratio
Pharmacology	8.2	6.6	5.4	4.7	3.7
Chemical Engineering	12.3	9.9	8.2	7.0	25.8
Colour Chemistry	12.6	10.1	8.4	7.2	5.6
Civil Engineering	21.4	17.2	14.2	12.3	16.0
Computer Science	6.4	5.2	4.3	3.7	3.0
Social Sciences	21.5	17.2	14.3	12.8	26.7
Applied Physics	21.4	17.3	14.3	12.3	7.9
Applied Biology	17.5	14.2	11.7	10.1	8.4
Materials Science	17.1	13.8	11.4	9.8	7.2

Table 7.3 : Academic Staff Cost of Course in relation to Teaching Load with the Current Enrolment

	Teaching Load				
	Current Average for Board of Studies	25% increase	50% increase	75% increase	Obtained from U.K. Staff: Student Ratio
	£	£	£	£	£
Pharmacology	28,200	22,700	18,600	16,200	12,700
Chemical Engineering	42,300	34,100	28,200	24,100	88,800
Colour Chemistry	43,300	34,700	28,900	24,800	18,900
Civil Engineering	71,500	59,200	48,900	42,300	55,000
Computer Science	22,000	17,900	14,800	12,700	10,300
Social Sciences	74,000	59,200	49,200	44,000	91,900
Applied Physics	73,600	59,500	49,200	42,300	27,200
Applied Biology	60,200	48,900	40,200	34,700	28,900
Materials Science	58,900	47,100	39,200	33,700	24,800

It will be seen that the potential savings are substantial. Table 7.4 shows the total annual savings from the nine courses together if teaching loads were increased, compared with the situation with the present teaching load.

Table 7.4 : Total Savings on 9 Courses in relation to Increased Teaching Load with the Current Enrolment

	Increase in Teaching Load		
	25%	50%	75%
Number of Staff Saved	26.8	46.2	58.5
Total Annual Saving in Staff Cost (£)	93,300	159,000	201,000

It is unlikely that staff establishment would be cut to the extent necessary to generate increases in teaching loads of the sizes quoted above. What is more likely is that during an expansion of student numbers the growth in staff numbers would be so restricted as to force an increase in average teaching load.

FIGURE 7·1 : STAFF NUMBERS AND COST WITH DIFFERENT TEACHING LOADS (t)

(PHARMACOLOGY)

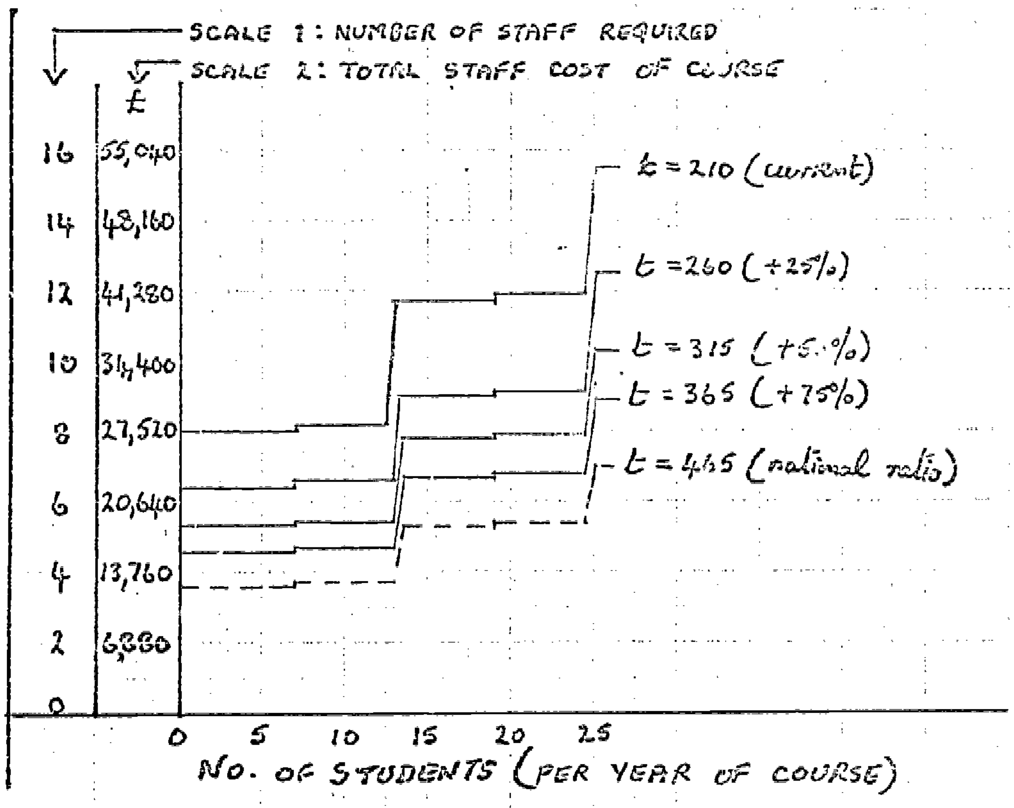


FIGURE 7·2 : STAFF NUMBERS AND COST WITH DIFFERENT TEACHING LOADS (t)

(COMPUTER SCIENCE)

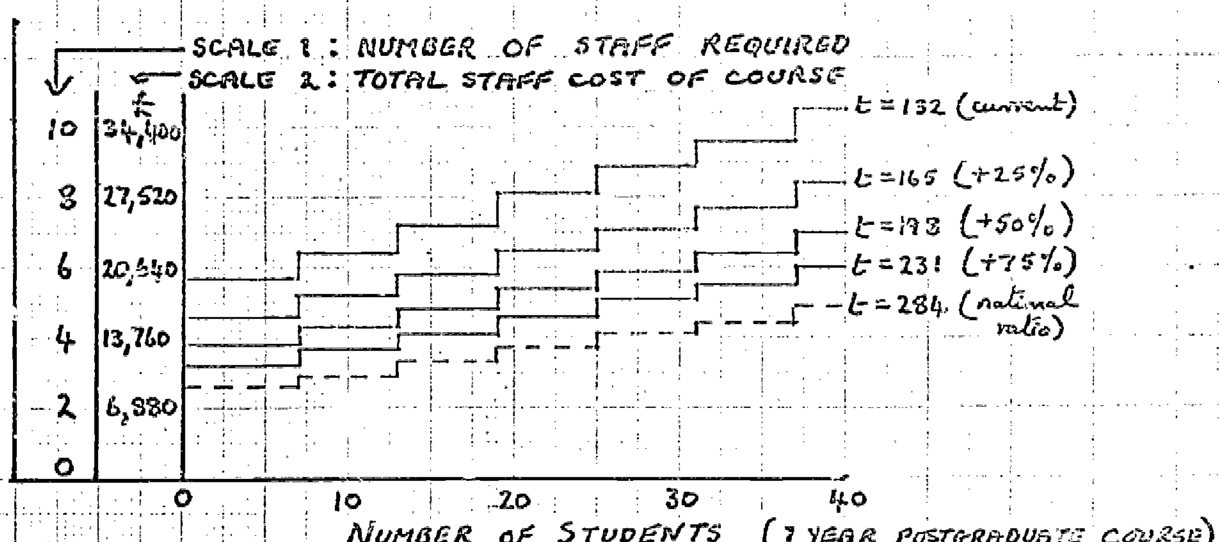


FIGURE 7·3 : STAFF NUMBERS AND COST WITH DIFFERENT TEACHING LOADS (t)

(CHEMICAL ENGINEERING)

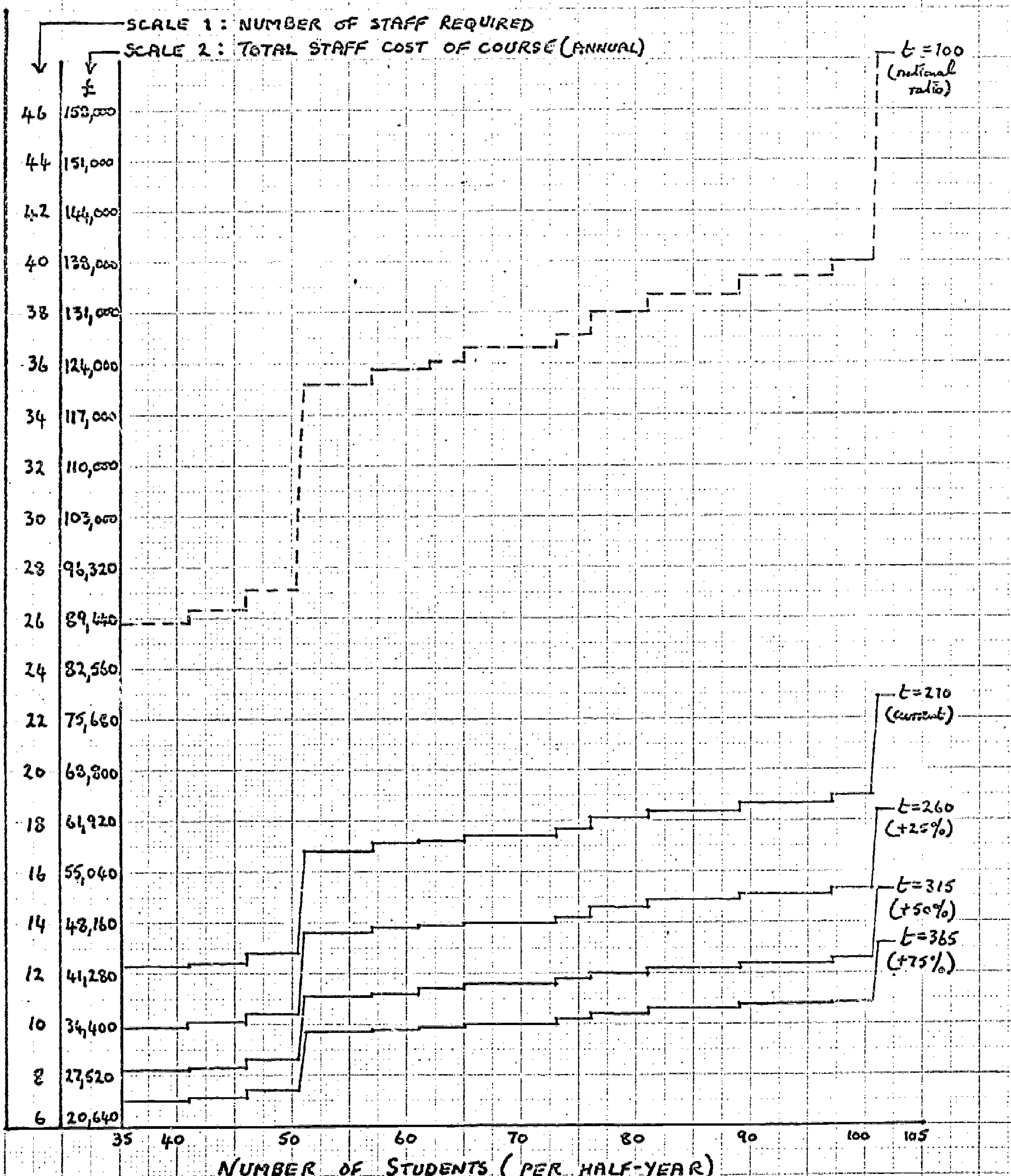
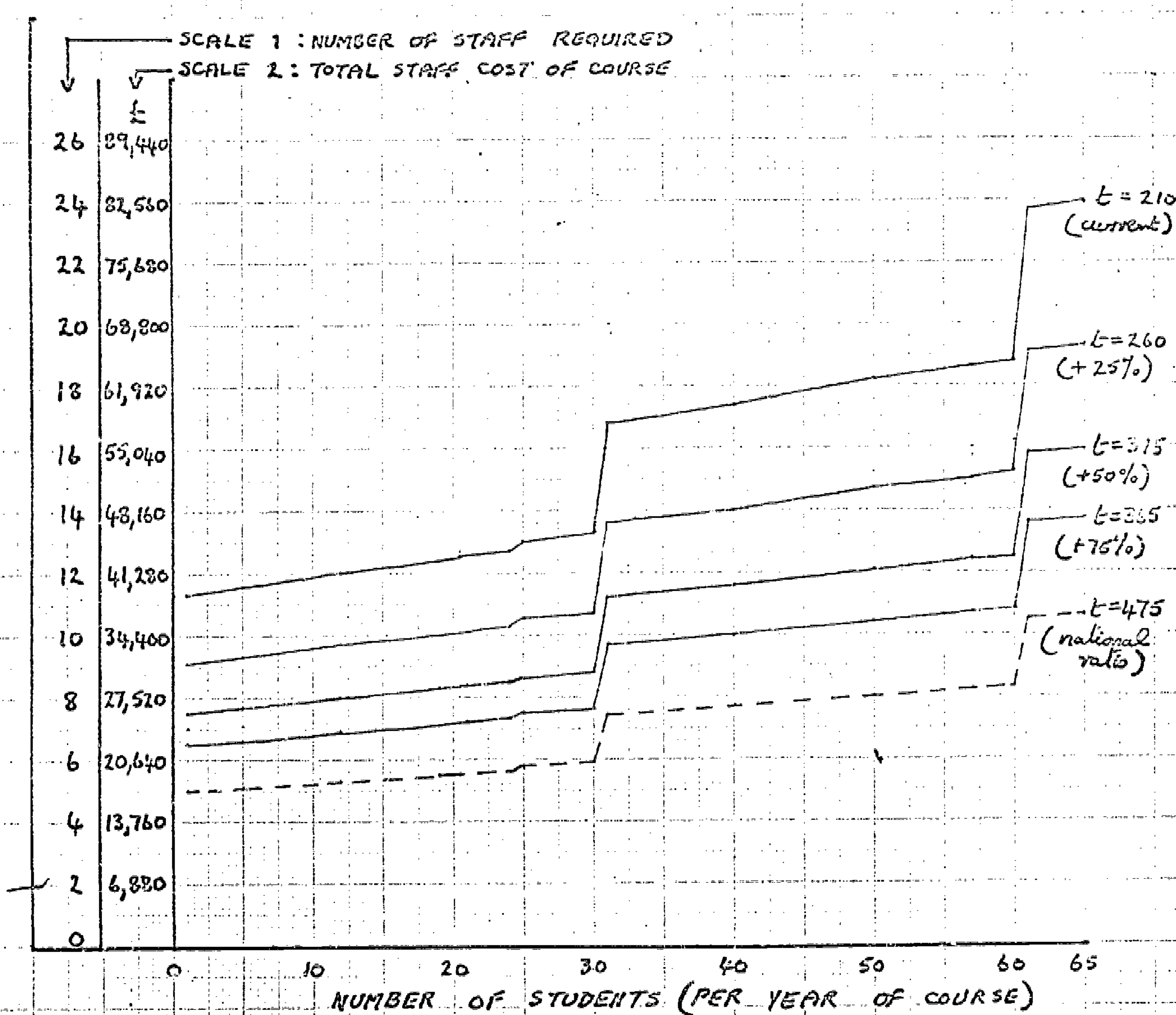
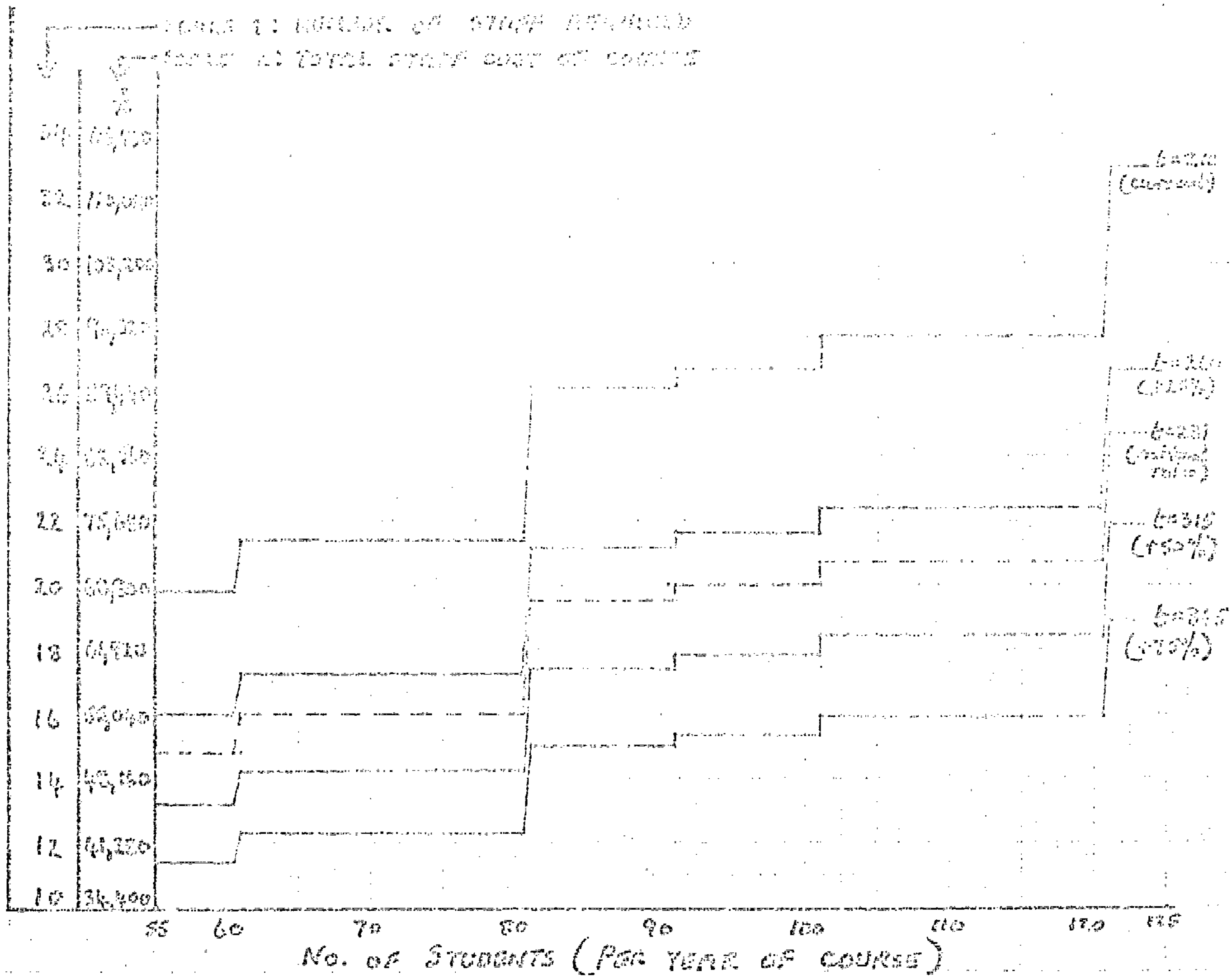
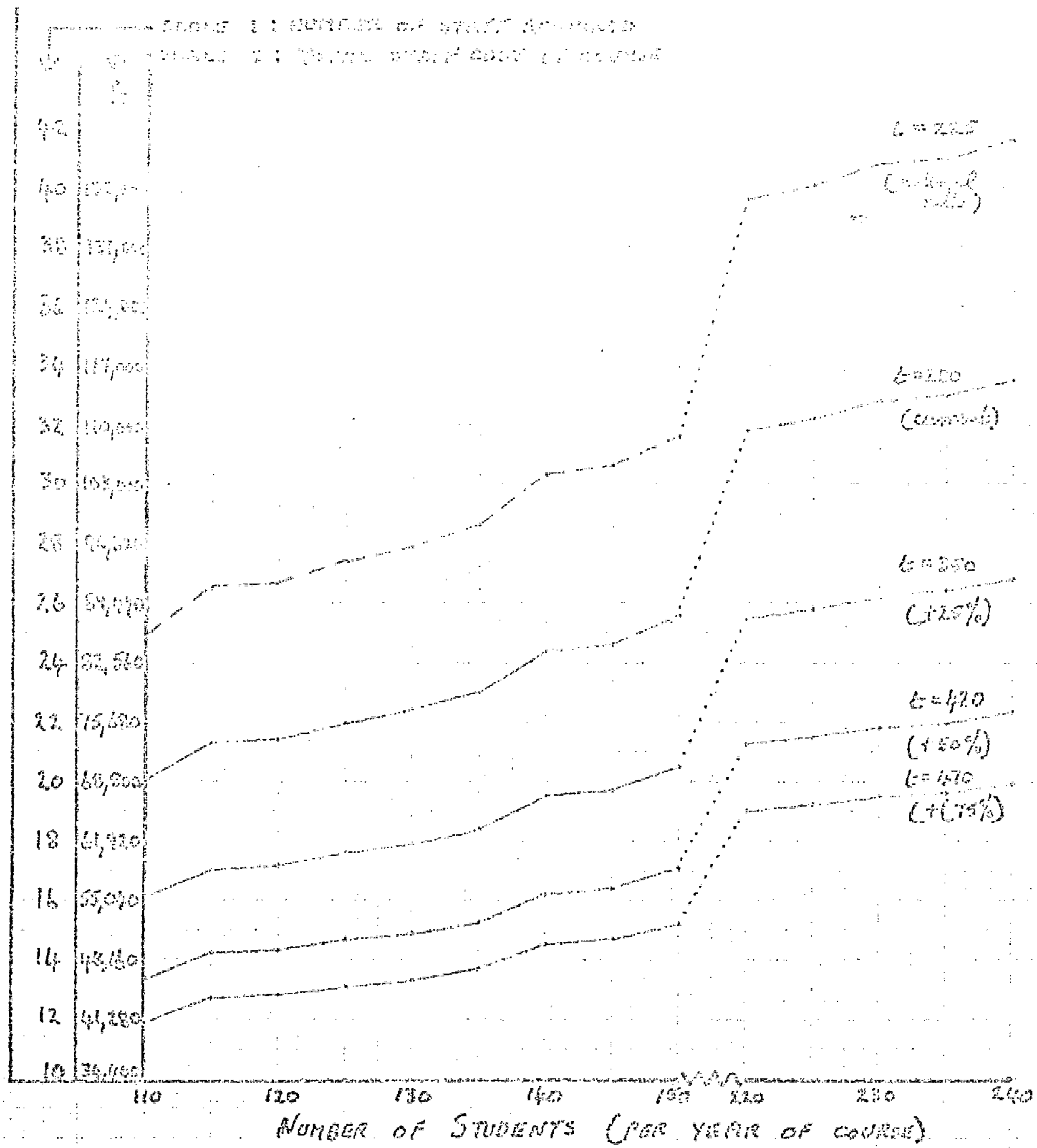


FIGURE 7·4 : STAFF NUMBERS AND COST WITH DIFFERENT TEACHING LOADS (t)

(COLOUR CHEMISTRY)




10 12 14 16 18 20 22 24 26 28 30 32 34
34,400 41,280 48,160 55,040 61,920 68,800 75,680 82,560 89,440 96,320 103,200 110,080 116,960
55 60 70 80 90 100 110 120 125
No. of Students (Per Year of Course)



40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
96,000
88,440
82,560
75,690
68,800
61,920
55,040
48,160
41,280
34,400
110
120
130
140
240
NUMBER OF STUDENTS (PER YEAR OF COURSE)
$b = 220$
(current)
$b = 330$
(+25%)
$b = 420$
(+50%)
$b = 470$
(+175%)

FIGURE 7·7: STAFF NUMBERS AND COST WITH DIFFERENT TEACHING LOADS (t)

(APPLIED PHYSICS)

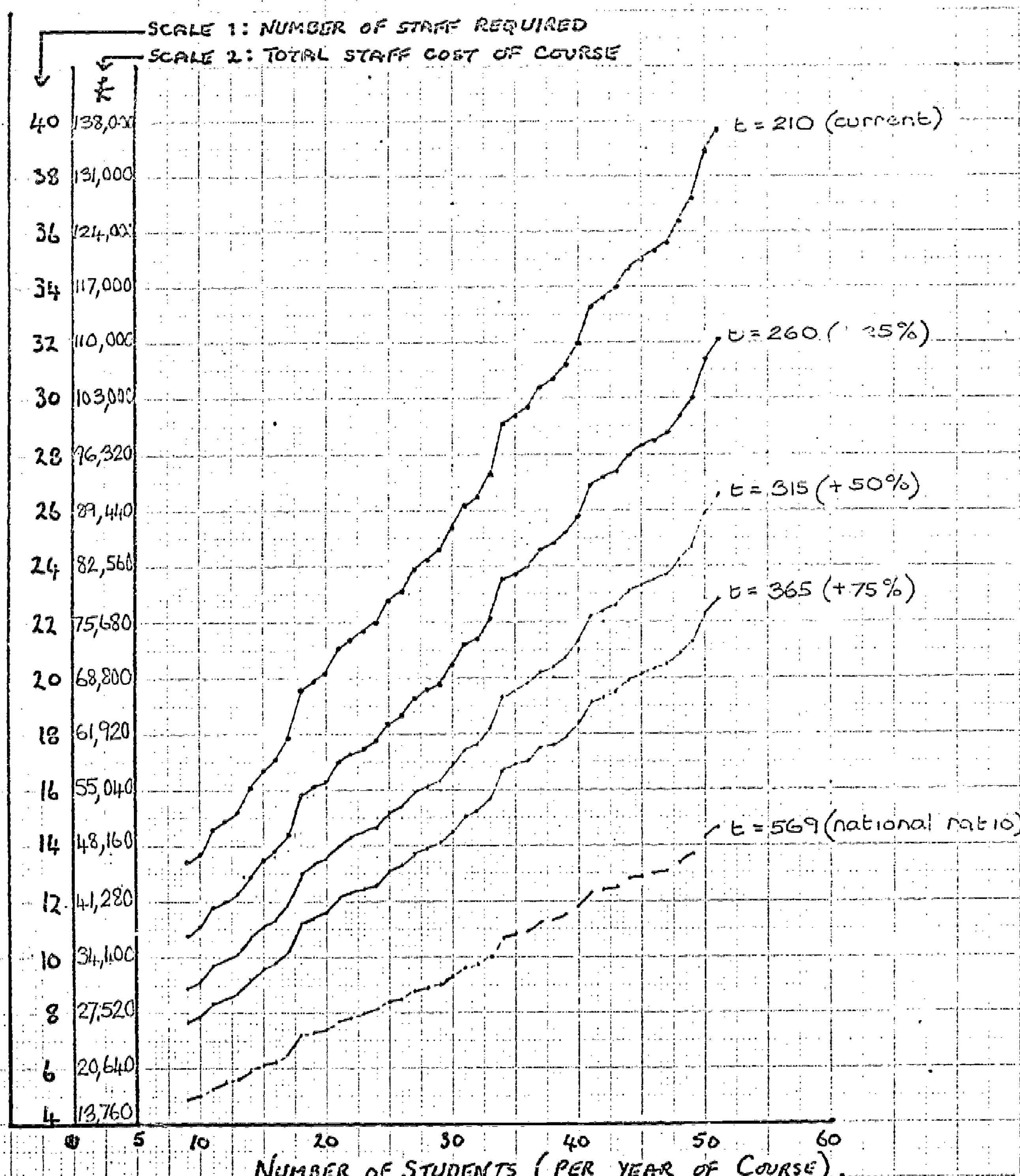


FIGURE 7·8 : STAFF NUMBERS AND COST WITH DIFFERENT TEACHING LOADS (t)

(MATERIALS SCIENCE)

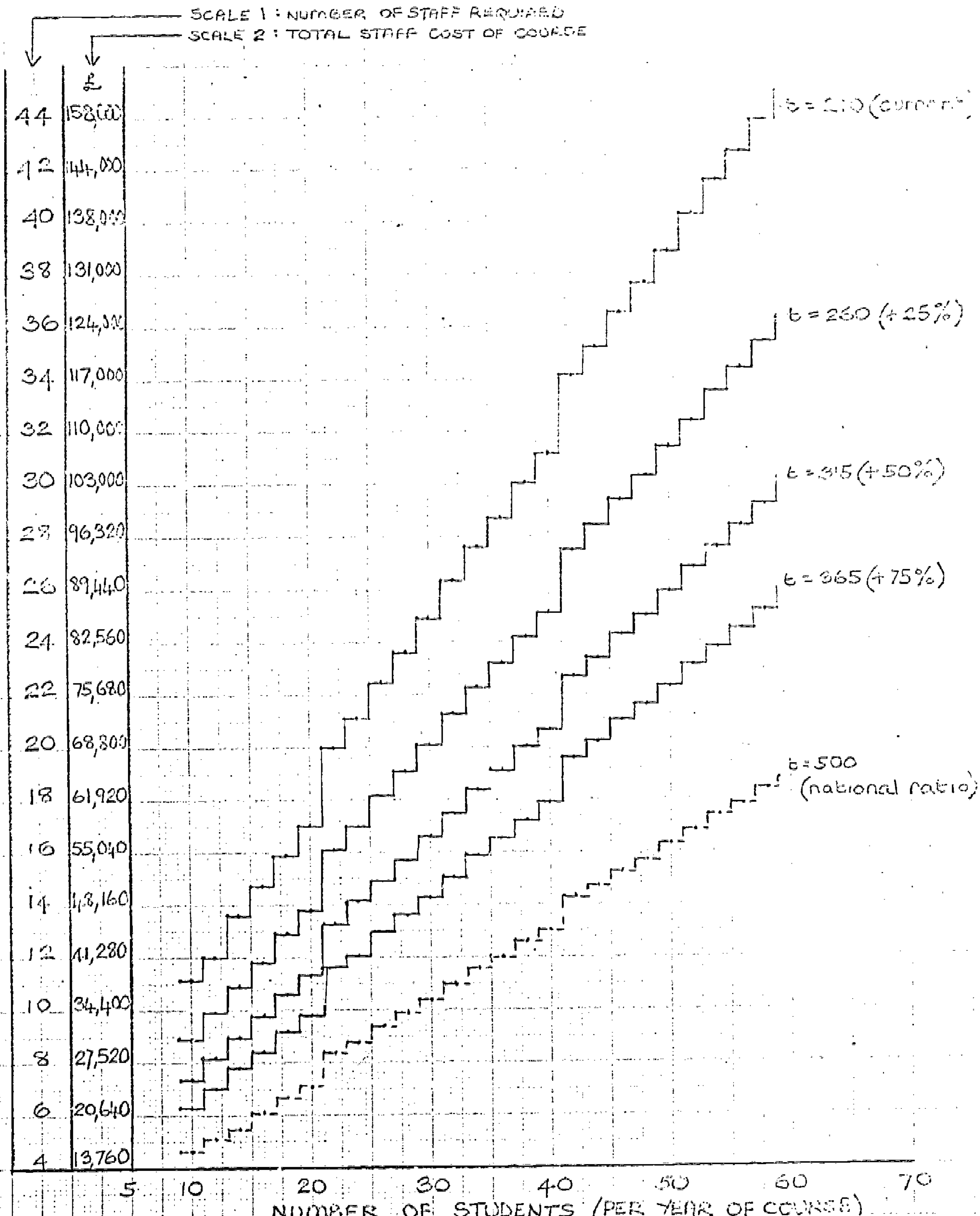
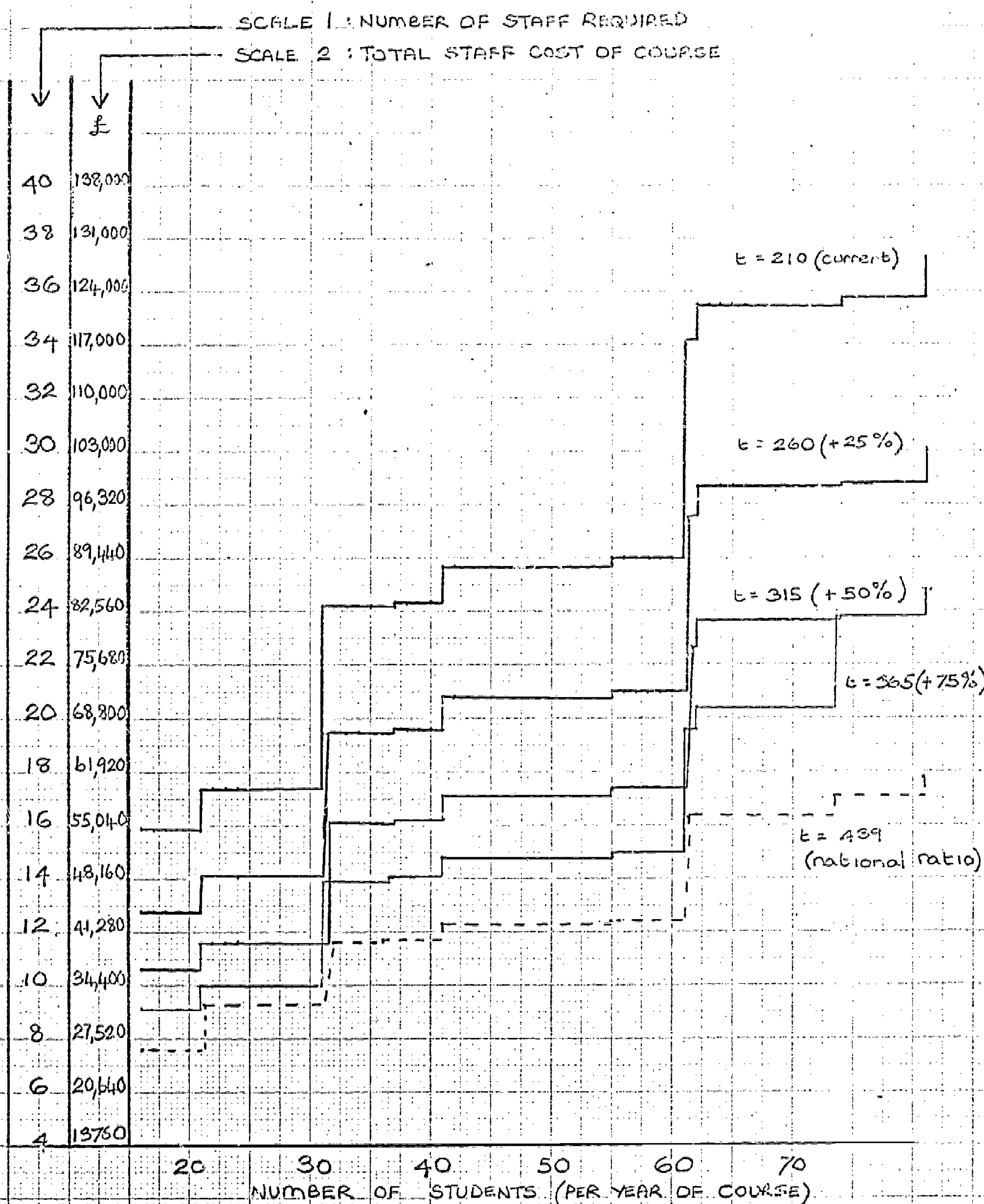


FIGURE 7.9: STAFF NUMBERS AND COST WITH DIFFERENT TEACHING LOADS (t)

(APPLIED BIOLOGY)



Accordingly, we postulate the same increases in student numbers as were considered in Chapter 5. Numbers are increased to approximately twice their present size, care being taken to choose optimum points corresponding to troughs in the Staff Cost Index.

Tables 7.5 and 7.6 respectively, show, at an optimum level of enrolment approximately double the present, the number of academic staff required, and the academic staff cost of the course, for each teaching load.

Table 7.5 : Academic Staff Numbers in relation to Teaching Load with an Approximate Doubling of Enrolment

Course	Teaching Load				
	Current Average for Board of Studies	25% increase	50% increase	75% increase	Obtained from U.K. Staff: Student ratio
Pharmacology	11.9	9.6	7.9	6.8	5.4
Chemical Engineering	19.0	15.3	12.6	10.9	40.0
Colour Chemistry	18.8	15.2	12.5	10.8	8.3
Civil Engineering	27.7	22.4	18.4	15.9	20.7
Computer Science	8.1	6.5	5.4	4.6	3.8
Social Sciences	33.5	26.8	22.3	19.9	41.7
Applied Physics	36.4	29.4	24.3	20.9	13.4
Applied Biology	26.1	21.0	17.4	15.0	12.5
Materials Science	31.2	25.2	20.8	17.9	13.1

Table 7.6 : Academic Staff Cost of Course in Relation to Teaching Load with an Approximate Doubling of Enrolment

Course	Teaching Load				
	Current Average for Board of Studies	25% increase	50% increase	75% increase	Obtained from U.K. Staff: Student Ratio
	£	£	£	£	£
Pharmacology	40,900	33,000	27,200	23,400	18,600
Chemical Engineering	65,400	52,600	43,300	37,500	138,000
Colour Chemistry	64,700	52,300	43,000	37,200	28,600
Civil Engineering	92,900	76,700	63,300	54,700	71,200
Computer Science	27,900	22,400	18,600	15,800	12,700
Social Sciences	115,000	92,200	76,700	68,500	143,000
Applied Physics	125,000	101,000	83,600	71,900	46,100
Applied Biology	89,800	72,200	59,900	51,600	43,000
Materials Science	107,000	86,700	71,500	61,600	45,100

Table 7.7 shows the total annual savings from the nine courses together if, at the higher level of enrolment, teaching loads were increased, compared with the situation if teaching loads were held constant as student numbers increased.

Table 7.7 : Total Savings on 9 Courses in relation to Increased Teaching Load with an Approximate Doubling of Enrolment

	Increase in Teaching Load		
	+25%	+50%	+75%
Number of Staff Saved	41.3	71.1	90.0
Total Annual Saving in Staff Cost (£)	142,000	245,000	310,000

Table 7.8 presents the academic staff cost-per-student at different teaching loads, showing how the cost falls with increased enrolment and increased teaching loads.

Table 7.8 : Academic Staff Cost-per-Student in Relation to Increased Enrolment and Increased Teaching Load

Course	Full Academic Staff Cost per Student				
Enrolment:	Current	Approximate Doubling			
Teaching Load:	Current	Current	+25%	+50%	+75%
	£	£	£	£	£
Pharmacology	3123	1715	1375	1133	975
Chemical Engineering	530	328	263	217	188
Colour Chemistry	2058	1060	872	717	620
Civil Engineering	1085	774	639	528	456
Computer Science	1850	1165	932	774	609
Social Sciences	615	480	384	320	285
Applied Physics	3346	2610	2104	1742	1500
Applied Biology	2455	1447	1203	997	717
Materials Science	3292	2700	2167	1787	1540

In summary, the combined effect of an increase in enrolment to an "optimum" point approximately double the present intake, together with a 50% increase in teaching load, whilst maintaining the existing course structure is to reduce the full academic staff cost per student by between 46% and 65%.

3) EFFECT OF TEACHING LOAD ON UNIT COSTS

In this section we study, with the aid of a hypothetical example, the effect of increasing teaching load on the economic cost-per-student defined in Part 2.

Let us suppose that expansion of a course from 120 students to 160 causes the weekly number of teaching meetings to increase from 72 to 96. We further suppose that there are at present 12 staff teaching an average of 6 hours per week, and that, overall, 50% of their time is devoted to work connected with the course. Average cost of a member of staff is £3440 per year, thus the total staff cost of the course is £20,640 (£3440 x 12 x 50%), and staff cost-per-student is £172 (£20,640/120).

Now if staff numbers are held at 12 as enrolment increases, the teaching requirement of each staff member rises from 6 to 8 hours per week. The staff:student ratio is worsened and staff are required to teach 33% more hours per week.

What effect does this have on cost per student? Let us assume for the moment that in order to teach one-third more hours, each member of staff must increase the total time he devotes to the course by one-third, i.e. that preparation and marking increase in direct proportion to the amount of actual teaching.

Staff can be compensated in either of two ways for the increased time devoted to the course:

(a) by an increase in their remuneration commensurate with the increase in their workload. Since staff spend 50% of their time on work connected with the course, the increase of a third in their course work represents an increase of a sixth in their total workload. If salaries were increased by a sixth (£573 per head) the total cost of the course would be £27,520 (i.e. £20,640 + (12 x £573)), and average cost per student remains at £172. <u>Thus there is no saving in average cost if staff remuneration increases in direct proportion to workload.</u>

(b) by a commensurate reduction in their other duties, e.g. in their research activities. It might be thought that this would reduce average economic cost per student because no extra expenditure on staff is incurred in teaching the additional students. This, however, is not so. By increasing the time devoted to the course by a third, staff now spend 66.6% of their time on the course and 33.3% on research and other duties; thus instead of allocating half their salary (£1720 per head) to the course, two-thirds (£2293 per head) must now be alloted. Total cost of the course would be £27,520 and average cost per student £172, just as it was in (a) above when staff were actually paid for their increased teaching duties. What has happened in this case is that staff have shifted part of their effort from other activities to the course; consequently, the cost of that effort must be transferred to the course. The extra students are produced at the same cost per student as previously, using resources transferred from other activities. The one-third increase in the number of students on the course is catered for by a one-third reduction in research effort. There has been no increase in efficiency, no reduction in quality, but an alteration in the relative amounts of different outputs being produced.

Now the assumption that the total time devoted to the course (including preparation, marking, etc.) is *directly* proportional to the number of hours of actual teaching, is not necessarily valid. Indeed in the case we are considering, where the greater teaching load is due solely to the need to repeat existing teaching meetings, and where there is no change in the teaching content of the course, it is extremely unlikely that total time devoted to the course will increase by anything like the same proportion as the number of hours of teaching. There may be additional marking, but there will probably be little if any extra preparation.

Let us reconsider the example, this time assuming that the additional load on staff is limited exclusively to the extra two hours of teaching. Assuming (quite arbitrarily) that staff work an average of 40 hours per week, then additional remuneration of 2/40 of existing salary might be paid to staff, i.e. £172 per head. This adds £2,064 (£172 x 12) to the cost of the course, making the total cost £22,704, or approximately £140 per student instead of £172. Alternatively, if staff are compensated by a reduction in their other duties then the effect is to transfer 2/40 of total staff costs £2,064) from research, etc., to the cost of the course. As above, the total cost of the course is £22,704 and average cost approximately £140 per student. In this last case the one-third increase in the number of students on the course is catered for by a reduction of only one-tenth i.e. from 20 to 18 hours per week, in other activities.

We can now draw two conclusions. Firstly, that if it is desired to maintain the quality of education, in terms of group size and teaching content of the course, savings in cost per student can be achieved only if staff increase the number of hours they teach in greater proportion than the time required for preparation, marking, etc. Insofar as the expansion of student numbers consists of taking more students on existing courses, it seems likely that this condition will hold. The analysis in Chapter 5 of the effects of increasing enrolment, showed that the extra teaching meetings generated were simply "repeats" of existing meetings; if these are taught by the same member of staff it is probable that no extra preparation will be needed.

The second conclusion is that whether staff are directly remunerated for additional course work or have their other duties correspondingly lightened, the effect on economic cost per student on the course is the same. In the first case the extra resources required for the course (staff overtime) are bought with additional expenditure; in the other case they are shifted from other activities, and their cost must also be transferred from those activities and added to the cost of the course; admittedly there is no increase in total expenditure, but there is a loss of the other outputs, notably research. Insofar as the priority is to increase undergraduate numbers without an equal increase in expenditure then the loss of research effort may well be an acceptable price, particularly if the conditions of our first conclusion also hold. (What must obviously be avoided is a situation in which staff are paid more for their extra teaching, but themselves reduce their other activities in order to "make time" for the extra course work; this could mean a loss of other outputs without any fall in cost-per-student on the course). In other words, by increasing teaching loads, the cost of the additional students is met, not by bringing in extra resources from outside the university, but by reducing the output of the research side of university activities.

At a time of expansion of student numbers, this may not mean an absolute fall in research activity. As additional staff are employed it is possible to reduce the proportion of time (averaged over all members of staff, existing and new) devoted to research without any absolute reduction. Indeed, there is no prima facie reason why, because the number of undergraduate students is to be, say, doubled, that research activity should also be doubled. And yet the maintenance of a constant teaching load, through a period of expansion, in fact provides the resources necessary for this parallel increase in research. Furthermore, as we saw in Chapter 5, the mainten nce of a constant staff:student ratio allows teaching load to fall, thus actually increasing the proportion of staff time available for research.

Thus, whilst the concept of economic unit costs is not particularly helpful in measuring the absolute savings due to increased teaching loads, it is valuable in highlighting a vital question :- "Does the nation, for every £1,000 spent on additional academic staff to teach the extra students it wants, also want to spend a further £1,000 on research?".

PART 4

UTILISATION OF BUILDINGS

The financing of university buildings in the United Kingdom can conveniently be divided into two: the building's capital cost, and the cost of maintaining and operating it. These together constitute between one-third and one-half of cost per student in different courses, so that any savings which might be made in them are worth investigating.

The capital cost of an existing building is "sunk" in that none of it can be saved or retrieved unless the building is sold or rented out. However, the building can be utilised more fully, by teaching more students in a given period of time. This leads to savings because the additional students will not require new buildings, which would have had to be built if the level of utilisation of the existing buildings had not been improved. The additional capital cost of providing a new teaching place is estimated by the Department of Education and Science at £3000 (or £300 annually at 10% over 60 years), although this figure includes recreational and catering facilities.[1]

At the same time the costs of maintaining and operating existing buildings may increase with their greater utilisation. However, the increase is not likely to be more than proportionate to student numbers, and will probably fall pro rata.

There are two broad ways in which a building may be used more fully:

(i) more intensively

(a) by using more fully the available flow of room-hours prescribed by the length of the working day, week, and academic year

(b) by using more of the seats in each room, by ensuring that each class meets in a room no bigger than is necessary to accommodate it.

Chapter 9 considers the effects on costs of more intensive utilisation of teaching accommodation.

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1. U.K. Department of Education and Science: Education Planning Paper No. 2: "Students in Higher Education in England and Wales", HMSO, 1970, Table 14, p. 28. A footnote is given to the figure of £3000 as follows: "Including acquisition of land, building costs and professional fees and initial furnishings. An apportioned share of the cost of circulatory space and of those recreational and catering facilities provided for all students, whether or not residential, is also included. Student residence is excluded."

(ii) more extensively, by increasing the length of the working day and/or week and/or academic year. This will increase the number of room-hours available in a given year with a fixed stock of accommodation. Chapter 10 considers the cost implications of more extensive use.

Both methods facilitate a fuller utilisation of existing university buildings, and thus avoid the cost of putting up new buildings. Eventually, however, existing buildings will reach full capacity and any further expansion of student numbers will require a new building. Possible economies here are considered in Chapter 11.

The capital cost of a new building will constitute a high step in the finan- cost of the university, at least in the short run when the building is being constructed. This raises the question of constructing new university buildings at a lower cost per square foot. Also, student numbers will tend to increase slowly so that the new building will not become reasonably utilised until after a few years of use. Economies might be made if university building programmes could be more closely related to the expansion of student numbers, so that small units of buildings, possibly pre-fabricated, are added as required instead of putting up one large building from the start. Alternatively, pressure on accommodation might be allowed to become severe before new buildings are constructed, or enrolment policy may be so planned as to bring new buildings rapidly into full use.

Firstly however we consider the existing level of utilisation of teaching accommodation in the University of Bradford.

CHAPTER 8

THE EXISTING UTILISATION OF TEACHING ACCOMMODATION

a) General Purpose Teaching Accommodation

Table 8.1 shows the degree of utilisation of rooms by type and size in the university as a whole.[1] (Certain buildings remote from the main campus or due for early demolition are excluded.) The number of hours actually timetabled for each room is found as a percentage of the current 32 hours per week maximum available.[2] The average utilisation rate for the whole university is 58.7%. Figures are aggregated for all rooms of the same type and size, and the result is shown in Column 7 of the Table. Comparisons may be made between the utilisation of:

(1) rooms of different types, and,
(2) rooms of the same type, but of different sizes.

(1) Rooms of different types

The striking point here is that drawing offices are very much under-utilised compared with other room types. They average only 23.3% utilisation of room-hours per week compared with other room types which vary between 58.8% and 63.6% utilisation. All eight drawing offices are scheduled for only 58 hours per week in total. If these could be used at the current rate of utilisation of the other room types (i.e. 58.7%), then three drawing offices only (providing about 100 hours per week) would be sufficient to meet present needs, instead of the eight at present available. It seems likely, therefore, that some of these spare drawing offices could be converted to general teaching rooms, leaving enough excess capacity for any expansion of student numbers in the short-term.

It may be thought that drawing offices are too specialised to be shared by different schools. However, according to a recent internal university report, this is not the case in the engineering schools, which use six of the eight drawing offices concerned. There are plans to make the use of offices more flexible between the schools, although it is thought unlikely that more than one drawing office will be converted.

(2) Rooms of different sizes

Comparing the utilisations of rooms of the same type but of different capacities is difficult because of lack of data concerning the group sizes involved in

1. This includes the five major university buildings, viz. Main, Civil Engineering & Nuclear Science, Chemistry & Chemical Technology, Chemical Engineering, and Wardley House.
2. This is the current basic teaching week at the University of Bradford (9:00 - 1:00 and 2:00 - 5:00, Mondays to Fridays, excluding Wednesday afternoons).

Table 8.1 TEACHING ROOM UTILISATION BY ROOM TYPE

(1970 - 1971)

Type of Room (1)	Size of room (range of no. of seats) (2)	No. of rooms of size in University* (3)	Maximum no. of room/hours per week available ((3) x 32 hrs) (4)	Hours per week scheduled for use (5)	Surplus hours per week (4) - (5) (6)	Percentage Utilisation $(\frac{(5)}{(4)} \times 100)\%$ (7)
(1) Drawing Office	6	1	32	0	32	0
Drawing Office	16 - 18	3	96	22	74	22.9
Drawing Office	32 - 42	2	64	18	46	28.1
Drawing Office	60 - 72	2	64	18	46	28.1
TOTAL		8	256	58	198	23.3
(2) Lecture Theatre	70 - 72	3	96	60	36	62.5
Lecture Theatre	80 - 95	5	160	117	43	73.1
Lecture Theatre	105	1	32	12	20	37.5
Lecture Theatre	126 - 144	2	64	32.5	31.5	50.8
Lecture Theatre	161 - 216	3	96	43	53	44.8
TOTAL		14	448	264.5	183.5	63.6
(3) Lecture Rooms	15 - 20	13	416	258	158	62
Lecture Rooms	24 - 30	27	864	550.5	313.5	63.7
Lecture Rooms	35 - 44	17	544	348.5	195.5	64.1
Lecture Rooms	50 - 60	8	256	154	102	60.2
TOTAL		65	2080	1311	769	63
(4) Others	12 - 20	12	384	217	167	56.5
Others	30 - 60	3	96	65	31	67.7
TOTAL		15	480	282	198	58.8
OVERALL AGGREGATE		102	3264	1915.5	1348.5	58.7

Laboratories (other than Social Sciences) are excluded

*i.e. Main, Wardley, Civil Engineering, Chemistry, and Chemical Engineering/Nuclear Science Buildings

Table 8.2 (continued) TEACHING ROOM UTILISATION BY BUILDING

Type of Room (1)	Size of room (range of no. of seats) (2)	No. of rooms of size in University (3)	Maximum no. of room/hours per week available ((3) x 32 hrs) (4)	Hours per week scheduled for use (5)	Surplus hours per week (4) - (5) (6)	Percentage Utilisation $(\frac{(5)}{(4)} \times 100)\%$ (7)
WARDLEY HOUSE						
Lecture Room	15 - 20	8	256	157	99	61.3
Lecture Room	26 - 30	5	160	123	37	76.9
Lecture Room	35 - 40	4	128	95.5	32.5	74.8
Language Lab.	16 - 20	3	96	64	32	66.7
Seminar Room	15 - 20	6	192	103	89	53.6
Geog. Lab.	20	1	32	17	15	53.1
Psych. Lab.	11 - 20	1	32	15	17	46.8
Lecture Theatre	72	1	32	20	12	62.5
Lecture Theatre	144	1	32	16.5	15.5	51.6
TOTAL		30	960	611	349	63.6
CIVIL ENGINEERING BUILDING						
Lecture Room	20 - 26	3	96	12	84	12.5
Lecture Room	36	4	128	62	66	48.4
Lecture Room	60	1	32	0	32	0
Drawing Office	60 - 72	2	64	18	46	28.1
Lecture Theatre	126	1	32	16	16	50
Lecture Theatre	216	1	32	12	20	37.5
TOTAL		12	384	120	264	31.3

Laboratories (other than Social Sciences) are excluded

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each class hour. Although the larger capacity rooms may be well utilised in terms of room-hours, they often house relatively small classes which it would be quite possible to hold in smaller rooms. The problems of timetabling, and the lack of a stock of rooms of the appropriate sizes within the university, may give rise to this placing of small groups in large rooms.

There is little variation in utilisation rates for rooms of different sizes. In the case of lecture theatres, the largest of them tend to be used less than the small. This situation may be reversed over the next five or ten years, however, for the expected expansion in student numbers, along with the growing use of the modular system of teaching, whereby students on several different courses attend the same lectures simultaneously, should lead to many very large lecture groups.

In Table 8.2 the stock of rooms is broken down by building. The Table shows little variation between buildings in the average utilisation of rooms with the single exception of the new Civil Engineering building. Whereas the four other buildings vary between 61.3% and 63.6% utilisation, Civil Engineering has a utilisation rate of only 31.3%. This low figure arises from the fact that it is the newest of the teaching buildings at Bradford.[3] The School of Civil Engineering is stationed in the building and is responsible for virtually the whole of the 31.3% usage. The building's under-utilisation is thus aggravated by its lack of use by other schools, and this is probably because of the difficulties of changing the central timetables. As a result, only additional class-hours are likely to be scheduled in the new building, and then only when space is not available in the area at present used by the school concerned. It would be pointless to move existing meetings into the Civil Engineering building just for the sake of improving its utilisation. However, it is clear that there is considerable surplus space in this building, and the present central control of room allocation should ensure that this space is brought into use as the demands of other schools increase with the growth of their student numbers.

Apart from the Civil Engineering building, the utilisation slightly exceeds the rate of eighteen hours a week (or 56% utilisation assuming the Bradford 32 hour week) suggested in a report of the Committee of Vice-Chancellors and Principals,[4] as a minimum at which a university should be considered for a new building.

Probably the most under-utilised of all rooms in Bradford University are the Great and Small Halls and the Main Lecture Theatre. Together they cover a considerable floor area and encompass an even larger volume of air. They are not timetabled for any regular teaching periods, but at least one of them could be in use at any time without seriously restricting their availability for public and social occa-

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3. The cost figures quoted in Chapter 3 relate to the year during which Civil Engineering moved from the Main Building into its own premises. The figures consequently include part of the costs of both these buildings.
4. The Committee of Vice-Chancellors and Principals of the Universities of the United Kingdom: "The Utilisation of Non-Specialised Teaching Rooms, K. M. Davies, 1968

Table 8.2 TEACHING ROOM UTILISATION BY BUILDING

Type of Room (1)	Size of room (range of no. of seats) (2)	No. of rooms of size in University (3)	Maximum no of room/ hours per week available ((3) x 32 hrs) (4)	Hours per week scheduled for use (5)	Surplus hours per week (4) - (5) (6)	Percentage Utilisation $(\frac{(5)}{(4)} \times 100)\%$ (7)
MAIN BUILDING						
Lecture Theatre	70 - 72	2	64	40	24	62.5
Lecture Theatre	80 - 90	4	128	84	44	65.6
Lecture Theatre	161	1	32	11	21	34.4
Lecture Rooms	24	17	544	345	199	63.4
Lecture Rooms	30 - 35	4	128	56	72	43.8
Lecture Rooms	40 - 44	6	192	156	36	62.5
Lecture Rooms	50 - 54	2	64	51	13	79.7
Drawing Office	6	1	32	0	32	0
Drawing Office	16	2	64	21	43	32.8
Drawing Office	32	1	32	15	17	46.9
Tutorial Room	12	1	32	18	14	56.3
Computing	30	1	32	25	7	78.1
Geog. Room	40	1	32	22	10	68.8
TOTAL		43	1376	844	532	61.3

Laboratories (other than Social Sciences) are excluded

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Table 8.2 (continued) TEACHING ROOM UTILISATION BY BUILDING

Type of Room (1)	Size of room (range of no. of seats) (2)	No. of rooms of size in University (3)	Maximum no. of room/hours per week available ((3) x 32 hrs) (4)	Hours per week scheduled for use (5)	Surplus hours per week (4) - (5) (6)	Percentage Utilisation ($\frac{(5)}{(4)}$ x 100)% (7)
CHEMISTRY BUILDING						
Lecture Room	30	2	64	47.5	16.5	83.6
Lecture Room	55	2	64	40	24	62.5
Lecture Room	105	1	32	12	20	37.5
TOTAL		5	160	99.5	60.5	62.2
CHEMICAL ENGINEERING AND NUCLEAR SCIENCE BUILDING						
P.G. Lecture Room	20	3	96	96	0	100
P.G. Lecture Room	40	1	32	7	25	21.9
Lecture Room	60	3	96	63	33	65.6
Lecture Theatre	95	1	32	33	-1	103.1
Lecture Theatre	164	1	32	20	12	62.5
Drawing Office	18	1	32	1	31	3.1
Drawing Office	42	1	32	3	29	9.4
Project Room	60	1	32	18	14	56.25
TOTAL		12	384	241	143	62.8

Laboratories (other than Social Sciences) are excluded sions, and their large capacity would be especially valuable for large lectures given in common to students on several courses.

We have shown the utilisation of general teaching rooms and drawing offices at one institution, namely Bradford University. It would be useful to know how far the situation here is typical of other universities.

The report of the Committee of Vice-Chancellors referred to above contained the results of a survey covering the utilisation of lecture, seminar, and tutorial rooms at 47 universities in the United Kingdom. The results of the survey were broken down into five different classes of university. Regarding the three classes which together constituted the bulk of the universities -- the "larger", "smaller", and "science and technology" classes -- it was found that each of these classes averaged 1.6 seats per student, which showed that the U.G.C. norms in terms of areas (or roughly, seats) per student seemed to be applied (the other classes of university averaged slightly less). On the other hand, the weekly class-hours per room averaged 12.1 for the "larger" and "smaller" universities, but 18.1 for the "science and technology" universities. The general teaching area in the last class of universities was thus used more intensively, probably reflecting a greater number of class-hours per student. The significant point is that the U.G.C. norms on space-per-student do not distinguish between differences in average teaching hours per course between universities, so that the "larger" and "smaller" universities with their apparently lighter average teaching loads have excess space.

b) Teaching Laboratories

Laboratories are normally used either for teaching or for research, although some researchers may use a teaching laboratory in a spare period for research work of a simple or small-scale nature. Because laboratories are highly specialised, they are allocated to the school for whose use they were designed. The school itself then timetables its teaching laboratories. Data on the utilisation of teaching laboratories has proved difficult to obtain, but has been gathered from five schools of study, and this is shown in Table 8.3.

Table 8.3 Utilisation of Teaching Laboratories

Discipline (1)	No. of Labs (2)	Max. no. of room hours available / week (2) x 32 hrs (3)	Hours/week scheduled for use (4)	"Surplus" hrs/week (3)-(4) (5)	Percentage Utilisation $\frac{(4)}{(3)} \times 100$ (6)
Applied Physics	4	128	45	83	35%
Electrical Engineering	11	352	148	204	42%
Colour Chemistry	5	160	27	133	17%
Pharmacy	13	416	209	207	50%
Applied Biology	4	128	61	67	48%
AVERAGE	37	1184	490	694	41%

Laboratories are highly expensive to construct, service, and maintain compared with general teaching areas. Hence if laboratories are essential for a course, it is desirable that they should be used as intensively as possible in order to spread the cost as widely as possible. However, the limited evidence in Table 8.3 shows that laboratories tend to be considerably under-utilised in terms of hours actually scheduled for use. At the same time the complaint is sometimes heard, for example in Biology, that laboratory accommodation is tight. This paradox may be related to the fact that laboratory classes often require considerable preparation, particularly in the biological sciences; hence many laboratory classes are held in the afternoons, leaving the mornings free for preparation, and thus causing a lower level of utilisation. Because of this, 100% utilisation is likely to be impossible to achieve, and the "surplus hours" figures in Table 8.3 should therefore be viewed with caution.

Probably the best long-run answer from the point of view of economy would be to abandon laboratory work for teaching purposes. At Bradford, Chemical Engineering have gone a long way towards doing this, arguing that their students gain laboratory experience during their industrial periods. However, in other schools, there is considerable resistance to even reducing laboratory practicals. In the case of the Life Sciences, it is argued that many firms would refuse to take students without laboratory experience, for their industrial periods. The alternative is to lengthen the working day to provide sufficient time both for the preparation and for actual teaching

It has so far proved impossible to devise a measure of the capacity of laboratories, because on different years of different courses students may work alone, in pairs, or in small groups. The number of laboratory "stations" is not therefore directly related to the number of students that can be accommodated, nor in the case of some subjects is the number of "stations" constant. This makes it extremely difficult at present to judge whether or not laboraoties are being used efficiently. Further research into the factors affecting the area of laboratories required in different subjects would be invaluable, as the cost of laboratory space is a major element of cost per student.

c) Surplus Area Based on U.G.C. Norms

The university has made its own comparison[5] of the accommodation actually in use in 1969-70 and its theoretical entitlement under U.G.C. planning norms, based on the number of students enrolled in 1969-70. Table 8.4 summarises the findings.

Table 8.4 Actual Accommodation and Theoretical Entitlement Based on U.G.C. Norms, 1969-70

Type of Accommodation	Actual Area (sq.ft.)	Theoretical Entitlement (sq.ft.)	Excess over Entitlement
Staff Offices	77,416	71,750	8%
General purpose teaching rooms	75,271	36,282	108%
Laboratories	272,507	174,947	56%

5. University of Bradford, Document SC3/70-71, Appendix 2, October 1970

The entitlement for staff offices relates only to staff financed by U.G.C. funds; the 8% surplus is available for use by separately financed research staff. The excess of general purpose teaching rooms bears out the findings on utilisation presented earlier in this chapter. The U.G.C. would itself treat the laboratory norms with caution; nevertheless they confirm the low levels of laboratory utilisation in the sample of schools of study investigated in this report.

It is worth noting that although the percentage utilisation of laboratories (41% in the departments studied) is lower than that of general purpose teaching rooms (61.3% over the whole university), the excess of actual area over the entitlement according to U.G.C. norms is less in the case of laboratories than for general purpose teaching rooms. This throws some doubt on the validity of the U.G.C. norms, particularly those relating to laboratory areas.

Indeed one might go further and question whether it is useful to define any norm relating space to student numbers. Space requirements (in terms of square foot-hours) can be calculated fairly accurately from the structure of the course. It would, consequently, be more realistic to require universities to justify their teaching accommodation requirements in terms of the teaching that will be provided for different courses, rather than on the number of students likely to be registered.

CHAPTER 9

ECONOMIES ARISING FROM MORE INTENSIVE UTILISATION OF TEACHING ACCOMMODATION

Economies from the more intensive use of teaching accommodation can be realised in either of two ways: either through selling or renting out some of the existing stock of buildings, or by increasing the throughput of students. The first alternative is rarely practicable, whereas the second is highly relevant at a time when a major expansion of student numbers is under consideration.

The economies occur because capital and maintenance costs are spread over a greater number of students. The ratio of capital cost to maintenance cost over the whole university is approximately 2:1, so that two-thirds of the saving is in the already sunk capital cost of the building, and is not therefore reflected by a reduction in current expenditure. However the more intensive utilisation does preclude or delay the investment of further capital in new buildings, and thus affords saving in future capital expenditure.

The analysis presented here follows logically from Part 3 in using the structure of a course to determine the number of teaching meetings at different levels of enrolment. From this the accommodation implications can be deduced since each teaching meeting requires the use of one room-hour, and the size and type of the student group taught determines the size (i.e. number of seats, laboratory benches, etc.) and type (i.e. lecture, seminar, laboratory, etc.) of the room required for that hour.

Hence, given a particular course structure and a certain level of student numbers on the course, it is possible to calculate the number of room-hours in rooms of various sizes and types required each week. Such an analysis may have two possible uses:

(i) to examine the present capacity of existing buildings, and
(ii) to plan the composition of new buildings.

In either case, two major constraints apply. The first is that for any building, the number of room-hours available is determined by the number of teaching rooms in the building and the length of the working day, week, and academic year. The second constraint is the problem of timetabling, of fitting a particular group with the appropriate lecturer in a room of the right size and type at the right time. For this reason it is unlikely that a 100% utilisation of room-hours can ever be achieved, and some lesser rate must be taken as the practical maximum.

The better the match between the accommodation required and the accommodation available, the greater will be the utilisation of individual rooms. However, the accommodation requirements of a course will tend to change as student numbers on the course increase, and more and larger teaching meetings occur. For this reason, accomodation which once matched the requirements of the course might become increasingly unsuitable. This emphasises the importance of proper planning of future accommodation requirements.

Table 9.1 Teaching Meetings Required by Civil Engineering with 60 students per year

Type of Meeting	Maximum size of Meeting (g)	Number of meetings required with 60 students (G)	Actual Meeting size with 60 students	Number of meetings per each student c per year	No. of meetings (M) (in hours) Per Year	Per Week
YEAR 1						
Lectures	No max.	1	60	300	300	10
Ex. Classes	40	2	30	30	60	2
Drawing Prac.	40	2	30	135	270	9
Laboratory	40	2	30	60	120	4
Class Ex/Diss	30	2	30	60	120	4
Class Ex/Diss	20	3	20	75	225	7.5
					SUB-TOTAL	36.5
YEAR 2						
Lectures	No max.	1	60	270	270	9
Ex. Classes	40	2	30	60	120	4
Laboratory	40	2	30	120	240	8
Classes	30	2	30	60	120	4
Classes	20	3	20	60	180	6
Drawing Prac.	40	2	30	90	180	6
8 options	30	8	7.5	25 x 8	200	6.6
					SUB-TOTAL	43.6
YEAR 3			Industrial Training			
YEAR 4						
Lectures	No max.	1	60	120	120	4
Lectures (8 options)	No max.	8	7.5	30 x 8	240	8
Classes	40	2	30	60	120	4
Classes (8 options)	40	8	7.5	25 x 8	200	6.6
Design Office	40	2	30	270	540	18
Laboratory	20	3	20	75	225	7.5
					SUB-TOTAL	48.1
					TOTAL	128.2

Table 9.2 Teaching Meetings Required by Civil Engineering with 180 students per year

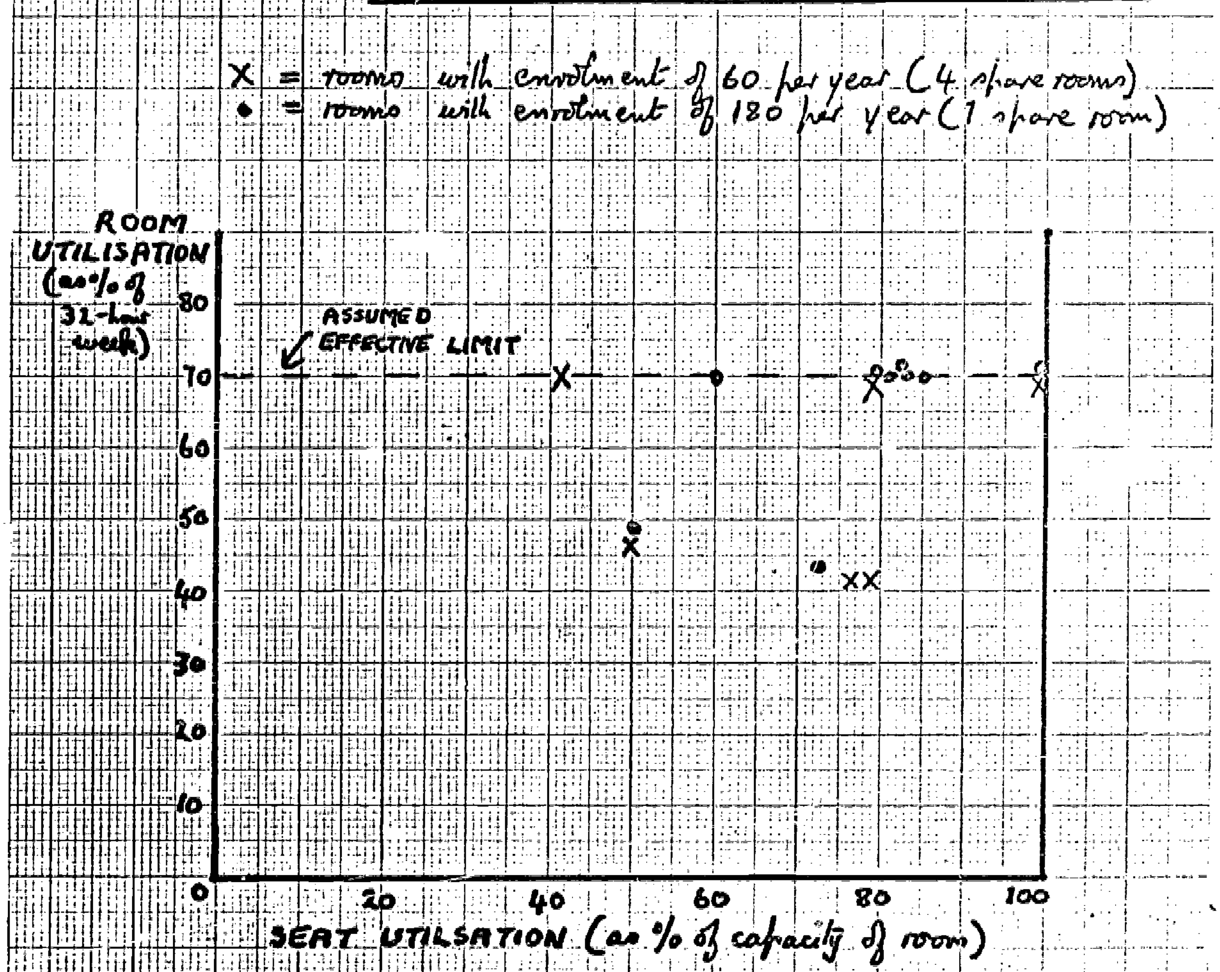
Type of Meeting (1)	Maximum size of meeting (2)	Number of meetings required with 180 students $\frac{180}{(2)}$ rounded up (3)	Actual meeting size with 180 students $\frac{180}{(3)}$ (4)	Number of meetings per each student per year (5)	No. of meetings (in hours) Per Year (3)x(5) (6)	Per Week (6)/30 (7)
YEAR 1						
Lectures	No max.	1	180	300	300	10
Ex. Classes	40	5	36	30	150	5
Drawing Prac.	40	5	36	135	675	22.5
Laboratory	40	5	36	60	300	10
Class Ex/Diss	30	6	30	60	360	12
Class Ex/Diss	20	9	20	75	675	22.5
					SUB-TOTAL	82
YEAR 2						
Lectures	No max.	1	180	270	270	9
Ex. Classes	40	5	36	60	300	10
Laboratory	40	5	36	120	600	20
Classes	30	6	30	60	360	12
Classes	20	9	20	60	540	18
Drawing Prac.	40	5	36	90	450	15
8 options	30	8	22.5	25 x 8	200	6.6
					SUB-TOTAL	90.6
YEAR 3			Industrial Training			
YEAR 4						
Lectures	No max.	1	180	120	120	4
Lectures (8 options)	No max.	1	180	30 x 8	240	8
Classes	40	5	36	60	300	10
Classes (8 options)	40	8	22.5	25 x 8	200	6.6
Design Office	40	5	36	270	1350	45
Laboratory	20	9	20	75	675	22.5
					SUB-TOTAL	101.5
					TOTAL	274.1

a) Civil Engineering

A detailed analysis is presented in the following series of tables of the undergraduate course in Civil Engineering, which is housed exclusively in its own building. The numbers of meetings for groups of different sizes and types are calculated with a student population firstly of 60 in each year (Table 9.1) and then 180 in each year (Table 9.2) The figure of 60 is approximately the present enrolment.

These meetings are then fitted into the available accommodation in the building. Two major constraints are used. Firstly, each group must be fitted into the smallest room of the right type which will take it. Secondly, because of the problem of timetabling, we assume that each room cannot be used for more than 70% of the working week of 32 hours (i.e. 22.4 hours). This is an arbitrary figure which can be varied if necessary. The results with both 60 and 180 students are shown in Figure 9.1.

FIGURE 9·1: ROOM AND SEAT UTILISATION IN RELATION TO INCREASED ENROLMENT IN CIVIL ENGINEERING



In Figure 9.1, each 'x' represents a single room when enrolment is 60, and each '.' a room when enrolment is 180. The horizontal axis measures the average number of seats in use when the room is occupied as a percentage of those available in the room. Here, it is theoretically possible to achieve a 100% utilisation of seats. The vertical axis measures the utilisation of hours for each room as a percentage of the weekly maximum of 32 hours. Because we have assumed a maximum of 70% utilisation of room-hours, a "ceiling" has been drawn on the graph at the 70% level.

Consequently, it is possible to plot the position of each room first with 60 and then with 180 students on each year of the course. Figure 9.1 shows a pronounced shift towards the top right when student numbers are increased, indicating an increase in the utilisation of rooms. At the same time, more rooms are being used with the 180 intake (only one spare, compared with four originally).

The analysis shows that the building is at present heavily under-utilised and that, even without exceeding 70% utilisation of room-hours, enrolment could be trebled.

There will be a considerable saving in cost-per-student. The trebling of student numbers is achieved in the same teaching accommodation as at present. Teaching space cost-per-student consequently falls to one-third. If we assume that all other items of cost increase pro-rata with student numbers then the saving in total cost-per-student is 16% as illustrated in Table 9.3.

Table 9.3 Saving in Cost-per-Student through the More Intensive Utilisation of Teaching Accommodation: Civil Engineering

	Present Cost per Student with intake of 60 each year of course (£)	Cost per Student with intake of 180 in each year of course (£)	% Saving
Classroom cost	151	50	67%
Laboratory cost	462	154	67%
Other space costs	417	417	---
Total Capital & Maintenance Costs	1030	621	40%
Teaching Costs	956	956	
Administrative, Library, Student Facility, General and Miscellaneous Expenditures	523	523	---
TOTAL COST PER STUDENT	2509	2100	16%

b) Other Schools of Study

Civil Engineering may present a special case because it has the exclusive use of its own building, and the accommodation available to it is clearly defined. Other departments tend to share general-purpose teaching accommodation. Accordingly, a more generalised study has been made of five other schools of study using a simplified approach but still based on the structure of the course in question and the number and size of teaching meetings required at different levels of enrolment.

The method adopted is to postulate increased rates of utilisation of teaching laboratories within the existing 32-hour week, and then to calculate the number of students that could be enrolled. Next the demand made by this increased enrolement for classroom space is calculated, and checked against the available classroom hours. Finally cost per student is re-calculated for the enlarged enrolment using the same teaching accommodation. We have sought to improve laboratory utilisation, rather than classroom accommodation, because of the substantially greater contribution it makes to cost per student.

Table 9.4 Additional Laboratory Hours Available Per Week at Different Levels of Utilisation

School of Study	Laboratory -Hours User per Week (1)	% Utilisation (assuming a 32-hr week) (2)	Additional hours available per week at different levels of utilisation of labs				
			60% (3)	70% (4)	75% (5)	80% (6)	100% (7)
Pharmacy	209	50	41	82	103	124	207
Colour Chemistry	27	17	69	85	93	101	133
Electrical Eng.	148	42	63	98	116	134	204
Applied Biology	61	48	16	28	35	41	67
Applied Physics	45	35	32	45	51	57	83

Column 1 of Table 9.4 shows the number of hours per week that the teaching laboratories of the five schools are in use. Column 2 shows the percentage utilisation assuming a 32-hour week. Columns 3 to 7 show the additional laboratory hours that would be used if utilisation were raised to various levels between 60% and 100%. In order to allow time for preparation and clearing up of laboratories, 80% utilisation is assumed to be the effective maximum.

We may use the type of analysis developed in Part 3 of this report to calculate the additional number of students that could be taught using the extra laboratory hours made available as utilisation rises.

Using the notation of Part 3 and representing by Lu the additional laboratory hours available at u% utilisation, we may say that the number of extra students (S) is:

$$S = \frac{Lu}{c} \cdot g$$

where c = number of hours of laboratory teaching that each student must receive per week, and g is the number of students in the teaching group.

Table 9.5 shows the number of extra students that could be taught in each course at each improved level of laboratory utilisation.

Table 9.5 Increase in Student Numbers in Relation to Increased Laboratory Utilisation

% Laboratory Utilisation	Pharmacy		Colour Chem.		Elect. Eng.		App. Biology		App. Physics	
	Extra Lab-Hours	Extra Students	Extra Lab-Hours	Extra Students	Extra Lab-Hours	Extra Students	Extra Lab-Hours	Extra Students	Extra Lab-Hours	Extra Students
60%	42	120	69	210	63	270	16	30	32	90
70%	83	240	85	270	98	420	28	90	45	120
75%	103	300	93	300	116	480	35	90	51	150
80%	124	360	101	330	134	570	41	120	57	150

The expansions postulated are of a very large order indeed. Nevertheless, in terms of the actual additional laboratory teaching required and the existing low levels of utilisation, they appear possible. The effect on laboratory cost per-student would be correspondingly substantial, and this is shown in Table 9.6.

Table 9.6 Laboratory Cost per Student in Relation to Increased Laboratory Utilisation

% Laboratory Utilisation	Pharmacy		Colour Chemistry		Electrical Eng.		Applied Biology		Applied Physics	
	Lab-Cost per Student (£)	% of Existing Lab-Cost	£	%	£	%	£	%	£	%
Existing	945	100	1338	100	756	100	339	100	604	100
60%	616	67	321	24	376	50	246	73	332	64
70%	471	50	261	20	292	39	183	54	280	46
75%	420	44	243	18	268	35	183	54	240	40
80%	372	39	222	17	240	31	156	46	240	40

If we disregard Colour Chemistry, with its abnormally low level of utilisation, the saving in laboratory cost per student of expanding numbers so that laboratories are used for 80% of a 32-hour week, varies between 54% and 69%.

The increased number of students will place additional demands on general purpose teaching accommodation, and Table 9.7 shows the additional classroom-hours per week required for the various expansions. The calculations are based on the number of contact hours and the teaching group sizes operated at the present time, using the type of analysis described in Part 3.

Table 9.7 Additional Lecture and Classroom Hours Required per Week in Relation to Increased Laboratory Utilisation

% Laboratory Utilisation	Pharmacy		Colour Chemistry		Electrical Eng.		Applied Biology		Applied Physics	
	Extra Students	Extra Classroom Hours	Ex. St.	Ex. Hrs	Ex. St.	Ex. Hrs	Ex. St.	Ex. Hrs	Ex. St.	Ex. Hrs
60%	120	36	210	44	270	69	30	10	90	21
70%	240	58	270	48	360	88	90	10	120	36
75%	300	76	300	60	480	130	90	10	150	39
80%	360	80	330	62	570	153	120	20	150	39

The next step is to check whether there is sufficient general purpose teaching accommodation (lecture theatres, classrooms, seminar rooms, etc) available to meet this demand. Not only must there be sufficient room-hours, but those rooms must be sufficiently large to hold the lectures or classes. In Table 9.8 the combined demand of the five courses for additional room-hours is arranged by size of room required.

Table 9.8 Additional Lecture and Classroom-hours Required by Room-Size

Classroom Size (in seats)	Laboratory Utilisation			
	60%	70%	75%	80%
20 - 30	65	94	119	137
31 - 60	2	38	22	40
61 - 80	58	---	24	24
81+	55	108	150	153
TOTAL	180	240	315	354

In measuring the classroom-hours available to meet this demand, one has to remember that lecture rooms and classrooms are interchangeable between departments, so that any expanding course may make use of any classroom in the university. On the other hand, courses other than the five under consideration may also be expanding and require additional classroom-hours themselves. In order to simplify the analysis it is assumed that, since the five courses in question currently enroll approximately one-third of the university's students, one-third of the currently surplus room-hours may be made available to them, whilst the other two-thirds is retained to enable expansion of other courses.

In Table 9.9 the additional room-hours that would be available to the five courses in question at different levels of classroom utilisation are shown.

Table 9.9 Additional Classroom-hours Made Available by Room-size

Classroom Size (in seats)	Additional Room-hours Available at each level of Classroom Utilisation							
	65%	70%	75%	80%	85%	90%	95%	100%
up to 20	35	51	66	82	97	113	128	144
21 to 30	3	18	32	47	61	75	90	104
31 to 60	13	29	45	61	77	93	109	125
61 to 80	8	11	14	17	19	22	25	27
81+	8	14	20	25	31	37	43	49

By comparing the demands for classroom-hours expressed in Table 9.8 with the additional supply presented in Table 9.9, it is possible to see the implications of improved laboratory utilisation.

If laboratory utilisation were raised to 80% the additional classroom-hours required by the extra students would, in the case of rooms of below 80 seats, push classroom utilisation to between 90% and 95%, and would require many classes of 20 to 30 students to be held in rooms in the 30 and 60 seat bracket. Such high levels of classroom utilisation might present timetabling difficulties, although these could be alleviated by scheduling some lectures and classes outside the normal bounds of the 32-hour week. There would however be a serious shortage of room-hours in rooms exceeding 80 seats (153 extra hours required, only 40 available at 100% utilisation). Clearly in this range additional rooms would need to be built. At the other end of the scale there would still be a surplus of room hours in the small rooms of under 20 seats, and it would be possible to convert some of these to staff offices for the additional academic staff that would be required to teach the increased intakes.

In Table 9.10 revised figures are shown for the total cost-per-student in each of the five courses, due to improved utilisation of both laboratories and classrooms. The figures make allowance for the need to provide additional rooms of over 80 seats, and assume that these can be provided at the existing average cost per square foot. It is assumed that cost-per-student of all other items remains constant, although as we shall see in Part 5 there are likely also to be substantial economies in technical staff cost-per-student.

Table 9.10 Reduction in Total Cost-per-Student in Relation to Increased Laboratory Utilisation

% Laboratory Utilisation	Pharmacy		Colour Chemistry		Electrical Eng.		Applied Biology		Applied Physics	
	Total Cost per Student	% of Existing Cost	£	%	£	%	£	%	£	%
EXISTING	£3294		3918		3603		3110		3682	
60%	2957	90	2802	71	3151	87	2999	96	3275	89
70%	2777	84	2737	70	3054	85	2917	94	3215	87
75%	2712	82	2717	69	3026	84	2917	94	3131	85
80%	2671	81	2694	69	2994	83	2885	93	3131	85

It is apparent that there is considerable scope for improving the utilisation of laboratories, very often trebling the number of students without exceeding 80% utilisation. The effect on total cost per student is a reduction of between 7% and 19% in four of the courses, and 31 in Colour Chemistry with its current very low level of utilisation.

The University Grants Committee has already informed the University of Bradford that it is unlikely to be allowed any additional science buildings during the next quinquennium, and the levels of utilisation described in this chapter would clearly support their attitude. It would be useful to know at what level laboratories in other universities are used. In view of the high capital cost of providing laboratory space, there would appear to be a good case for insisting on much higher levels of utilisation before further accommodation is considered.

CHAPTER 10

ECONOMIES ARISING FROM THE MORE EXTENSIVE UTILISATION OF TEACHING ACCOMMODATION

In this chapter we remove the limitations applied in Chapter 9 that teaching must take place within a 32-hour week and within the existing framework of academic terms.

The chapter consists of two sections. In the first, we relax the 32-hour week assumption, and assume that buildings will be in use for teaching for more hours per week, and that more students will be enrolled to take advantage of this extra availability of laboratories and classrooms. This part of the analysis is essentially an extension of that carried out in Chapter 9 where the level of intensive utilisation was gradually increased. The method adopted is to gradually increase the number of hours available and to see how many more students could be accommodated, and consequently how economic cost-per-student might be expected to fall.

In the second section we alter the whole pattern of the academic year so that there are two separate student populations being taught in parallel. The effect of this is to use teaching accommodation 48 weeks of the year, and by also extending the length of the working week to enable student numbers to be doubled within the existing stock of buildings.

In each case substantial potential economies in capital and maintenance cost per student are identified.

1) Use of Teaching Accommodation for More Hours per Week

In this section we continue the analysis applied to five courses in Chapter 9, by alternatively postulating teaching weeks of 40, 50 and 60 hours instead of the present 32 hours. This means that teaching meetings may be held at any time within a total period of 40, 50 or 60 hours per week, instead of only 32, thus enabling more meetings to be held each week, and easing the problem of timetabling.

This extension of the working week does not mean that staff are required to work longer hours. In calculating cost-per-student it is assumed that staff costs per student are unchanged, implying that as the number of students increases, additional staff are recruited to maintain the same staff:student ratio. It does, however, mean that staff will be required to do some of their teaching outside what is at present regarded as their normal working week.

At each postulated length of week, we calculate the number of additional laboratory-hours that would be available to each of the five courses under consideration. We then calculate the number of additional students that could be enrolled to the course in order fully to utilise these extra laboratory-hours, assuming that the course structure, in terms of contact hours and group sizes is unchanged. Next the demand for classroom space generated by this increased enrolment is worked out and checked against the available classroom-hours. Finally the economic cost per student (as defined in Part 2), is recalculated with the same total teaching accommodation cost being spread over the greater number of students.

Increasing the utilisation of teaching accommodation either by more intensive use or by more extensive use are each viable policies on their own, but they are not mutually exclusive. Indeed they are closely complementary, and it is unlikely that any university would attempt substantially to extend the length of its teaching week without first seeking to ensure that classrooms and laboratories achieved a high rate of utilisation during the existing period of teaching. Accordingly, in the analysis that follows, we assume that the 80% intensive utilisation, which in Chapter 9 was taken as the maximum practicable, is also achieved over the longer working weeks now under examination.

Table 10.1 shows the number of extra laboratory-hours that become available for use as the length of the teaching week is extended, and 80% intensive utilisation allowed.

Table 10.1 Additional Laboratory-Hours Available per Week with Different Lengths of Teaching-Week at 80% Intensive Utilisation

School of Study	Additional Laboratory-Hours Available Per Week			
	32 hr. week	40 hr. week	50 hr. week	60 hr. week
Pharmacy	124	207	311	415
Colour Chemistry	101	133	173	213
Electrical Engineering	134	204	292	380
Applied Biology	41	67	99	131
Applied Physics	57	83	115	147

Using the type of analysis developed in Part 3 of this report, we can calculate the additional number of students that could be taught using the extra laboratory hours that become available as the teaching week is lengthened. The number of extra students is shown in Table 10.2.

Table 10.2 Additional Number of Students Possible Using Existing Laboratories For Longer Teaching-Weeks at 80% Intensive Utilisation

School of Study	Number of Additional Students		
	40 hr. week	50 hr. week	60 hr. week
Pharmacy	500	690	870
Colour Chemistry	430	550	670
Electrical Engineering	770	1030	1280
Applied Biology	160	220	290
Applied Physics	200	280	350

Such big increases in the number of students using the existing teaching-laboratories mean that laboratory cost <u>per student</u> will fall substantially. Revised figures of laboratory cost-per-student are shown in Table 10.3

Table 10.3 Laboratory Cost per Student in Relation to Longer Teaching Weeks

Laboratory Utilisation	Pharmacy		Colour Chemistry		Electrical Eng.		Applied Biology		Applied Physics	
	Lab-Cost per Student (£)	% of Existing Lab-Cost	£	%	£	%	£	%	£	%
Existing	945	100	1338	100	756	100	339	100	604	100
40 hours at 80%	294	31	177	13	184	24	108	32	172	28
50 hours at 80%	237	25	144	11	144	19	87	26	128	21
60 hours at 80%	198	21	114	9	124	16	72	21	112	18

As expected, there are substantial economies. The saving in laboratory cost per student of expanding numbers so that laboratories are used for 80% of a 60-hour week for 4 of the courses is between 79% and 84%. This, however, tends to overstate the savings slightly, as the use of buildings for longer hours will generate some increase in maintenance costs.

The greatly increased numbers of students will generate additional demand for classroom-hours. In Chapter 9, it was found that if laboratories were used for 80% of a 32 hour week, there would be severe pressure on classroom accommodation. This pressure, it was noted, would raise the utilisation of medium-sized rooms to 90 - 95%, which would probably involve some extension of the 32 hour week to solve practical timetabling problems. This safety-valve would not of course be available if the standard teaching week were extended to 60 hours. We have therefore, in estimating total cost per student, with longer working weeks assumed that additional classroom accommodation will be required pro rata for all extra students beyond the number enrolled when the working week was 32 hours, and intensive utilisation 80%. In other words, there is no further reduction in classroom cost per student below the levels obtained when rooms are used for 80% of a 32 hour week.

In Table 10.4 we show total economic cost per student for each of the five courses with different working weeks, assuming that laboratories are used for 80% of the time, and that the additional classrooms required are provided at the current cost per square foot.

Table 10.4 Reduction in Total Cost-per-Student in Relation to Longer Teaching Weeks

Laboratory Utilisation	Pharmacy		Colour Chemistry		Electrical Eng.		Applied Biology		Applied Physics	
	Total Cost per Student	% of Existing Cost	£	%	£	%	£	%	£	%
EXISTING	£3294		3918		3603		3110		3682	
40 hours at 80%	2593	79	2649	68	2938	81	2837	91	3083	84
50 hours at 80%	2536	77	2613	67	2898	80	2816	90	3039	82
60 hours at 80%	2497	76	2586	66	2878	80	2801	90	3023	82

It will be seen that an extension of the teaching week to 60 hours and intensive utilisation of 80%, enables student numbers to be increased to an extent which reduces the total economic cost-per-student by between 10% and 24%. This total cost is the average for <u>all</u> students on the course, not just the additional ones, where strict marginal cost is almost zero. Although the increase in the number of students is very large, the proportionate saving in total cost per student is not great. However the savings represent the avoidance of constructing expensive new laboratory accommodation, for which large capital sums would be required.

It is recognised that there are practical problems of increasing both the intensive degree of utilisation, and the length of the teaching week. In particular there may be timetabling difficulties, and it may be necessary to find some form of inducement to academic and technical staff to work outside the conventional working hours. However, in view of the cost of providing new accommodation, it is important to utilise existing space as fully as possible. The levels of utilisation, both of laboratories and classrooms, quoted in Chapter 8, leave considerable scope for improvement, and the potential savings identified in Chapter 9 and so far in Chapter 10, provide ample economic inducement to attempt to make such an improvement. In view of this, further more detailed study of the advantages and problems of spreading teaching over a longer working week, is justified.

2) Re-arrangement of the Academic Year

It is beyond the scope of this report to consider the academic and administrative arguments for and against re-arranging the pattern of the academic year, to avoid the long periods during which university buildings are not, at present, in use. Our concern here is to estimate the reduction in the unit economic costs defined in Part 2, that might accrue if some such alternative system were adopted.

The University of Bradford already operates several different types of academic year for different courses, and these were described in Chapter 3. Some of these courses already utilise teaching accommodation for up to 42 weeks of the year. In this chapter we take each course that at present operates on a conventional 3-year 3-term system, or on a "thick-sandwich" system (3 conventional years with a complete interspersed year in industry), and translate it into a double-entry system, explained below.

Hypothetical Pattern of Academic Year

The academic year is divided into 4 terms, thus:

Term 1	12 weeks, October - December
break	2 weeks, Christmas
Term 2	12 weeks, January - March
Term 3	12 weeks, April - June
break	2 weeks, Midsummer
Term 4	12 weeks, July - September

There are two intakes of students per year, one in October, and one in April. Each intake attends for two twelve-week terms with a fortnight's break between them, and then leaves the university for six months.

In order to enable the same amount of teaching as at present to be given, it is necessary to increase the length of the working week. At present the total hours available for teaching to a conventional 3 year course or to a thick-sandwich course equals 3168 hours (3 years x 3 terms x 11 weeks x 32 hours per week). If the normal teaching week is extended to 44 hours, then 3168 hours will still be available under the revised system (3 years x 2 terms x 12 weeks x 44 hours). A working week of 44 hours, if confined to 5 days, means that lectures may start at any time from 9:00 a.m. to 6:00 p.m.

Students thus receive the same amount of teaching per year, but concentrated into a six-month period instead of the present $8\frac{1}{2}$ months. Against this, they have a clear six months away from the university between each year of their course. It would thus be possible to complete a conventional 3 year course in $2\frac{1}{2}$ years. Thick sandwich courses could either involve a complete year in industry in which case they would last $3\frac{1}{2}$ years instead of four; or split the industrial year between the two six-month gaps in university study, in which case they could be completed in 3 years.

There are of course numerous other patterns that could be adopted with fewer or greater disadvantages; the method described above is chosen simply to represent the possibility of a double intake.

Effects on Costs of Revising the Academic Year

The re-arrangement enables the number of students on courses at any one time to be doubled, without increasing at all the number actually present in the university at that time. Consequently no additional classrooms or laboratories are required, so the cost-per-student of these two items will be halved.

The doubling of intakes implies a doubling of the total teaching load, so we assume a doubling in the number of academic staff, and consequently academic staff office space. The average teaching load is unchanged, but will be concentrated into six months, leaving staff free of undergraduate teaching responsibilities for the other six months of the year. Cost per student of academic staff and their offices is unchanged.

It is further assumed that expenditure on administrative, libraries, and student facilities is doubled, also the area, and therefore the annual cost of administrative offices. Cost per student of these items, therefore, remains the same.

For the remaining elements of cost, two alternative assumptions are made -- the "pessimistic" and the "optimistic". Pessimistically it is assumed that the area, and the annual cost, of study facility space (such as libraries and reading rooms) and student facility space (such as refectories), expenditure on technical staff, and the annual cost of teaching equipment and materials will increase pro rata with student numbers.

Under the optimistic alternative the following assumptions are made:

1) Study facility and student facility space - no increase in total area and annual cost because at any one time no more students are physically present in the university. Cost per student therefore falls by half.

2) Expenditure on technical staff - only a 50% increase, because no extra staff are required for the fourth term (the existing staff are already paid for the whole year), but the extension of the working week involves shift-working at augmented rates of pay. Technical staff cost per student consequently falls by a quarter.

3) Annual cost of teaching equipment and materials - only a 50% increase, because although materials expenditure may be expected to increase pro rata with student numbers, no additional equipment will be necessary. It is possible, however, that the more intensive use of equipment will require it to be renewed more frequently.

The assumptions made are fairly approximate. Too much accuracy should not therefore be placed on the results quoted below. They do however give a broad indication of the extent to which cost per student might be expected to fall.

The results obtained are summarised in Table 10.5, which shows the percentage savings in cost per student in each of the eleven courses considered.

Table 10.5 Percentage Savings in Economic Cost-per-Student Associated with Two Intakes of Students Annually

Course	Pessimistic Assumptions: Capital and Maintenance Costs	Pessimistic Assumptions: Total Cost per Student	Optimistic Assumptions: Capital and Maintenance Costs	Optimistic Assumptions: Teaching Costs	Optimistic Assumptions: Total Cost per Student
Laboratory-based					
Civil Engineering	29.7	12.2	46.4	12.9	23.9
Applied Biology	24.6	6.7	45.8	10.6	18.1
Pharmacy	35.5	15.6	47.6	14.6	26.8
Materials Science	27.2	8.4	47.5	11.9	20.7
Applied Physics	31.3	11.7	48.0	13.6	24.0
Opthalmic Optics	31.9	10.4	48.1	11.3	21.8
Textile Technology	31.6	12.4	46.8	11.5	23.1
Classroom-based					
Business Studies	20.0	7.0	45.2	7.3	17.9
Social Sciences	11.7	3.9	43.4	3.6	15.6
Mathematics	18.7	7.4	45.0	3.1	18.7
Statistics	17.6	5.6	49.9	2.8	16.8

Note: Under the Pessimistic Assumptions there are no savings in teaching costs per student.

The potential savings are substantial. Under the optimistic set of assumptions, the reduction in capital and maintenance costs per student varies between 43% and 50%. Savings in teaching costs (through the fuller use of technical staff and equipment) vary between 10½% and 14½% in laboratory-based courses, and 2.8% and 7.3% in classroom-based courses. The reduction in total cost per student ranges from 15.6% to 26.8%.

Even under the pessimistic set of assumptions (which allow only for economies in classroom and laboratory space costs) the savings in total cost per student rise to 15.6%, and the average saving for the eleven courses is 9.2%.

The savings that might be achieved, even allowing that some of them are of a capital nature and will not be reflected in the recurrent grant, are substantial, and would justify detailed study of the possibility of introducing some form of double-intake system.

CHAPTER 11

ECONOMIES IN THE COST OF NEW BUILDINGS

As the number of students in a university increases, new buildings will sooner or later be required to accommodate them. A new building constitutes a major expense both to the university and to the U.G.C., in the short-term due to its construction costs, and in the longer-term, to its maintenance and running costs. Hence there is a considerable incentive to reduce the cost of new buildings.

There are two broad ways in which the cost per student of new buildings can be reduced:

(i) a reduction in the initial cost-per-square-foot of the building

(ii) a closer matching of new buildings with student numbers.

1) Reduction in Capital Cost

The initial capital cost per square foot of a building can be cut without reducing the basic facilities which the building must provide. We use the words "basic facilities", for if the aim is to cut costs, then some facilities, taken in the widest sense of the term, will have to be forgone.

The capital cost of a building can be reduced simply through a deterioration of standards. Lower maximum floor loadings could be used, especially in science buildings in those areas which are not initially planned to take laboratories and heavy equipment. The disadvantage of this is the loss of flexibility in the future use of space. Buildings could be made lower, but covering a larger area of ground so as to ensure that all the heavy floor loadings could be put on the ground floor (this happens at present with the heaviest laboratories), although the problem of insufficient site area may arise. This is especially a problem in urban sites, where even if the land were available, it might be too expensive. Cheaper materials and poorer finishes could also be used without reducing the essential basic facilities.

The implementation of suggestions such as these could result in savings of only a few percent in cost per square foot, because the bulk of the cost is incurred in the basic structure where savings can not be made.

To show the possible size of savings, we postulate a reduction of 10% in the capital cost of all the non-residential buildings owned by the university, and of the non-teaching equipment in them. (Rented buildings are ignored.) The cost of land, and the annual maintenance costs are assumed unchanged.

In 1970-71 the annual capital cost of the buildings and equipment in question is £655,973. The annual capital cost of land and the annual maintenance expenditure amount to £393,416, giving a total annual capital and maintenance cost of £1,049,389. A 10% reduction in the cost of buildings and non-teaching equipment causes a 6.25% reduction in total annual capital and maintenance cost, and consequently a 6.25% reduction in cost per square foot. In Table 11.1 we show the consequent savings in cost-per-student on each course. It will be noted that the savings are small, ranging between only 1.7% and 3.1% of total cost-per-student.

Table 11.1 Savings in Cost-per-Student Resulting from a 10% Reduction in the Capital Cost of Buildings and Non-teaching Equipment

Course	Present Capital and Maintenance Cost per Student (£)	Saving (£)	Present Total Cost per Student (£)	% Saving in Cost per Student
Chemical Engineering	908	56.7	2557	2.2
Civil Engineering	1030	64.4	2509	2.6
Electrical Engineering	1278	79.1	3603	2.2
Mechanical Engineering	1768	110.5	3991	2.7
Applied Biology	849	53.0	3110	1.7
Pharmacy	1446	89.4	3294	2.7
Chemistry	1915	119.7	3874	3.1
Colour Chemistry	1888	118.0	3918	3.0
Materials Science	1134	70.8	3680	2.0
Opthalmic Optics	1011	63.2	2999	2.1
Applied Physics	1375	85.4	3682	2.3
Textile Science	1245	77.8	3156	2.5
Business Studies	710	44.3	2114	2.1
Modern Languages) Social Sciences) Applied Soc. Studies)	Teaching takes place in rented accommodation			
Mathematics	907	56.6	2307	2.4
Statistics	563	35.1	1775	2.0

There are two arguments against reducing the capital cost per square foot of new university buildings.

The first is the aesthetic argument that university buildings should exude an "academic atmosphere", and that this would be lost if construction costs were cut. Similarly, there is the citizen's interest in having fine civic buildings. Although these arguments carry weight, it should be pointed out that there is a trade-off between such aesthetic considerations and economic factors; the cost of having one is the loss due to not having the other. The citizen who takes pride in the architecture of a new university building is, at the same time, the taxpayer footing the bill.

If public money must be saved in the university sector, then it is better to reduce the costs of buildings rather than of other factors (such as staff) which have a more direct influence over the output of the sector. (Indeed in strict output budgeting terms one might define "the fulfilment of civic pride" as a separate programme and charge the additional costs of buildings better than purely functional to this programme instead of to the teaching of students.)

The second argument against reducing the initial capital cost of a building is a purely economic one -- that the annual maintenance costs of the building over its lifetime may be increased. This inverse relationship between the initial capital cost of buildings and their subsequent annual maintenance costs has been postulated by Zimmerman[1] in a study of school buildings in California. However, he has been criticised by Macdowall[2] for not concentrating on the relative economies of the relationship. Macdowall argues that the reduction in annual maintenance costs per square foot postulated by Zimmerman, discounted to the present, and looked upon as the benefits arising from the additional investment, amounts to a rate of return of less than one percent. The additional investment is clearly uneconomic if measured solely in terms of saving on maintenance expenditures. If this analysis can be applied to university buildings, and certainly it is the opinion of the Architect's Office in this university that such reductions in capital cost would not lead to any appreciable increase in maintenance expenditures, then the case for cheaper university buildings is strengthened.

2) Matching New Buildings More Closely with Student Numbers

Even if the cost of a new building is reduced, the cost in the early years will still be high relative to the "output" it produces. This is because buildings come in large discrete amounts, whereas student intakes increase more gradually. Consequently, new buildings are often initially under-utilised, as is the Civil Engineering building in this university.

The problem could be alleviated by having a large expansion in student numbers in the university coinciding with the first use of the building. However, the discontinuity in student numbers would lead to many diseconomies such as a lack of ancilliary facilities, and a difficulty of obtaining new academic staff and fitting them into the courses concerned. Even so, since intake can only be into the first year of a course, there must be some under-utilisation in the first two or three years of an expansion programme.

An alternative solution would be to expand in rented accommodation until such times as numbers merit the construction of a new building. This would have the advantage of postponing the construction of a new building, and the associated expenditure until it could be well utilised.

1. W. J. Zimmerman: "The Relationship of Initial Cost and Maintenance Cost in Elementary School Buildings", School of Education, Stanford University, California
2. Guy Oddie (OECD), "School Building Resources and Their Effective Use", ed. Macdowall, Chapter X, pages 89 to 90.

Unfortunately, this situation may not be easy to arrange. Sufficient additional rented accommodation would have to be forthcoming at the appropriate time as student numbers increase, and then all the rented accommodation would have to be relinquished when the new building is completed. It is questionable whether leases are sufficiently flexible, while for universities in rural sites, such accommodation would not be available. Moreover, rented accommodation generally could not be used for laboratories. Nevertheless there is a useful flexibility in possessing a certain proportion of rented accommodation suitable for general teaching and for offices on a short-term lease, and which could easily be transferred between departments as requirements varied.

A third possibility is to add the extra accommodation in small increments by the use of pre-fabricated buildings. Such buildings can be erected more quickly than those of a conventional type, and if they are constructed on a wide enough scale significant economies of scale through mass production of components could be achieved, thus also lowering the overall capital cost. The economics of the CLASP[3] system of prefabrication in the United Kingdom has been described as follows:[4]

> "The CLASP system was originally designed for the construction of schools, but it was expected from the outset that it would also be used for other types of building. At its present stage of development, it is economical for buildings up to four storeys high with medium spans and moderate upper floor loads, and can be used for comparatively small buildings with the characteristics (about £15,000 in cost) and quite large ones (£650,000 is the largest so far projected) because very little site plant is required in either case. It has been used successfully for schools, offices, fire stations, ambulance stations, welfare buildings, workshops, and libraries. But although buildings of any area can be produced with the components, the minimum annual programme is £1M worth of building each year. This is the "minimum mass" on which the prefabricated components begin to pay off their overheads. Even at this figure the production rate is still rather small to make the system competitive in cost with other types of building, and a programme of over £4M is required to make the use of the system really economical. By the inevitable economics of factory quantity production, the bigger the building programme as a whole, the lower will be the cost of the system for each individual building.

The U.G.C. is investigating the use of prefabrication for university buildings, but apparently so far without much success. The problem appears to be that universities have a much wider variety of building requirements than do schools, and that each university is to a lesser or greater degree a special case. Hence economies of mass production are not easily realised because of the large variety of components required. Many of the buildings at the University of York were constructed using a modified form of the CLASP system, but it seems that the extensive modifications required absorbed any possible economies. The buildings at York cost much the same as standard university buildings.

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3. CLASP: Consortium of Local Authorities Special Program
4. "The Story of CLASP", Building Bulletin 19, Ministry of Education (now DES), June 1961, HMSO, page 31

The main limiting factor with prefabricated buildings is that the structures can only support moderate span and floor loadings. This makes them unsuitable for laboratories, workshops, and computer rooms, unless these can be housed on the ground floor. Nonetheless, there seems to be little reason why such systems as CLASP could not be used for blocks of class and seminar rooms, staff offices, and the like.

Most British universities have their quota of imposing architecture. Prefabricated buildings of the CLASP type could be a means of adding general teaching space relatively quickly at a low cost to match increasing student numbers.

CHAPTER 12

FACTORS AFFECTING THE DEMAND FOR TECHNICAL STAFF

This chapter attempts to isolate the demand factors for university technical staff, which accounts for a major proportion of university spending on academic departments -- 12.9% in the University of Bradford 1969/70 -- and to suggest possible economies in the planning of existing and proposed academic departments which are consumers of technical staff.

The University of Bradford, in common with other universities, already operates a principle of general guide-lines in assessing proposed expenditure on technical staff, but these guide-lines allow for a wide variation of establishment between Boards of Studies, and indeed between individual departments in the same Board. The Bradford guide-line relates technical staff establishment to academic staff, and similar criteria are applied in many other universities, including the University of Dublin.

Whether an academic staff-based criterion is used, or the technical staff establishment is treated as part of an overall ancillary staff budget, as in the University of Lancaster, considerable discretion is exercised by departmental heads, in consultation with university planning authorities.

We attempt below to identify an overall space-based relationship between teaching and research laboratories and technical staff establishments, which can be applied in different institutions, and yet allow for the alternative emphases which those institutions place on different disciplines and teaching methods.

University of Bradford

The data collected relates to the University of Bradford, for the academic year 1969/70. As a former College of Advanced Technology, and then a technological university, the emphasis in Bradford lies to a great extent in Science and Engineering disciplines, which are the main consumers of technical staff.

Within the university, the Steering Committee of the Academic Planning Committee has laid down some general ratios for academic/technical staff[1] but these allow for variation between departments and are not sacrosanct. At the present time all requests for additions to establishment are reviewed on their merits by a specially constituted sub-committee of the university, and financial constraints mean that only the most urgent cases can be considered.

In assessing the cost of staff in the year 1969/70 we have taken "full-cost" i.e., we have applied the total cost of all salaries, including associated insurance and superannuation contributions, to the various departments. To allow for variation

1. Engineering, Physical and Life Sciences 1.3:1; Modern Languages 6.5:1; all other departments 17.5:1.

within scales we have assumed the median of all scales in force in that year (with the exception of Chief Technicians, where the maximum seemed more relevant), and have added 10% for associated costs.

We have excluded all technical staff not funded directly by the university, i.e. those employed from research grants or other outside funds, but have included the grade of Experimental Officer and Senior Experimental Officer at the higher level of technical support.

The existing establishment in Bradford was re-assessed in 1968 by the application of a points system for the various grades of technical staff,[2] and this system has been used in preparing tables for the University of Bradford, and also in the comparable tables for the University of Lancaster.

Khanna and Bottomley in their earlier paper[3] subdivided the costs of "producing" first-degree graduates under six main headings, one of which was the salaries of teaching and technical staff, and expenditure on teaching equipment and materials. Their original assessment of technical staff costs was arrived at by assigning a proportion of total technical staff term-time salaries which assumed that the technical staff time input to undergraduate teaching was similar to that of academic staff. This was later revised to take account of the disparity in actual laboratory hours teaching given in the various departments, and a revised set of costs was prepared, relating undergraduate time-input to the division between undergraduate, and research and postgraduate, laboratories in each department. (These are the costs discussed in Part 2 and presented in detail in Appendix 2.) This paper attempts to show the factors which led to their observed distribution of technical staff.

A. Relationship of Technical Staff Establishment to Academic Staff and Student Numbers in Each Department

It is necessary first to demonstrate that the guide-lines referred to above do not provide a precise indicator to the technical staff needs of any individual department. Since many departments in Bradford have also an academic staff:student ratio in the region of 1:10, variations in the academic:technical staff ratio are also reflected in the ratio of technical staff to students. The figures relate to 1969/70, and the student numbers are weighted in line with generally used U.G.C. weightings.

2.

Senior Experimental Officer	10 points	Junior Technician	3 points
Experimental Officer	9 points	Laboratory Assistant	4 points
Chief Technician	8 points	Labourer	4 points
Senior Technician	7 points	Scanner (part-time)	2 points
Technician	5 points		

3. R. K. Khanna and J. A. Bottomley: "Costs and Returns on Graduates of the University of Bradford", Accounting and Business Research, No. 1, Winter 1970.

Table 12.1 Academic:Technical Staff Ratios

Department	Recommended Ratio	Actual Ratio
Chemical Engineering	1.3:1	1.4:1
Civil Engineering	1.3:1	0.9:1
Electrical Engineering	1.3:1	1.9:1
Mechanical Engineering	1.3:1	1.3:1
Industrial Technology	1.3:1	3.5:1
Biological Sciences	1.3:1	1.3:1
Pharmacy	1.3:1	0.8:1
Chemistry/Colour Chem.	1.3:1	1.0:1
Physics	1.3:1	0.9:1
Textiles	1.3:1	1.0:1
Business Studies	17.5:1	15.5:1
Social Sciences/Applied Social Studies	17.5:1	22.5:1
Modern Languages	6.5:1	5.5:1

It is clear that the recommended ratios are just that, and wide variations are observed. The particularly poor ratio in Industrial Technology reflects the department's small size, and the sharing of laboratory facilities and practical teaching within the Board of Studies.

In general, departments in the Boards of Life Sciences and Physical Sciences are better staffed than those in Engineering, with the exception of Civil Engineering.

In view of the attempt to standardise establishment on a points system however, it is possible that actual numbers of staff are not a precise guide. A figures of 5.5 staff points, being the mean weight of the technical staff in all departments, was accordingly substituted in the recommended ratio. For convenience, the resultant ratio 1.3:5.5 is inverted to give a recommended ratio of 4 technical staff points for each academic staff member.

Table 12.2 Technical Staff Points per Member of Academic Staff

Department	Recommended Number of Points	Actual Number of Points
Chemical Engineering	4	3.8
Civil Engineering	4	6.0
Electrical Engineering	4	3.5
Mechanical Engineering	4	5.0

.....continued

Department	Recommended Number of Points	Actual Number of Points
Industrial Technology	4	1.9
Biological Sciences	4	5.1
Pharmacy	4	6.7
Chemistry/Colour Chem.	4	5.0
Physics	4	6.0
Textiles	4	6.6
Business Studies	0.3	0.4
Social Sciences/Applied Social Studies	0.3	0.2
Modern Languages	0.8	0.9

The picture remains the same, and it seems clear that the distribution of technical staff is not related to that of academic staff.

As a further check, the ratio of student enrolment:technical staff is compared for each department, in conjunction with the existing student:academic staff ratio. While the expected variations are repeated, they do not appear to reflect the concomitant variations in the student:academic staff ratio.

Table 12.3 Number of Students per Member of Academic and Technical Staff

Department	Students per Member of Academic Staff	Students per Member of Technical Staff
Chemical Engineering	14.1	20.3
Civil Engineering	16.6	14.4
Electrical Engineering	10.9	20.6
Mechanical Engineering	10.6	13.7
Industrial Technology	4.1	14.1
Biological Sciences	9.9	10.7
Pharmacy	9.5	7.4
Chemistry/Colour Chem.	9.6	10.0
Physics	11.2	10.3
Textiles	13.7	13.7
Business Studies	9.1	142.5
Social Sciences/Applied Social Studies	10.6	23.9
Modern Languages	11.2	61.5

Table 12.4 shows the cost of technical staff per registered student in each department in 1969/70. The cost of technical staff has been divided by the number of

undergraduate and postgraduate students registered in the department. No weightings have been applied to postgraduates, but part-time students have been weighted $\frac{1}{2}$. The table shows wide variations in per-student cost between departments, and indicates the weight of expenditure which technical staff incurs.

Table 12.4 Technical Staff Cost per Registered Student

Department	Technical Staff Cost per Student-Year (£)
Chemical Engineering	66
Civil Engineering	83
Electrical Engineering	69
Mechanical Engineering	106
Industrial Technology	93
Biological Sciences	117
Pharmacy	155
Chemistry/Colour Chemistry	121
Physics	123
Textiles	108
Business Studies	8
Social Sciences/Applied Social Studies	5
Modern Languages	18

B. The Role of University Technical Staff

Having considered, but discarded, the assumption that the distribution of technical staff between departments is purely arbitrary, the next step is to consider the precise role which the university technician plays.

There are three main consumers of "technician time":

1. Servicing of teaching laboratories
2. Servicing of research laboratories
3. Self-training (including part-time release).

The third of these can be set aside, as it depends on the criteria laid down for promotion in the universities, and is not itself an element of demand.

Observations of university departments shows that those departments which are laboratory-based, e.g. medicine, engineering, and science, are consumers of technical staff where lecture and library-study based departments (arts, etc) are not. This correlation cannot, however, be applied in a more rigorous way. The amount of practical teaching given in an individual department does not, in itself, provide a simple guide to its demand for technical staff. The Chemical Engineering department, which requires a minimal amount of laboratory-based teaching (not more than 54 hours per student in any year) has 27 technical staff, while Civil Engineering has 23 staff to service from 264 hours practical teaching per student in the first year to over 1,000 in the final year.[4]

To assess the total demand for technical staff, generated by the demands of both practical teaching and research, information was collected on the total laboratory space in each department, classified as "research" or "teaching" laboratories. (Table 12.5) Research laboratories are assumed to be more intensive in their use of technical staff, by virtue of their more expensive equipment and of the higher level work being carried out, and a factor of 3 is assigned to the area of these laboratories. Thus a technician who services undergraduate teaching is assumed to be responsible for three times the area of a technician employed in a research laboratory. (This factor of 3 is the standard U.G.C. weighting for full-time science-based research students.)

Some departments are in process of changing to new accommodation, or have recently done so. Civil Engineering, in particular, has recently exchanged its cramped accommodation in the Main Building for a new Civil Engineering building; both the old and the new laboratory areas are separately treated in the calculations below.

The total laboratory area (unweighted) in the university is approximately 250,000 sq.ft. This represents 1,200 sq.ft. per technician. Teaching laboratories constitute approximately 75% of this space, and the remainder is for research. Applying the weight of 3 to a research technician, suggests that, on average, the university requires approximately one member of the technical staff (or 5.5 points) for each 1,600 sq.ft. of teaching laboratory, and for each 540 sq.ft. of research laboratory.

Table 12.5 Laboratory Area and Technical Staff Points
(University of Bradford)

Department	Technical Staff Points	Teaching Labs (sq.ft.)	Research Labs (sq.ft.)
Business Studies	11	231	
Industrial Technology	13	3,000	
Social Sciences and Modern Languages	30	3,611	200
Textile Technology	66	6,141	411
Biological Sciences	67	4,886	2,136

.....continued

4. These figures assume group sizes in line with the departments own assessment as to the educationally acceptable maximum; between 20 and 40 in the case of Civil Engineering, and 50 in Chemical Engineering.

Department	Technical Staff Points	Teaching Labs (sq.ft.)	Research Labs (sq.ft.)
Electrical Engineering	112	19,298	3,100
Mechanical Engineering	114	29,564	3,460
Civil Engineering (old)	119	7,342	4,362
Civil Engineering (new)	110	26,387	18,015
Physics	136	10,812	3,930
Chemical Engineering	148	7,132	16,080
Pharmacy	218.5	28,917	13,944
Chemistry	247.5	25,702	20,784

The relationship between laboratory area[5] and technical staff establishment (expressed in points) shown above is highly significant. The correlation coefficient is 0.8828, or 0.9537 with the alternative accommodation figure for Civil Engineering and the significance in each case is less than 0.01.

University of Lancaster

Comparable data was obtained from the University of Lancaster.

Table 12.6 Laboratory Area and Technical Staff Points (University of Lancaster)

Department	Technical Staff Points	Teaching Labs (sq.ft.)	Research Labs (sq.ft.)
Environmental Sciences	79	11,245	6,744
Chemistry	89	21,186	12,584
Biology	113	27,679	15,371
Physics	157	12,000	24,694

The overall picture is of a more research-oriented laboratory structure, and more generous allocation of laboratory space. Expenditure on technical staff in Lancaster is treated as part of an overall ancillary staff and resources budget, but even with the restricted degrees of freedom, the relationship ($r = 0.883$) is still significant ($P < 0.05$).

5. Weighted 3:1 in the case of Research Laboratories.

Effects of Variation in the Teaching:Research Laboratory Ratio on Existing and Expanding Departments

To study the effect of a variation in the balance between teaching and research laboratories I have taken two areas in the University of Bradford (Electrical Engineering and Pharmacy) and compared the results of doubling their student numbers:

1) with their existing ratio of teaching:research laboratories, and
2) with an altered ratio of 3:1 in line with the university average.

The main points of difference between the departments are:

(a) Electrical Engineering is more teaching:research laboratory based (6.2:1) than Pharmacy (2.1:1).

(b) Pharmacy has a markedly better academic:technical staff ratio (0.8 against 1.9).

(c) Pharmacy is correspondingly more expensive in its use of technical staff (£155 per student-year against £69).

The following assumptions are made:

(1) Doubling of existing student numbers
(2) No spare laboratory space at point of increase
(3) Existing academic staff:student ratio maintained
(4) Existing square footage per technician maintained
(5) Doubling of total laboratory space

Table 12.7 Electrical Engineering

	Present Teaching: Research Laboratory Ratio	3:1 Teaching: Research Laboratory Ratio
Student Numbers	722	722
Teaching Labs (sq.ft.)	38,596	33,597
Research Labs (sq.ft.)	6,200	11,199
Research Labs (weighted area)	18,600	33,597
Ratio of teaching:research labs (actual area)	6.2:1	3:1
Ratio of teaching:research labs (weighted)	2.1:1	1:1
Sq.ft. per teaching technician (approx.)	1,680	1,680
Sq.ft. per research technician (approx.)	560	560
Number of teaching technicians	23	20
Number of research technicians	11	20
Number of academic staff required	64	64
Number of technical staff required	34 (+17)	40 (+23)
Ratio academic:technical staff	1.9	1.6

1. The extra number of technicians required for the increased enrolment is 6 (or 3 if a similar alteration of ratio was applied to the Department of Electrical Engineering as it is presently constituted).

2. The ratio of academic:technical staff would still exceed the recommended university ratio of 1.3:1.

If the department wishes to shift the emphasis towards research laboratories, but is precluded by financial considerations from recruiting the additional technical staff, an alternative approach is to alter the amount of laboratory space which each technician is required to service.

If the existing 17 staff were to service an altered area of 16,780 sq.ft. of teaching laboratories (against 19,298) and 5,600 sq.ft. of research laboratories (against 3,100), while maintaining the constraint that research laboratories are three times as intensive in their demand for staff, the area serviced by each technician would be:

	Existing Ratio	Altered Ratio
Teaching technician	1,680 (sq.ft.)	1,974
Research technician	560	658

Table 12.8 Pharmacy

	Present Teaching: Research Laboratory Ratio	3:1 Teaching: Research Laboratory Ratio
Student Numbers	662	662
Teaching Labs (sq.ft.)	57,834	64,292
Research Labs (sq.ft.)	27,888	21,430
Research Labs (weighted area)	83,664	64,290
Ratio of teaching:research labs (actual area)	2.1:1	3:1
Ratio of teaching:research labs (weighted)	0.7:1	1:1
Sq.ft. per teaching technician (approx.)	1,665	1,665
Sq.ft. per research technician (approx.)	555	555
Number of teaching technicians	35	39
Number of research technicians	50	39
Number of academic staff required	65	65
Number of technical staff required	85 (+42.5)	78 (+35.5)
Ratio academic:technical staff	0.76	0.83

1. There is a saving of 7 technicians on the number required for the increased enrolment (or 3.5 for the department as presently constituted, but with an altered laboratory ratio).

2. Altering the laboratory areas would mean a reduction in the area of space serviced by each technician, if the existing staff establishment was maintained, of the following order:

	Existing Ratio	3:1 Ratio
Teaching technician	1,655 (sq.ft.)	1,489
Research technician	555	496

Estimating the Demand for Technical Staff

We have endeavoured to show that the demand for technical staff is influenced more by the physical demands of a department, in terms of laboratory space, than by a derived demand from other academic staff establishment, or student enrolment. This is exemplified in considering alternative proposals:

1) to expand an existing department, and,
2) to establish a new department.

1. Expansion of an existing department

In the case of technical staff, a space-derived demand would create the following alternatives:

1. Linear expansion in line with present norms of teaching and laboratory space per technical staff (which is equivalent to an expansion based on the existing academic:technical staff ratio).

2. Reduced demand for additional technical staff by:

    (a) increasing the ratio of teaching:research laboratories within the department

    (b) increasing the square footage of laboratory space serviced by each technician.

3. Increased demand for technical staff by:

    (a) reducing the ratio of teaching:research laboratory space within the department

    (b) reducing the square footage of laboratory space serviced by each technician.

With a declared aim of effecting economies, option 2(a) offers the maximum scope. I have assumed that all laboratory space within the department was fully utilised at the point of expansion, and that the ratio can be altered by the conversion of existing laboratories, or by an altered balance in the proposed additional accommodation. If however teaching laboratories were not fully utilised, and the expansion can be accommodated in existing laboratories, it may well be that no additional technical staff will be required.

2. Establishment of new departments

To forecast the demand for technical staff requires the following information:

1. Proposed area of teaching laboratories -- this will be derived from course structure and amount of practical hours instruction to be given (A).

2. Proposed area of research laboratories -- derived from research interests of department, and proposed post-graduate instruction to be given (B).

3. Average laboratory space (sq.ft.) serviced by each teaching technician in the university (a).

4. Average laboratory space (sq.ft.) serviced by each research technician in the university (b).

(a) and (b) are calculated as follows:

P = total area of teaching laboratories in the university
Q = total area of research laboratories in the university
R = total number of technical staff in the university

$$a = \frac{P + 3Q}{R} \qquad b = \frac{a}{3}$$

The number of technical staff required in the new department (x) can then be estimated by the formula:

$$x = \frac{A}{a} + \frac{B}{b} = \frac{A}{a} + \frac{B}{\frac{a}{3}} = \frac{A + 3B}{a}$$

CONCLUSIONS

1. The main purpose here has been to show that the demand for technical staff is related neither to the student enrolment, nor to academic staff complement.

2. Based on the data supplied by the Universities of Bradford and Lancaster, the demand for technical staff within a department appears to be related to laboratory area. A close correlation is observed between the size of the technical

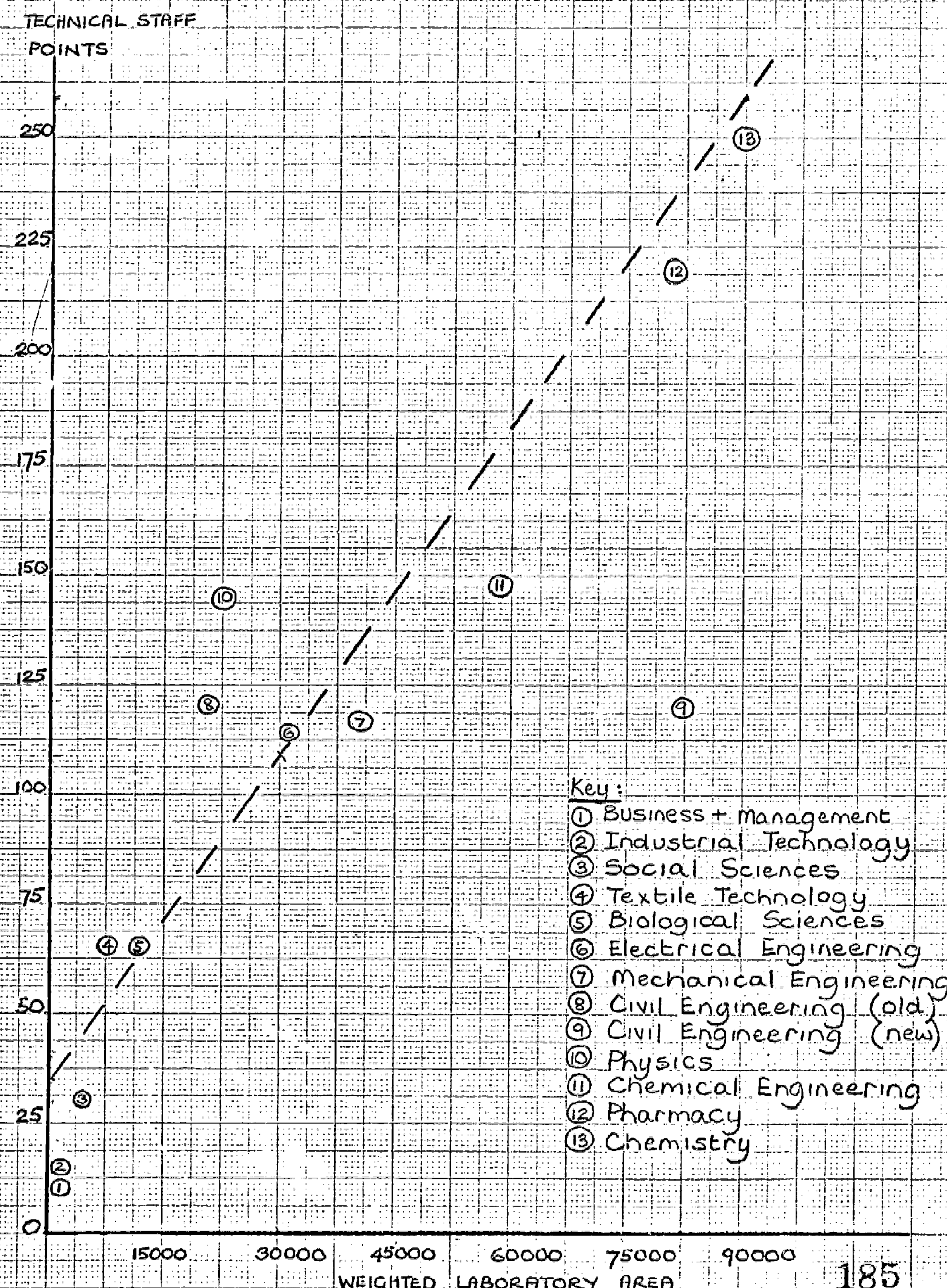
staff in a department (measured on a points basis) and laboratory area, when research laboratories are weighted as 3.

3. Assuming that research laboratories are more intensive in their use of technical staff, potential economies can be obtained by increasing the ratio of teaching: research laboratories.

4. Economies can also be obtained by increasing the area of laboratory space serviced by each technician, but on University of Bradford data, this option presents less scope for significant savings.

5. Provided there is unused capacity in either teaching or research laboratories, it is likely that expansion of undergraduate numbers will not require additional technical staff.

FIGURE 12.1: LABORATORY SPACE (WEIGHTED) x TECHNICAL STAFF ESTABLISHMENT (POINTS)



PART 6

COSTING OF ACADEMIC DEVELOPMENT PROPOSALS

The primary aim of this project has been to investigate potential economies in cost per student, with special reference to Bradford University. One of our most significant findings is that it is easier to gain such economies through an expansion of student numbers, more fully using existing facilities, than by attempting to cut costs while keeping student numbers constant. Although the cost of the university increases in total, the cost per student declines.

The large expansion of student numbers forecast in British universities over the next decade gives scope for the utilisation of such economies. Hence one of the concerns of the project has been with the planning for expansion within the University of Bradford, especially with a view to seeking economies in the proposals currently being made by the various schools for the forthcoming quinquennium (1972-3/1976-7). The purpose of this part of the report is to show the methodology adopted, and the results obtained.

In Chapter 13 a method for costing expansion proposals to produce an incremental (marginal) cost per student is described. In Chapter 14, this method is used to cost some specific expansion proposals actually submitted to the Academic Planning Committee of the University of Bradford for the forthcoming quinquennium. The scope for potential economies in these proposals is then investigated in the light of the findings of Parts 3, 4 and 5 of this report.

CHAPTER 13

INCREMENTAL COSTS

The purpose of this chapter is to describe a method of calculating the cost per student of additional students on particular courses in the university.

The use of "marginal" cost per student is rejected in favour of "incremental" cost per student for this purpose. The difference between the "static" accounting procedure used for calculating the historic average cost per student in Part 2 and the "comparative static" procedure required for calculating incremental cost per student is emphasised (Section 1, below). A more flexible approach is deemed essential for incremental costing in the university, and this is embodied in a discussion of the significance and use of "accounting units" (2).

The reasons why incremental cost per student is likely to be lower than average cost are discussed, particular attention being paid to the fuller utilisation of present resources within the university (3).

The output-budgeting question of the distribution of the cost of additional resources between various outputs is then considered (4), and the chapter closes with equations showing how the incremental cost per student is calculated (5), and details of the factor prices used (6).

1. Average Costs and Incremental Costs

The analysis of unit costs in universities in Part 2 of this report provides a picture of the average cost per student of the undergraduate outputs of the University of Bradford at a particular point in time. Here we are concerned with the costs of expanding student numbers from this position into the future, particularly with a view to finding economies.

Because of the output-budgeting requirement that all of the university's resources must be attributed to one output or another, the average cost per student is inflated by the inclusion of important resources, such as accommodation and equipment, which are currently under-utilised. For this reason, it is possible to expand student numbers without a pro rata increase in expenditures on these items; the additional cost incurred per additional student, the so-called "incremental" (marginal) cost per student, will be lower than the present average cost per student. Following the normal relationship between average and incremental (marginal) functions, the average cost per student will decline with the expansion of student numbers.

The additional cost per additional student is referred to as the "incremental" cost per student in preference to the term "marginal" cost. Marginal cost is defined as the increase in total cost resulting from an increase in output of one unit, or in this case, an increase of one student. The expansion proposals, however, deal with increases in student numbers in annual steps of up to twenty or more, amounts which are not marginal but incremental. Hence we should properly use the term "incremental cost per student".

At this point the distinction between the cost accounts needed for the calculation of historic average costs and those needed for calculating incremental costs should be made clear. The former is a "static" costing procedure, showing the costs of various outputs as they existed at a particular point of time in the past; these costs are analogous to a photograph. On the other hand, the calculation of incremental costs implicitly involves "comparative statics", since by definition they are calculated from changes in cost at the margin. These changes in cost can only occur in a time dimension; hence incremental costs are analogous to a movie film. For this reason, the "static" approach for incremental costing is inappropriate. Further, because of the transfer of resources within the university to secure their more intensive utilisation, a more flexible approach is required. We now discuss this approach in detail.

2. Accounting Units

In costing the expansion of an organisation so diverse as a university, it is important to define the "accounting unit" to which the costs relate. The costing of a particular proposal may involve one or more accounting units -- the university, the school of study, or the course itself. Each simultaneously gains or loses resources, and hence adds to or reduces its costs, in its "transactions" with the "outside world" (which is defined as everything outside of the accounting unit). The following example makes these principles clear; it illustrates the use of different accounting units for costing a proposal, and thus the different costs which arise.

Example: Suppose that a room costed at £500 per year is transferred from School A to School B in order to accommodate an expansion of a course in the latter. If everything else remains the same, the total cost of the accounting unit -- School A -- falls by £500, while the total cost of the accounting unit -- School B -- rises by £500. On the other hand, if the university is chosen as the accounting unit for the "transaction", its total cost remains unchanged, since the "plus" £500 to School B is cancelled by the "minus" £500 to School A.

It might be argued that School A, by losing the room, would not be able to maintain its output of teaching hours. Hence, the increase in teaching hours in School B facilitated by the extra room might be offset by the decline in teaching hours in School A, as a result of the loss of the room. This is unlikely to be so, however, because of the under-utilisation of rooms in the University of Bradford. School A will typically be able to maintain its output of teaching hours despite the loss of a room by modifying its timetable so as to utilise its remaining rooms more fully. At the same time, School B can increase its own teaching hours with the aid of the extra room. Hence overall student numbers can be increased without requiring any additional accommodation as far as the university is concerned. The reduction in the total cost of School A without any commensurate decline in its output can be looked upon as an enforced economy of scale, external to the expansion of School B.

In the example we have a situation in which one transaction leads to three different results, in terms of changes in total cost, depending upon which accounting unit is employed, a situation not encompassed within the scope of the static accounting procedure. By exclduing the time factor, the "static" procedure precludes the possibility of changes in total cost; by excluding the possibility of internal shifts in resource use, the "static" procedure also precludes the possibility of the costs of a particular proposal differing between accounting units.

To provide for this last possibility more than one accounting unit must be used. If, in the case of the above example, the only additional resource required by School B to expand its course is one room costing £500 per year, the other resources being found unused within the school, then the additional cost to School B is £500. This £500 represents the change in the total cost of the accounting unit School B. If it is divided by the additional student numbers it gives an incremental cost per student to School B.

As far as the university is concerned, however, the proposal incurs no additional costs. The incremental cost per student to the university is therefore zero.

On the other hand, if the room is rented from outside the university at £500 per year, then the additional cost both the School B and to the university is £500 (assuming that the other resources required are found within School B, as before). The £500 is the addition to the total costs of both accounting units incurred as a result of implementing the proposal; the incremental cost per student to both School B and the university is £500 divided by the number of additional students.

The university accounting unit thus shows the extra costs incurred by the university as the result of the expansion of student numbers. If these costs are in financial terms, they show the extra cash sums which will have to be paid out per year. This is of interest to the university's financial administration and to the University Grants Committee. On the other hand, if the costs are in economic (social opportunity) cost terms, they roughly indicate the loss of output to the national economy as the result of drawing the additional resources into university use.

The degree to which the cost of a proposal to the School concerned is greater than the cost to the University indicates the degree of absorption of internal spare resources. This is highly relevant for internal planning purposes. For example, the reason for the comparative cheapness of a particular proposal to the university may be because of a large absorption of internal spare resources. This will be shown in the costs incurred by the School. Insofar as these spare resources are non-specialised, their shortage consequent upon the acceptance of the proposal, may make subsequent proposals more expensive from the university's viewpoint. And the cost to the university may be the most important economic criterion for comparison between courses.

For the purposes of costing individual proposals however, each proposal is taken in isolation, assuming all other student numbers constant. The significance of the School accounting unit does not decline however, because it indicates the expected degree of absorption of internal resources.

In costing each proposal, we also assume that all central expenses, such as central administrative, library and student facility expenditure, remain constant. It is considered that the expansion of student numbers involved in a single proposal is insufficient to incur any additional costs in these items.

3. Accounting Units and Inventories of Spare Resources

The analysis so far shows that where a proposal requires additional resources it is necessary, in order to calculate its cost, to:

(i) define the accounting units to be used. We have used two accounting units, the University and the School. The use of a third, the Course, is theoretically possible, but impracticable because of the difficulty of obtaining sufficiently detailed data.

(ii) specify the source of the additional resources involved, whether they are to be found within or outside the accounting units concerned.

One implication of this analysis is that the various accounting units -- the University and the School -- have inventories of spare resources. More precisely they have inventories of spare resource-hours. Thus a classroom being used for ten hours a week implies an excess capacity of twenty-two unused room-hours per week, assuming the normal thirty-two hour week and perfect timetabling. In the unit-costing in Part 2, these unused room-hours were attributed to the users of the room in proportion to the hours which it was used by them. It follows, therefore, that if we deal in resource-hours, the total cost of an accounting unit is composed of two elements:

(i) engaged resource-hours,

(ii) unused resource-hours,

where (i) comprises those resource-hours actually being used to produce university outputs, and (ii) comprises the remaining resource-hours available, which are not being used and thus may be considered open to the possibility, subject to certain constraints, of being absorbed in expansion by that or another accounting unit.

The major constraint is the problem of drawing a line between the two categories (i) and (ii) above for a particular resource. The use of accommodation is the most clear-cut case, but even here there are practical difficulties in timetabling a full thirty-two hour week. If a room is being used only ten hours a week, in practice it is unlikely that it can be timetabled for alternative uses for all the remaining twenty-two hours. On the other hand, it is possible, as shown in Part 4, to extend the week above 32 hours if existing accommodation is fully stretched yet more room-hours are required. The case of staff is more difficult because of the absence of any formal definition of duties or of any standard for the length of the working week.

This concept of an inventory of spare resource-hours for each accounting unit is important, since these resource-hours may be used to expand output without increasing the cost of that accounting unit. That is, during expansion, resource-hours within the accounting unit are transferred from the "unused" to the "engaged" category. Consequently, the cost of unused resource-hours goes <u>down</u> and that of engaged resource-hours goes <u>up</u>, while the overall total cost of the accounting unit remains <u>unchanged</u>.

If the cost figures produced for an expansion proposal show that the incremental cost to the University accounting unit is of a similar order of magnitude to that of the School accounting unit, then the implication is that most of the resources required are coming from outside the university, and that few, if any, economies from fuller utilisation of existing resources are being obtained. To maximise these economies we need to maximise the extent to which the University's incremental cost is lower than that of the School, subject to the constraints outlined above.

4. "Fullcost" vs. "Partcost" of Resources

A problem with new units of resources required by an expansion proposal is that for part of the time they may be employed upon work not connected with the proposal in question. The most obvious case concerns academic staff, for although the justification for their original employment may be to share the additional workload of a new or expanded undergraduate course, they are expected to do some personal research, and may also teach on postgraduate or other undergraduate courses. It is possible, therefore, to distinguish two sets of costs. The first (the "full-cost") attributes the whole cost of the resource to the proposal in question, on the basis that the resource would not otherwise have been employed. The second set of costs (the "part-cost") attributes to the proposal only that proportion of a resource which it is estimated will be devoted to the proposal in question. The balance has been ignored in the costing of the proposal. Because we are dealing with future costs, the estimates are necessarily approximate.

Table 13.1 Distribution of Staff Time Between Undergraduate and Postgraduate Activities

Grade of Staff	Undergraduate Activities		Postgraduate Activities		Total	
	Average Hours per week	%	Average Hours per week	%	Average Hours per week	%
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Professor	22	47	24	53	46	100
Reader	15	28	38	72	53	100
Senior Lecturer	13	48	14	52	27	100
Lecturer	26	57	20	43	46	100
Overall Average	23	52	21	48	44	100

In the case of academic staff we have used the distribution found in 1968 and described in Table 13.1. The proposals costed all relate to undergraduate cour. so the percentages in Column (3) have been used.

For equipment and accommodation the professors concerned were asked to mal estimates. In the case of materials, full-cost equals part-cost because of their status as "consumables".

5. The Calculation of Incremental Cost

Given a time series of the student numbers of a proposal and the associated total cost for the accounting unit concerned, the incremental cost per student year (on either a full-cost or part-cost basis) is calculated as follows:

$$TVC_{A_t} = TC_{A_t} - TC_{A_{t-1}} \quad (1)$$

where

TVC = total variable cost
TC = total cost
subscripts A = accounting unit concerned
t = annual time period involved

$$ISN_{C_t} = TSN_{C_t} - TSN_{C_{t-1}} \quad (2)$$

where

ISN = incremental student numbers
TSN = total student numbers
subscript C = course concerned

$$IC_C = \frac{TVC_{A_t}}{ISN_{C_t}} \quad (3)$$

where

IC = incremental cost per student-year on the course expansion.

We calculate the cost per student-year, rather than the cost per student per year of the course as in Part 2, because the estimates of resource requirements do not distinguish between years of the course.

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1. Source: R. K. Khanna and M. Shattock, "Analysis of University Staff Time", unpublished paper (University of Bradford), 1967-8, page 18.

Table 13.2 Total Annual Financial and Economic Costs of Buildings (1969-70)

Buildings	Land		Capital Value of Buildings and Non-Teaching Equipment		Annual Rent	Annual Maintenance	Annual Insurance Premium	Total Annual Cost	
	Capital Value (1)	Annual Interest at 7% (2)	Current Insured Values (3)	Annual Value at 7%x50yrs (4)	(5)	(6)	(7)	Financial (5)+(6)+(7) (8)	Economic (2)+(4)+(5)+(6)+(7) (9)
	£	£	£	£	£	£	£	£	£
Main Building	23,000	1,610	3,675,174	266,303		218,965	2,353	221,318	489,231
Chemistry & Chem.Tech.	9,000	630	1,403,736	101,715		50,664	1,018	51,682	154,027
Chem.Eng. & Nuc.Sci.	10,000	700	1,413,170	102,398		57,101	1,145	58,246	161,344
Civil Eng.	5,000	350	1,013,320	73,425		16,427	318	16,745	90,520
Wardley House			60,000*	4,348*	33,815	51,055		34,870	89,218
AGGREGATE	47,000	3,290	7,565,400	548,189	33,815	394,212	4,834	432,861	984,340

*Equipment only

Table 13.3 Annual Financial and Economic Cost per Weighted Square Foot for the Aggregate of the Five Buildings (1969-70)

Total Annual Cost in £'s		Total Assignable Area (sq.ft.)	Weighted Assignable Area (sq.ft.)	Annual Cost Per Weighted Square Foot in £'s	
Financial	Economic			Financial (1)/(4)	Economic (2)/(4)
(1)	(2)	(3)	(4)	(5)	(6)
432,861*	984,340*	493,675+	656,269	0.7	1.5

*Source: Table 13.2 +Source: Resident Architect's Office, University of Bradford

Table 13.4 Annual Financial and Economic Cost per Square Foot Weighted by Room Type (1969-70)

Room Type	Weighting Factors	Cost per Weighted Square Foot		Weighted Cost Per Actual Square Foot	
		Financial (£)	Economic (£)	Financial (2) x (3) (£)	Economic (2) x (4) (£)
(1)	(2)	(3)	(4)	(5)	(6)
(1) All rooms except laboratories	1.0	0.7'	1.5'	0.7	1.5
(2) Laboratories - Elect.Eng., Mech. Eng., Civ.Eng., Chem.Eng., Nuc. Sci., Textiles	1.67	0.7	1.5	1.2	2.5
Pharmacy, Chemistry, Chemistry Technology	1.65	0.7	1.5	1.2	2.5
Biology	1.57	0.7	1.5	1.1	2.4
Physics, Material Science, Opthalmic Optics	1.38	0.7	1.5	1.0	2.0
Mathematics, Management, Social Sciences, Languages	1.0	0.7	1.5	0.7	1.5

'Source: Table 13.3

6. Financial and Economic Costs

In this section we indicate the actual prices used to cost units of the various resources required by expansion proposals. The rationale behind the method is described in Chapter 1, pages 1.3 to 1.6. We will now deal with each major resource in turn.

(i) Accommodation

Here a cost per square foot, weighted for accommodation of different types, is produced. This cost is an aggregate for the five major university buildings.

The first stage of the calculation is shown in Table 13.2, where the total annual cost of each of the buildings is calculated and aggregated (Columns (8) and (9)).

In Table 13.3 these aggregate annual financial and economic costs are divided by the aggregate weighted assignable area of the buildings to produce an annual cost per weighted square foot. The weighted assignable area is greater than the actual assignable area because laboratory square footage is increased in the same proportion as its capital cost exceeds that of other accommodation.[2]

The conversion of the cost per weighted square foot produced in Table 13.3 into a weighted cost per square foot for rooms of different types is accomplished in Table 13.4 using the same weighting factors. The resulting figures used in costing the additional accommodation requirements of proposals are shown in Columns (5) and (6).

(ii) Teaching Equipment

The financial cost of a new piece of equipment is the purchase price, attributed to the year of its purchase.

The annual economic cost is found by multiplying the initial purchase price by an annuity factor. A figure of 0.11 has been used, which approximates to an annuity factor of 7% over 15 years.

(iii) Academic, Administrative and Technical Staff

The midpoints of the current salary scales have been used as the cost of each grade of staff. The corresponding superannuation and National Insurance payments are included, and the totals are shown in Table 13.5 (Column (5)). It is assumed that the economic and financial costs of staff are equal.

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2. Weights are based on U.G.C. capital allowances for different types of buildings; see Chapter 2 for details.

Table 13.5 Average Staff Costs*

Grade (1)	Salary (2)	Superannuation (3)	National Insurance (4)	Total Staff Cost ie (2)+(3)+(4) (5)
(1) Academic Staff				
Professor	£5610	£560	£100	£6270
Senior Lecturer/ Reader	3800	380	100	4280
Lecturer	2454	245	100	2799
(2) Administrative Staff				
Clerical	1131	68	55	1254
Typist	702	42	50	794
Secretary	1131	68	55	1254
Administrative/ Professional	1560	94	60	1714
(3) Technical Staff				
Chief Technician	2178	218		2396
Senior Technician	1551	155		1706
Technician	1222	122		1344
Junior Technician	710	71		781
Laboratory Assistant	972	97		1069

*Source: Personnel Division, Bursar's Office, and the Finance Office, University of Bradford

(iv) Materials

Both the financial and economic cost of materials are taken to equal their purchase price, attributable to the year in which they are purchased

For the purpose of the costing all prices are assumed constant at the 1970 level.

Conclusion

Once the above methodology has been grasped it is easier to calculate the incremental cost per student-year of a proposed course expansion, than to produce a current average cost per student per year for the same course using the methodology of Chapter 2. This is partly because the concern is only with the relatively minor changes in total cost of a course at the margin, rather than with delimiting the total cost, and partly because future planning necessarily involves data which is less detailed and results which are less precise.

CHAPTER 14

COSTING OF PROPOSALS AND POTENTIAL ECONOMIES

(1) Introduction

In this chapter, the methodology described in Chapter 13 is used to cost expansion proposals actually made at Bradford University for the quinquennium 1972-3 to 1976-7.

The collection of data involved close co-operation with the Schools concerned. Once the expansion of student numbers in a particular course had been provisionally decided by the university's Academic Planning Committee, a meeting was arranged between the professor concerned, or his nominee, and a member of the project team. At this meeting the professor was asked what additional resources he would require, and could reasonably expect to obtain, in order to cope with the proposed expansion.

It was frequently emphasised by the professors that, due to the nature of the exercise, the information is tentative. Some of the information is based upon current norms (e.g. the staff:student ratio), but this does not detract from its usefulness, because such norms can be changed in order to observe the effect on costs. It seemed likely that the results of such sensitivity tests on incremental costs per student-year would differ from those produced from similar tests on average cost per student. This is important because our aim is to find economies in future planned expenditures. These can be modified relatively easily because they have not yet occurred, in contrast to present expenditures, which are committed in advance and thus cannot easily be reduced. Existing equipment and buildings have to be maintained and academic staff cannot be dismissed, but future commitment need not be increased by adding to the stock of these resources, and this is often possible because of present surplus capacity.

The chapter is divided into sections, each concerned with an analysis of an individual expansion proposal. Where appropriate, this analysis is carried out under three headings as follows:

(i) Financial Costs of the Proposal

Here proposals are examined in the light of their financial costs, i.e. in terms of the extra money cost to the accounting units concerned. Of particular importance is the University accounting unit, which shows the extra financial outlay to be incurred by university if the proposal is adopted, and thus also by the government which furnishes the university's exchequer.

The financial cost to the School accounting unit is usually higher insofar as the proposed expansion involves the School in assuming a greater burden of the financial cost of existing university buildings. This cost is not an addition to the university's costs, and thus does not figure in its accounts.

The difference between the "full-cost" of the proposal and the "part-cost" will also be noted.

(ii) Comparison with the Present Average Costs per Student[1]

The purpose of this section is to link the incremental costs of the proposal (using economic part-cost for the School accounting unit) with the existing average costs as shown in Part 2. This poses two problems.

The first is that the incremental costs are calculated in terms of cost per student-year, i.e. the total cost of a course in year X divided by the total student numbers, regardless of year or grade, on the course in the same year; in contrast, the average costs are presented in terms of the cost per student per year of the course, i.e. the total cost of a course in year X is broken down into the total cost of each year or grade, and these are divided by the student numbers in those years or grades. In order to make these figures comparable the average cost figures calculated in Part 2 are modified to produce an average cost per student-year. This is done by dividing the total cost of the course in 1969-70 by the total student numbers on the course in that year.

For example, in the case of Chemical Engineering (see Appendix 1, Table 1) the total cost of the course of £225,507 in 1969-70 is divided by the 349 students on the course in that year. This gives an average cost per student-year of £646, compared with the costs per student per year of £767, £642, £633 and £515 for the 1st, 2nd, 3rd and 4th year students respectively.

The second problem is that we do not know how costs have changed in the current year (1970-71). Consequently, it is arbitrarily assumed that the total cost of a course in 1969-70 remains the same in 1970-71 despite the possible increase in total student numbers on the course between those two years.

(iii) The Sensitivity of Costs to Various Economies

Here we examine the sensitivity of the cost of a proposal (economic part-cost to the School accounting unit) to the implementation of various economies suggested earlier in the report, such as worsening the marginal staff:student ratio,[2] applying the norms relating technical staff requirements to laboratory areas, using accommodation more intensively and extensively, etc.

A concluding section compares the costs and economies of all the proposals.

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1. As presented in Part 2 of this report.
2. The marginal staff:student ratio is used because we are concerned with the additional resources required by an expansion proposal. The ratio is obtained by matching additional staff numbers with additional student numbers; this differs from the normal staff:student ratio, i.e. the average ratio, which is calculated by matching total staff numbers with total student numbers.

(2) Costing of Proposals

(A) Applied Biology

The Undergraduate School of Applied Biology is a well-established school with a first year intake of 33 in 1970-71. It is proposed to increase the intake to a maximum of 60 by 1976-77, this expansion being sustained by the buoyancy of student demand, but limited by the need for biology graduates in industry.

The School has teaching commitments to other schools, e.g. Pharmacology, and these are likely to increase in the future if proposals for certain new courses are accepted, e.g. Environmental Studies, Chemistry with a Biology option. However, in this costing all other student numbers are assumed constant.

(i) Financial Costs of the Proposal

Table 14.1 and Figure 14.1 indicate the additional financial costs (TVC) of the proposal to the two accounting units.

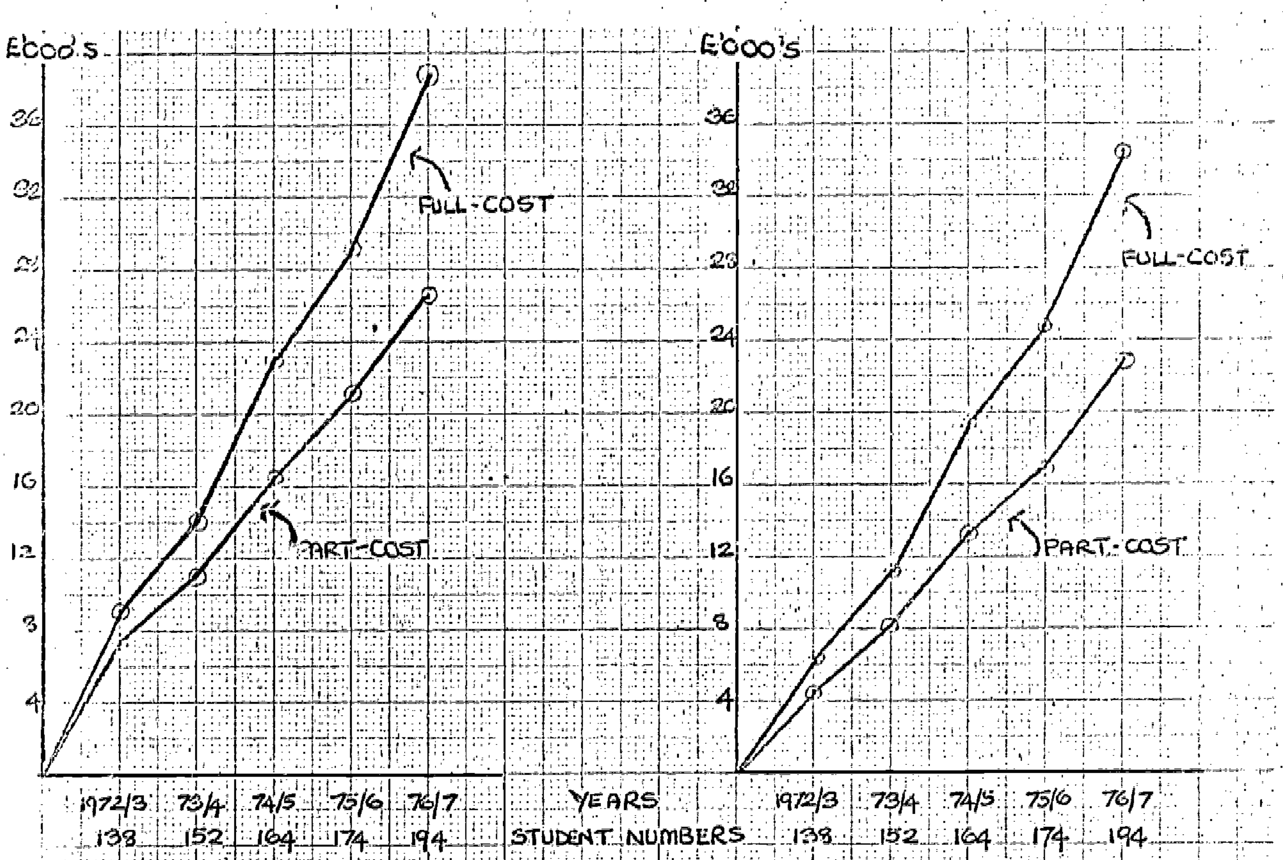


Fig. 14.1(a) SCHOOL Accounting Unit

Fig. 14.1(b) UNIVERSITY Accounting Unit

Figure 14.1 : APPLIED BIOLOGY - Additional Financial Costs

Table 14.1 APPLIED BIOLOGY: Additional Financial Costs (TVC)

			1971/2	1972/3	1973/4	1974/5	1975/6	1976/7
Student Numbers:	Total		126	138	152	164	174	194
	Incremental		0	12	14	12	10	20
			£	£	£	£	£	£
(1) Staff:	Full-Cost	TVC	0	4,951	8,819	16,692	20,835	29,765
	Part-Cost	TVC	0	3,141	5,805	10,248	13,188	17,831
(2) Accommodation:								
	Full-Cost	TVC	0	2,880	2,985	3,247	4,197	4,407
	Part-Cost	TVC	0	2,880	2,939	3,103	4,006	4,095
(3) Equipment:								
	Full-cost	TVC	0	700	1,200	1,700	2,200	2,700
	Part-cost	TVC	0	700	1,200	1,700	2,200	2,700
(4) Materials:								
	Full-Cost) Part-Cost)	TVC	0	800	1,100	1,400	1,700	2,000
AGGREGATE COST - SCHOOL Accounting Unit (i.e. (1) + (2) + (3) + (4))								
	Full-Cost	TVC	0	9,331	14,104	23,039	28,932	38,871
	Part-Cost	TVC	0	7,521	11,044	16,449	21,094	26,626
AGGREGATE COST - UNIVERSITY Accounting Unit (i.e. (1) + (3) + (4))								
	Full-Cost	TVC	0	6,451	11,119	19,792	24,735	34,464
	Part-Cost	TVC	0	4,641	8,105	13,348	17,088	22,531

The cost to the University accounting unit is the more important because it shows the extra financial outlays, above the present, to be incurred by the university. The School accounting unit shows the financial cost from the viewpoint of internal pricing; the cost is higher because the school will assume a greater proportion of the costs of existing university buildings. This extra accommodation cost to the school does not constitute an extra cost to the university, and thus is not included in its accounts.

Figure 14.1 also shows the differences between "full-cost", i.e. the entire cost of each additional resource required by the course expansion, and the "part-cost", i.e. the proportion of the cost of each additional resource which can be attributed to the time actually spent on the course, in the widest sense. In this case, the only resources affected are academic staff and consequently their offices, but this is sufficient to make total part-cost amount to only 65 percent of the total full-cost for the university. The remaining 35 percent can be attributed to outputs not related in any way to the proposal in question, i.e. staff research and postgraduate work.

(ii) Comparison with the Present Average Costs per Stu t[3]

Table 14.2 and Figure 14.2 show how the costs per student-year in Applied Biology are expected to change as student numbers increase. Based upon

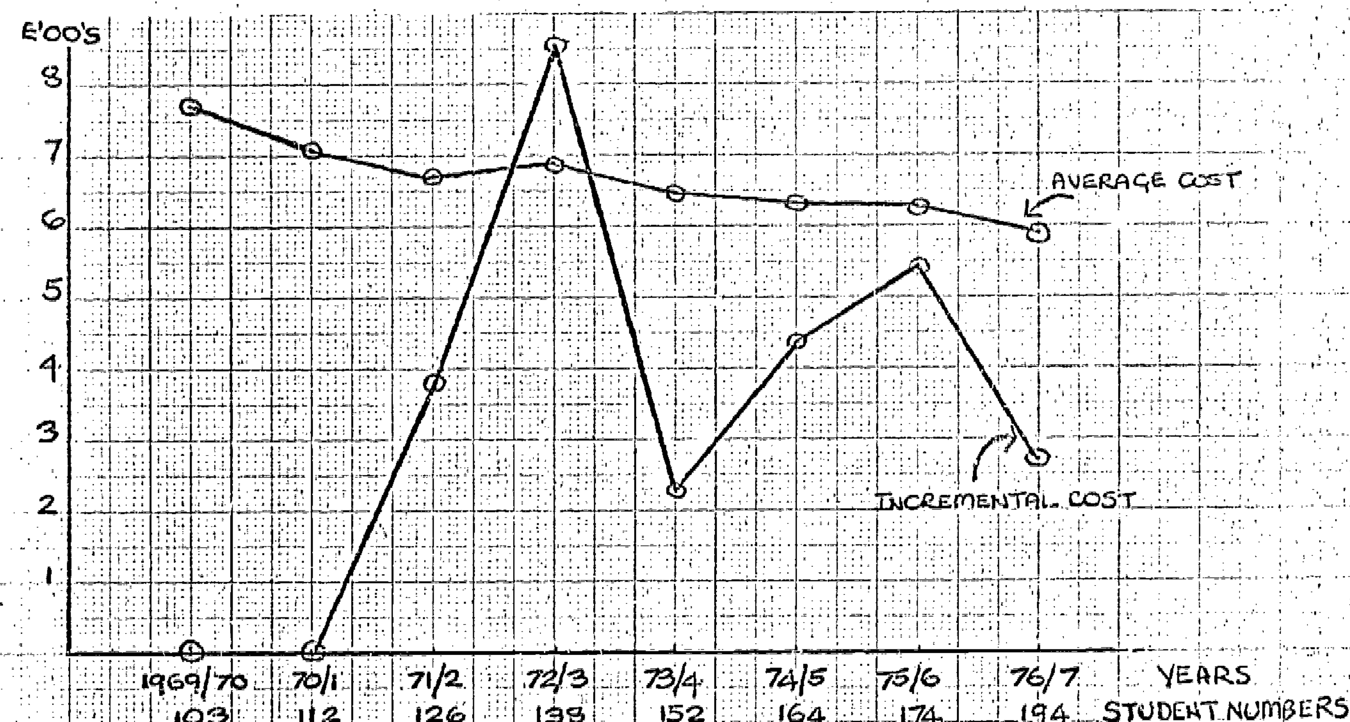


Figure 14.2 : APPLIED BIOLOGY - Average and Incremental Costs per Student-Year 1969/70 - 1976/77

Source : Appendix 3, Table 1

[3] See Appendix 2, Table 6

Table 14.2 APPLIED BIOLOGY: Changes in the Cost of the Course with an Expansion of Student Numbers*

Items of Expenditure	TOTAL COST 1969/70 (1)	TOTAL COST 1976/77 (2)	Percentage Change between (1) and (2) i.e. $\left(\frac{(2)-(1)}{(1)} \times 100\right)\%$ (3)
1. Capital & Maintenance Costs	£21,827	£30,791	41%
2. Teaching Costs	41,626	66,903	61%
3. Administrative Expenditure	10,609	11,403	8%
4. Library Expenditure	2,387	2,387	0%
5. General Expenditures	3,003	3,003	0%
A. Total Cost	£79,452	£114,487	44%
B. Total Student Numbers	103	194	88%
C. Average Cost Per Student-Year (i.e. A ÷ B)	771	590	-23%
D. Total Variable Cost	0	£35,035	--
E. Incremental Student Numbers	0	91	--
F. Incremental Cost Per Student-Year (i.e. D ÷ E)	0	385	--

* Source: Appendix 3, Table 1

estimates from the School, average cost per student-year should decline through the quinquennium from £771 in 1969-70 to £590 in 1976-77, a fall of 23 percent. This indicates that expanding student numbers in a well-established School will lead to economies, even when they are not deliberately being looked for, because the basic resources are already available. Marginal increments to the existing stock of resources are relatively small, as shown by the incremental cost per student-year. The sharp uneveness of this line is due to the intake of new resources failing to coincide exactly with the increases in student numbers. This is most marked in 1972-73 when a relatively large intake of resources, mainly due to the acquisition of two laboratories, coincides with a relatively small increment in student numbers. Taking the period as a whole the incremental cost per student-year averages £385.

Overall, an 88% increase in student numbers can be accommodated with a 44% increase in total cost.

(iii) The Sensitivity of Costs to Various Economies

Figure 14.3 shows the results of four sensitivity tests.

Figure 14.3(a): subtracting the cost of additional accommodation reduces the School total and incremental cost by 30 percent. This accommodation will be found within existing buildings, so that the saving will be made by the university. However, the additional accommodation required by the School represents a drain on the spare capacity at present available within the university. If, instead, the school's existing accommodation could be used more fully, a saving of up to 30 percent on the total and incremental cost could be made.

The fuller use of existing laboratories, which at present have a utilisation rate of 48 percent,[4] might remove the need for the additional laboratories which form three-quarters of the extra accommodation cost. This alone would lead to a saving of 23 percent in total and incremental cost, as well as having other cost reduction implications, which are discussed below. However, it is felt in the School that existing laboratories are reaching their full capacity and that any additions to student numbers will require extra laboratory space.

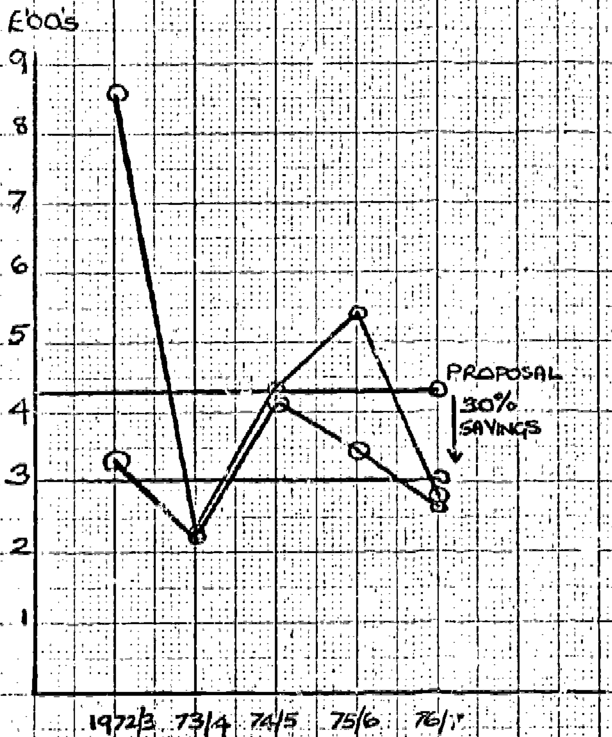
Figure 14.3(b): subtracting the cost of additional equipment and materials reduces the School total and incremental cost by 13 percent. The possibility of saving the equipment element is remote because it is related to student numbers, rather than to additional laboratories as tends to be the case in the Engineering Schools. Also, if laboratory work is to continue in the school then it is doubtful whether the materials budget, which is already stretched, can be cut. A consideration of the technical staff requirements below makes a reduction of the materials budget less likely and less desireable.

Figure 14.3(c): reducing the technical staff requirements to accord with the university average (which Biology at present closely matches) of 5.5 technical

4. Source: Chapter 8, Table 8.3

Figure 14.3: APPLIED BIOLOGY - Sensitivity Tests

Source: Appendix 3, Tables 2 and 3.



YEARS

Fig. 14.3(a) Accommodation

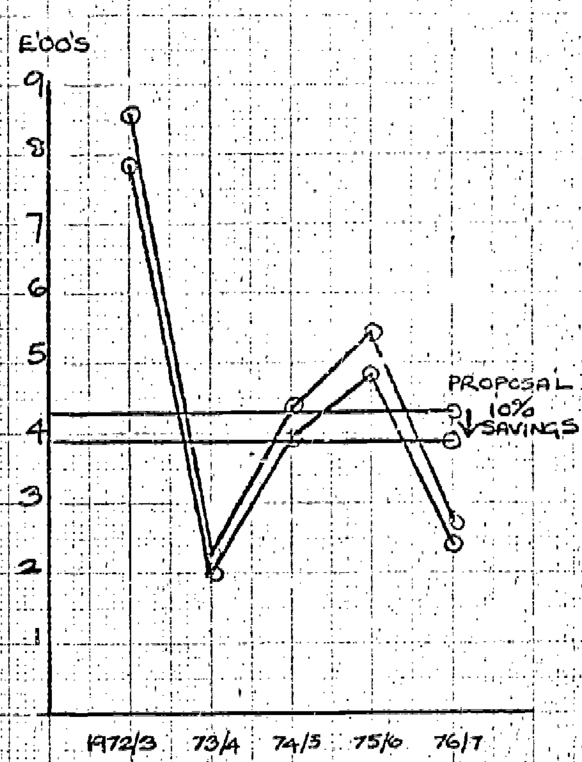


Fig. 14.3(b) Equipment & Materials

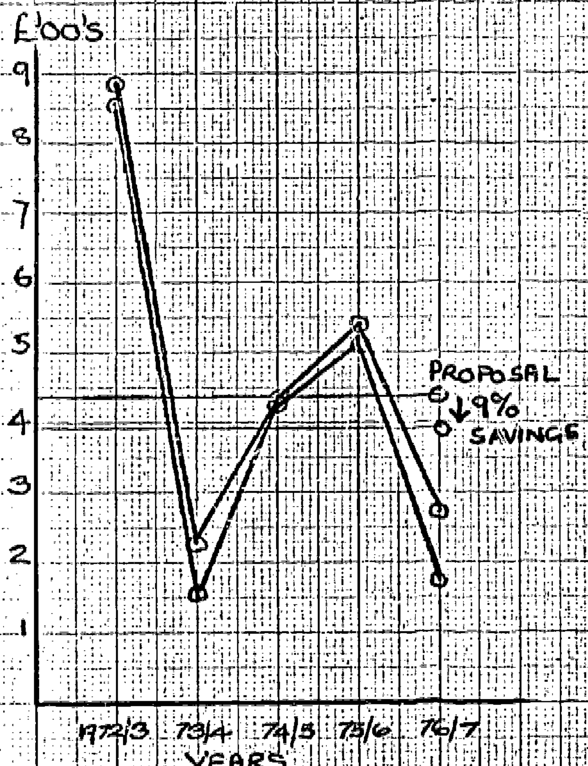


Fig. 14.3(c) Technical Staff

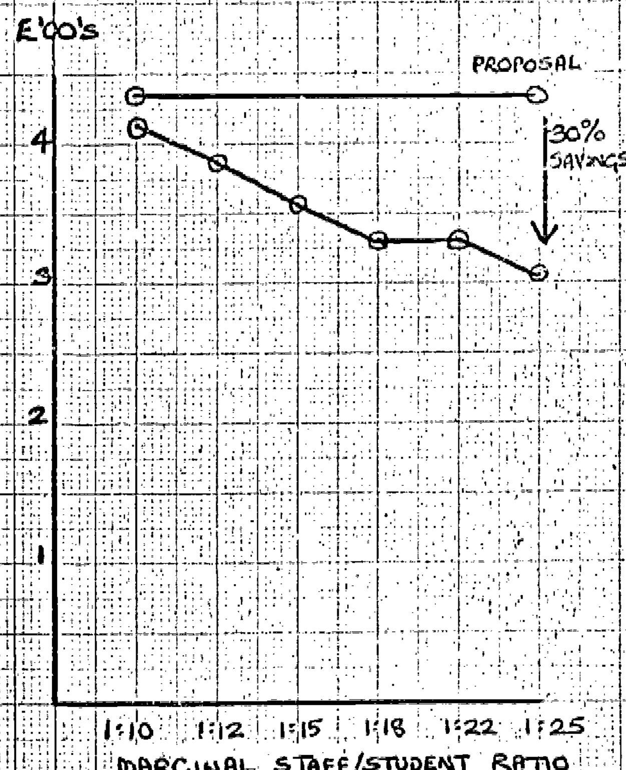


Fig. 14.3(d) Academic Staff

staff points for every 1600 square feet of teaching laboratory area[5] reduces the School total and incremental cost by 9 percent. The technical staff requirements amount to 20 staff points by 1976-77, compared to 10 staff points using the university average and the extra teaching laboratory area required.

If, as suggested above, no extra laboratories are required then the norm would imply that no extra technical staff are required, resulting in a 19 percent saving in cost. However, it seems likely that the more intensive use of existing laboratories might require some additional technical staff.

The shortage of materials mentioned above has repercussions on the technical staff requirements, especially in the lower grades. The shortage of materials, and the long time-span of biology experiments which means that much of the stock is in use at any one time, causes peaks in the cleaning of materials. This requires more technical staff than would otherwise be the case. Insofar as the cost of a "block" of extra materials is less than the alternative cost of an extra technical staff member, some substitution of materials for technical staff would be economic at the margin.

Figure 14.3(d): progressively worsening the marginal staff:student ratio from the proposed ratio of less than 1:10 to 1:25 leads to a savings in School total and incremental cost of up to 30 percent. As a rough approximation, the average staff:student ratio will fall from the present 1:10 to 1:13 by 1976-77 with a marginal ratio of 1:25.

The actual increase in contact hours resulting from the higher student numbers will not be great,[6] so that some reduction in this ratio is justified. Because the additional staff costs form a considerable proportion of the total additional costs of the proposal, reducing the ratio will lead to sizeable economies.

Summary

(i) Significant economies of scale are evident in Applied Biology even though no deliberate attempts have been made to find them. An 88% increase in student numbers can be accommodated with a 44% increase in the total cost of the course.

(ii) The key to potential further economies seems to be of a twofold nature. Firstly, if existing laboratories were used more fully, then the need for additional laboratories would be removed (23% saving), and with it much of the additional technical staff (19% saving) and equipment (3% saving).

Secondly, the marginal staff:student ratio can be reduced to some extent without increasing the average teaching load per staff member. A worsening of the ratio of up to 1:25 leads to savings of up to 30%.

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5. See Chapter 12.
6. See Chapter 5

(iii) Owing to past decisions on the allocation of resources, which have left the School with relatively little excess capacity compared to other schoools, Applied Biology is in a less favourable position to expand by more fully utilising existing resources. Of particular importance in this respect is laboratories, the fuller use of which may only be possible through a lengthening of the working day.

(B) Electrical Engineering

The Undergraduate School in Electrical Engineering is a well-established school. It hopes to expand from an intake of 78 in 1970-71 to 90 by 1976-77. This will lead to student numbers increasing from 264 to 311 over the same period.

The Professor of Electrical Engineering believes that no additional resources will be required for this expansion. The reason is that there already exists capacity to accommodate a first year intake of 90, because in the past entries of this magnitude have been accommodated. The School has thus suffered from declining student enrolments, a manifestation of the swing from the sciences in recent years, which has left its laboratories relatively underutilised.[7] However, this year there has been a decided upturn in the student intake which may presage future increasing enrolments in the School.

Other science schools, such as Mechanical and Civil Engineering, Chemistry, Physics, etc., are faced with a similar enrolments problem, and because it is so wide-ranging, it has been given careful consideration by the Academic Planning Committee of the University of Bradford.[8]

The committee has decided that a solution to the problem is to foster mixed arts-sciences courses which, it is hoped, will encourage arts students to do some science whilst taking their degrees. This will help maintain the provisional recommendation of the University Grants Committee for a 55:45 arts:science distribution of students during the forthcoming quinquennium, and will supply industry's apparently growing need for "generalist" rather than "specialist" graduates.

In Electrical Engineering, however, an attempt to introduce a new course involving equal proportions of Electrical Engineering and Modern Languages has been withdrawn after preliminary discussions. The student numbers on this course would not have contributed towards the School's proposed attainment of an intake of 90 for the full Electrical Engineering course, but they would have helped to increase the utilisation of its laboratories and equipment.

For the purposes of this costing we simply assume that (a) the total cost of the course in 1969-70[9] remains unchanged (in real terms) through the quinquennium, and that (b) the desired student numbers are forthcoming. The resulting cost figures are shown in Table 14.3 and Figure 14.4. The average cost per student-year falls by 21% from £891 in 1969-70 to £708 in 1976-77. Because there are no additions to total cost despite the sizeable increments in student numbers, i.e. total variable cost is zero, it follows that the incremental cost per student year is also zero.

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7. The rate of utilisation of Electrical Engineering teaching laboratories is 42% (see Chapter 8, Table 8.3). The Professor has pointed out that it is impossible to use specialised laboratories throughout the whole week. Many of these are project laboratories, and by the very nature of project work these can only be occupied for a few hours of the week.
8. See, for example: "Report of the Undergraduate Panel of the Academic Planning Committee to the full Academic Planning Committee", Registry Files, 1970, paras 6-9.
9. Source: Appendix 2, Table 3.

Table 14.3: ELECTRICAL ENGINEERING -- Changes in the Cost of the Course with an Expansion of Student Numbers, 1969/70 to 1976/77*

Items of Expenditure	TOTAL COST 1969/70 (1)	TOTAL COST 1976/77 (2)	Percentage Change between (1) and (2) i.e. $(\frac{(2)-(1)}{(1)} \times 100)\%$ (3)
1. Capital & Maintenance Costs	£78,481	£78,481	0%
2. Teaching Costs	107,273	107,273	0%
3. Administrative Expenditures	25,688	25,688	0%
4. Library Expenditures	3,705	3,705	0%
5. General Expenditures	4,940	4,940	0%
A. Total Cost	£220,087	£220,087	0%
B. Total Student Numbers	247	311	26%
C. Average Cost per Student-Year (i.e. A ÷ B)	891	708	21%
D. Total Variable Cost	0	0	--
E. Incremental Student Numbers	0	64	--
F. Incremental Cost per Student-Year (i.e. D ÷ E)	0	0	--

* Source: Appendix 3, Table 4

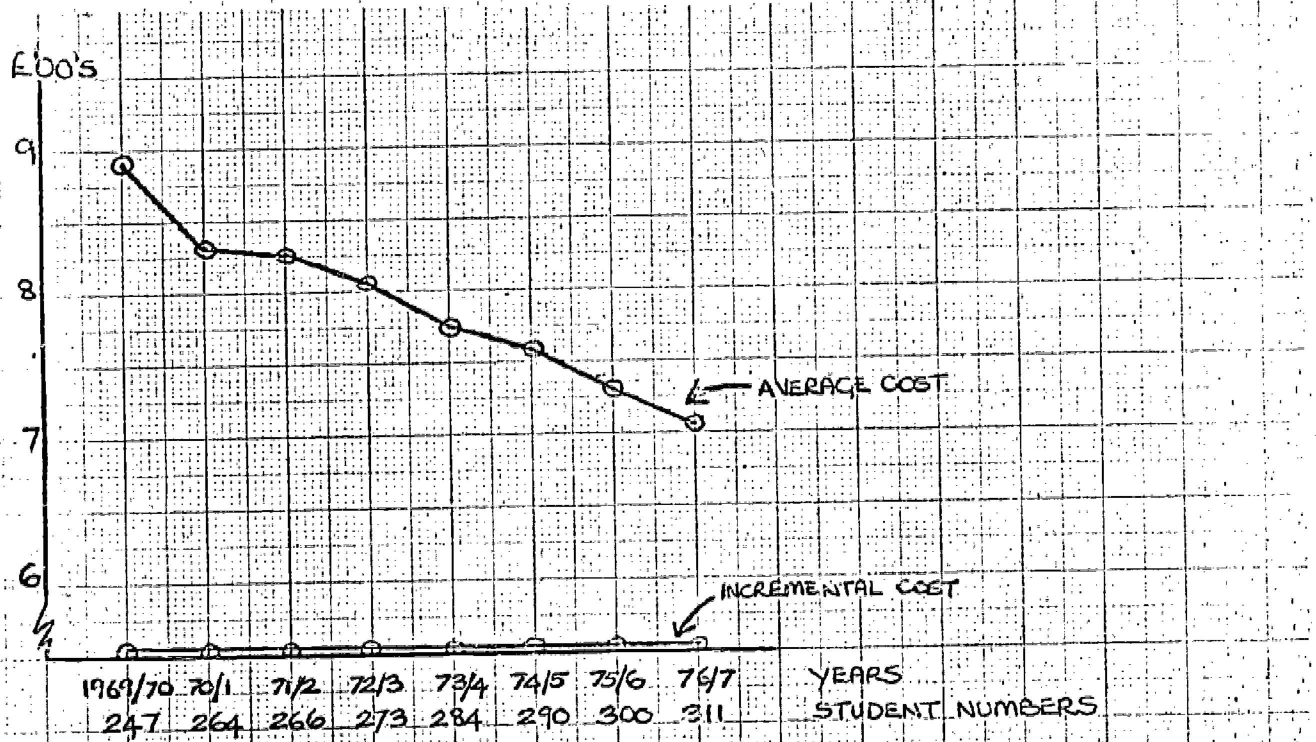


Figure 14.4 : ELECTRICAL ENGINEERING - Average and Incremental Cost per Student-Year 1969/70 - 1976/77

Source : Appendix 3, Table 4

Summary

(1) There is considerable scope for economies of more intensive utilisation of existing resources in Electrical Engineering, especially with regard to laboratories and equipment. The total cost of the course should remain unchanged and the average cost per student-year should fall by 21% from £891 in 1969-70 to £708 in 1976-77.

(2) At present it is uncertain whether the extra student numbers required to achieve this will be forthcoming.

(C) Chemical Engineering

The Undergraduate School of Chemical Engineering is a well-established school, having the largest undergraduate student population of the five schools in the Board of Engineering. It is proposed to expand the intake of 95 in 1970-71 to 120 by 1976-77, for which there is ample capacity. The school has probably suffered less than the other engineering schools from the swing of student demand towards the arts. By adding a management economic option to the course, it is believed that the target intake will be achieved.

(i) Financial Costs of the Proposal

Table 14.4 and Figure 14.5 show the total additional financial costs (TVC) of the proposal to expand Chemical Engineering.

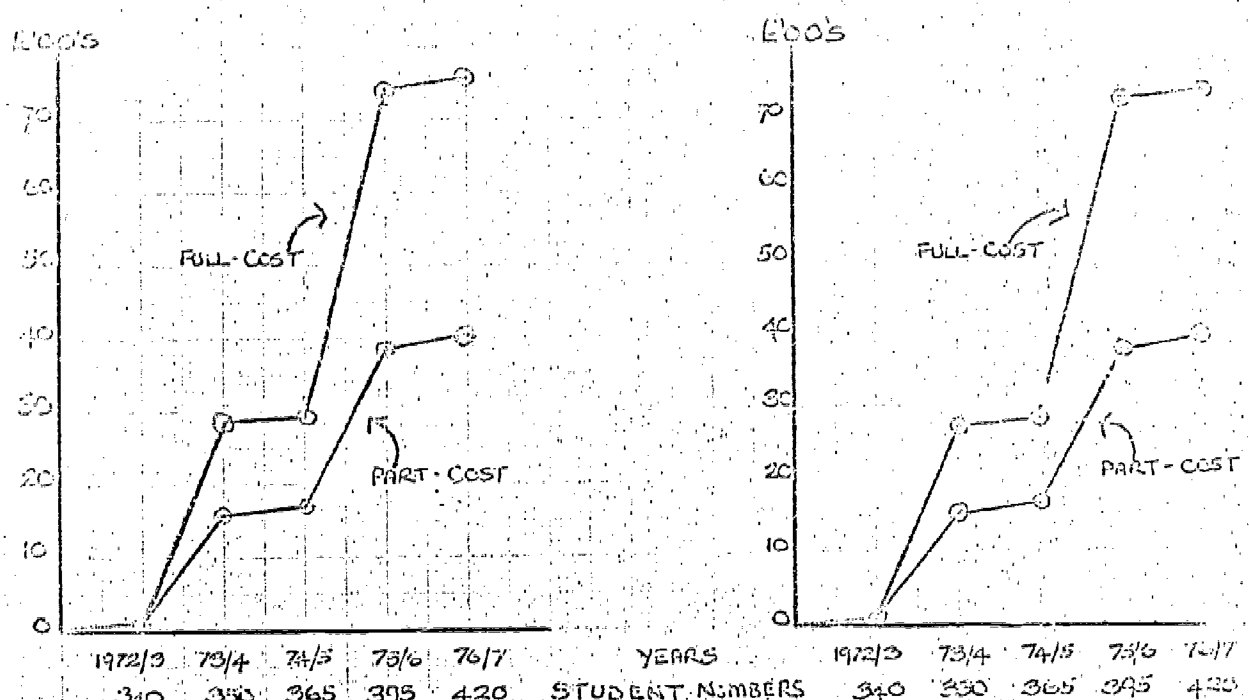


Fig. 14.5(a) SCHOOL Accounting Unit   Fig. 14.5(b) UNIVERSITY Accounting Unit

Figure 14.5 : CHEMICAL ENGINEERING - Additional Financial Costs

Source : Table 14.4

Table 14.4 CHEMICAL ENGINEERING

Additional Financial Costs (TVC)

			1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
Student Numbers:	Total		341	340	350	365	395	420
	Incremental		0	-1	10	15	30	25
(1) Staff	Full-cost	TVC	0	0	2799	2799	7079	7079
	Part-cost	TVC	0	0	1595	1595	3649	3649
(2) Accommodation	Full-cost	TVC	0	0	105	105	210	210
	Part-cost	TVC	0	0	59	59	109	109
(3) Equipment	Full-cost	TVC	0	30	-70	30	80	180
	Part-cost	TVC	0	30	-70	30	80	180
(4) Materials	F/P-cost	TVC	0	-1	9	24	54	79
AGGREGATE COST School Accounting Unit (ie (1)+(2)+(3)+(4))								
	Full-cost	TVC	0	29	2843	2958	7423	7548
	Part-cost	TVC	0	29	1593	1708	3892	4017
AGGREGATE COST University Accounting Unit (ie (1)+(3)+(4))								
	Full-cost	TVC	0	29	2738	2853	7213	7338
	Part-cost	TVC	0	29	1534	1649	3783	3908

Table 14.5 CHEMICAL ENGINEERING

Changes in the Cost of Chemical Engineering with an Expansion of Student Numbers to an Intake of 120*

Item of Expenditure	TOTAL COST		% Change between (1) and (2) i.e. $(\frac{(2)-(1)}{(1)} \times 100)\%$
	1969/70 (1)	1976/77 (2)	
(1) Capital and Maintenance Costs	79,533	79,769	0%
(2) Teaching Costs	97,114	100,869	4%
(3) Administrative Expenditures	36,645	36,645	0%
(4) Library Expenditure	5,235	5,235	0%
(5) General Expenditures	6,980	6,980	0%
A. TOTAL COST	225,507	229,498	2%
B. Total Student Numbers	349	420	20%
C. Average cost per Student Year (i.e. A ÷ B)	646	546	-15%
D. TOTAL VARIABLE COST	0	3,991	---
E. Incremental Student Numbers	0	71	---
F. Incremental Cost per Student Year (i.e. D ÷ E)	0	56	---

* Source: Appendix 3, Table 5

The difference in financial cost between the School and University accounting units is small because the additional accommodation required only amounts to two additional staff offices. These will be found internally, thus adding to the cost of the School but not to that of the University.

The bulk of the additional cost arises from the employment of two new academic staff. This, coupled with the fact that they may be expected to spend a considerable proportion of their time on work not associated with the course in question, results in the financial part-cost amounting to only 53 percent of the full-cost. In other words, little more than half of the total additional financial cost to be incurred by the university on the expansion can be attributed in advance to the outputs of the course concerned.

(ii) Comparison with the Present Average Costs per Student[10]

Table 14.5 and Figure 14.6 show how the cost per student-year is expected to change as student numbers increase through the quinquennium.

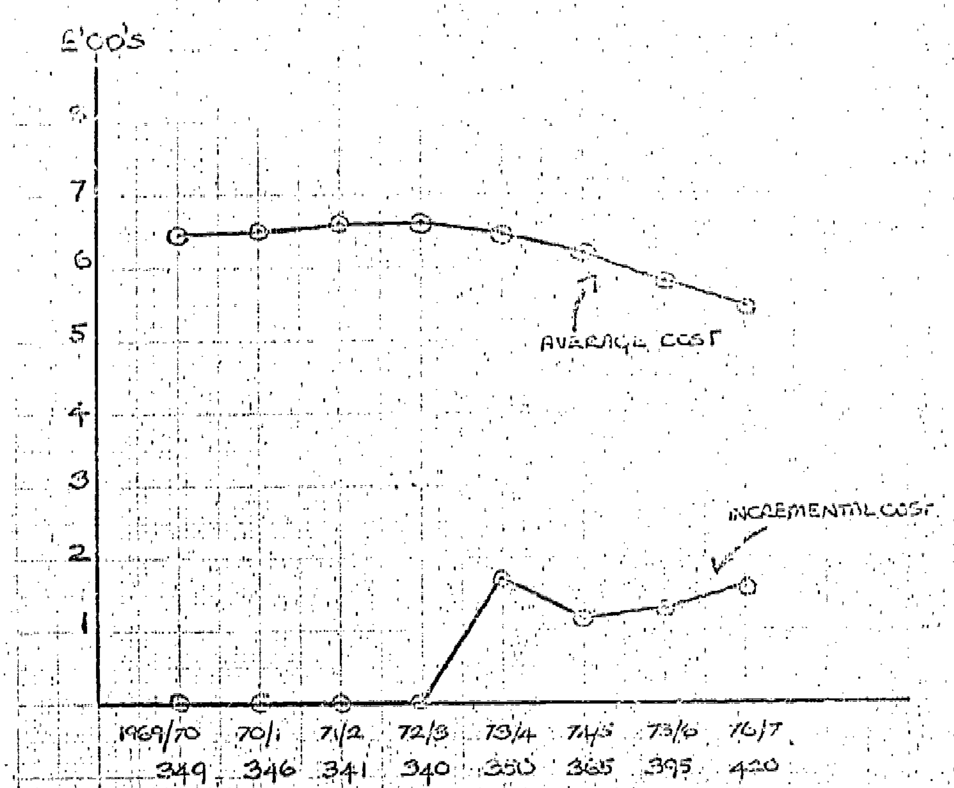


Figure 14.6 CHEMICAL ENGINEERING - Average and Incremental Costs per Student - Year 1969/70 - 1976/77

Source : Appendix 3, Table 5

10 See Appendix 2, Table 1

The average cost per student-year declines from £646 in 1969-70 to £546 in 1976-77, a fall of 15 percent. Like Applied Biology, this illustrates the relative cheapness of expanding well-established schools. The incremental cost fluctuates due to the irregular intake of resources, but over the quinquennium it averages £56 per student-year.

Table 14.5 shows that between 1969-70 and 1976-77 <u>a 20 percent increase in student numbers can be accommodated with only a 2 percent increase in total cost</u>.

(iii) <u>Sensitivity of Costs to Various Economies</u>

It should be noted that the Chemical Engineering undergraduate course is an "end on", "thin sandwich" course because this influences the nature of the economies and the degree to which they can be made. The "thin sandwich" involves two streams of students, each alternating six months in industry throughout the four years of the course. The course is "end on" because as one stream of students leaves the university the other stream arrives from industry, so that at any one time in the academic year of forty-six weeks, only half the total number of students on the course will be in the university. The fact that the Chemical Engineering students only spend two years in the university is one reason why the graduates are relatively cheap to produce compared to those of other four year courses.

Table 14.5 in the previous section shows that the addition to total annual cost amounts to only £3,991, so that the scope for sensitivity testing is limited. However, when one considers that the comparable figure for Applied Biology is £35,035, it may be useful to examine reasons for the difference.

Although Applied Biology is planning a rather smaller absolute expansion in student numbers than Chemical Engineering, the proportionate expansion is much larger (i.e. 54% compared to 23%). Furthermore, the present capacity of Applied Biology is a good deal more limited than that of Chemical Engineering, so that the school will be expanding proportionately more quickly from a less favourable present position.

In this situation, bringing the question of expensive laboratory facilities into account highlights an important reason for the difference in expansion costs. Applied Biology has much laboratory work in its undergraduate course and to expand it estimates that 2880 square feet of extra laboratory space is required. In contrast, Chemical Engineering has no laboratory work at all except for individual projects in the third year when research laboratories are used. Consequently, the potential for heavy additional expenditures on laboratories, along with the associated equipment and technical staff, is removed. It is believed in the School that the students gain sufficient laboratory experience in their sandwich periods in industry. On the other hand, in Applied Biology it is argued that the industrial firms which take students for their sandwich periods require previous laboratory experience.

The other major resource which renders the expansion of Applied Biology relatively expensive compared to that of Chemical Engineering is staff. Much of the additional staff requirement in Applied Biology is for technicians, the need for which is related to the extra laboratory area. In Chemical Engineering we have seen that only two extra (academic) staff are required, and this cost comprises 90 percent of the £3991 total annual cost of the expansion without including the cost of their offices.

At this point an examination of Figure 5.3 will be useful. In proposing an expansion from a half-yearly intake of just over 45 (i.e. 95 for the whole year), to 60 (i.e. 120 for the whole year), the requirements of two extra staff is roughly in line with the projected extra teaching load. However, in terms f the cost of academic staff per student (i.e. the Staff Cost Index),[1] the expansion is not very economical. The index line in Figure 5.3 shows that although there will be a small drop in the cost per student, the expansion involves moving from near the bottom of one downward-sloping section of the curve to the top of the next, the "break point" being associated with a group size of 50. Further economies in the cost of academic staff per student could be gained if the expansion is continued beyond the half-year intake of sixty. However, this formula may not necessarily be closely adhered to, as we now go on to show.

Although the proposal involves an expansion of the intake from 95 to 120, and this can be achieved very cheaply, it is believed that the School <u>could</u> expand to an intake of 160 with <u>no</u> additions to present capacity. The cost implications are shown in Table 14.6 and Figure 14.7, although these may be slightly optimistic for reasons given below.

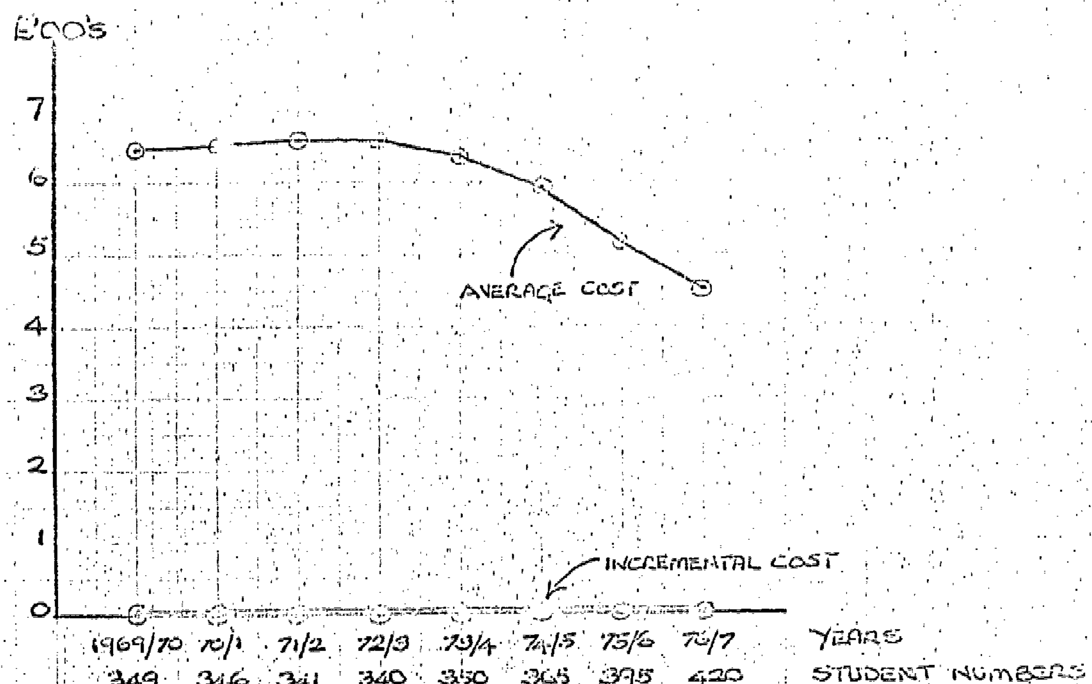


Figure 14.7: CHEMICAL ENGINEERING — Average and Incremental Costs per Student - Year, 1969/70 - 1976/77

Source: Appendix 3, Table 6.

1. For a full discussion of the Staff Cost Index and related topics, see Ch. 5.

Table 14.6: CHEMICAL ENGINEERING

Changes in the Cost of the Course with an Expansion of Student Numbers to an Intake of 160*

Item of Expenditure	TOTAL COST		% Change between (1) and (2) i.e. $\left(\frac{(2)-(1)}{(1)} \times 100\right)\%$
	1969/70 (1)	1976/77 (2)	
(1) Capital & Maintenance Costs	79,533	79,533	0%
(2) Teaching Costs	97,114	97,114	0%
(3) Administrative Expenditure	36,645	36,645	0%
(4) Library Expenditures	5,235	5,235	0%
(5) Student Facility Expenditure, etc	5,980	6,980	0%
A. TOTAL COST	225,507	225,507	0%
B. Total Student Numbers	349	500	43%
C. Average Cost per Student Year (i.e. A ÷ B)	646	451	-30%
D. TOTAL VARIABLE COST	0	0	--
E. Incremental Student Numbers	0	151	--
F. Incremental Cost per Student Year (i.e. D ÷ E)	0	0	--

* Source: Appendix 3, Table 6

Such an expansion is possible in a variety of ways, the two extremes of which are as follows:

(a) by maintaining the present course structure and increasing the present low teaching load of academic staff, or

(b) by changing the course structure and maintaining the teaching load constant.

We will briefly discuss each in turn.

(a) The present low work-load of academic staff must be explained and also qualified. Because the nature of the course results in only half the total number of students being in the university at any one time, the staff:student ratio in this sense is effectively halved to 1:7. Consequently, the average weekly teaching load per staff member is about four and a half hours, compared with at least six hours for the university as a whole. However, this teaching load has to be borne for forty-six weeks of the year instead of the usual thirty-three, and it is composed entirely of lectures and tutorials, rather than the less demanding laboratory supervision which forms a sizeable proportion of the load of most other schools. Also, each staff member spends three weeks of every year visiting students in industry.

It is believed that the intake of 160 could be accommodated on the present course structure by increasing the present teaching load of staff to around the university average. Because of their teaching commitments over and above the normal 33-week year as explained above, this would reduce their working conditions to below that of other academic staff.

Because this would involve allocating more of the existing staff and accommodation resources to the course and away from other outputs, they should be included in Table 14.6 and Figure 14.7. Their absence renders these figures slightly optimistic. But the most important cost would be the degree of loss of the other outputs which the redirected resources would otherwise have produced.

(b) It is often remarked in the School that the Chemical Engineering course has proved to be a flexible one. The alternative to (a) is thus to modify the course structure in such a way as to maintain the current teaching load of staff. Tutorials which, because of the small group size involved, are relatively expensive of staff time, could be replaced by lectures in which the whole intake can be taught simultaneously. The result may be a deterioration in the quality of the student output, but the experience of the school suggests that this need not be so.

If this alternative were to be chosen to accommodate an intake of 160, the cost projections in Table 14.6 and Figure 14.7 are less open to charges of optimism because little re-organisation of the current resource use would be involved.

The fact remains, however, that the proposed expansion to an intake of 120 is probably more realistic in the light of projected student demands and of the demands of industry.

Summary

Chemical Engineering can expand its student numbers very cheaply for the following main reasons:

(i) present excess capacity in the School
(ii) the end-on thin sandwich nature of the course
(iii) the lack of laboratory work in the School
(iv) the flexibility of the course.

However, at present it seems doubtful whether student demand will be sufficient to reap the full benefits of such economies.

(D) Industrial Technology and Management

The Undergraduate School of Industrial Technology and Management is a very new school, for there will be no fourth year students on the course until next academic year (1971-72).

The School has been able to attract a high proportion of students with an arts background to a course which comprises 50 percent engineering subjects (the other 50 percent is management), and thus has helped to reverse the swing of student demand from the sciences. Also, it has already been noted that there appears to be a shift in industry's demand for graduates towards those with "generalist" rather than "specialist" backgrounds,[12] such as those produced in Industrial Technology.

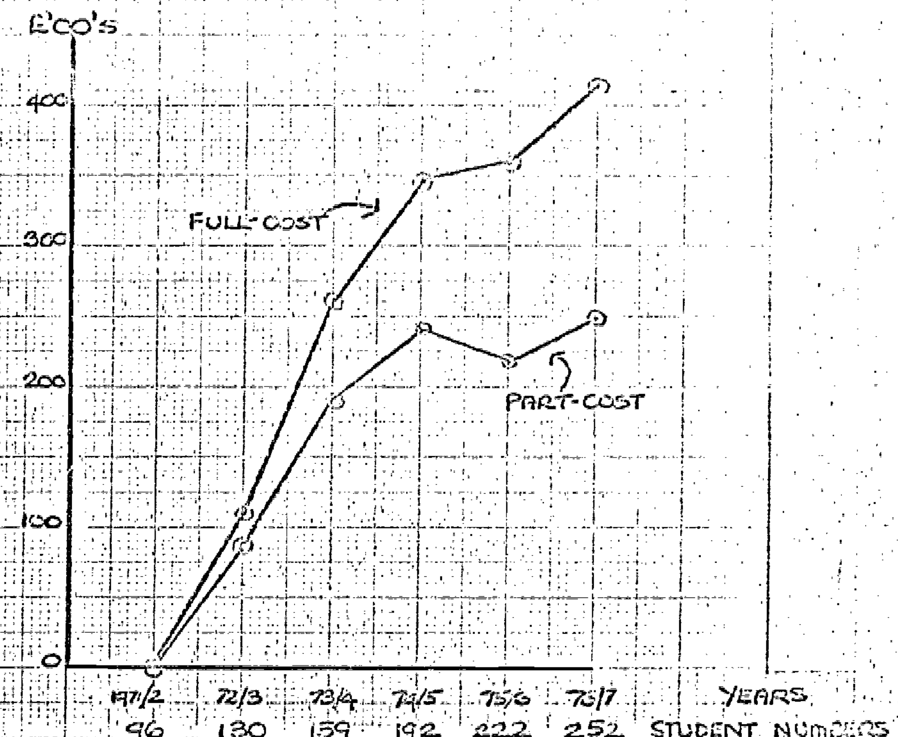


Figure 14.8: INDUSTRIAL TECHNOLOGY AND MANAGEMENT — Additional Financial Costs

Source: Table 14.7

14.16

12. See: "Report of the Academic Planning Committee, 26th April, 1971", op cit

Table 14.7: INDUSTRIAL TECHNOLOGY AND MANAGEMENT – Additional Financial Costs (TVC)

		1971/2	1972/3	1973/4	1974/5	1975/6	1976/7
Student Numbers: Total		96	130	159	192	222	252
Incremental		0	34	29	33	30	30
		£	£	£	£	£	£
(1) Staff: Full-Cost	TVC	0	6,942	18,534	26,931	35,354	40,952
Part-Cost	TVC	0	4,534	11,493	16,280	21,273	24,464
(2) Accommodation:							
Full-Cost	TVC	0	0	0	0	0	0
Part-Cost	TVC	0	0	0	0	0	0
(3) Equipment:							
Full-Cost	TVC	0	4,000	7,500	7,500	0	0
Part-Cost	TVC	0	4,000	7,500	7,500	0	0
(4) Materials:							
Full-Cost) Part-Cost)	TVC	0	100	200	300	400	500
AGGREGATE COST – SCHOOL Accounting Unit (i.e. (1) + (2) + (3) + (4))							
Full-Cost	TVC	0	11,042	26,234	34,731	35,754	41,452
Part-Cost	TVC	0	8,634	19,193	24,080	21,673	24,964
AGGREGATE COST – UNIVERSITY Accounting Unit (i.e. (1) + [redacted] + (3) + (4))							
Full-Cost	TVC	0	11,042	26,234	34,731	35,754	41,452
Part-Cost	TVC	0	8,634	19,193	24,080	21,673	24,964

For these reasons, the School hopes to expand considerably over the quinquennium from an intake of 27 in 1970-71 to one of 75 in 1976-77. As a result, total student numbers will increase over the period from 57 to 252. In the School it is felt that these figures are on the low side, and that the desireability of producing more generalist undergraduate students will come to be more widely accepted in the university. This might well lead to an upward revision of the planned 75 intake for 1976-77.

Thus we are dealing with a School, at present small, which will expand considerably over the next few years. Large economies of scale may therefore be expected.

(i) Financial Cost of the Proposal

Table 14.7 and Figure 14.8 indicate the additional annual financial costs of the proposal.

The cost to the University and School accounting units is the same because no additional accommodation is required during the next quinquennium. However, a large addition to the School's stock of accommodation will take place during the final year of the present quinquennium (1971-72). This will be discussed below.

Figure 14.8 also shows the difference between the full-cost and the part-cost of the proposal, i.e. the difference between the cost of all the additional resources requested, and the cost of that proportion of the resources which can be attributed, in the widest sense, to the course concerned. In 1976-77 the part-cost amounts to 60 percent of the full-cost, implying that the balance of 40 percent cannot be attributed to the output of the course.

(ii) Comparison with the Present Average Costs per Student[13]

Table 14.8 and Figure 14.9 indicate how the cost of the Industrial Technology course is expected to change as student numbers increase. Based on estimates from the School, the average cost per student-year declines through the quinquennium from £1045 in 1969-70 to £298 in 1976-77, a reduction of 71 percent.

So dramatic a fall warrants further investigation.

There are considerable economies of scale to be obtained by expanding the School from its present small size. This is implied in Figure 14.9 by the fact that the line measuring the incremental cost per student-year lies below that representing average cost. The former follows its usual erratic course, largely because of the irregular intake of additional resources, but it averages £198 over the period covered. The highest value, in 1971-72, results from a large intake of additional accommodation which is sufficient until 1976-77.

13. See Appendix 2, Table 4

Table 14.8 : INDUSTRIAL TECHNOLOGY AND MANAGEMENT - Changes in the Cost of the Course with an Expansion of Student Numbers*

Items of Expenditure	TOTAL COST 1969/70 (1)	1976/77 (2)	Percentage Change between (1) and (2) i.e. $(\frac{(2)-(1)}{(1)} \times 100)\%$ (3)
1. Capital and Maintenance Costs	£10,992	£21,576	96%
2. Teaching Costs	15,330	46,929	206%
3. Administrative Expenditure	3,690	5,404	46%
4. Library Expenditure	525	525	0%
5. General Expenditure	819	819	0%
A. Total Cost	£31,356	£75,253	140%
B. Total Student Numbers	30	252	740%
C. Average Cost per Student-Year (i.e. A + B)	1045	298	-71%
D. Total Variable Cost	0	£43,897	-
E. Incremental Student Numbers	0	222	-
F. Incremental Cost Per Student-Year (i.e. D + E)	0	198	-

* Source: Appendix 3, Table 7

Overall, an expansion of student numbers of 740% can be accommodated with an increase in the total cost of the School of 140%.

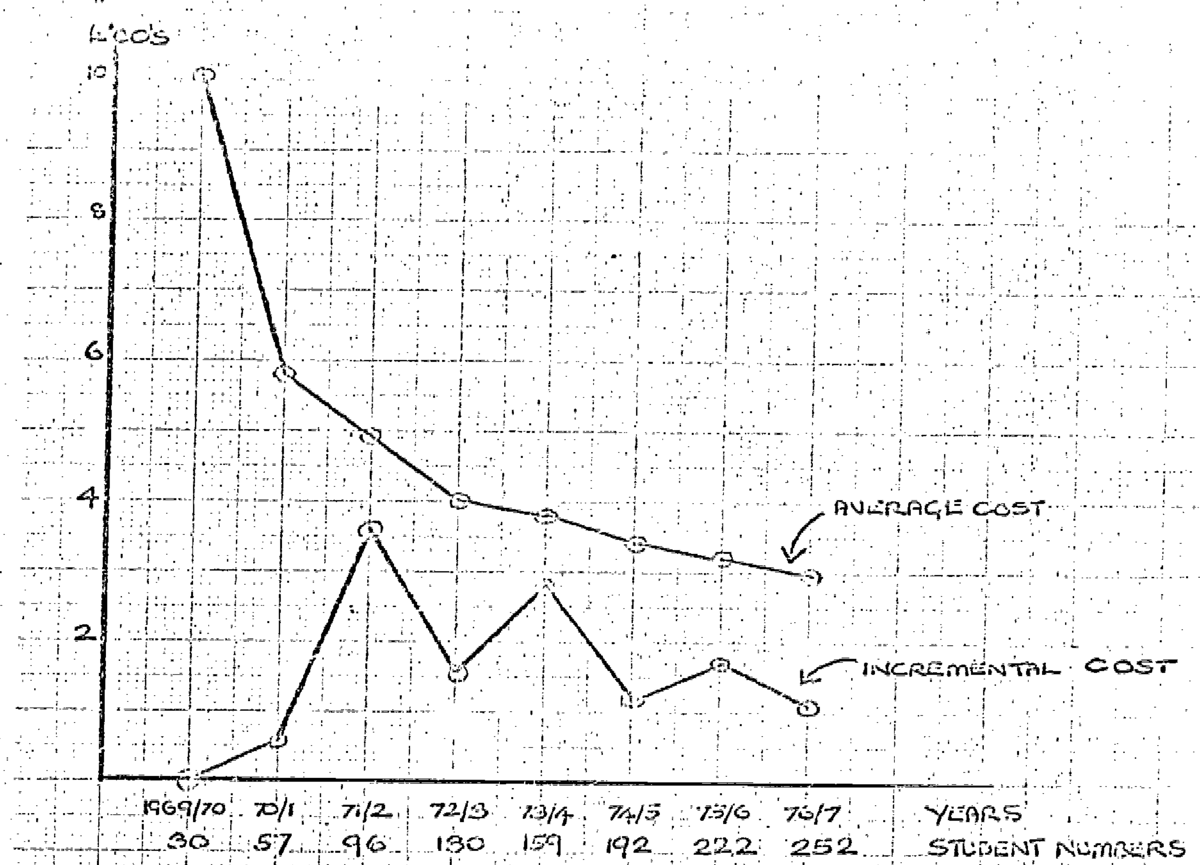


Figure 14.9 : INDUSTRIAL TECHNOLOGY AND MANAGEMENT

Average and Incremental Costs Per Student Year, 1969/70 - 1976/7

Source : Appendix 3, Table 7

(iii) Sensitivity of Costs to Various Economies

Figure 14.10 shows the results of three cost sensitivity tests.

Figure 14.10(a): subtracting the cost of additional equipment and materials reduces the School total additional and incremental cost by 9 percent, a relatively minor saving.

Figure 14.10: INDUSTRIAL TECHNOLOGY AND MANAGEMENT - Sensitivity Tests

Source: Appendix 3, Tables 8 and 9

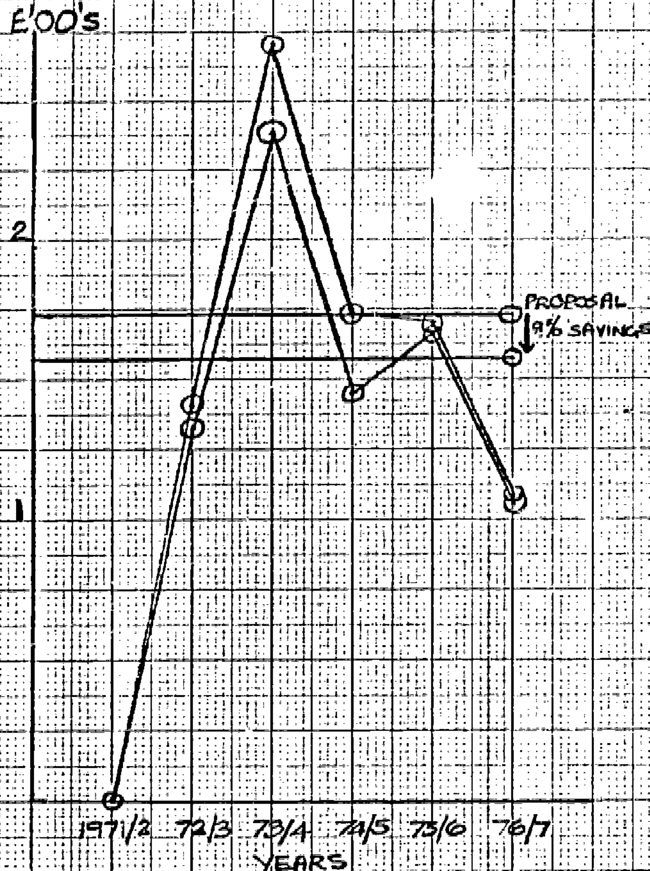


Fig 14.10(a) Equipment & Materials

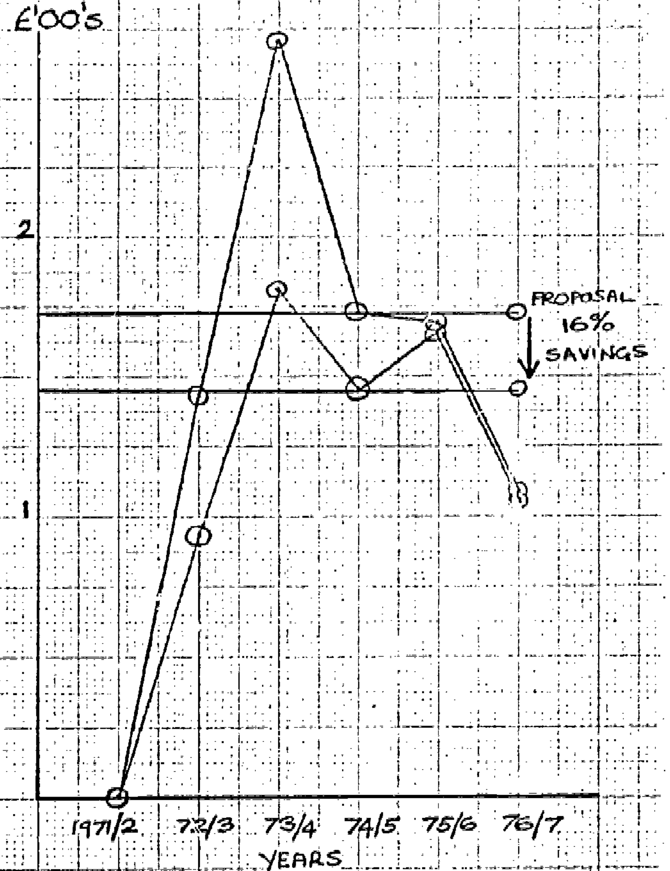


Fig 14.10(b) Ancillary Staff

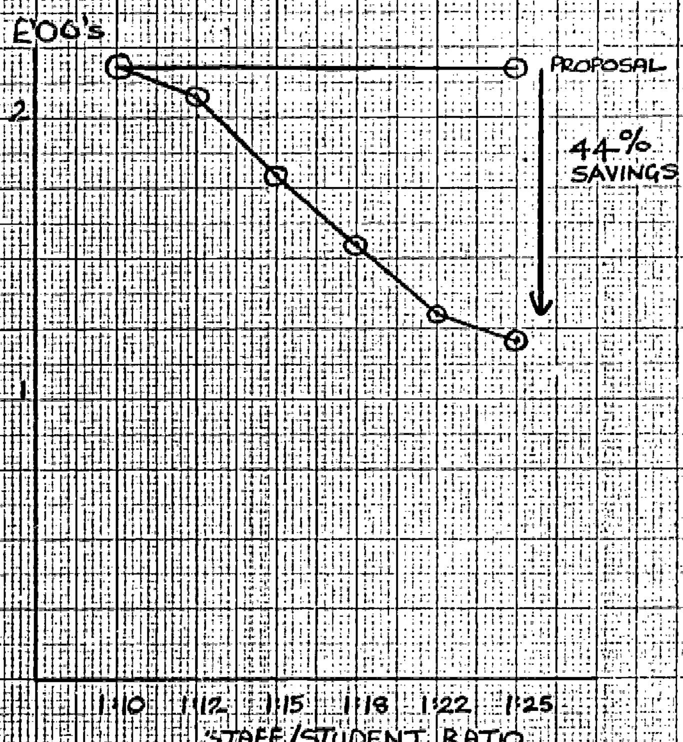


Fig. 14.10(c) Academic Staff

Figure 14.10(b): subtracting the cost of additional ancilliary staff reduces the School annual additional and incremental cost by 16 percent.

The ancilliary staff required amount to two technicians and one administrative officer. The additional laboratory area of 1807 square feet merits little more than one extra technician, if the ratio of one technician to 1600 square feet of laboratory area is applied,[14] but the rapid expansion of the school probably merits the extra staff member.

The administrative officer takes over the work which otherwise would be carried out by academic staff. His appointment is in lieu of that of another academic staff member.

Figure 14.10(c): progressively worsening the marginal staff:student ratio from 1:10 to 1:25 leads to savings in the School's annual additional and incremental costs of up to 44 percent. As a rough approximation, the average staff:student ratio will fall from the present 1:6 to 1:13 by 1976-77 with a marginal ratio of 1:25. Since the increase in contact hours in Industrial Technology is likely to increase at a rate less than pro rata with student numbers, there is justification for some reduction in the ratio.[15] Once again, this seems to be the source of the greatest potential economies.

Figure 14.11: this figure illustrates the problem of the utilisation of additional accommodation associated with expanding student numbers. Accommodation tends to come in large discrete "lumps", whereas student numbers increase more slowly in a series of smaller jumps. In this example, the extra accommodation is a converted mill building which will be shared equally with the School of Material Science and Technology.

Line A shows that the cost of additional accommodation allocated to Industrial Technology has a large step jump in 1971-72 as a result of the large expansion of the School's accommodation at the beginning of that year. This line can be looked upon as forming a constraint on the upward expansion of student numbers, which is shown by the line B. If we make the most optimistic assumptions about the utilisation of accommodation, namely that

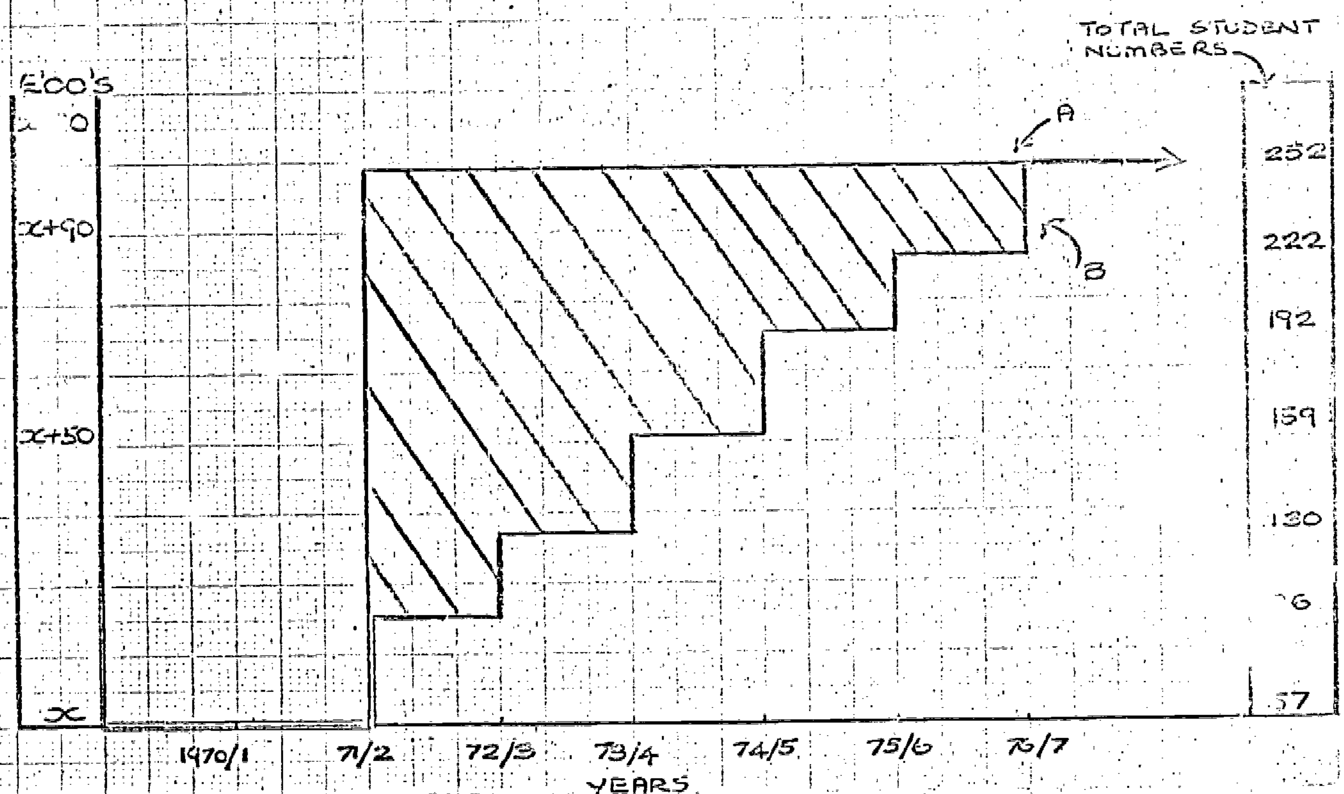
(a) the current 57 students constitute the maximum capacity of the present (1970-71) accommodation, so that the lines A and B have the same starting point in 1971-72; and that

(b) the 252 students in 1976-77 will fill the additional accommodation, so that the two lines will again coincide;

then the line B can be interpolated between the two points of contact with line A in 1971-72 and 1976-77 with the actual step increases in student numbers in each year. The area of diagonal shading between the two lines gives a rough approximation of the excess capacity of the additional accommodation, as compared with the total additional accommodation which covers the vertical distinace between line A and the horizontal axis.

The problem is how such transitory excess capacity in accommodation can be used, or put in another way, how the excess can be avoided in the first place. This question is discussed in Chapter 11, Section 2.

Figure 14.11: INDUSTRIAL TECHNOLOGY AND MANAGEMENT - Accommodation and Student Numbers



Key:

x = Cost of present stock of accommodation

A = Additional accommodation costs

B = Total Student Numbers

Summary

(i) As expected, economies of scale are more marked with the expansion of a small School than with a well-established school (71% decline in average cost).

(ii) In the case of Industrial Technology, the exceptional expansion of student numbers (by 740%) is an important factor. These can be accommodated with only a 140 percent increase in the School's total cost.

(iii) Reducing the staff:student ratio offers the greatest potential for further economies (up to 44% with a marginal ratio of 1:25).

(E) Mathematical Sciences

The Undergraduate School of Mathematical Sciences is a well-established school, running undergraduate courses of its own and supplying a considerable amount of service teaching to other schools. In costing the School's expansion it is assumed that its service teaching commitment remains unchanged.

At present the School produces three degrees, viz a B.Tech. Honours in Mathematics; a B.Tech. Honours in Statistics; and a B.Sc. Ordinary in Mathematics and Statistics. This is done by means of a modular course structure; that is, by using blocks of individual teaching courses, which are combined in different ways to produce the three degree courses. All students have a common first year.

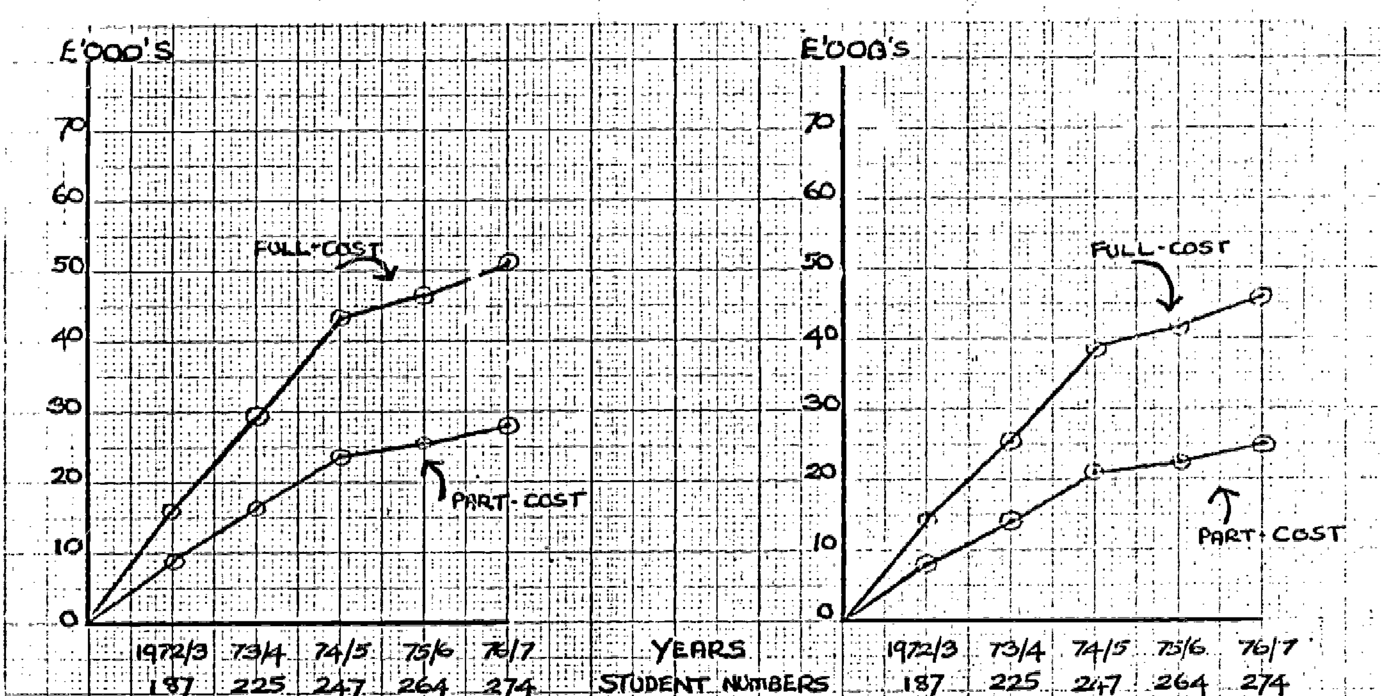


Fig. 14.12 (a) SCHOOL Accounting Unit

Fig. 14.12 (b) UNIVERSITY Accounting Unit

Figure 14.12: MATHEMATICAL SCIENCES – Additional Financial Costs

Source: Table 14.9

Table 14.9 MATHEMATICAL SCIENCES: Additional Financial Costs (TVC)

		1971/2	1972/3	1973/4	1974/5	1975/6	1976/7
Student Numbers:	Total	166	187	225	247	264	274
	Incremental	0	21	38	22	17	10
(1) Staff:							
Full-Cost	TVC	0	12,677	22,555	35,677	38,476	42,756
Part-Cost	TVC	0	6,840	12,085	18,811	20,406	22,461
(2) Accommodation:							
Full-Cost	TVC	0	1,800	3,975	4,837	5,062	5,287
Part-Cost	TVC	0	1,086	2,201	2,650	2,779	2,887
(3) Equipment:							
Full-Cost	TVC	0	1,430	1,540	1,540	1,540	1,540
Part-Cost	TVC	0	943	1,016	1,016	1,016	1,016
(4) Materials:							
Full-Cost) Part-Cost)	TVC	0	300	1,275	1,500	1,575	1,650
AGGREGATE COST-SCHOOL Accounting Unit (i.e. (1) + (2) + (3) + (4))							
Full-Cost	TVC	0	16,207	29,345	43,554	46,653	51,233
Part-Cost	TVC	0	9,169	16,577	23,977	25,776	28,014
AGGREGATE COST- UNIVERSITY Accounting Unit (i.e. (1) + (3) + (4))							
Full-Cost	TVC	0	14,407	25,370	38,717	41,591	45,946
Part-Cost	TVC	0	8,083	14,376	21,327	22,997	25,127

It is proposed to extend this modular system by adding to the computing element and introducing an economics option. In this way the common first year will be maintained and three new degree courses will be introduced, viz a B.Tech. Honours in Computing, a B.Tech.Honours in Mathematics and Economics, and a B.Sc. Honours in Mathematical Sciences. The modular system thus allows a variety of courses to be run comparatively cheaply even though the student numbers on any one of the courses may be insufficient to be economical.

This costing concerns the expansion of this modular system. At present it is not known what student demand will be for the new computing option, and how this demand will affect the resources required by the computing centre. We assume that the extra resources requested by the School includes the necessary resources to teach the computing option (e.g. computer terminal, academic staff based on the 1:10 staff: student ratio). In this way it is possible to cost an overall expansion in the first year intake of the School from 45 in 1970-71 to 90 in 1976-77, regardless of the breakdown of numbers between the six degree courses.

(i) Financial Costs of the Proposal

Table 14.9 and Figure 14.12 indicate the additional financial cost (TVC) of the proposal to the School and University accounting units.

The University accounting unit is the more important because it shows the additional cash outlays to be incurred by the university as a result of the implementation of the expansion proposal. The cost to the School accounting unit is higher because the additional accommodation required by the proposal, which will be found within existing buildings, involves the School of Mathematical Sciences assuming a greater share of the annual cost of these buildings.

Figure 14.12 also shows the difference between the "full-cost", i.e. the whole cost of each additional resource required by the expansion proposal, and the "part-cost", i.e. the proportion of the cost of each resource which can be attributed to time spent on the courses in question. The part-cost amounts to only 54 percent of the full-cost for the university in 1976/77, the balance being attributable to other School outputs.

(ii) Comparison with the Present Average Costs per Student[16]

Table 14.10 and Figure 14.13 show how the costs per student-year in Mathematical Sciences is expected to change as student numbers increase. Based upon estimates from the School, the average cost per student-year should decline from £541 in 1969/70 to £386 in 1976/77, a fall of 29 percent.

[16] See: Appendix 2, Tables 11 and 12. The relevant figures from these tables have been aggregated to give the total cost of the former Undergraduate School of Mathematics.

Table 14.10 MATHEMATICAL SCIENCES - Changes in the Cost of the Course with an Expansion of Student Numbers*

Items of Expenditure	TOTAL COST		Percentage Change between (1) and (2) i.e. $(\frac{(2)-(1)}{(1)} \times 100)\%$
	1969/70	1976/77	
	(1)	(2)	(3)
1. Capital & Maintenance Costs	£28,408	£32,195	13%
2. Teaching Costs	25,800	50,393	95%
3. Administrative Expenditure	15,194	15,783	4%
4. Library Expenditure	2,340	2,340	0%
5. General Expenditures	5,070	5,070	0%
A. Total Cost	76,812	105,781	38%
B. Total Student Numbers	142	274	93%
C. Average Cost per Student-Year (i.e.A ÷ B)	541	386	-29%
D. Total Variable Cost	0	28,969	-
E. Incremental Student Numbers	0	132	-
F. Incremental Cost per Student-Year (i.e.D ÷ E)	0	219	-

*Source : Appendix 3, Table 10.

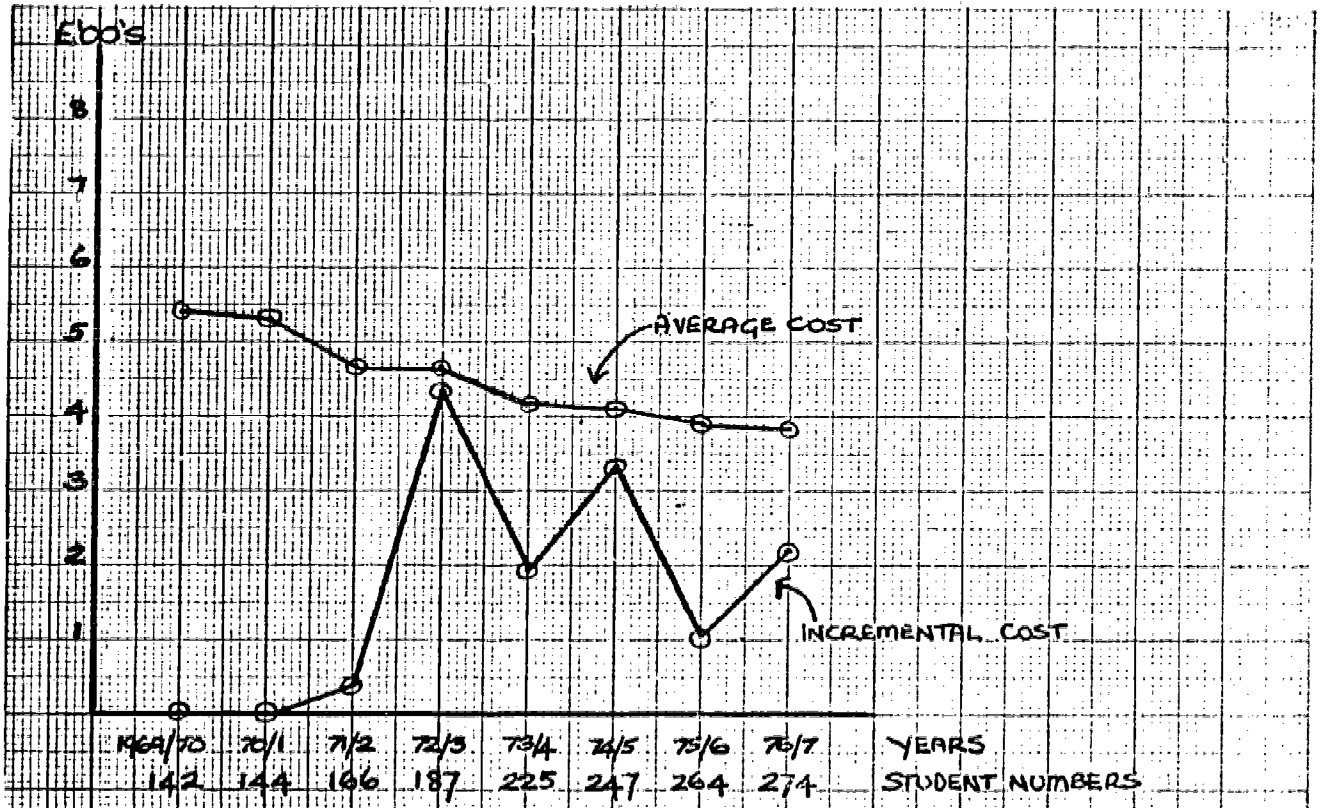


Figure 14.13 : MATHEMATICAL SCIENCES - Average and Incremental Costs per Student-Year 1969/70 - 1976/77

Source : Appendix 3, Table 10

This is a considerable economy of scale when the number of degree courses offered is being doubled, a situation permitted to a large extent by the use of the modular course structure.

Following the usual relationship between average and incremental (marginal) functions, the incremental cost per student-year is a good deal lower than the downward-sloping average cost functions. Over the period 1969/70 to 1976/77, it averages £219 per student-year.

Overall, it is estimated that a 93 percent increase in student numbers can be accommodated with a 38 percent increase in total costs.

(iii) The Sensitivity of Costs to Various Economies

Figure 14.14 shows the results of four sensitivity tests on the total cost and the incremental cost per student-year.

Figure 14.14 : MATHEMATICAL SCIENCES – – Sensitivity Tests

Source : Appendix 3, Tables 11 and 12

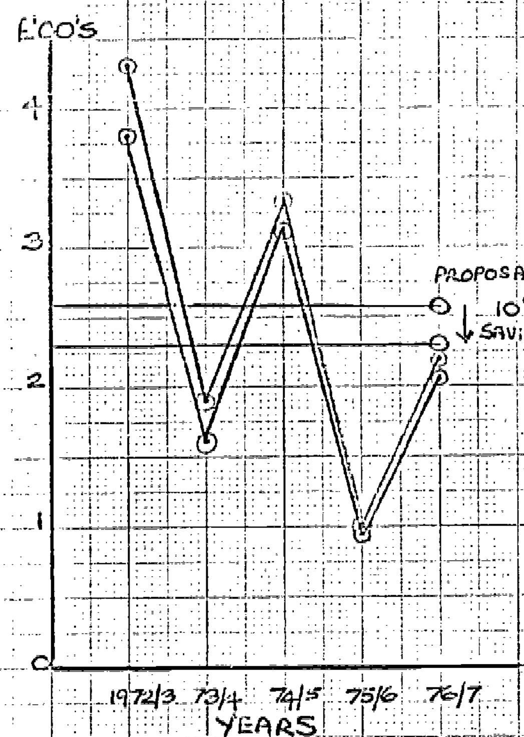


Fig. 14.14 (a) Accommodation

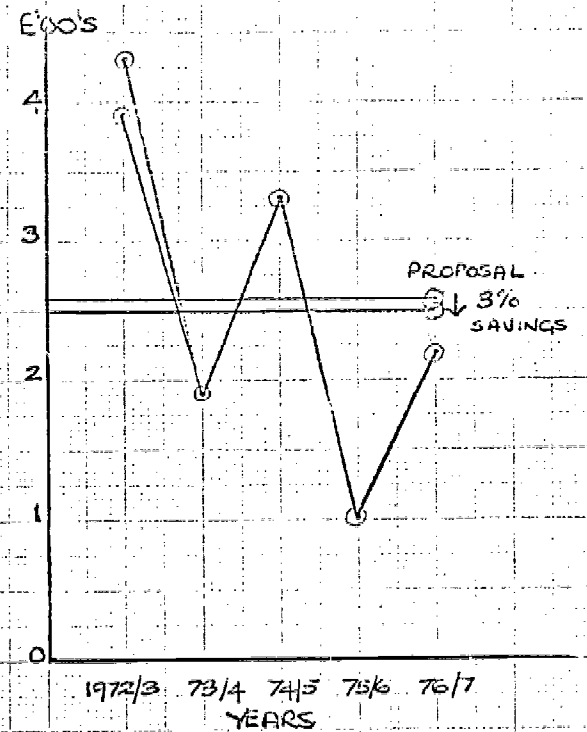


Fig. 14.14 (b) Equipment

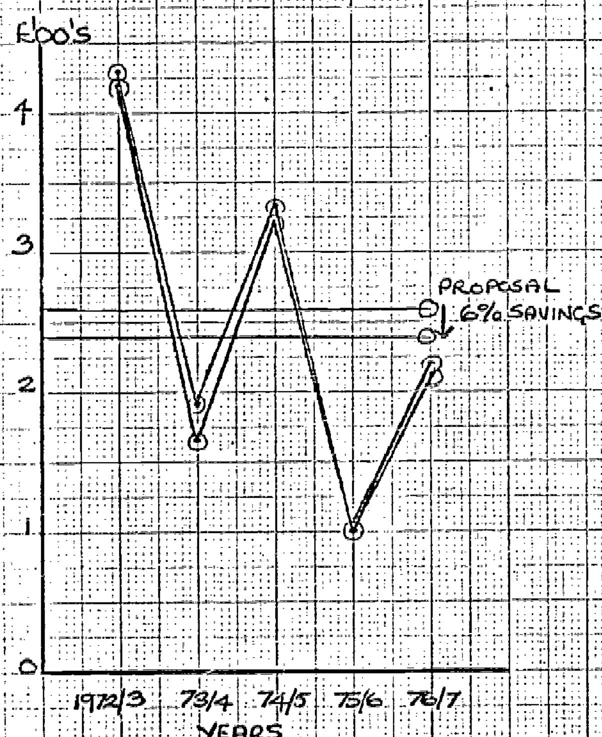


Fig. 14.14 (c) Materials

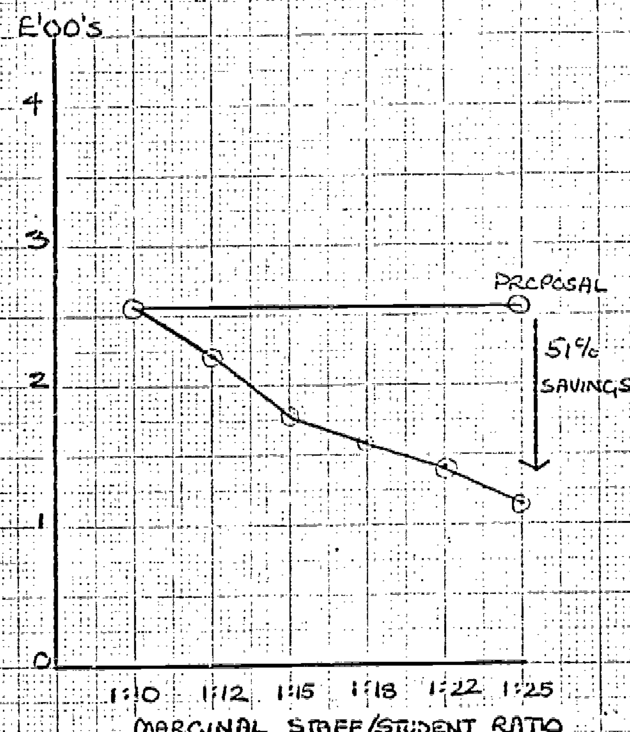


Fig. 14.14 (d) Academic Staff

Figure 14.14(a): removing the accommodation element reduces the cost of the proposal by 10 percent.

Figure 14.14(b): removing the equipment cost reduces the cost by 3 percent.

Figure 14.14(c): removing the materials element reduces the cost by 6 percent.

Figure 14.14(d): progressively worsening the marginal staff: student ratio to 1:25 leads to savings of up to 51 percent. This is hardly surprising when additional staff costs amount to 78 percent of the total cost, but once again it seems that the staff:student ratio offers the greatest scope for effecting economies. As a rough approximation, the average staff:student ratio would fall from the present 1:10 to 1:14 by 1976/77 with a marginal ratio of 1:25.

Summary

(i) The School of Mathematical Sciences can expand with considerable economies of scale. A 93 percent increase in student numbers can be accommodated with a 38 percent increase in the total cost.

(ii) This economy of scale can be achieved with a doubling of the number of degree courses offered to six. The modular course structure explains the unusual juxtaposition of these two facts.

(iii) A worsening of the marginal staff:student ratio appears to offer the greatest scope for savings (up to 51% with a marginal ratio of 1:25).

Wider Applicability of Modular Course Structure

The modular course structure, which in the School of Mathematical Sciences has succeeded in combining variety of degree courses with economy, when student numbers on each course have only been at modest levels, might be applied to other undergraduate schools in the Board of Physical Sciences at the University of Bradford. Here there are a number of schools where economies of scale will be hard to achieve because they are

(a) comparatively small, and
(b) they are not planned to expand greatly during the forthcoming quinquennium.

These are shown in Table 14.11 with present student numbers and those planned for the end of the next quinquennium.

The best hope for achieving economies of scale in such Schools probably lies in introducing common courses where this is feasible. In notes to the Academic Planning Committee, at least two of the Schools in Table 14.11 - Colour Chemistry and Materials Science - have stated that joint courses offer one avenue towards reducing cost per student.

Table 14.11 PHYSICAL SCIENCES - Schools with less than 100 students in 1970/71*

School	Student Numbers			
	Intake 1970/71	Planned Intake 1976/77	Total 1970/71	Planned total 1976/77
Applied Physics	26	33	76	115
Colour Chemistry	21	30	85	97
Materials Science	23	30	74	97
Opthalmic Optics	23	25	57	72
Textile Technology	19	25	73	89

*Source: "Report of the Academic Planning Committee to the General Committee of Senate, 26th April, 1971", page 11.

Common courses in the first year of the undergraduate engineering courses (e.g. Mathematics) would probably be possible, as already occurs in most other universities, but the Schools concerned have so far resisted such changes.

The possibility of a common first year in the Life Sciences has also been discussed.

(F) Pharmacy

The Undergraduate School of Pharmacy is a well established school which runs one of the largest Pharmacy degree courses in the United Kingdom. The School has a good demand from students, and hopes to expand the intake from 90 in 1970/1 to 120 by 1976/7, thus maintaining, if not actually increasing, it's proportion of the projected annual number of graduates required by industry.

Until recently, the course was of three years duration with no sandwich period in industry, but this year (1970/1) an alternative sandwich course is being offered. This is a four year course with two six month periods in the second and third years spent in industry. Students will become members of the Pharmaceutical Association immediately upon graduation, while the students on the three year course will have to complete the normal year of 'postgraduate apprenticeship' before achieving membership.

The student number projections used in this costing are based upon the assumption of a gradual increase in the popularity of the sandwich course compared with the three year course, which as a result will take an increasing proportion of the total intake.

(i) Financial Cost of the Proposal

Table 14.12 and Figure 14.15 indicate the additional financial cost (TVC) of the proposal to the School and University accounting units.

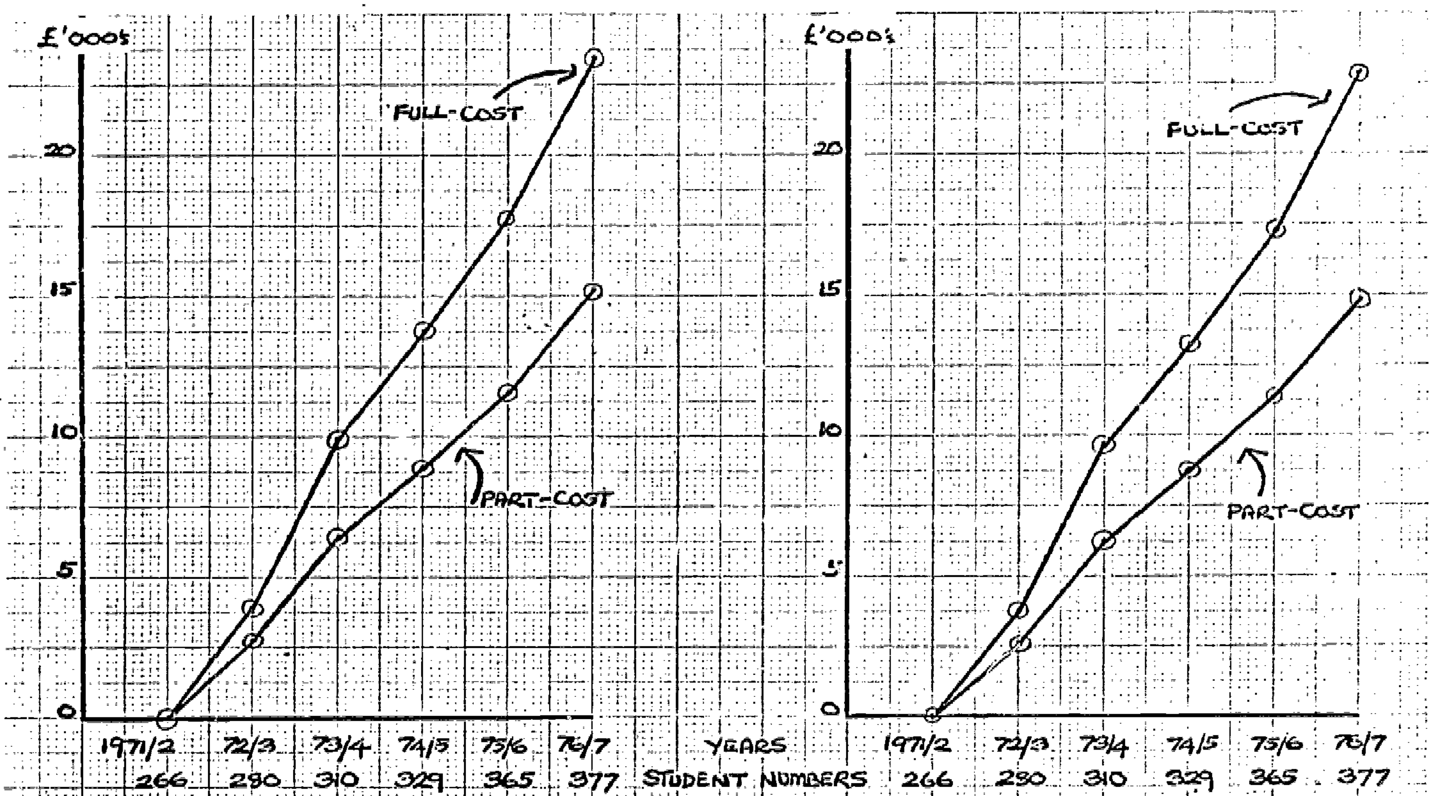


Fig. 14.15(a) SCHOOL Accounting Unit

Fig. 14.15(b) UNIVERSITY Accounting Unit

Figure 14.15 : PHARMACY — Additional Financial Costs

Table 14.12 PHARMACY - Additional Financial Costs (TVC)

		1971/2	1972/3	1973/4	1974/5	1975/6	1976/7
Student Numbers	Total	266	280	310	329	365	377
	Incremental	0	14	30	19	36	12
		£	£	£	£	£	£
(1) Staff: Full-Cost	TVC	0	2,799	7,079	9,878	12,677	16,957
Part-Cost	TVC	0	1,595	3,649	5,244	6,840	8,894
(2) Accommodation:							
Full-Cost	TVC	0	105	210	315	420	525
Part-Cost	TVC	0	60	111	171	231	282
(3) Equipment:							
Full-Cost	TVC	0	442	1,190	1,564	2,040	2,652
Part-Cost	TVC	0	442	1,190	1,564	2,040	2,652
(4) Materials:							
Full-Cost) Part-Cost)	TVC	0	559	1,505	1,978	2,580	3,354
AGGREGATE COST - SCHOOL Acco unting Unit (i.e.(1)+ (2) + (3) + (4))							
Full-Cost	TVC	0	3,905	9,984	13,735	17,717	23,488
Part-Cost	TVC	0	2,656	6,455	8,957	11,691	15,182
AGGREGATE COST - UNIVERSITY Accounting Unit (i.e.(1)+ (3) + (4))							
Full-Cost	TVC	0	3,800	9,774	13,420	17,297	22,963
Part-Cost	TVC	0	2,596	6,344	8,786	11,460	14,900

The cost to the School accounting unit is slightly higher because of the extra staff offices required which will be found within existing buildings. However, the cost to the University is probably more important because it shows the additional actual outlays to be incurred if the proposal is implemented. Since the additional accommodation required will be found internally this does not constitute an extra cost to the university.

Figure 14.15 also shows the difference between the full-cost i.e. the entire cost of the additional resources required by the proposal, and the part-cost, i.e. the proportion of the cost of each additional resource which can be attributed to time spent on the course in question. In Pharmacy the part-cost amounts to 65 percent of the full-cost for the University accounting unit, implying that the balance can be attributed to outputs other than those of the course (e.g. postgraduate work and personal research of staff).

(ii) Comparison with the Present Average Costs per Student[17]

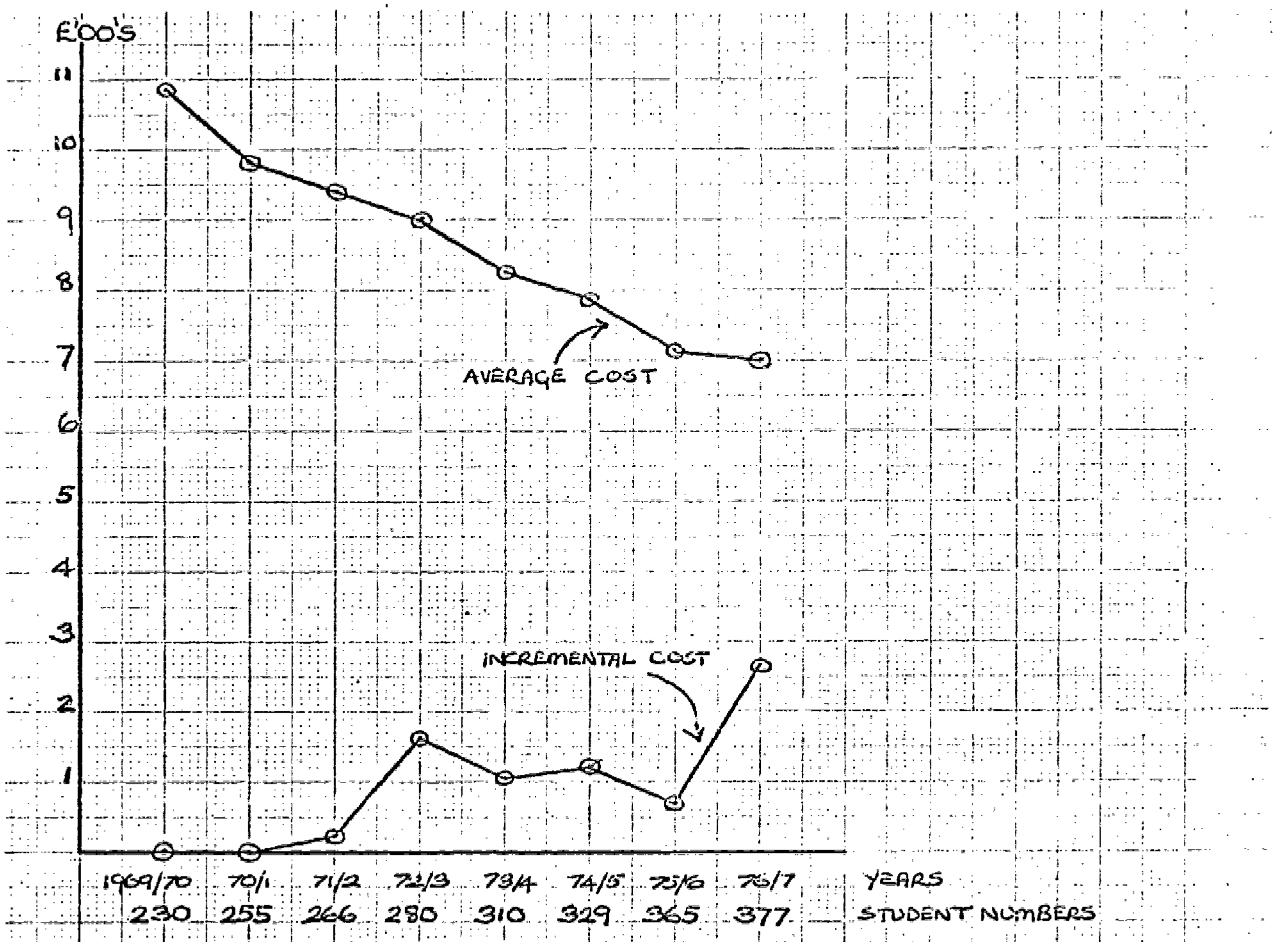


Figure 14.16 : PHARMACY - Average and Incremental Costs per Student - Year, 1969/70 - 1976/77

Source: Appendix 3, Table 13.

17. See Appendix 2, Table 7.

Table 14.13 PHARMACY - Changes in the Cost of the Course with an Expansion of Student Numbers.*

Items of Expenditure	Total Cost 1969/70	1976/77	Percentage change between (1) and (2) ie. $(\frac{(2)-(1)}{(1)} \times 100)\%$
	(1)	(2)	(3)
1. Capital & Maintenance Costs	£110,878	£111,478	1%
2. Teaching Costs	99,611	113,026	13%
3. Administrative Expenditure	23,230	23,230	0%
4. Library Expenditure	7,590	7,590	0%
5. General Expenditure	8,970	8,970	0%
A. Total Cost	250,279	264,294	6%
B. Total Student Numbers	230	377	64%
C. Average Cost per Student-Year (i.e.(A)÷(B))	1,088	701	-36%
D. Total Variable Cost	0	14,015	-
E. Incremental Student Numbers	0	147	-
F. Incremental Cost per Student-Year (i.e.(D)÷(E))	0	95	-

* Source: Appendix 3, Table 13.

Table 14.13 and Figure 14.16 show how the costs per student-year in Pharmacy are expected to change as student numbers increase. Based upon estimates from the School, average cost per student-year should decline through the quinquennium from £1088 in 1969/70 to £701 in 1976/77, a fall of36 percent. Large economies of scale are thus in evidence. a result of the considerable excess capacity, particularly in laboratories, present in the School.

Relatively few additional resources are required, as indicated by the incremental cost per student-year curve. The irregularity of this curve is largely a result of variations in the rate of increase of student numbers each year relative to a fairly constant rate of increase of total cost. Over the period in question, however, the incremental cost per student-year averages £95.

Overall, a 64 percent increase in student numbers can be accommodated with a 6 percent increase in total cost.

(iii) Sensitivity of Costs to Various Economies

Figure 14.17 shows the results of three cost sensitivity tests.

Figure 14.17(a): subtracting the cost of academic staff and their staff offices reduces the cost of the proposal by 69 percent. Only five additional staff members are required, which, with the 111 extra students, gives a very low marginal staff:student ratio of 1.22.

Apart from the staff offices, no other additional accommodation is required. There is ample excess capacity, especially in laboratories and related facilities,[18] to accommodate the expected expansion in student numbers.

Figure 14.17(b): subtracting the equipment element of the proposal reduces the cost by 7 percent. The equipment required will be replacement items; no new heavy pieces of equipment are envisaged since existing laboratories are well stocked with these and no new laboratories will be required. As with the other proposals, it is assumed that there will be no major advances in instrumentation during the quinquennium under review.

Figure 14.17(c): subtracting the materials element reduces the cost of the proposal by 24 percent. The amount of additional materials required is extrapolated forward on the current per student allocation, this being related to laboratory work.

Summary

(i) The School of Pharmacy can expand with considerable economies of scale. A 64 percent increase in student numbers can be accommodated with only a 6 percent increase in the total cost of the course.

(ii) This degree of economy is facilitated by (a) the more intensive use of existing capacity, especially laboratory facilities (including technicians and equipment), and (b) the very low marginal staff:student ratio.

(iii) Because additional academic staff and their associated staff offices form the bulk of the cost of the proposal (69 percent), this area would seem to offer the greatest potential for further economies.

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*The technical staff cost per student-year is higher in Pharmacy than in any other school. See: Chapter 12, Table 12.4

Figure 14.17 : PHARMACY - Sensitivity Tests

Source : Appendix 3, Table 14.

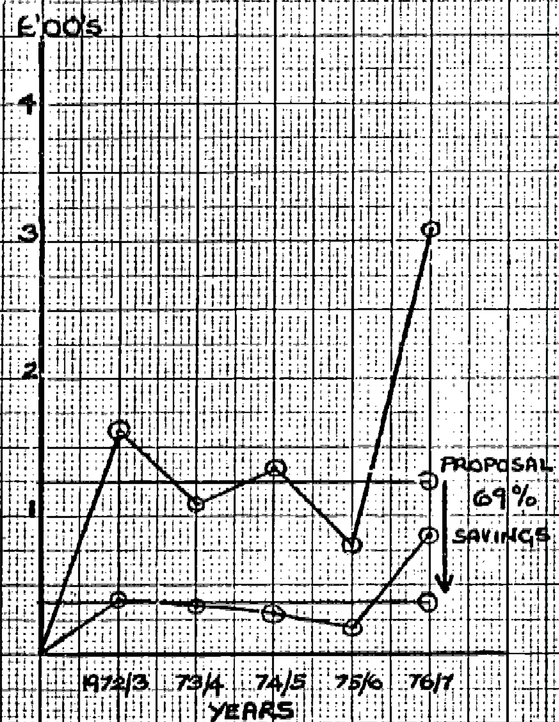


Fig. 14.17(a) Staff & Staff Officers

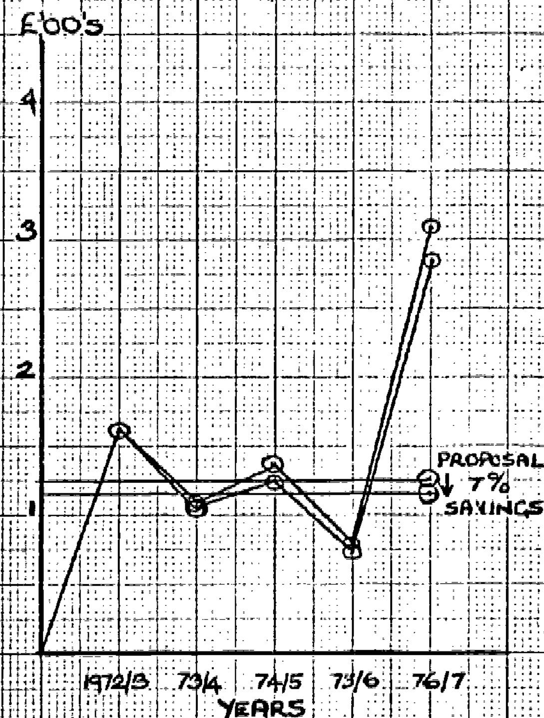


Fig. 14.17(b) Equipment

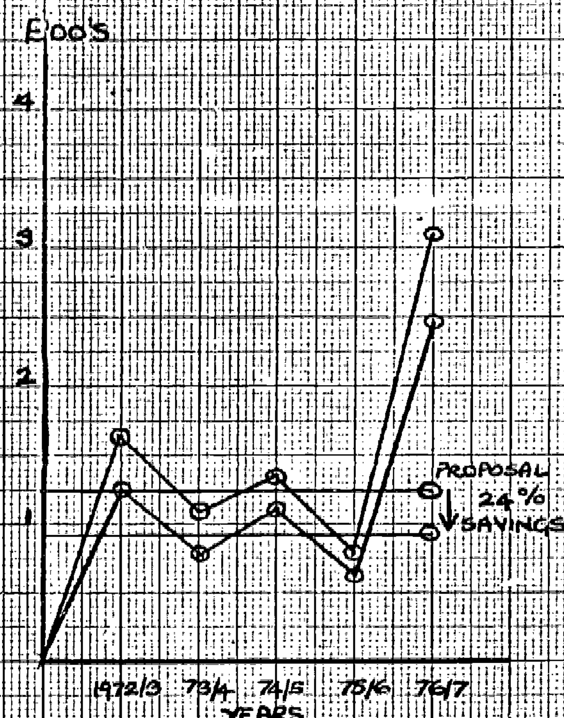


Fig. 14.17(c) Materials

3) Summary and Conclusions

The results of the above costings should be regarded with some caution for two reasons. Firstly, the cost figures are produced on the basis of future estimates of what resource requirements are likely to be. These estimates assume (a) the continuation of present levels of resource allocation (making allowance, of course, for the underutilisation of existing accommodation and equipment), and (b) that no major changes will occur in the course, including the large-scale replacement of equipment brought about by advances in technology.

Secondly, owing to the timing of planning within the University of Bradford, only six expansion proposals have been costed to date, and so the results may not be representative of all proposals. Nevertheless, the proposals cover schools in three out of the present four Boards of Studies. Only the Board of Social Sciences is unrepresented, but results here are not likely to differ much from those of the other Boards. The six proposals cover 1,101 undergraduate students out of the total of 2,861 in the University in 1969/70.

These particular proposals were chosen, partly because all involved at least sizeable expansions of student numbers on already existing courses, and partly because the schools concerned more readily co-operated. The new and hybrid courses proposed, the costing of which should prove more difficult, will be examined later.

Bearing these factors in mind the major conclusions may be presented as follows.

i) Economies of Scale

Table 14.14 and Figure 14.18 show that the average cost per student-year falls markedly for all six proposals between 1969/70 and 1976/77. This is important because it is based upon the additional resources which professors themselves say they will need, and embodies no deliberate attempt to find economies. The economies of scale arise through the fuller utilisation of existing capacity.

The fall in average cost varies from 15 percent for Chemical Engineering to 71 percent for Industrial Technology and Management. However, the average cost per student-year, weighted by student numbers for all six proposals, declines from £802 to £552, a fall of 31 percent.

Overall, an increase of 66 percent in the total student numbers engaged on the six courses can be accommodated with an increase in total cost of only 14 percent. However, the assumption that central expenses will remain constant during the expansion of student numbers on one proposal will probably not be valid when several proposals are considered together. It is likely that the expansion of student numbers involved on the six proposals will be sufficiently large to require additional central facilities. This would result in an increase in total cost of more than the figure of 14 percent, though probably not significantly more.

	Applied Biology			Electrical Engineering			Chemical Engineering		
	1969/70 (1)	1976/77 (2)	%age change from (1) to (2) (3)	1969/70 (4)	1976/77 (5)	%age change from (4) to (5) (6)	1969/70 (7)	1976/77 (8)	%age change from (7) to (8) (9)
A. Total Cost £	79,452	114,487	44	220,087	220,087	0	225,507	229,498	2
B. Total Student Numbers	103	194	88	247	311	26	349	420	20
C. Average Cost per Student-Year £	771	590	-23	891	708	-21	646	546	-15
D. Total Variable Cost £	-	35,035	-	-	0	-	-	3,991	-
E. Incremental Student Nos.	-	91	-	-	64	-	-	71	-
F. Incremental Cost per Student-Year £	-	385	-	-	0	-	-	58	-

Continued ......

	Industrial Technology			Mathematical Sciences			Pharmacy			The Average		
	1969/70 (10)	1976/77 (11)	%age change from (10) to (11) (12)	1969/70 (13)	1976/77 (14)	%age change from (13) to (14) (15)	1969/70 (16)	1976/77 (17)	%age change from (16) to (17) (18)	1969/70 (19)	1976/77 (20)	%age change from (19) to (20) (21)
A.£	31,356	75,253	140	76,812	105,781	38	250,279	264,294	6	883,493	1,009,400	14
B.	30	252	740	142	274	93	230	377	64	1,101	1,828	66
C.£	1,045	298	-71	541	386	-29	1,088	701	-36	802	552	-31
D.£	-	43,897	-	-	28,969	-	-	14,015	-	-	125,907	-
E.	-	222	-	-	132	-	-	147	-	-	727	-
F.£	-	198	-	-	219	-	-	95	-	-	173	-

Table 14.14: Summary of School Expansion Costs

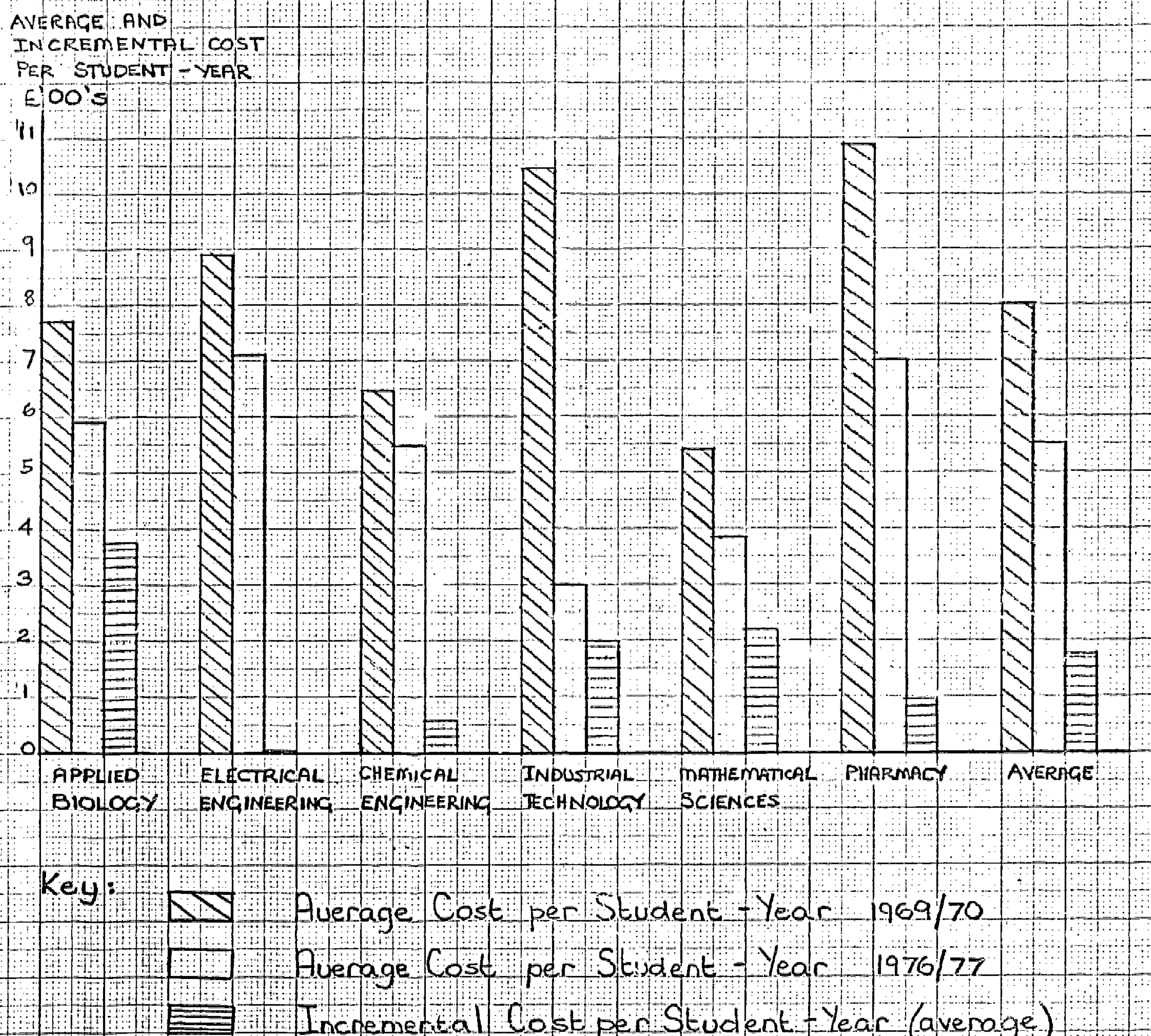


Figure 14.18 : SUMMARY OF THE AVERAGE AND INCREMENTAL COSTS OF PROPOSALS.

There is a very good positive correlation ($r = 0.9524$) between the rate of fall of average cost per student-year between 1969/70 and 1976/77 for each proposal and the rate of increase in total student numbers involved over the same period. It implies that the greater the rate of increase in student numbers on any particular course, the greater will be the rate of fall in the average cost. However, this result must be regarded with caution as it is based on only six pairs of readings.

ii) Excess Capacity

The reductions in average cost result from the low incremental costs per student-year, i.e. the low additional cost per additional student-year. This varies considerably between proposals, from zero for Electrical Engineering to £385 for Applied Biology, but averages £173 for all six proposals (average weighted by student numbers).

The incremental cost broadly reflects the current degree of excess capacity of specialised resources available within the school concerned. Although all six can expand with considerably less than pro rata increases in cost because of this excess capacity, some schools are in a more favourable position than others to achieve low cost expansion. The reason is a mixture of past university resource allocation decisions, the nature of the course which influences it's demand for resources (especially laboratory facilities), and other factors, which have left some schools with much excess capacity and others with relatively little.

Thus Pharmacy and Chemical Engineering are in a comparatively favourable position, as shown by their low incremental costs of £95 and £58 respectively. In contrast, Applied Biology is reaching maximum capacity in present laboratory facilities and therefore will be relatively expensive to expand (IC = £385). On the other hand, Electrical Engineering will be able to expand with no additional cost because student enrolments have dropped short of capacity in recent years (IC = £0).

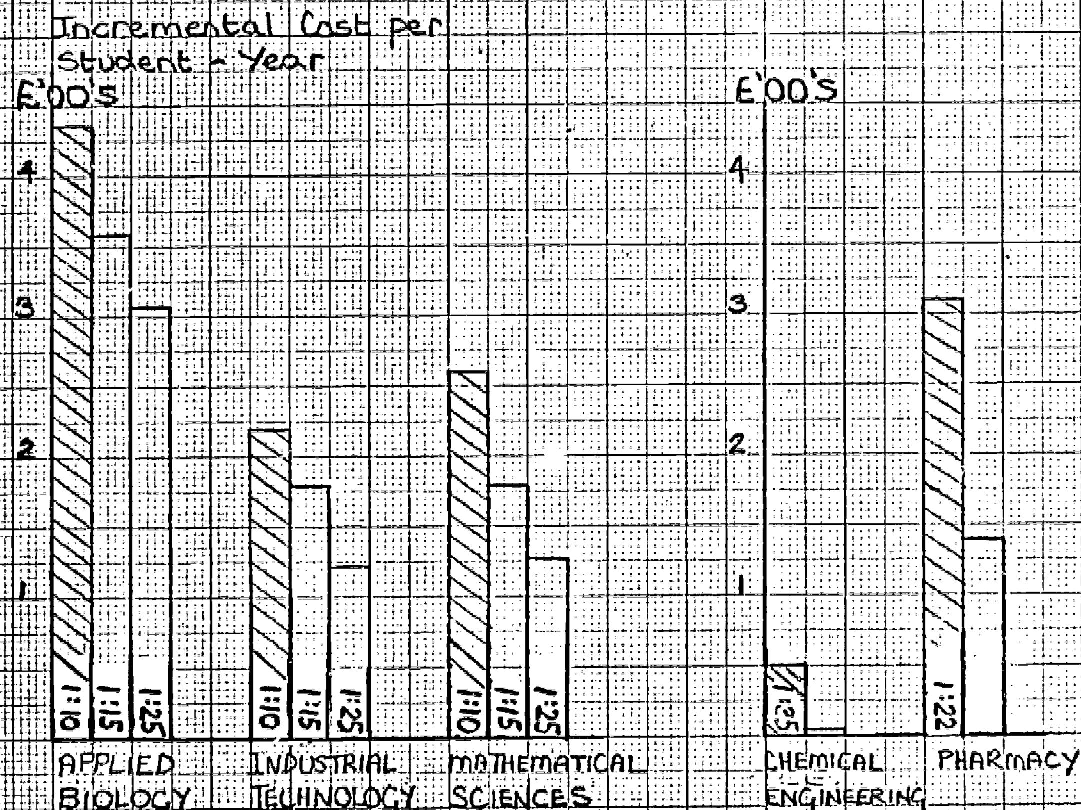
Past events evidently have an important influence on the cost of proposals. In Applied Biology, it is felt that the School's past demands for resources have been modest and that it should not now be penalised when there is a real need for extra resources for expansion.

iii) <u>Sensitivity Tests</u>

It has already been noted that considerable economies of scale can be obtained without deliberate attempts at economy. If further economies are to be made, then the greatest potential lies in reducing academic staff requirements, since they form the bulk of the cost of most proposals.

Figure 14.19 shows a summary of the results of sensitivity tests on the academic staff element in the incremental cost of the proposals. For the three proposals in Figure 14.19(a) the <u>marginal</u> staff:student ratio is reduced from the proposal of around 1:10 to 1:15 and 1:25. The two remaining cases are shown in Figure 14.19(b), where the few additional staff required, which lead to very low marginal ratios, are removed altogether. In both cases, considerable proportional savings are effected.

Should the savings lead to a decline in the quality, if not the quantity, of the output of student-years, then the savings may be false ones. However, Chapters 4 and 5 present a method for progressively "worsening" the staff:student ratio associated with a particular course as student numbers on it increase. This economy can be achieved without reducing the quantity or quality of the teaching received by students and without increasing the teaching load of staff.



(a) Varying Marginal Staff : Student Ratio

(b) Removing Staff element from the proposal

Key:

Incremental cost of the proposal

Incremental cost after sensitivity tests

Figure 14.19 : SENSITIVITY TESTS ON THE ACADEMIC STAFF COSTS OF PROPOSALS

PART 7

PLANNING NORMS AT THE UNIVERSITY LEVEL

CHAPTER 15

UNIVERSITY PLANNING MODELS

This chapter introduces the models of Bradford University described in Chapter 16, and the results they produce presented in Chapter 17. It consists of two parts. The first deals with general problems of economic model building and testing. The second considers the common structure and particular problems of models of educational institutes. The reason for starting with general problems is to explain the difficulties involved in appraising models of educational institutes. When adverse criticism is levelled against a model it is likely to take the form "the model is wrong!"; but it is our contention that normally the criticism should be "it is the wrong model!"

ECONOMIC MODELS

Introduction

The word "model" is used in many ways by both natural and social scientists. Several writers have waded through this plurality of usage in an attempt to reform the word to a single meaning[1,2,3]. Since they have so far failed to persuade scientists to adopt one of these particular meanings we must explain the usage of the word "model" in this text. It is used as a synonym for "theory", and this usage is slightly restricted after the paragraphs dealing with the testing of models. This usage ignores the word's association with "ideal", as in "model husband", and with "simulacrum", as in "model ship".

The Use of Mathematics

If a theory is to be of a non-trivial nature some of its statements must be derived from others by the use of logic or mathematics. If there exists for a theory a set of statements from which all the others can be derived, and this set contains no superfluous members, it is called the set of axioms of the theory. The use of the phrase "mathematical model" is frequently encountered when some of the statements of a theory are derived by mathematics or are quantified. This is misleading unless it is realised that it is not the mathematics which constitutes the model.

This can be illustrated by the following simple example, typical of what is to follow, of a system having two axioms:

---

1. Brodbeck, M., "Models, Meanings and Theories", in "Symposium on Sociological Theory", Editor Gross, L., Haper & Row, 1959.
2. Suppes, P., "The Meaning and Use of Models", in "The Concept and Role of Models", Edited Reidel, D., Dordrecht, 1961.
3. Black, M., "Models and Metaphors", Ithaca, 1962.

$$h_1 = \frac{s}{g_1} \cdot l_1 \qquad (1)$$

$$h_2 = \frac{s}{g_2} \cdot l_2 \qquad (2)$$

from which can be derived by addition:

$$h_1 + h_2 = s\left(\frac{l_1}{g_1} + \frac{l_2}{g_2}\right) \qquad (3)$$

A model of this system of three formulae is given by substituting:

h_1 for the number of classroom hours required to give a lecture

h_2 for the number of classroom hours required to give a tutorial

g_1 for the maximum group size permitted for each lecture

g_2 for the maximum group size permitted for each tutorial

s for the number of students to receive lectures and tutorials

l_1 for the length of a lecture, in hours

l_2 for the length of a tutorial, in hours.

Equations (1), (2) and (3), together with the model, form a simple theory whose full statement, in any other form, would be extremely tedious.

Testing a Model

The "classroom hours" theory above differs in an important respect from those of the natural sciences. For the majority of natural science theories there is no great problem as to what constitutes a test. Indeed, since it is very common for the motive of the natural scientist to be the desire to explain some phenomenon, his theories do not become known unless they are capable of passing the rudimentary test of at least offering some explanation. But the motive of the social scientist is more often the desire to solve some social problem. Unfortunately the ability of a theory to offer a solution to a social problem is no test for it. Were it otherwise the activities of the newspaper letter-writing theorists would have wrought Utopia long ago.

The desire to explain some phenomenon by means of the "classroom hours" theory is not very strong. In this case an explanation is probably redundant. The use of the words "classroom-hour", "lecture", "group size", etc. implies all the explanation required. The essential characteristic of such theories is that they offer some possibility of being used to control the phenomena whose model is encorporated in them. It follows from this that objective prediction is not to be expected of them; no more than one would expect an accelerator pedal to predict the speed of a car. Thus there is only one test. An attempt to control the phenomenon aided by the theory. If this fails, the theory must be rejected or modified. Since tests of this kind can be both difficult and expensive, some method of deciding whether or not to go ahead with one is needed. In the rest of this text, the word "model" describes theories of this type and the word "system" describes the phenomenon whose control is desired.

Consistency

Obviously a model which contains mathematical or logical faults is not worth trying out. It can be rejected out of hand, or at least sent back for correction.

Relevance

The models must offer the possibility of controlling those facets of the systems which are of interest. If it is desired to control student numbers, cost and student failure rate in a university, a model offering the possibility of controlling only the first two and, either ignoring failure rates, or determining them by student numbers and cost, is less satisfactory than a model offering the possibility of controlling all three factors. Of course desire alone is not a sufficient condition for ensuring possibility.

Plausibility of Axiom

Since the validity of the deductions from the axioms, or non-deduced statements, can be easily verified, the main brunt of critical examination must fall on the axioms. For example, the axioms of the "classroom hours" model above can be criticised on several grounds:

(a) s/g may take only integer values.

(b) If a single lecture or tutorial lasts more than one or two hours, some break should be allowed.

(c) Some provision should be made for the time taken for lecturers and students to move from one classroom to another.

Approximation

Approximations used in a model may not be satisfactory over the full range of variations of which the model is technically capable of being used. For example, the approximation that academic staff salary scales remain constant while the staff:

student ratio varies between 9 and 12 might be quite reasonable but the approximation would be suspect if the ratio varied between 5 and 50. Another form of approximation which should be carefully looked for, takes the form of omissions. It is most unlikely that any model of an educational institute or system could incorporate all the determinates of academic staff salary scales, building costs or other important factors.

Crucial Tests

As has been said above, the only test for these models is a test by trial. But these are not crucial tests. There is no way of determining the extent to which a successful or unsuccessful result should be attributed to the use of the model rather than to any other factor. The foundation of our judgment remains insecure.

MODELS OF EDUCATIONAL INSTITUTES

Introduction

The common characteristic of models of educational institutes is their concern with the allocation of resources. The models are variously tagged: cost model, resource allocation model, planning model, simulation model, etc.

The basic form of these models is that of a simple, open input-output model showing how the "inputs" (educational resources) to the institute can be combined to yield the "outputs" (graduates, students, etc.). Thus the form of the models implies sets of relations

$$f(x,b) = 0 \qquad (4)$$

where x is a set of input variables, and b is a set of output variables.

To this basic form some authors[4,5] have grafted an optimizing feature. This consists of a function of either the inputs or outputs or both, which yields some scalar measure of the performance of the institute. This may be expressed as

$$\text{Max } f(b) \quad \text{or} \quad \text{Min } f(x) \qquad (5)$$

subject to $g(x,b) = 0$.

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4. Fox, K. A., McCamley, F. P., Plessner, Y., "Formulation of Management Science Models for Selected Problems of College Administration", U. S. Department of Health, Education and Welfare, 1967.
5. Rasmussen, H. J., "On Decentralised Planning in a University System", The Technical University of Denmark, 1970.

Static and Dynamic Models

A useful subdivision of models with the basic form (4), above, can be made. Those that have "time" as an explicit variable are called dynamic, and the others are called static.

Static models are usually built to answer such questions as:

(a) What will be the annual cost of running an institute of some specified size and character?[6]

(b) How should the available space and staff effort be deployed between the various functions of an institute?[7]

(c) What is the requirement for certain resources of an institute of some specified size and character?[8]

(d) How many students can be taught in an institute of some particular size?

The type of problems which have stimulated the development of dynamic models do not differ greatly from those which have lead to the construction of statis models. In general there is no explicit concern with the nature of the process by which some desired final state is reached. Interest is focussed on the final state of the institute. It could be argued that this is rash; that there is no final state; that the educational institutes will be forever in a state of flux. This argument, however, may be countered by the assertion that any "point" on the "path" between two states is itself a state, and can hence be judged by the same criteria used for the judgment of the final state.

Thus dynamic models can be conceived of as being linked static models, producing one set of reports for each of several time intervals (usually the academic year). They can be represented by the following equations:

$$\left.\begin{aligned} f_t(x_t, b_t) &= 0 \\ g_t(x_{t+1}, b_{t+1}, x_t, b_t) &= 0 \end{aligned}\right\} \qquad (6)$$

6. Magnussen, O. A., "A Model for the Estimation of Current Costs at an Institution of Higher Learning", O.E.C.D. Conference on University Planning, Paris, 21.IV.69.
7. Legg, K., "Note on the Extension of Work on an Analytical Approach to University Staff and Facilities Planning", O.E.C.D./C.E.R.I. Conference on Institutional Management in Higher Education, Paris 27.XI.69.
8. Judy, R. W., Levine, J. B., "A New Tool for Educational Administrators. Educational Efficiency Through Simulation Analysis", University of Toronto Press, 1966.

Level of Detail

The importance of dynamic models lies in their usefulness for planning. The five-year planning period of the British universities has caused the model presented in Chapter 5 to be built, whilst the need to give budget requirements in advance to State and Provincial legislatures is one of the main reasons for the construction of the American and Canadian models[9,10,11].

Although the need to have some forecast of future financial requirements, and the ability to justify the forecast, is of great weight, it is not the sole reason for desiring a glimpse of the future. Particularly in large institutes the task of co-ordinating a host of minor departmental plans becomes extremely difficult. For it is at the departmental level that the majority of proposals for changes in courses, the addition of new courses and research projects are instigated. It is for this reason that in both models presented in this work the "course" or individual research project is used as the basic element, rather than aggregations of statistically similar courses and projects. This does not imply that models which do not descend to this level of detail are useless. The reconciliation of departmental plans, as suggested above, is not the only concern of institutional administrators.

Decision Models

The models mentioned above have all been constructed for the use of administrative officers in conjunction with the appropriate university committees, or government agencies; for it is these people whose concern is for the institutes as wholes. The models are designed to facilitate and improve their ability to make decisions. They are constructed in such a way that the effects of certain hypothetical decisions can be calculated. This is done by incorporating a certain class of variables called decision variables. Examples of these are staff:student ratios, maximum number of students to be admitted into any one lecture, and the proportion of academic staff holding the rank of professor. Values are assigned to these variables by the user of the model, to discover the effects of changing particular values on the values of other variables which are functionally related to them. Decision variables are the independent variables of normal mathematical parlance, and the "functionally related variables" are the dependent variables. For example, let:

x_1 = the number of academic staff

x_2 = the average salary

y = the institute's academic salary expenditure.

9. Judy, op cit
10. Scarborough, C. W., Daniel, J. N., "Management Use of Simulation in Long-Range Planning for Colleges and Universities", Peat, Marwick, Livingstone & Co., 1968.
11. Koenig, H. E., Keeney, M. G., Zemach, R., "A Systems Model for Management, Planning, and Resource Allocation in Institutes of Higher Education", Michigan State University, 1968.

Then

$$y = f(x_1, x_2) = x_1 \cdot x_2$$

Here x_1 and x_2 are independent variables and y is a dependent variable. Whether a variable is classed as dependent or independent depends on its use, not on any inherent characteristic. The above equation could be recast as

$$x_1 = g(x_2, y) = y/x_2$$

where x_1 is the dependent variable and x_2 and y the independent variable.

Another classification of variable used in these models is into endogenous exogenous variables. This, again, is not based upon inherent characteristics of the variable. Exogenous variables take on values which are determined by the environment in which the system being modelled is situated; the values of endogenous variables are determined within the system. Since the two models presented in Chapter 16 are intended to be useful both to university administrators and to central agencies we have not made use of this distinction. The distinction is relevant, however, to models designed for only one type of user[12,13].

Relationships Between Variables

All attempts to forecast human behaviour are fraught with difficulty, prone to egregious error, or so banal as to only interest mystics. If a relationship between several variables is postulated and found reasonable in a particular institute at a particular time, it is only by an act of faith that this relationship can be considered likely to hold over a period of time or when the values of the variables suffer a change of any sizeable extent. Nevertheless all who attempt to construct models of educational institutes, and similar systems, are committed to use such relationships.

With static models there is no alternative to incorporating the best relationship that can be discovered and viewing with caution forecasts which apply to an institute separated by time or value of "variables" from the one on which the model was based.

With dynamic models it is possible to assume that the relationship between variables change with time; it is thus possible to talk of "dynamic" relationships. Using equation (6) above:

$$f_t \neq f_{t+n},\ g_t \neq g_{t+n}$$

where n is a positive or negative integer.

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12. Judy, op cit
13. Scarborough, op cit

However, these "dynamic" relationships are grounded in present knowledge. "Dynamic" relationships change with time in a predetermined manner, and should thus be treated with the same caution as those used in static models.

Size of Models and the Use of Computers

As expected, the use of computers to handle the calculations of a model is correlated with the size of the models. The small static models of Magnussen and Legg do not make use of computers, whereas the larger models of Judy, Peat, Marwick, Livingstone & Co., and Koenig would be impossible to operate manually. These last three models are dependent on computers not merely for their calculations, but also for the supply of information on which the calculations are based. This information is drawn from what is commonly called a "data base". This consists of the computerised records of the institute's administrative offices organised in a management information system. Since the University of Bradford's records are not yet computerised, the models presented in Chapter 16 require only information which is readily available from other sources, mainly the clerical records of the university. Furthermore, when a model must be incorporated in a management information system, it will be extremely costly, in comparison to other models, to build and test.

Transferability of Models

On starting work on this project the possibility of adopting an existing model of some other institute to the needs of the University of Bradford was considered. It proved impossible to find a suitable one. The European models offered little more than an idea -- a scheme for collecting data. The North American models, on the other hand, seemed to offer too much. Page after page of detailed specifications, Fortran coding and flow charts. As was mentioned in the preceding paragraph, the need of a data base made it impossible easily to adapt a model such as Judy's C.A.M.P.U.S. to help with Bradford's planning process.

However, there seems to be no fundamental objection to transferring at least the skeleton of a model from one institute to another. It is, of course, only when the model is computerised that any saving in time or money can be achieved by adapting an existing model rather than by building an original one.

Although it would be rash to attempt to set down the conditions under which a model could be successfully transferred from one institute to another, it seems safe to say that unless both the level of detail required, and the nature of the possible decisions are the same in the two institutes, there will be little hope of success. Obviously a model such as that of Oliver[14], where undergraduate student numbers are only broken down by year of entry, will be of little use in planning course

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14. Oliver, R. M., Hopkins, D. S. P., Armacost, R., "An Academic Productivity and Planning Model for a University Campus", University of California, Berkeley, 1970

size in particular departments in another university. In the same way, a model which allows administrators to determine academic staff salary scales will be of small use in a country where these are fixed centrally.

As mentioned already, it is unlikely that the functional relationships between variables can be assumed to remain constant when the model is transferred to a different institute. It is probably these relationships which would require the greater bulk of adaption if a model seemed transferable. If appreciable results are obtained by the use of prototype models in British universities, it would seem wasteful for 40 similar establishments to perform identical model building work. Two ways to avoid this duplication of effort would be:

1) By designing a series of small separate computer programs, each capable of performing some minor role in the calculations of a model, and all capable of being linked to each other.

2) By developing a compiler and computer language designed for the needs of educational institute model builders. Such a compiler could be written either using a high level computer language, or using a compiler-compiler.

CHAPTER 16

THE BRADFORD UNIVERSITY PLANNING MODELS

Introduction

Two computerised models of Bradford University are described in this chapter. One, a static model, (in which "time" does not occur as an explicit variable), and the other a dynamic model, (having time as an explicit variable). As explained in Chapter 15, a dynamic model can be conceived of as a series of linked static models; this conception underlies the work presented here.

After a general paragraph on the purpose of the models a detailed description of the static model is given. The dynamic model is described by mentioning its features additional to the static model. The chapter ends with some notes on the programming of these models.

Purpose

These models are concerned with the allocation of resources by the administration and governing bodies of the university. Many of the decisions controlling resources can be expressed by quantitive rules which are usually called "norms", and it is these forms of resource allocation decisions that these models deal with. A decision to increase the amount of space given over to laboratories can be expressed as a change to a norm, and hence lies within the scope of the models. A decision to exchange the functions of two similar laboratories cannot be so expressed, and hence is outside the scope of the models. It is to the "general" rather than the "particular" that norms are related -- with quantitive resource allocation policy decisions. Both models attempt to trace the quantitive consequences of this class of decision -- to trace the consequences of setting resource allocation norms to particular values.

STATIC MODEL

Dependent Variables

Within the model the consequences of setting resource allocation norms to particular values are represented by the values of certain variables -- dependent variables. The values of the dependent variables are based on the assumption that the university operates for one year with a given set of resource allocation norms.

The dependent variables fall into three groups:

(a) Staff numbers
(b) Space requirements in square feet
(c) Cost

Staff

Four types of staff are dealt with by the model:

i) Academic staff
ii) Technical staff
iii) Administrative and clerical staff
iv) Library and computer staff

i) The academic staff consist of all the lecturers, senior lecturers, readers and professors of the university. Research staff are excluded from the model since policy decisions concerning them are only tentatively connected with other functions of the university. However the research staff are a significant proportion of the academic staff as can be seen in Table 16.1.

Table 16.1 Academic and Research Staff 1966 to 1971

Year	Academic Staff (excluding research staff)	Research Staff
1966	335	70
1967	345	83
1968	368	82
1969	368	72
1970	385	78
1971	405	76

For the years 1970 and 1971 separate figures are available for the number of research staff supported by external grants, and those supported from general sources of finance. In March 1970, 28 were financed by grants leaving 50 not so financed; by March 1971 the number supported by grants had risen to 36 and the others had fallen to 40.

ii) The technical staff includes all laboratory assistants, junior technicians, technicians, senior technicians and chief technicians I and II.

iii) The administrative and clerical staff consists of the administrative and professional employees, typists, machine operators, clerical employees and those paid on the miscellaneous officers pay scale. A distinction is made in the model between staff working in the central administration of the university and staff working in the Schools and Boards of Studies. This is done because there is considerable variation between the Schools in their utilisation of administrative and clerical staff, as shown in Table 16.2.

Table 16.2 Expenditure on Salaries 1969/70

School of Study	Expenditure on Salaries in Academic Year 1969/70		Ratio (1)/(2)
	Academic (1)	Clerical & Secretarial (2)	(3)
Research in Education	18,366	2,477	7
Pharmacy	103,171	3,871	27
Chemical & Control Eng.	13,274	7,720	2
Civil Engineering	54,837	1,776	31
Electrical Engineering	86,751	4,934	18
Mechanical Engineering	64,576	3,330	19
Textile & Industrial Tech.	53,274	4,037	13
Biology	39,175	1,794	22
Mathematics	85,354	2,653	32
Chemical Technology	143,351	8,960	16
Physics	77,721	6,115	13
Management & Administration	78,493	9,195	9
Social Science	132,768	6,541	20
Modern Languages	67,600	3,856	18

Note: Academic staff salaries exclude research staff, but include part-time and visiting staff.

iv) The library and computer staff consists of all librarians and library clerical and secretarial employees, computer operators, programmers, and other computer employees (excluding those who work on the administrative computer).

Space

Seven types of space are recognised by the model:

i) Academic staff space
ii) Administrative and clerical staff (in schools) space
iii) Technical staff space
iv) General teaching space
v) Laboratory space
vi) Central administrative and clerical staff space
vii) Library and computer space.

i) Academic staff space consists of the personal rooms of all academic staff (excluding research staff). The academic staff rooms are used for tutorials.

Administrative and clerical staff (in schools) space consists solely of office ce.

) Technical staff space consists of a small personal allocation of space in oratories or workshops.

General teaching space includes all lecture rooms, classrooms and seminar rooms.

All laboratory space, irrespective of subject and level, is considered together the model.

Central administrative and clerical staff space consists of office space for all se employees itemised under (iii) in the previous paragraph, who are not employed ectly in the Schools of Study.

) Library and computer space consists of office space, reading room, shelving ce, stacking space, computer room, data preparation space, reception areas, etc.

These space requirement variables all refer to net square feet, including y those areas which are directly attributable to the university's academic re-rements for teaching and research. This is the same convention as that used by University Grants Committee.

Cost

Six dependent cost variables are included in the model. They are:

i) Academic cost
ii) Administrative cost
iii) Equipment and materials costs
iv) Maintenance cost
v) Library and computer costs
vi) Imputed rent

Academic cost includes the salaries, insurance and superannuation of all grades academic, clerical, secretarial and technical employees.

Administrative cost consists of the salaries, insurance and superannuation of inistrative officers, clerical and secretarial staff, and expenditure on printing, tionery, advertising, telephones, postage, recruitment, travel, subsistence allow-es, audit fees, legal expenses, office equipment, O & M consultancy.

Equipment and materials cost consists of expenditure on equipment and materials for teaching and research, and the payment of demonstrators.

Maintenance cost consists of expenditure on cleaning, heating, lighting, repairs, ting, gardens, furniture and security.

v) Imputed rents result from applying a rental per square foot to the various areas of accommodation used by the university.

Decision Variables

The decision variables of the static model consists not only of the norms mentioned above, but also contain other variables which can represent quantitive elements of policy which are not in the form of rules. The most important of these are variables used to represent the number of students on each course. These are described in the paragraph headed "Level of Detail".

Norms

The norms used in the model are described in three groups corresponding to the resource whose allocation they govern:

(a) Academic Staff
(b) Other Staff
(c) Space

Academic Staff Norms

The basic norm used for the allocation of academic staff is the staff:student ratio. This ratio, however, is not just dependent on the number of students. Since there are many types of student within the university each requiring different amounts of supervision and teaching, a system of weights is included in the norms. The sum of the numbers of each type of student multiplied by the appropriate weight, is called the "full-time equivalent" (F.T.E.) student number. As a further sophistication the model provides the ability to allocate, dependent upon the size of teaching group, more or fewer staff than would be allocated by a straight-forward application of the staff:student ratio to the weighted student numbers.

The following is the full list of academic staff allocation norms used in the model:

1. Staff:Student Ratio
2. Student Weight, full-time, undergraduate
3. " " thin sandwich, undergraduate
4. " " thick sandwich, undergraduate on course
5. " " thick sandwich, undergraduate in industry
6. " " full-time, postgraduate, research, Science or Technology
7. " " full-time, postgraduate, research, Social Sciences
8. " " full-time, postgraduate, course, Science or Technology, 0 to 10 students
9. " " full-time, postgraduate, course, Science or Technology, 11 to 20 students
10. " " full-time, postgraduate, course, Science or Technology, 20+ students

11. Student Weight, full-time, postgraduate, course, Social Sciences, 0 to 10 students
12. " " full-time, postgraduate, course, Social Sciences, 11 to 20 students
13. " " full-time, postgraduate, course, Social Sciences, 20+ students
14. " " part-time, postgraduate, research, Science or Technology
15. " " part-time, postgraduate, research, Social Sciences
16. " " part-time, postgraduate, course, Science or Technology
17. " " part-time, postgraduate, course, Social Sciences
18. " " full-time, postgraduate, Diploma in Textiles
19. " " Post Experience Course
20. Small Course 'Correction' formula indicator

"Other Staff" Norms

"Other Staff" consists of administrative, clerical and secretarial staff, employed both centrally and in the Schools of Study, computer and library staff, and technicians. Some of the norms are ratios of employees to full-time equivalent student numbers, for instance the staff:student ratio. In other cases a ratio of number of employees to academic staff is used.

The following is a full list of these norms:

1. Central Administrative and Clerical:F.T.E. student ratio
2. Computer & Library Staff:F.T.E. students ratio
3. Academic:Technical Staff ratio
4. Academic:Clerical & Secretarial Staff in Schools ratio.

Provision is made in the model for the use of up to six values of the last two norms.

Space Norms

The space norms state the amounts of floor space, in square feet, that are allocated to various kinds of staff and students for particular purposes. The norms are:

1. Office space for professors
2. Office space for other academic staff
3. Office space for administrative, clerical and secretarial staff
4. Room space for technicians
5. General teaching area per F.T.E. student
6. Laboratory area per F.T.E. student

Since the staff allocation norms do not distinguish professors from other academic staff, a further norm is included under this heading:

7. Percentage of academic staff posts taken by professors.

The relatively crude norms controlling the allocation of general teaching area and laboratory space are modified in the model by procedures which are explained in subsequent paragraphs.

Level of Detail

Although Bradford University has a well-defined organisational structure, with Boards of Studies and undergraduate and postgraduate Schools of Studies, it is not a fixed structure. This structure is intended merely to provide a framework for teaching courses and for research projects. Consequently, the basic level of detail adopted by the model is the undergraduate and postgraduate course, and the postgraduate research project. The following information is required for each course research project:

1. Course or project name
2. Number of students on 1st year of course
3. Number of students on 2nd year of course
4. Number of students on 3rd year of course
5. Number of students on 4th year of course
6. Percentage laboratory-based
7. Percentage classroom-based
8. Level indicator (undergraduate = 1; postgraduate = 2; post experience = 3; diploma in Textiles = 4)
9. Sandwich indicator (non-sandwich = 1; thin = 2; thick = 3)
10. Academic type indicator (Social Sciences = 1; Science or Technology = 2)
11. Time indicator (full-time = 1; part-time = 2)
12. Method indicator (research = 1; course = 2)
13. Industrial experience year (1, 2, 3 or 4; thick sandwich only)
14. Academic:Technical Staff ratio indicator
15. Academic:Administrative and Clerical Staff ratio indicator

The course or project name (1) is included only to help with the problem of collecting the information. Items (6) and (7) are included to make the norms covering the allocation of general teaching space and laboratory space more flexible. Items (14) and (15) are used to determine which of the six possible values of the "other staff" allocation norms (3) and (4) are relevant to a particular course or project.

Since some courses and research projects do not differ with respect to their resource allocation requirements, it is not necessary for them to be treated separately by the model. For this reason no upper limit is set to the number of students on a course or project.

Functional Relationships

These relationships are considered under four headings:

i) Academic Staff
ii) Other Staff
iii) Space
iv) Costs

i) Academic Staff

Academic staff, T, is simply related to the full-time equivalent student numbers, S, by the staff:student ratio norm r.

$$T = \frac{S}{r} \tag{1}$$

The full-time equivalent number is the sum of the products of the student numbers on each course and the appropriate student weight. The student weight is determined by the indicators listed in the paragraph headed "Level of Detail" (Items 9 to 13). In the case of sandwich courses the student weight can be varied from one year of the course to another.

This passage may be summarised by the formula:

$$T_a = \frac{1}{r} \sum_{i=1}^{C} \sum_{j=1}^{4} w_{ij}\, s_{ij} \tag{2}$$

where r = staff:student ratio

w_{ij} = weight for students on year j of course or research project i

s_{ij} = number of students on year j of course or research project i

C = total number of courses

ii) Other Staff

The number of technicians is determined by the allocation to each course since the academic:technical staff (t) ratio is decided at this level.

Thus the total number of technicians T_t is given by:

$$T_t = \frac{1}{r} \sum_{i=1}^{C} \left(t_i \sum_{j=1}^{4} w_{ij}\, s_{ij} \right) \tag{3}$$

Administrative, clerical and secretarial staff in Schools are determined in the same way as technicians, using the appropriate norm (Academic:Clerical and secretarial staff in schools ratio (u)).

Then, as above, the total number of such staff T_u is given by:

$$T_u = \frac{1}{r} \sum_{i=1}^{C} \left(u_i \sum_{j=1}^{4} w_{ij}\, s_{ij} \right) \tag{4}$$

Central administrative and clerical, and library and computer staff are determined in the same way as academic staff; they are related directly to the full-time equivalent student number, S, by means of the two ratios V (for administrative and clerical) and W (for library and computer staff). Thus the respective total numbers T_V and T_W are given by:

$$T_V = \frac{1}{V} S = \frac{1}{V} \sum_{i=1}^{C} \sum_{j=1}^{4} w_{ij} \, s_{ij} \qquad (5)$$

$$T_W = \frac{1}{W} S = \frac{1}{W} \sum_{i=1}^{C} \sum_{j=1}^{4} w_{ij} \, s_{ij} \qquad (6)$$

iii) Space

Academic staff office space (A_a), is given by summing the products of the number of professors and other academic staff by the norm giving their individual space allocation.

Thus,

$$A_a = T_a \left(\frac{P}{100} (a_1' - a_2') + a_1' \right) \qquad (7)$$

where P is the percentage of academic posts held by professors

a_1' is the space allocation norm for each professor

a_2' is the space allocation norm for other academic staff.

Administrative, clerical and secretarial staff office space is related to the number of employees by a straight-forward allocation per person irrespective of whether they are employed centrally or in the schools. Letting A_u denote this class of space:

$$A_u = u' \, T_u \qquad (8)$$

where u' is the office space for administrative, clerical and secretarial norm.

Similarly the technicians space allocation (A_t) give rise to no complications:

$$A_t = t' \, T_t \qquad (9)$$

where t' is the room space for technicians norm.

General teaching area (A_g), and laboratory area (A_l), are both related to weighted student numbers on each course or research project multiplied, respectively, by the values of the two items of course information:

percentage laboratory-based (b^1)
percentage classroom-based (b^2)

Thus,

$$A_g = \sum_{i=1}^{C} b_i^2 \sum_{j=1}^{4} w_{ij} \; s_{ij} \qquad (10)$$

$$A_l = \sum_{i=1}^{C} b_i^1 \sum_{j=1}^{4} w_{ij} \; s_{ij} \qquad (11)$$

iv) Costs

Within the model, variables used in cost calculations are similar to norms, in that their value can be controlled by the user. However, these variables do not represent quantitive rules. Rather, their function is to monitor the consequences of the quantitive rules.

Academic costs, which are all costs arising directly from employing staff of various kinds, are calculated by multiploying the number of employees of various kinds (academic, technician, administrative, clerical and secretarial) by an average cost figure taken from the University Accounts for the year 1966-67. (July 1966 is the base year for the Tress/Brown Index of University Costs and employment cost did not rise in the academic year 1966-67.)

Imputed rents are calculated by multiplying the net area of the various types of accommodation by a cost per square foot. These costs per square foot are calculated by amortising, over 50 years at 7%, the figure for new buildings quoted by the University Grants Committee publication "Notes on Procedure", after adjusting for gross square footage, again using the U.G.C. information.

The other four costs calculated by the model are arrived at using linear relations which have been derived from regression analysis of the cost data, staff and student numbers for the years 1965 to 1970. All cost figures were corrected to the levels of July 1966 using the Tress/Brown index of university costs.

Full details of the calculations and data underlying the cost relationships are given in Chapter 17.

DYNAMIC MODEL

Dependent Variables

The dependent variables of the dynamic model differ from those of the static model only inasmuch as they take on values for each of five years. The period of five years is chosen to coincide with the five-year planning and financing period of the British universities.

Decision Variables

In order simulate a five-year period with the model, information additional to that described earlier is required.

Norms

All the norms relating to the static model are included in the dynamic model, and they take on values for each of five years. In most cases the values of the norms would be expected to remain the same from one year to the next. This has been taken into account in the programming of the model in order to keep the amount of data preparation to a minimum.

However an additional class of norms, transition ratios, controlling the movement of students from one year of a course to another is included. These transition ratios are in groups of three: 1st year/2nd year; 2nd year/3rd year; 3rd year/4th year. Values are given for each of the four steps of the five years of the projection, and up to nine different groups may be used in any projection.

Level of Detail

The following information, additional to that required for the static model is required for each course or research project:

1. Number of students on the first year of course or project in the 2nd year of projection
2. Number of students on the first year of course or project in the 3rd year of projection
3. Number of students on the first year of course or project in the 4th year of projection
4. Number of students on the first year of course or project in the 5th year of projection
5. Transition ratio indicator.

The transition ratio indicator refers to one of the nine groups of transition ratios described above.

Functional Relationships

The functional relationships of the two models are the same. The dynamic model performs the same calculation as the static model, five times over, using a different set of norms and student numbers each time. The linkage between consecutive calculations is provided by the transition ratios. The number of students on year j of a course is in year k of the simulation; s_j^k, is assumed to equal $t_{j-1,j}$ given by:

$$s^{k}_{ij} = f^{k-1}_{j-1,j} \ s^{k-1}_{ij-1} \qquad (12)$$

where $f^{k-1}_{j-1,j}$ is the transition ratio for the link between the k-1 and the kth year of projection, referred to by the transition ratio indicator for the ith course, for the ratio of the number of students in the jth year of the course to those in the j-1 year.

Programming

Both models are programmed in ALGOL for the I.C.L. 1900 series computer. The programs require approximately twelve thousand words of core storage, line printer and card reader.

The program specifications, operating instructions, program listings and sample outputs may be found in Appendix 1.

CHAPTER 17.

ECONOMIES ARISING FROM VARYING NORMS AT THE UNIVERSITY LEVEL

(The Possible Use of the Bradford Planning Models)

Introduction

This chapter presents some of the numerical details and results of the models. Only the dynamic model is dealt with here since, as described in the preceding chapter, the static model can be regarded as a subset of the dynamic model. The numerical details are treated in two sections. The first gives details of an analysis of the University of Bradford's accounts over the last few years in order to establish cost relationships, and the second gives the values of the allocation norms. The results of the model are also treated in two sections. One demonstrates the use of the model to calculate the additional resource requirements needed to cater for expansions of existing courses and the introduction of new courses, and the other section shows how the model can be used to trace the consequences of varying the allocation norms.

Costs.

The five cost figures given by the model are:-

i Academic costs
ii Imputed rents
iii Maintenance
iv Administrative costs
v Equipment and Materials.

Academic costs and imputed rents have been described in chapter 16. The other three cost relationships are derived from a study of the University accounts for the last five years. The relevant figure are given in table 17.1

TABLE 17.1 : Expenditure on Maintenance, Administration, Equipment and Materials.

	1965/66	1966/67	1967/68	1968/69	1969/70
Maintenance expenditure less rents, rates and insurance (£)	200,351	272,169	290,309	331,309	390,202
Administrative expenditure less salaries (£)	162,493	209,793	211, 600	268,495	325,244
Expenditure on equipment and materials (£)	258,082	286,211	365,669	374,283	351,840

Before analysis the figures were adjusted to a base date, July 1966, using the Tress/Brown index of university costs compiled by the University Grants Committee. The values of the index over the appropriate period for non-supplemented expenditure (i.e. expenditure other than salaries and superannuation) are given in Table 17.2. The value of the index is calculated in six-monthly intervals, in January and July. Only the January values of the index are used to adjust the cost figures

Table 17.2: Tress/Brown Index. July 1966 = 100

Date	Index
Jan. 1966	97.4
Jan. 1967	100.3
Jan. 1968	105.0
Jan. 1969	110.0
Jan. 1970	117.0

The other figures used in the analysis are given in Table 17:3

Table 17.3: Student and employee numbers 1965-70

	1965/6	1966/7	1967/8	1968/9	1969/70
Full time equivalent students	2694	3271	3732	4097	4369
Number of full time students	2302	2694	2937	3142	3353
Number of Academic Staff	335	345	364	366	385
Number of Research Staff	70	83	81	71	79
Number of Technical Staff	194	232	234	220	222
Number of Administrative Offices	43	41	47	49	59
Number of Clerical Staff	181	199	218	236	267
Number of Weekly-paid Staff	418	461	480	520	558

A sophisticated attempt to analyse university costs over a period of years using simple or multiple regression models would have to cope with problems of multicolinearity, due to just those planning norms which are under investigation, and heteroscedasticity due to the five-year planning period. Even if these problems could be overcome there still remains the caveat of Chapter 15. It would be unreasonable to expect the most perfectly fitted model to give reliable forecasts.

Bearing this in mind, and the fact that the cost figures are incorporated in the model only to manifest the consequences of the quantitive rules used in resource planning, only simple linear relationships in independent variable are used.

Details of the least square estimates of the co-efficients of the equation

$$y = ax + b$$

for the three costs listed in Table 17.1 are given, together with the corresponding estimates of the co-efficient of correlation (r) in Table 17.4

Table 17.4: Details of linear regression analysis

Dependent Variable (adjusted cost figure)	Independent Variable	a	b	r
Maintenance	No. of full-time students	113.5	-49747	0.98
Administration	No. of full-time students	21.5	25160	0.69
Equipment and materials	No. of full-time equivalent students	34.9	180954	0.65

The weights used in calculating the number of full-time equivalent students are given in the next section. They are the weights that are used by the administration for resource allocation. It would, of course, have been possible to use a set of student weights which would give all three correlation ratios in Table 17.4 the value 1.00, but there would be no empirical justification for such weights.

In some cases a higher correlation ratio can be obtained by a change of independent variable. For example the co-efficient of correlation between Administrative cost and the number of Administrative Officers is 0.78 and the number of clerical staff is 0.79. Although under some circumstances both of these possible choices of independent variable would be preferred to the number of full-time students, in the context of the model of the university where the number of administrative and clerical staff are expressed as an allocation per student it is worth while accepting a correlation co-efficient of 0.69 to use a more fundamental relationship.

NORMS AND STUDENT NUMBERS

The values of the norms given in this section correspond to the state of the University of Bradford in the early part of the academic year 1970/71. The values have been taken from the documents of the academic planning committee of the University.

1.	Weighted staff:student ratio	12.4
	Student Weights	
2.	Full time undergraduate	1.0
3.	" " " (thin sandwich)	1.0
4.	" " " (thick sandwich – university)	1.0
5.	" " " (thick sandwich – industry)	0.4
6.	" " postgraduate research Sci. or Tech.	3.0
7.	" " " " Soc. Sci.	2.0
8.	" " " course Sci. or Tech. 0–10 students	3.0
9.	" " " " " " " 11–20 "	2.0
10.	" " " " " " " 20+ "	1.5
11.	" " " " Soc. Sci. 0–10 "	2.0
12.	" " " " " " 11–20 "	1.5
13.	" " " " " " 20+ "	1.25
14.	Part-time postgraduate research Sci. or Tech.	1.0
15.	" " " " Soc. Sci.	0.66
16.	" " " course Sci. or Tech.	1.0
17.	" " " " Soc. Sci.	0.66
18.	Full time postgraduate Diploma in Textiles	1.6
19.	" " Post-Experience Course	0.6
20.	Percentage of academic staff posts held by professors.	10%
21.	Ratio of F.T.E. students to central administrative and clerical staff	13.4
22.	Professor's staff office (sq. ft. per person)	200
23.	Other academic staff office (sq. ft. per person)	150
24.	Administrative & clerical staff office (sq. ft. per person)	75
25.	Technical staff office space (sq. ft. per person)	3
26.	General teaching area (sq. ft. per F.T.E. student)	20
27.	Laboratory area (sq. ft. per F.T.E. student)	65
28.	Academic:technical staff ratio (Sci. or Tech.)	1.3
29.	Academic:technical staff ratio (Soc. Sci.)	17.5
30.	Academic:secretarial staff ratio (non central) general value	5
31.	Academic:secretarial staff ratio (non central) Management School only	2
32.	transition ratio 1st.year:2nd. year	0.97
33.	" " 2nd. year:3rd. year	0.97
34.	" " 3rd. year:4th. year	0.97
35.	Research staff:Academic ratio	0.205

For each undergraduate or postgraduate course or research project incorporated in the model the following details need to be provided.

1. Course or project name
2. No. of students on the 1st. year of the course in the first year of the simulation.
3. No. of students on the 2nd. year of the course in the first year of the simulation.
4. No. of students on the 3rd. year of the course in the first year of the simulation.
5. No. of students on the 4th. year of the course in the first year of the simulation.
6. No. of new entrants in the second year of the simulation.
7. No. of new entrants in the third year of the simulation.
8. No. of new entrants in the fourth year of the simulation.
9. No. of new entrants in the fifth year of the simulation.
10. Percentage laboratory based.
11. Percentage classroom based.
12. Level (i.e. undergraduate, postgraduate, post-experience, Dip.Tech.)
13. Sandwich type (i.e. Non-sandwich, thin or thick).
14. Academic type (Social Science, pure science or technology)
15. Time (i.e. part-time, full-time)
16. Method (course or research)
17. Industrial experience year (only applies to thick sandwich courses).
18. Technical:Academic staff ratio for the course.
19. Administrative ratios for each year of the course.
20. Transition ratios for each year of the course.

For the courses and projects in existence in 1970/71 using the norms listed above the results of the model are given in Table 17.5

EXPANSION AND INTRODUCTION OF COURSES

One of the principal ways in which the University has expanded in the past has been by increasing the number of students on undergraduate and postgraduate courses. Some time before the beginning of planning quinquennium the Academic Planning Committee asks the relevant people to submit details of the size of courses they desire to run for the next five years. These figures for the expansion or contraction of existing courses are subject to alteration. This process may be repeated several times before a fixed plan is drawn up for the quinquennium. This final plan is subject to the financial constraint of the University Grants Committee.

The figures for the expansion and contraction of existing courses agreed by the academic planning committee have been used in the dynamic model to produce the results given in Table 17.6

Table 17.5 Model Results for 1970/71

Student No.s	Undergraduates	Full time Postgraduate	Part time Postgraduate	Full time equivalent total			
	2958	508	136	3683			
Staff No.s	Academic	Technical	Secretarial in Schools	Administrative	Total		
	302	166	68	275	811		
Space, sq. ft.	Academic	Technical	Secretarial in Schools	Teaching	Laboratory	Administrative	Total
	46876	497	5127	73666	126779	20615	273561
Costs (£)	Staff	Administrative	Equipment	Maintenance	Rent	Total	
	783593	99679	309501	343644	142891	1679307	

Two aspects of this proposed set of expansions and contractions are highlighted by the figures 17.1 and 17.2, showing total student numbers, (undergraduate, postgraduate both full and part-time) plotted against the number of academic (including research) staff and total cost (including imputed rent).

At the same time that the expansions and contractions considered above were put forward seven new courses were proposed. The details of these proposed courses have been incorporated into the dynamic model one at a time. A full report, in the format of Table 17.5, was produced after the addition of each course. Table 17.7 shows the increase in Full-time Equivalent (F.T.E.) student numbers over a period of five years that would be caused by the introduction of those courses.

Table 17.7: Increases in Student No.s due to New Courses.

Year	F.T.E. Student No.s	
	Without New Courses	With New Courses
1	3683	3683
2	4065	4065
3	4325	4407
4	4475	4660
5	4739	5049

If the assumption is made that the new courses are incorporated in the model in the order of desirability and that if not all the courses can be implemented, then certain courses (starting with the last), are discarded rather than the size of other courses reduced, then the 'cut-off' points can be obtained by use of the model. Figures 17.3 and 17.4 illustrate this usage. In both graphs the horizontal axis is used for the number of new courses. The increased demand for space, for all uses, at the end of five years is illustrated by the figure 17.3 and the increase in total cost at the end of five years by figure 17.4

VARIATION IN ALLOCATION NORMS

It is accepted by almost everyone that, for a variety of reasons, the allocation norms used in the University are going to change during the next few years. These changes may be the result of the imposition of some constraint imposed directly by some external agent, e.g. the quinquennial block grant, or less directly by some resource shortage, e.g. space.

To show how the model can be used to study the implication for allocation norms of such constraints figures 17.5 - 17.8 have been produced from computer simulations using the same results. All the existing courses, their proposed expansions and the proposed new courses

Table 17.6 Expansion and Contraction of Existing Courses 1971/76

Student No.s	Undergraduates	Full time Postgraduates	Part time Postgraduates	F.T.E. Total			
Year 1	2958	508	136	3683			
Year 2	3171	626	143	4065			
Year 3	3334	680	149	4325			
Year 4	3436	713	152	4475			
Year 5	3594	773	155	4739			
Staff No.s	Academic	Technical	Secretarial in Schools	Administrative	Total		
Year 1	302	166	68	275	811		
Year 2	333	186	75	303	898		
Year 3	357	201	81	323	961		
Year 4	368	208	84	334	995		
Year 5	390	221	89	354	1054		
Space, sq. ft.	Academic	Technical	Secretarial in Schools	Teaching	Laboratory	Administrative	Total
Year 1	46876	497	5127	73666	126779	20615	273561
Year 2	51678	559	5633	81308	143249	22754	305181
Year 3	55307	602	6063	86498	152448	24207	325126
Year 4	57073	625	6309	89497	157578	25046	336128
Year 5	60469	662	6710	94781	165711	26524	354857
Costs (£)	Staff	Administrative	Equipment	Maintenance	Rent	Total	
Year 1	783593	99679	309501	343644	142891	1679307	
Year 2	863848	106805	322837	381260	159352	1834101	
Year 3	924520	111465	331893	405864	169783	1943525	
Year 4	954047	114363	337126	421161	175525	2002222	
Year 5	1010802	119046	346346	445883	185326	2107404	

FIGURE 17.1

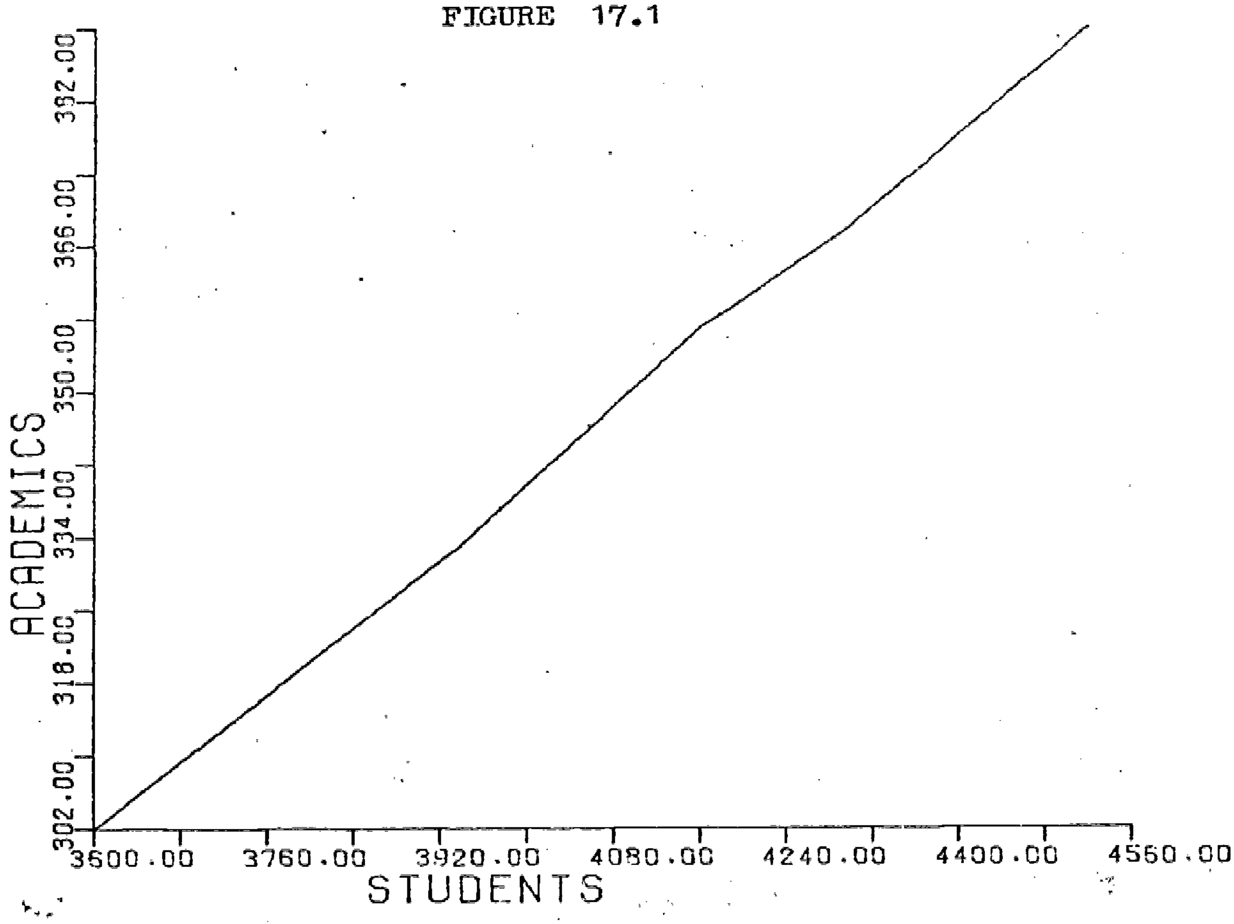


FIGURE 17.2

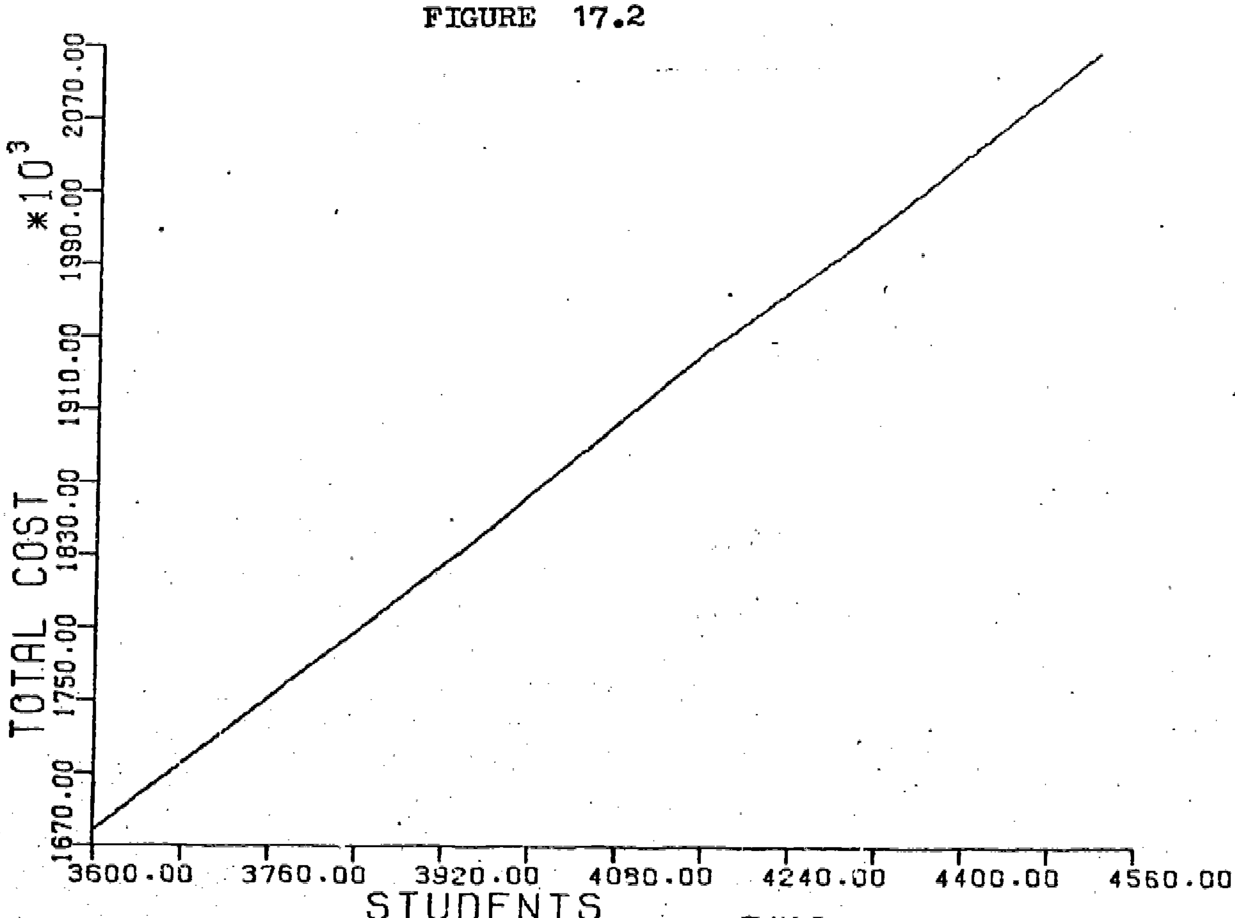


FIGURE 17.3

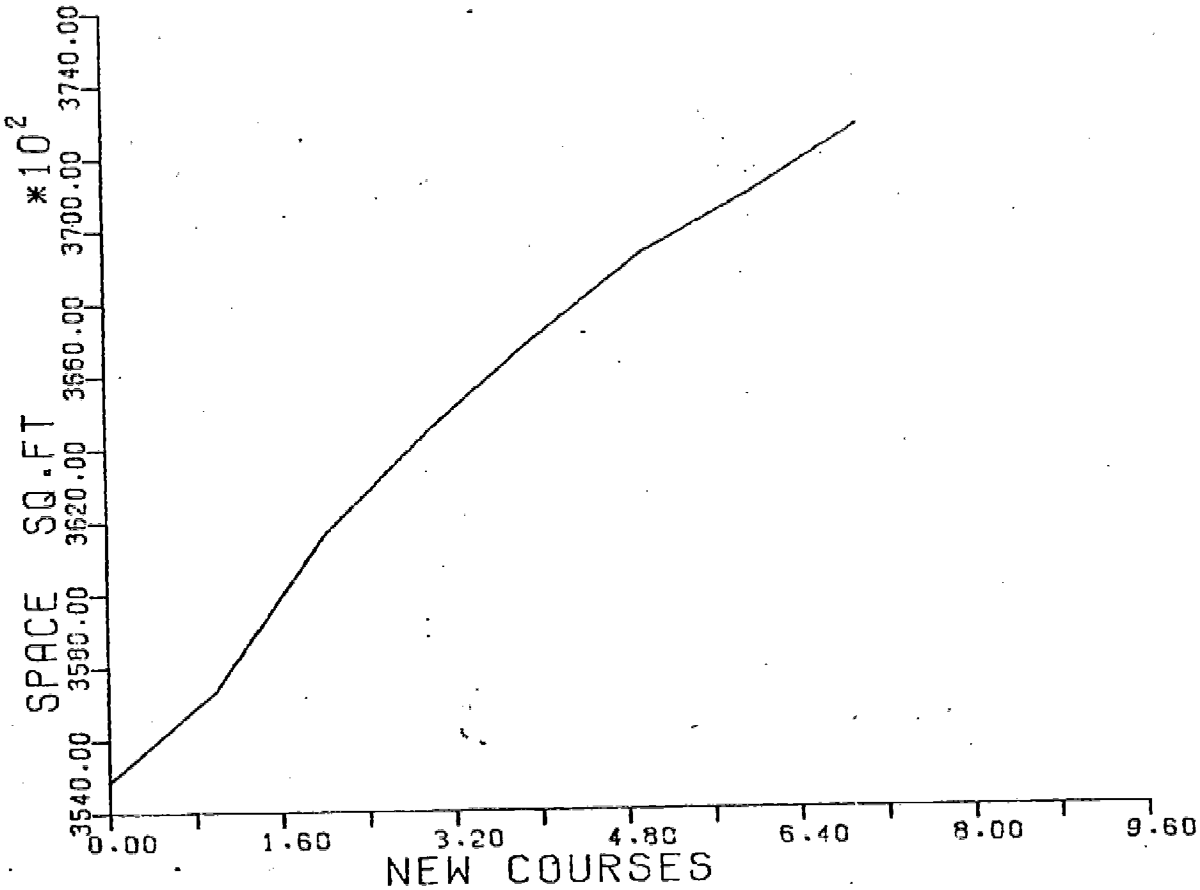
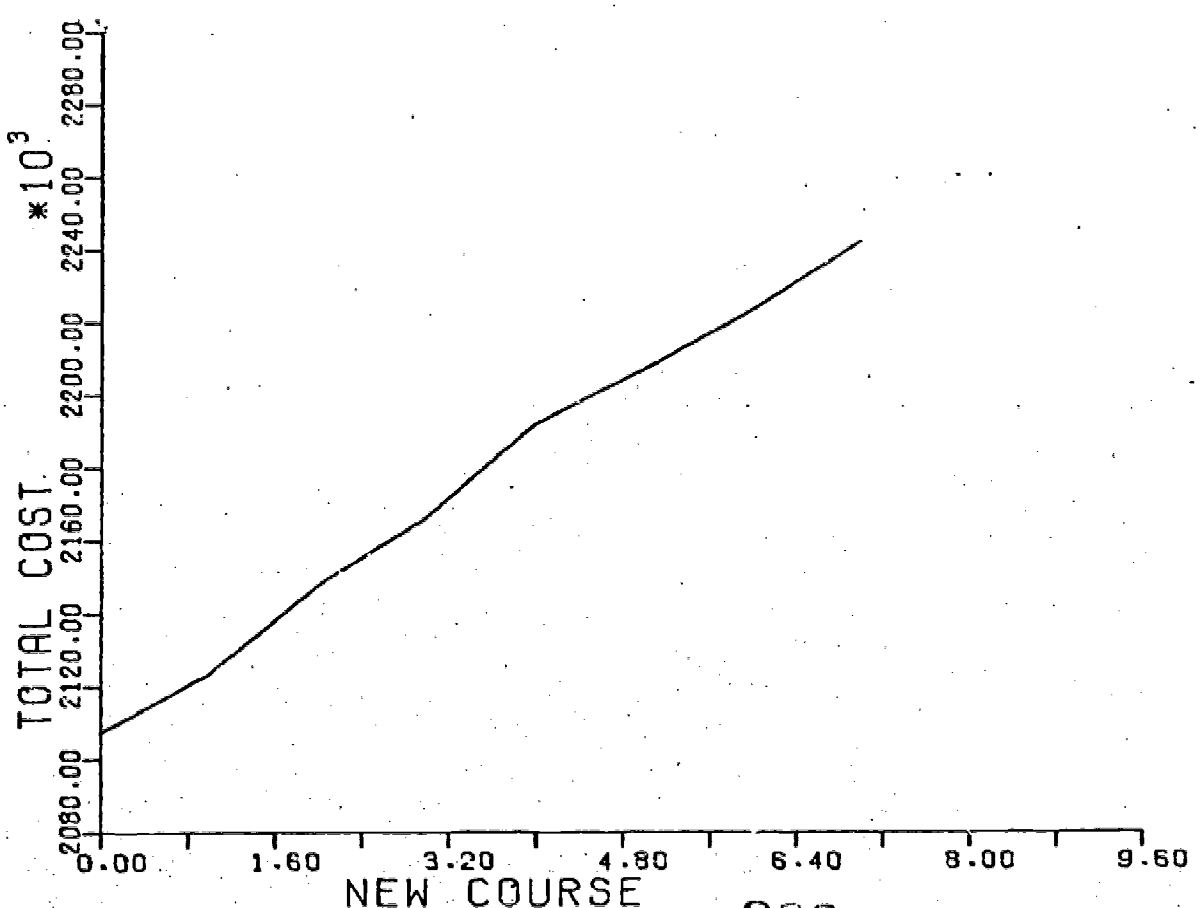


FIGURE 17.4



have been used in these simulations.

Figures 17.5 and 17.6 show total cost and total space requirements respectively as functions of the staff:student ratio. The staff:student ratio is allowed to vary over the range 8.0 to 16.0. (No. of students for each member of staff). These graphs were produced by performing the calculations for increments of 0.5 in the ratio.

Figures 17.7 and 17.8 show total space requirement and total cost respectively as function of the allocation norms for general teaching and laboratory space. The technique here has been to plot, in both cases, along the horizontal axis the simultaneous percentage change in the general teaching area and the laboratory area per F.T.E. student allocation norm. The changes considered have all been reductions. The graphs were produced by performing the calculations after every one of a series of simultaneous decreases of 5% in both norms.

We have so far performed only limited experiments using these models. It is intended during the next few months to carry out further simulations to test more fully the effects of changing various norms.

FIGURE 17.7

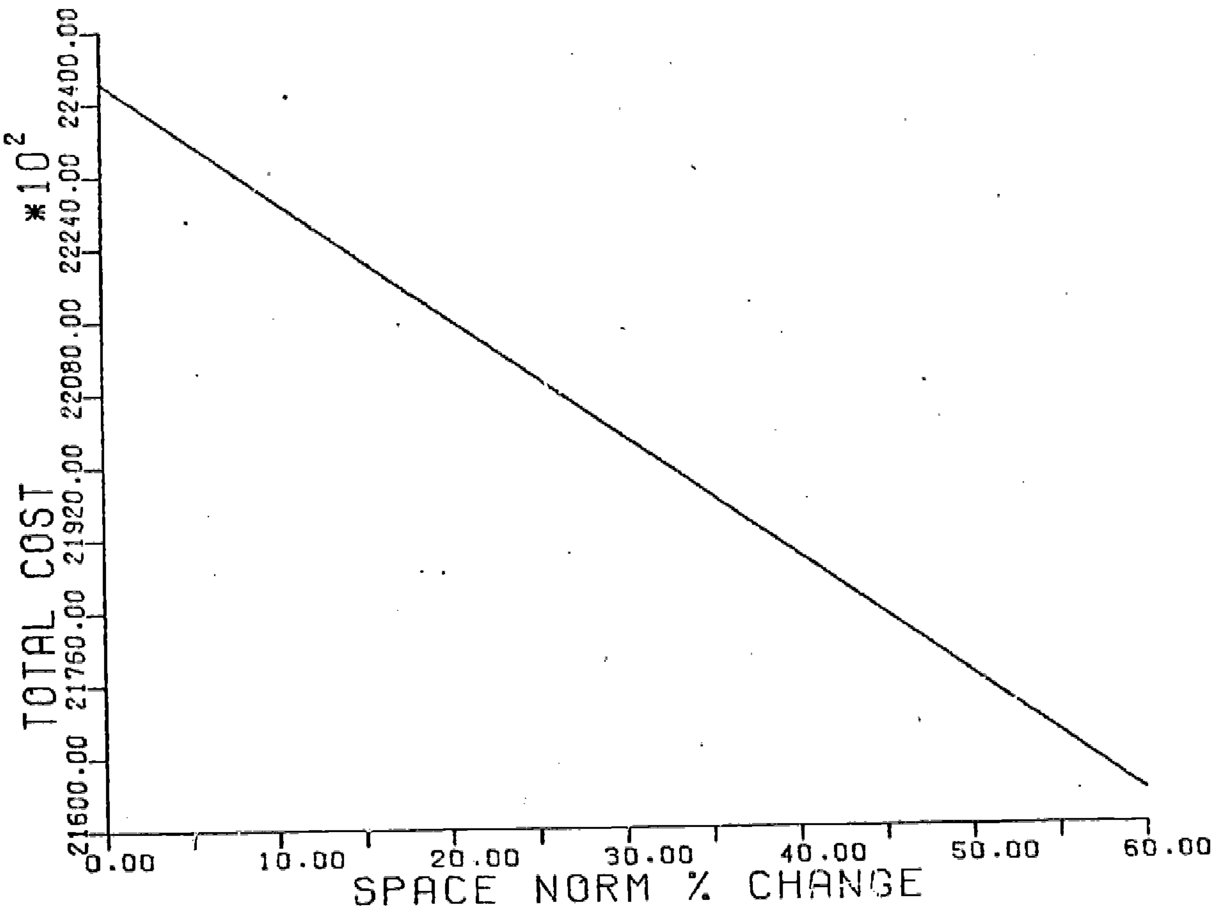


FIGURE 17.8

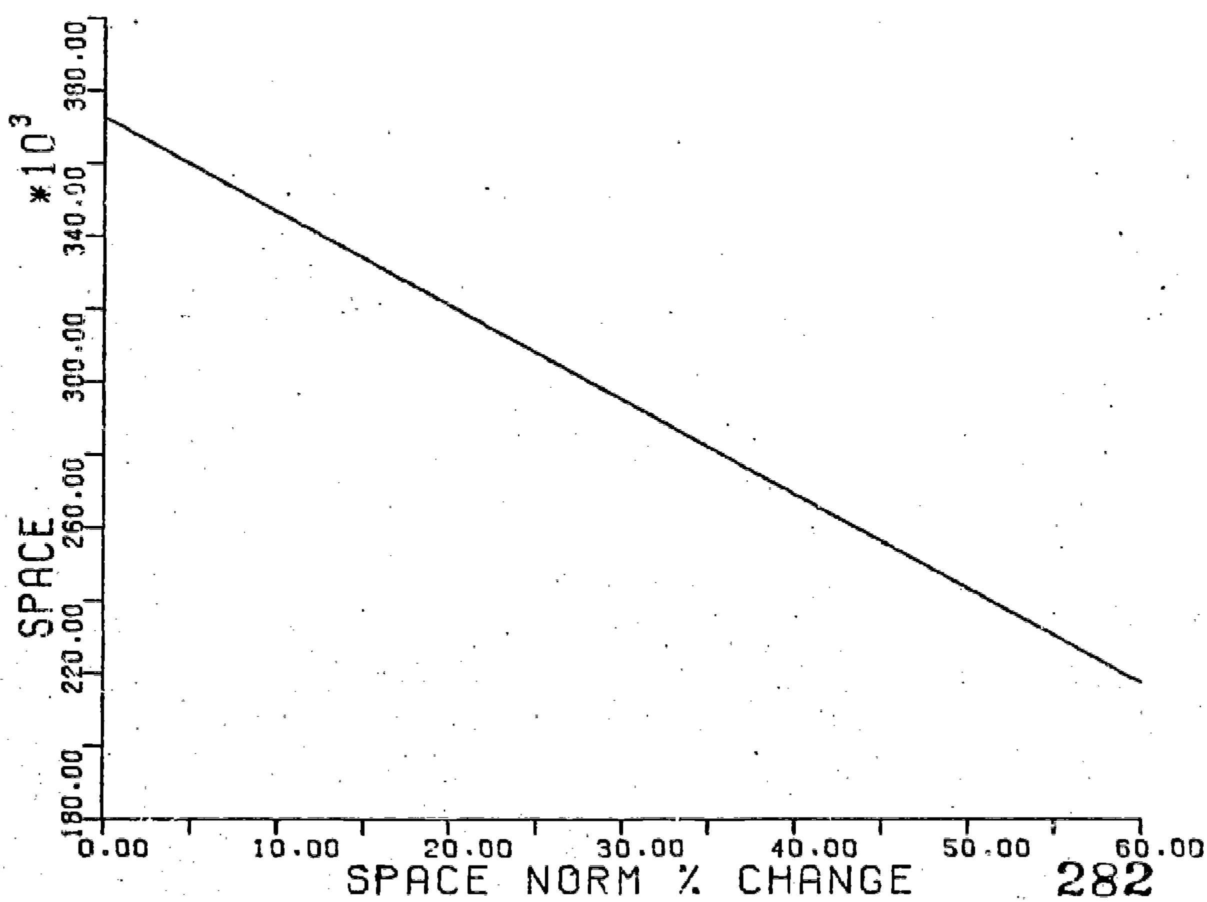


FIGURE 17.5

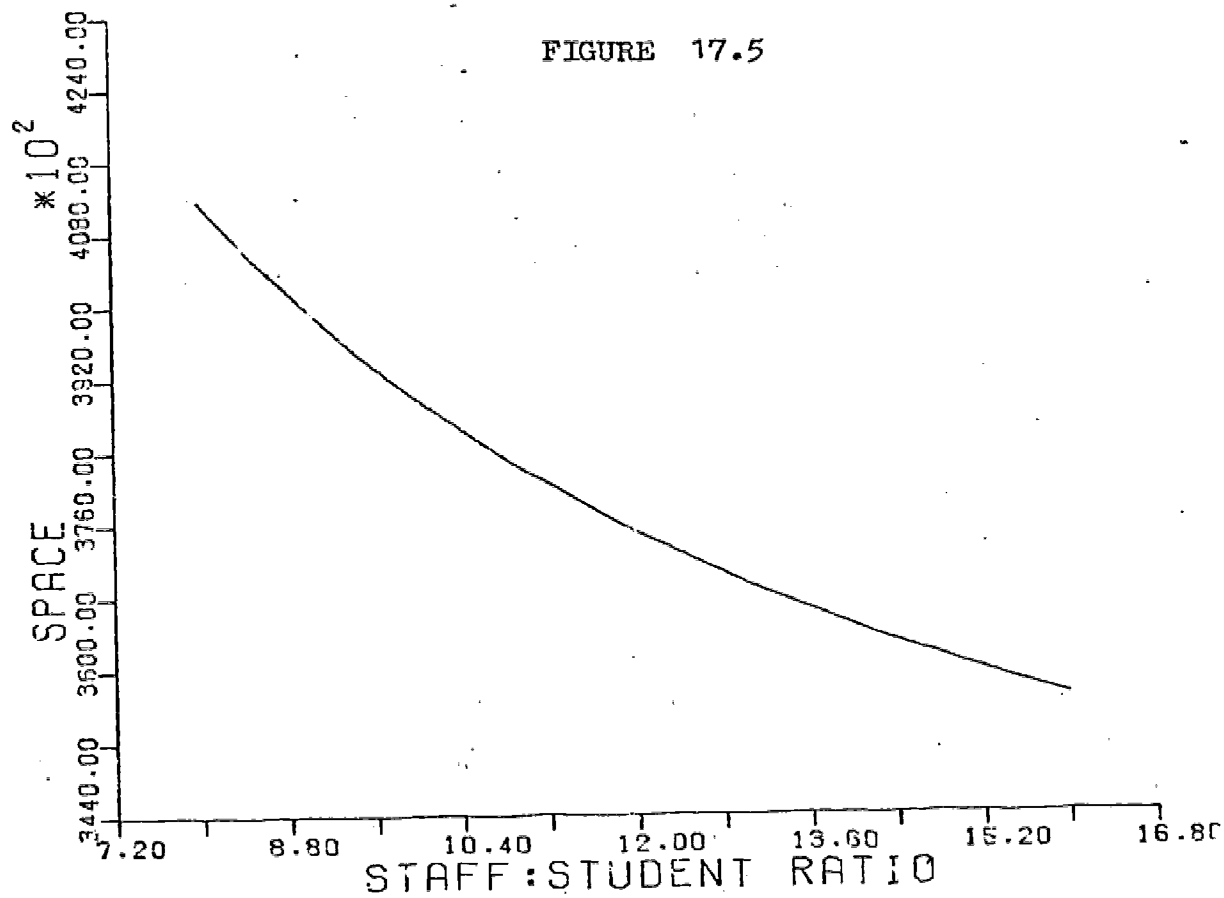
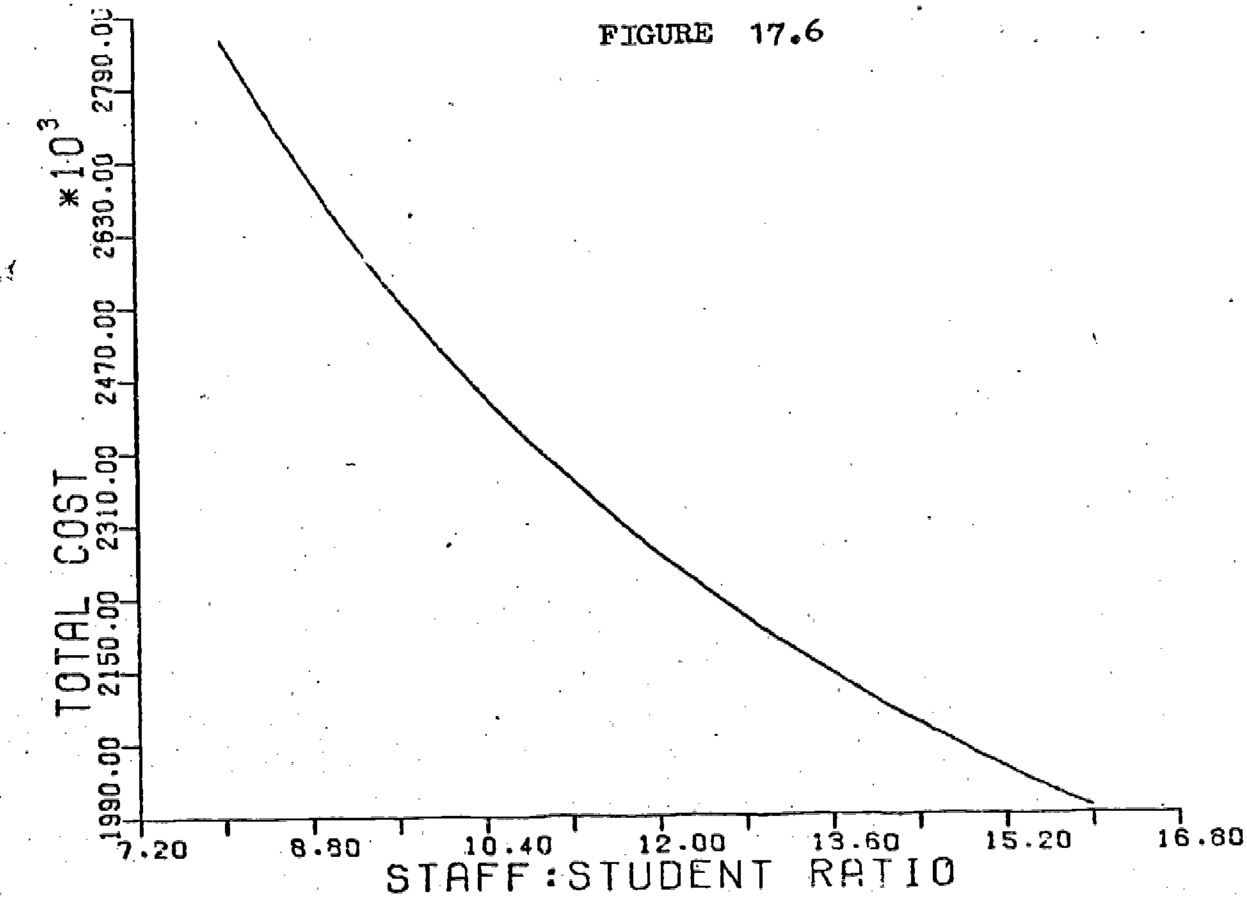


FIGURE 17.6



PART 8

EXISTING ECONOMIES OF SCALE

Those sections of this report concerned with the reduction of unit costs, have dealt at length with economies of scale. Other methods by which the cost of producing graduates could be lowered, for instance through a more extensive use of university buildings, require the implementation of such innovations as the four term year, the longer working day, etc. These involve a considerable change in university organisation and may thus be resisted by the university community.

In the context of the present trend towards an increasing university size, any economies of scale that there may be in the production of university graduates, are more likely to be realised.

This chapter seeks to examine and test for existing economies of scale in the University of Bradford, to see where economies may be found, and what order of size they are.

CHAPTER 18

A CROSS SECTIONAL STUDY OF STAFF COSTS IN RELATION TO COURSE SIZE

1. Economies of scale within Universities

Economies of scale are an important factor in the life of any society. They are said to occur when an increase in output is achieved with a less than proportionate increase in costs, this cost saving being entirely due to the increased scale of the operation.

When investigating economies of scale within a university, it must be decided what is to be taken as the unit of production. The output of a university is varied, but as this report is concerned with the cost of producing graduates, we will take the output as being the number of undergraduates undergoing a year's education. Using this output as a measure of scale, a number of potential units of production present themselves. Of these, three would seem the most practicable, they are - the University, the Board of Studies and the Course.

In discussing the applicability of greater specialisation and/or more efficient means of production to the University, the Board of Studies and the Course, as they increase in size, it is reasonable to consider only those opportunities for reduction of cost per student, that are a necessary or likely result of an increase in the size of the unit of production under consideration. Thus in the case of the University, we would expect that as it grows so administrative costs per student could decrease and that some university services such as accommodation and employment bureaux could be made less costly per student. As the Board of Studies grows we would also expect administration costs per student to be reduced, and possibly, where courses overlap, items of equipment of mutual interest for several of the courses may not need to be duplicated.

As a University or a Board of Studies expands, there is not necessarily a concomitant increase in the size of the courses that comprise the University or the Board. They may both grow by increasing the number rather than the size of the courses that comprise them. However, it is the course that is the basic unit of production and thus it is the course that offers the greatest scope for economies of scale. Teaching cost is a major item in the breakdown of cost per student and the course size and structure will largely determine how efficiently the lecturer's time is utilised. Whether a certain preparation time results in giving lectures to one group of ninety students, three groups of twenty students or one group of twelve is dependant on the particular course and thus we can see that course size can have great repercussions on teaching cost per student.

While teaching cost per student is of major importance, other economies may flow from increasing the size of a course. Technical staff may also be used more efficiently, for example, where one piece of equipment has to be set up for demonstration purposes, it makes no difference to the labour involved whether the demonstation is carried out in front of ten or twenty students, though in the latter case the work is rather more productive. Another illustration of an economy expected as a result of an increased course size is the cost of teaching equipment and materials per student. Some items of equipment will have to be acquired in amounts directly related to the number of students on a course and here few economies may be expected (although possibly bulk purchase may reduce cost per student). However, other items of equipment may be acquired more sparingly and where, because of indivisibility, one piece of equipment obtained for a course comprising 40 students would be sufficient for a course comprising 200, the particular economy from increasing the course size is obvious.

From this we can see that the course is the unit of production potentially able to obtain the greatest economies from an increase in size. We have seen that course size is by no means directly linked by University or Board of Studies size and thus, from the point of view of exploring economies of scale within the university, the Course will be the most profitable unit of production to investigate.

2. Methods of approach

When looking for economies of scale it is necessary to compare the cost of output of units of production operating at varying levels of output. In order to examine the economies of scale in Bradford University, there are two alternatives. Firstly the cost per student per year could be calculated for individual courses at various stages in their development. The major advantage of this approach is that the product remains relatively homogeneous. Thus we would in each case be comparing the cost of producing a particular type of undergraduate at different course sizes. The disadvantages here though are largely ones of data gathering, for no detailed costing of individual courses has been methodically carried out over the life of this institution. Even if costing had been carried out, there would have been considerable problems involved in making these costs comparable, for inflation would have affected various component of cost to different extents and no single calculation could solve this problem satisfactorily.

The second method, and the one used in this chapter, is that of a cross sectional study of courses at the university. Here data is available and the costs arrived at are comparable. The major drawback however, is the lack of homogeneity. Can one regard the production of a civil engineer as being comparable with the production of an economist?

It is true that the process of production in both cases involves the assimilation of knowledge, but the character of the knowledge, and to some extent the means of imparting it, are rather different. Thus assuming we arrived at the hypothetical result that the total cost of producing a civil engineer was £2,000, whilst the total cost per economist was £1,500, we then looked at the course sizes and found that the economics course consisted of 200 students, whilst the civil engineering course contained some 100 students. From this it would not be valid to contend that economists were produced more cheaply as a result of economies of scale. The means of imparting knowledge would be a much more likely cause of the disparity in costs. Civil engineers may require expensive equipment taking up large areas of floor space. They may require numerous technical staff and so on. On the other hand, economists may be happy with a number of books, six lectures and three tutorials per week.

3. Interpretation of Results

Recognising that the nature of a course may have a greater effect on cost than any economies of scale, it is necessary to subject the results to rigorous scrutiny. For example, if, as is expected, we find a negative relationship between course size and cost per student, it will be possible that this is a result of economies of scale. However, this would not be the only possibility. It could be that those courses comprising the greater number of students are cheaper per student purely because of their nature. If this was found to be so, then it might be possible to advance the hypothesis that courses expand in an inverse relation to their unit cost. This then will have to be considered when discussing the results. At present, it is likely that those courses with little laboratory work - mainly in the Board of Social Science - will turn out cheaper than other courses. If this is the case then it may be necessary to exclude them from the analysis in order to avoid their distorting influence. This and other possibilities will be considered.

From the above we can see that no exact relationship can be expected between course size and cost per student. What we are looking for is evidence of a general trend towards cost reduction per student as course size increases - a cost reduction that can only be satisfactorily explained as the result of economies of scale. In this section we examine the relationship between present course size and actual cost per student to see whether or not these expected economies actually occur. The cost figures used are the economic costs per student for different courses in 1969/70, defined and presented in Chapters 2 and 3 of this report.

Many of the components of these cost figures are unsuitable for use in investigating the existence of economies of scale. The Capital and Maintenance figures, for example, attribute the various university buildings with different costs per square foot. This results in those courses housed in the more expensive buildings being attributed with a higher Capital and Maintenance cost per student, than other courses housed in less expensive accommodation. The nature of the building in which a course is taught is not necessarily dependent on the type of course, and to some extent is an 'accident of history'. Indeed, the classroom tuition of the majority of courses could take place in the least expensive accommodation, with little resulting affect on productivity but with a large impact on the cost per student. The difference in cost per square foot, among the various university buildings, has a great effect on the capital and maintenance cost per student, of the various courses and thus precludes any meaningfull examination of the relationship between course size and the cost of any of the capital items.

The method of calculating the cost per student of the administrative, library and student facility items negates the possibility of any economies of scale there might be in these cost areas coming to light because of the simple pro rata method of allocating them over all students.

However, there is one group of cost components on which a meaningful investigation of economies of scale can be carried out. This is the group of Teaching Costs which have been calculated entirely on a course basis. The need to concentrate attention on this particular cost heading, is not as great a limitation as it may seem, for teaching cost accounts on average for over 40% of total costs and for approximately one half of the university's current expenditure. Thus, any economies of scale that we might discover as regards teaching costs, will have great significance.

The data on course size required adjustment to make the various course sizes comparable. The factors of production available to the various courses are a function, not so much of their nominal course size, as of the number of students on a course <u>who are studying within the university at any one time</u>. Thus for a conventional three year course, the simple numbers of registered students were acceptable. Where, because of the sandwich nature of a course, one quarter of the course's students were in industry at any one time, the figures were multiplied by three-quarters. Where a course was entirely of a double entry nature and thus only half the students on a course were present at any one time, the nominal figure was multiplied by one half. Where the first three years of a course were of a double entry nature, whilst during the last year both entries attended university for the full academic year, the nominal figure was multiplied by five-eighths. Despite the varied nature of these courses, all but one group of students complete a total of nine terms within the university and thus in this respect the various courses are reasonably comparable.

The analysis which is mainly cross sectional takes eighteen courses and compares their teaching cost per student with their effective (weighted) course size. These observations of course size and cost per student are plotted in figure 18.1. They show a negative relation between course size and teaching cost per student. The relationship has a poor correlation coefficient ($r = -0.3029$). However, the trend - of a reduced teaching cost per student the greater the course size - is reasonably definite. It can be seen in Table 18.1 that the greater is the average course size, the smaller is the average teaching cost per student.

Table 18.1 Teaching Cost per Student in Relation to Course Size

Weighted course size	Number of courses in group	Average Course size	Average teaching cost per student
> 160	5	216	£919
90 - 160	5	125	1043
55 - 90	4	73	1241
< 55	4	49	1372

The absence of a definite linear relationship is likely to be largely the result of including such a diversity of courses in the same sample. It has already been mentioned that laboratory-based and classroom-based courses may not be sufficiently comparable and this is seen to be the case, for irrespective of course size, classroom-based courses as a group are much cheaper than laboratory-based courses. In fact, classroom-based courses (with an average course size of 135 students) had an average teaching cost per student of £615, whilst laboratory-based courses (with an average course size of 115 students) had an average teaching cost of £1,466 per student. The sample was therefore devided into 'laboratory-based' and 'classroom-based' courses.

Classroom-based courses, which account for one-third of the sample, exhibit no relationship between course size and teaching cost per student. However, the sample, consisting of only six courses is limited, and the spectrum (ranging from mathematics to languages and social sciences) wide.

When the relationship between course size and teaching cost per student in the laboratory-based courses is investigated, a negative relationship is again evident. However, although there is a stronger correlation, it is still not significant at the 5% level. Figure 18.2 shows that the lack of fit results largely from three deviant courses, whose teaching cost per student is greater than one would expect from this course size.

In the case of Pharmacy, it can be seen in Table 18.2 that a high laboratory staff cost largely accounts for the discrepancy. (It was shown in Chapter 12 that Pharmacy has the highest student : Technical Staff ratio in the university. It was also suggested that the demand for technical staff is related to laboratory area and if this is the case then Pharmacy's high teaching cost may be largely attributable to its generous laboratory area). The Mechanical and Electrical Engineering Courses are also found to be a special case in that they have both experienced a relative difficulty in obtaining their quota of students. This has reduced their student:staff ratios, which at 10.6 and 10.9 respectively, were significantly lower than those of the other two engineering schools, Chemical Engineering (14.1) and Civil Engineering (16.6).

Figure 18.1: THE RELATIONSHIP BETWEEN COURSE SIZE AND TOTAL TEACHING COST PER STUDENT. (COMPLETE SAMPLE)

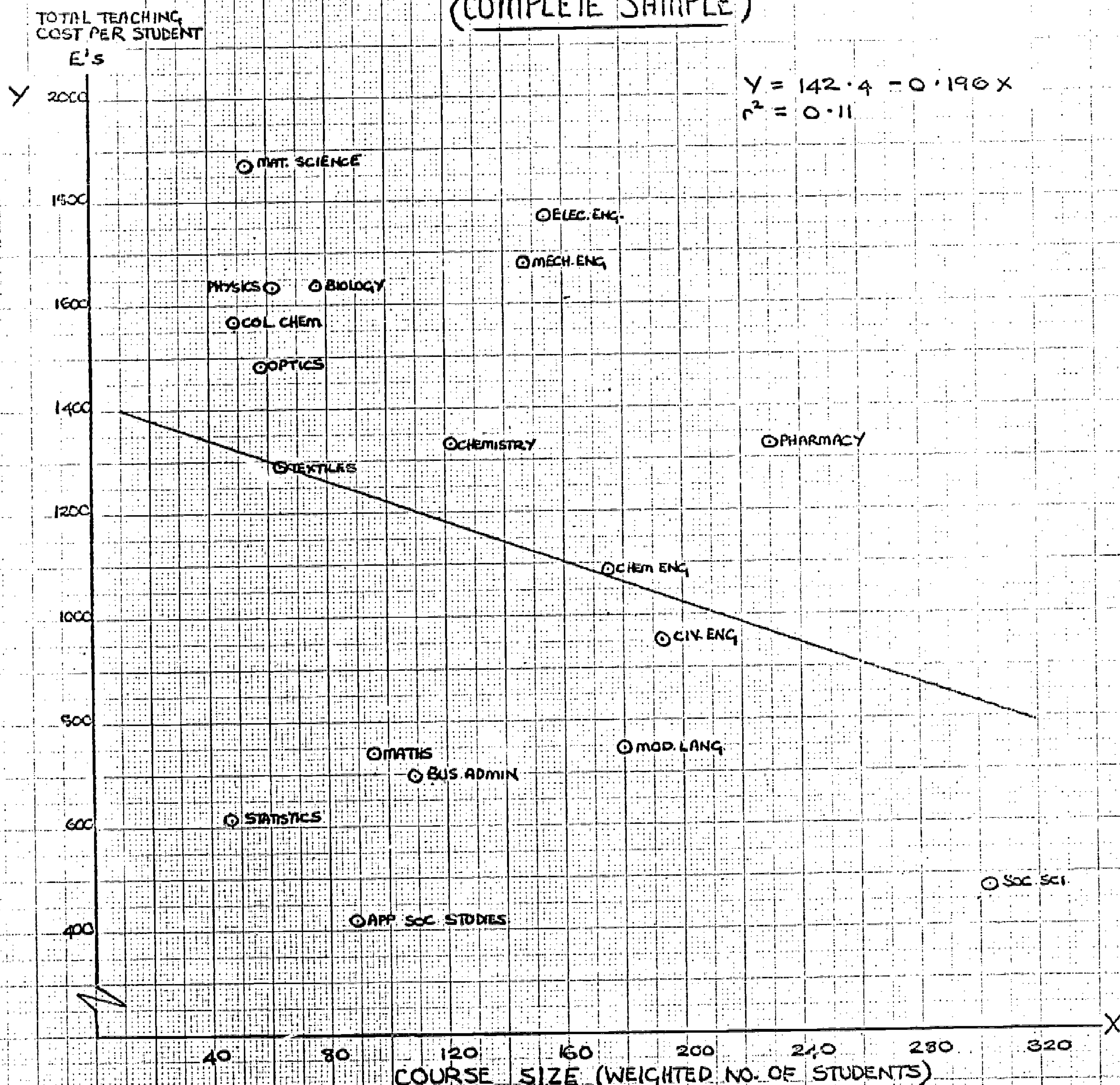


Figure 18.2: THE RELATIONSHIP BETWEEN COURSE SIZE AND TOTAL TEACHING COST PER STUDENT

(LABORATORY BASED COURSES)

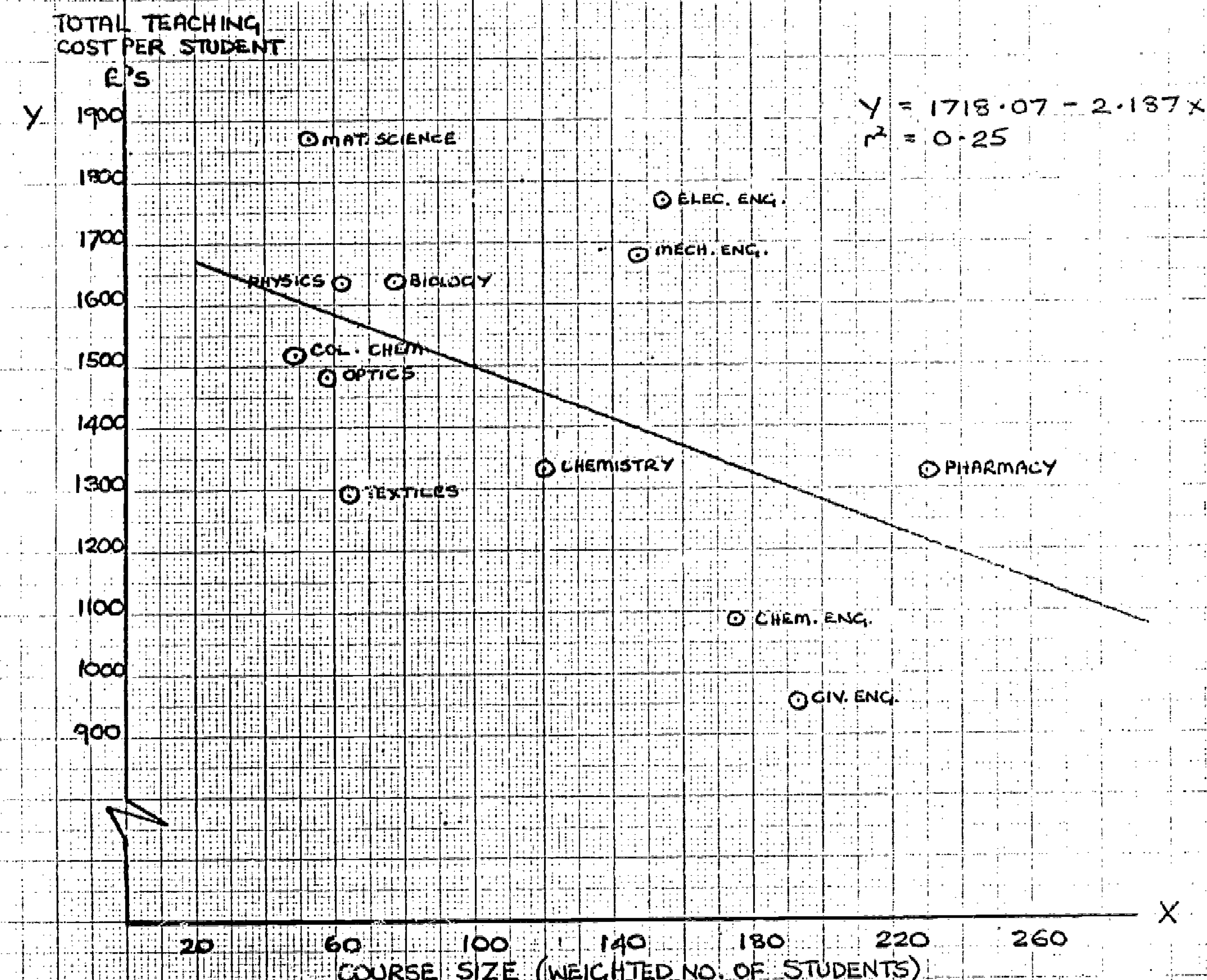


Table 18.2 : Course Size, Teaching Costs and Staff Costs

Course	Number of Registered Under-graduates*	Weight+	Weighted Number of Students	Teaching Cost per Student	Academic & Technical Staff Cost per Student	Technical Staff Cost per Student	Academic Staff Cost per Student
				£	£	£	£
Laboratory-Based Courses							
Pharmacy	230	1	230	1329	1023	474	549
Civil Engineering	257	3/4	193	956	698	240	458
Chemical Engineering	349	1/2	175	1089	821	204	617
Electrical Engineering	247	5/8	154	1769	1425	352	1073
Mechanical Engineering	235	5/8	147	1679	1439	452	987
Chemistry	162	3/4	122	1332	1032	432	600
Applied Biology	103	3/4	77	1639	1285	339	946
Textiles	85	3/4	64	1290	1164	468	696
Applied Physics	82	3/4	62	1635	1215	472	743
Optics	58	1	58	1484	1169	354	815
Material Science	70	3/4	53	1874	1454	472	982
Colour Chemistry	65	3/4	49	1517	1217	432	785
Classroom-Based Courses							
Social Science	303	1	303	475	424		406
Modern Languages	240	3/4	180	748	688		624
Business Administration	109	1	109	693	528		486
Mathematics	95	1	95	744	652		652
Applied Social Studies	89	1	89	419	351		327
Statistics	47	3/4	47	613	544		544

* Including students in industrial training.

+ Weight is determined by percentage of registered undergraduates in university at any one time

If these three courses are withdrawn from the sample, then the correlation between course size and teaching cost per student is much stronger, the coefficient of correlation, r^2, having a value of 0.714. Similarly, the relationship between course size and the cost of academic and technical staff per student is very strong with an improved r^2 of 0.86. The relationship between technical staff cost per student and course size was also very tight ($r^2 = 0.67$) and when academic staff cost per student is correlated with course size (this time including Pharmacy in the sample) the relationship is again very precise ($r^2 = 0.63$).

The strength of the relationship between course size and academic and technical staff cost per student suggests that these cost items are largely responsible for the negative relationship between teaching cost per student and course size. The other major cost item, expenditure on teaching equipment and materials per student, bears little relationship to course size.

While the evidence of economies of scale has so far been expressed only in terms of cost per student, it may also be expressed in terms of teaching hours per student. Thus, as well as finding that academic and technical staff cost per student is negatively related to course size, we would expect that the economic use of acedemic and technical staff resources is positively related to course size. However, no simple measure of economy in staff use is available. The academic and technical staff:student ratios are both unsatisfactory. The former fails to take service teaching into consideration, whilst the latter makes no allowance for those technical staff primarily facilitating research. Thus some other measure is required. In the case of academic staff, we use a measure of "tutorial equivalence".

If we take the annual teaching hours given to a course, and divide this by the number of students receiving this teaching, we obtain the average number of hours tuition each student would receive if all teaching was carried out on a 1 to 1 tutonial basis. This figure represents each student's "tutorial equivalent" hours received over the years he attends university. The sum of hours devoted to each individual 'year' of a course (1st, 2nd, 3rd and sometimes 4th) in one academic year, represents the average total number of "tutorial equivalent" hours received by the student as he passes through all the years of his course.

We would expect a student's "tutorial equivalent" hours to vary immensely with the weighted course size. We illustrate this by taking the case of two students, who each week attend 6 lectures, 3 seminars and 1 tutorial, each lasting 1 hour. One student is on a large course, the other on a small course. The average size of lecture, seminar and tutorial groups for the respective courses are as follows:-

Large Course –	Lectures	50	students
	Seminars	10	"
	Tutorials	2	"
Small Course	Lectures	30	students
	Seminars	5	"
	Tutorials	1	"

Thus, in each week the student on the large course will receive

$$\frac{6}{50} + \frac{3}{10} + \frac{1}{2} = 0.8 \text{ tutorial equivalent hours,}$$

whilst the student on the small course will receive

$$\frac{6}{30} + \frac{3}{5} + \frac{1}{1} = 1.8 \text{ tutorial equivalent hours.}$$

Thus, although the students attend similar numbers of lectures, seminars and tutorials, the more "efficient" nature of the larger course is reflected by the smaller "tutorial equivalent" hours given to each student.

In order to examine the relationship between "tutorial equivalent" hours per student, and course size, "tutorial equivalent" hours are calculated for students on laboratory-based courses, using annual teaching hours given to each course in the academic year 1969/70 and dividing these by the number of students on a course, present in the university during the year. This is shown in table 18.3

Table 18.3 : TUTORIAL EQUIVALENT HOURS PER STUDENT

Course	Weighted Number of students	Tutorial Equivalent hours per student
Pharmacy	230	26.96
Civil Engineering	193	data not available
Chemical Engineering	175	16.89
Electrical Engineering	154	43.8
Mechanical Engineering	147	42.43
Chemistry	122	23.52
Applied Biology	77	33.06
Textiles	64	56.38
Applied Physics	62	59.45
Optics	58	74.26
Material Science	53	58.17
Colour Chemistry	49	40.55

In Figure 18.3, the "tutorial equivalent" hours per student are plotted against weighted course size; the relationship is negative, with a correlation coefficient of $r^2 = 0.46$ - significant at the 5% level. It is seen that those courses whose teaching costs per student were shown in Figure 18.1 to be greater than expected, have a much higher "tutorial equivalence" than their size would suggest.

Thus as a measure of economy, "tutorial equivalence" lends weight to the analysis and to the evidence of economies of scale. "Tutorial equivalence" suffers from a drawback, in that a course that reduces the number of hours tuition received by its students will register a lower "tutorial equivalence" and thus will appear more economic of staff time. However, as there is no evidence to suggest that those students on larger courses receive fewer hours tuition than those students on smaller courses, we may regard a low measure of "tutorial equivalence" as resulting from a more economic utilisation of academic staff time and this appears largely dependent on course size. As with the economic use of academic staff time, economy in the use of technical staff will be dependent on such factors as the size of lecture groups and thus there is good reason to believe that technical staff use, if calculated in a similar manner to the above, would also reveal an increased economy as course size increases.

These findings substantiate those of Chapter 5. Here, by analysing the course structure, it was possible to hypothesise the way in which meetings increase as student numbers expand.[1] When expressed as a staff cost index, all courses showed an inverse relationship between cost per student and course size. The relationship however, was not linear, but a curve, asymptotic to both axes. It can be seen in Figure 18.4 that a similar curve fits the data for "tutorial equivalent". In fact, the fit appears more precise than the linear relationship of Figure 18.3.

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1. For methodology refer to Chapter 4 section (4).

Figure 18.3: THE RELATIONSHIP BETWEEN COURSE SIZE AND TUTORIAL EQUIVALENTS PER STUDENT

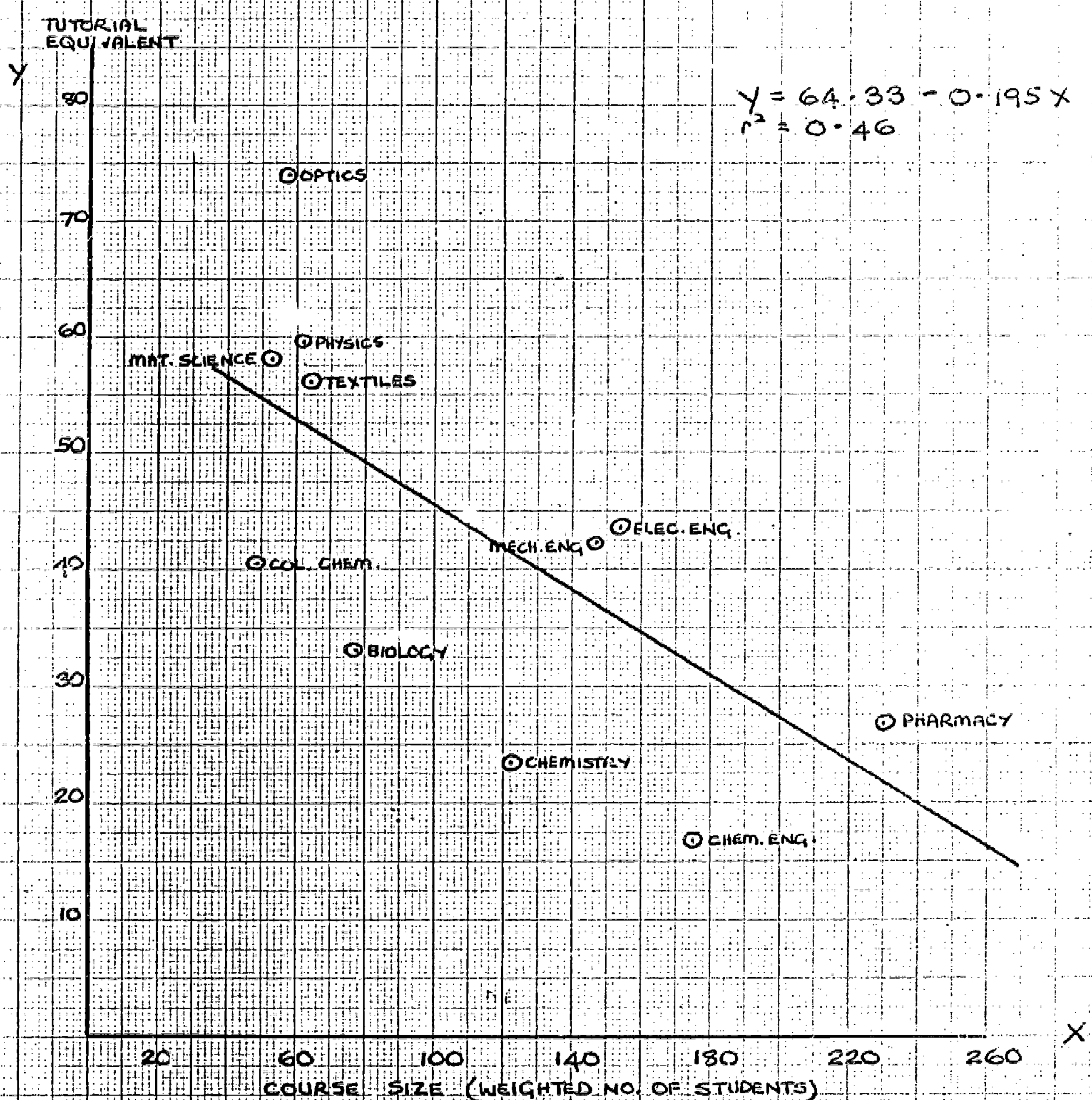
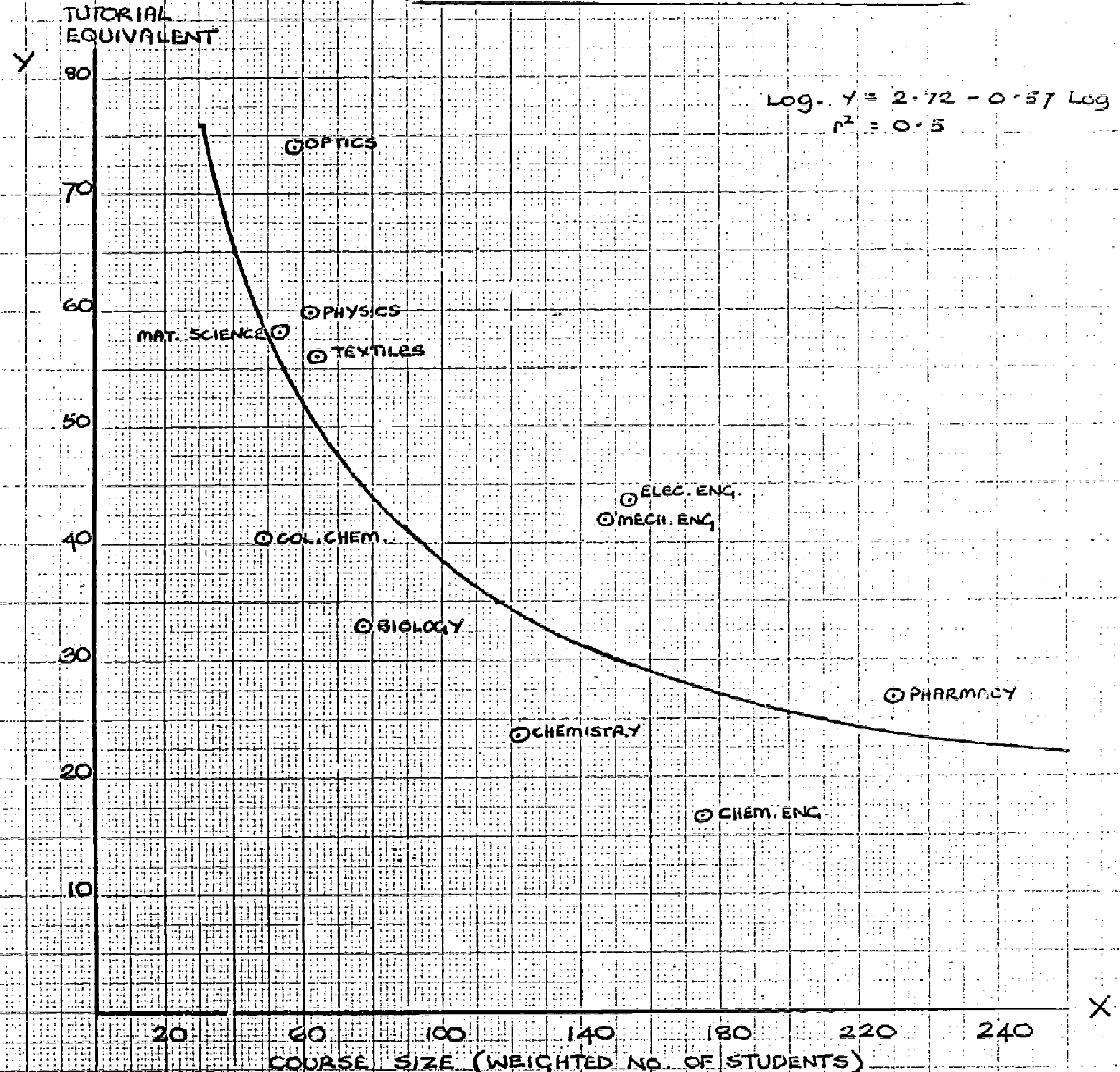


Figure 18.4: THE RELATIONSHIP BETWEEN COURSE SIZE AND TUTORIAL EQUIVALENTS PER STUDENT (WITH CURVILINEAR REGRESSION)



5. Implications for Expansion

The available evidence points in favour of some trend towards reduced costs per student as course size increases. In addition, these results are confirmed by the direct relationship between course size and the economic utilisation of staff time. In the context of university expansion, it is desirable from the cost viewpoint, for expansion to be carried out through increasing average course size, rather than increasing the number of courses. This consideration works against the establishment of further new universities and the diversification of existing ones. It makes for larger, more specialist universities and thus affects the nature of university life.

While a general trend towards a reduction of teaching cost per student has been discovered, as course size increases, it is by no means precise. However, using a variant of sensibility analysis, it is possible to give an idea of the possible cost implications arising from the establishment of universities with different average course sizes. From this some ideas may be obtained as to the merits of increasing course size at existing universities.

While the relationship between tutorial equivalents and course size appears to be the most precise, tutorial equivalents cannot easily be expressed in cost terms. However, as the academic staff cost per student of a course is to a large extent influenced by the tutorial equivalent of that course, it is useful to see how academic staff cost varies with course sizes.

In Figure 18.5, we see that academic staff cost per student varies with course size in much the same way as tutorial equivalent. Curve A represents the relationship between course size and academic staff cost per student, calculated using data for all the laboratory-based courses. However, as Electrical and Mechanical Engineering appear to be very much out of line with the general trend, curve B is calculated excluding these two courses.

Using these two relationships as a basis for prediction we illustrate in Table 18.4 the possible repercussions on the academic staff cost of a university comprising 3,000 students, of four different course sizes.

Table 18.4 : Relationship of Staff Costs and Course Size Mix

Relationship between course size and academic staff cost per student	Total academic staff cost of university of 3,000 students when this comprises			
	60 courses of 50 students each	30 courses of 100 students each	15 courses of 200 students each	10 courses of 300 students each
	£	£	£	£
A. Log Y = 3.299 - 0.213 Log X	2,595,000	2,238,000	1,932,000	1,770,000
B. Log Y = 3.52 - 0.34 Log X	2,613,000	2,076,000	1,650,000	1,437,000

The total academic staff cost decreases markedly as course size increases. Even with the least favourable projection 'A', the academic staff cost falls by 30% as the average course size increases from 50 to 300. With function 'B', academic staff cost falls by 45% for the same increase in course size.

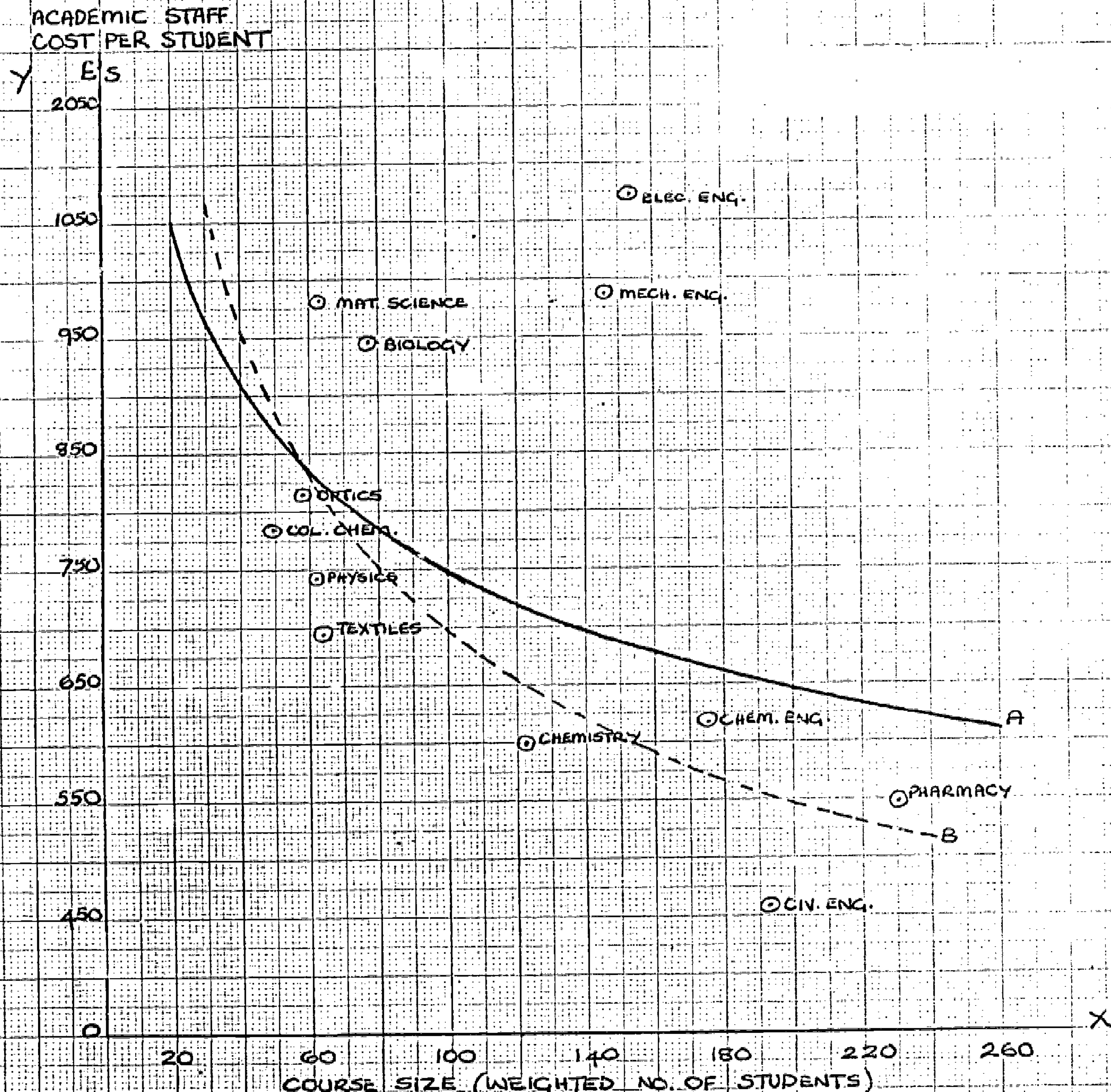
These projections show that potential economies from increasing course size are substantial. It must be noted however, that unless the universities take action to reduce staff:student ratio's as course size increases, these cost savings, as regards teaching undergraduates, will result in an increased cost attributable to research and other attentive demands on staff time.

6. Conclusion

The results of the statistical analysis point clearly towards a reduction of teaching cost per student as course size increases and to its carollary, an increase in the economic utilisation of academic staff resourses. These findings give empirical support to the analysis in Chapter 5 where it was deduced from the course structure of various courses, that teaching cost per student would decline as course size increased.

The relationship between academic staff cost per student and course size, is, as expected, not of a precise nature. However, by taking two possible relationships, it was seen that the possible savings resulting from an increase in course size are likely to be substantial.

Figure 18.5: THE RELATIONSHIP BETWEEN COURSE SIZE AND ACADEMIC STAFF COST PER STUDENT



KEY:

A: Represents the double logarithmic transformation least squares line for all the laboratory-based courses

B: Excludes the data for Mechanical and Electrical Engineering.

Regression Line A: $\text{Log } Y = 3.299 - 0.213 \text{ Log } X$
$r^2 = 0.21$

Regression Line B: $\text{Log } Y = 3.52 - 0.34 \text{ Log } X$
$r^2 = 0.7$

It was pointed out, however, that these economies, though definite as regards the teaching cost of undergraduates, may only represent a diversion of resources into the other outputs of a university. Unless universities reflect these economies by a progressive reduction of the staff:student ratio as course size increases there will be no reduction of costs to the university as a whole, though other activities such as research, may increase.

PART 9

CONCLUSION

CHAPTER 19

Summary of Principal Findings.

INTRODUCTION

1) The aim of this report is twofold:

(a) to measure the cost of teaching students in different courses, identifying the principal components of cost.

(b) to discover potential economies that might accrue under different circumstances; for instance, increased enrolment, revised teaching methods, greater utilisation of buildings and variations of planning norms.

2) The study uses data from the University of Bradford. Actual costs over the year 1969/70 are used in calculating the present costs of teaching students, In calculating costs in alternative situations, reference is made to actual expenditure since 1966 and to estimates for the quinquennium 1972/3 to 1976/7. In the main attention is limited to undergraduate courses.

3) The report is directed both to national educational authorities and to individual universities. On the one hand, it seeks to demonstrate to the Department of Education and Science and to the University Grants Committee, the areas in which economies are possible and their potential scale in relation to existing costs. It is hoped that it will be relevant at the time of determining global allocations to universities. On the other hand, it demonstrates to universities ways in which economies might be implemented. Although the exercise has been carried out in the context of the University of Bradford, the methods employed are of wider applicability.

4) Under the present system of British university financing and planning, universities know in advance, subject to certain specific exceptions, their income for a five-year period and the approximate number and type of students they will enrol. Cost-per-student for over the quinquennium has been determined before the students are enrolled. Once the quinquennium has begun there is no way to effect economies (since revenue and therefore expenditure have already been fixed) nor is there any incentive for universities to do so. The critical time to achieve economies is therefore before quinquennial recurrent grants are fixed and the power to do this lies with the University Grants Committee and the Department of Education and Science, not the individual universities. Thereafter universities must seek to react to such economies by implementing them as painlessly as possible

THE NATURE OF UNIVERSITY COSTS (Chapter 1.).

5) There is no single definition of "cost" in relation to the teaching of students. Two fundamental categories of the concept of cost must be distinguished:

(a) Cost in an "accounting" sense - an ex post allocation of costs that have already been sunk, to outputs that have been produced.

(b) Cost in a "planning" sense - an estimate of costs which are at present avoidable but which will be incurred if certain decisions are taken.

the figures put to these concepts may differ enormously. Only avoidable costs should be considered when decisions are being made. Conversely, it is incorrect to use avoidable costs alone as a measure of the resources devoted to producing output.

6) A further important distinction must be made between the financial cost of teaching students (whether to the university, the U.G.C. or the public sector) and the economic cost (to any of the above or to the national economy as a whole). This distinction is particularly important in the case of buildings and equipment. These should not be regarded as "free goods" once obtained, but their cost should be allocated to the students who use them over the lifetime of these assets. However, in taking decisions on future policy, if there is existing unused capacity in buildings or equipment, then it may correctly be regarded as having no cost. On the other hand, if additional space is required then it is the cost of providing that new space that is relevant.

THE PRESENT COST OF COURSES (Chapters 2 and 3)

7) In measuring this the "accounting" concept of cost is used in order to measure the resources that are being devoted to teaching students. An "economic" approach is used in that the cost of capital resources, such as buildings and equipment, are spread over the whole lifetime of the assets but the figures do not measure the true "opportunity cost", because the subjective nature of this concept causes major problems of measurement. "Output-budgeting" techniques are used to apportion the costs of resources over the different outputs (students on different courses, research, etc.) they contribute to producing.

8) In allocating the cost of resources to different programmes, the treatment of joint-costs has been a problem. These are the costs of resources, such as staff and teaching accommodation, that contribute to more than one programme. Thus any single member of academic staff may teach several courses and pursue research. In calculating economic cost per student these are distributed between courses and research in proportion to the time devoted to each activity. Although this achieves an equitable distribution of costs to different outputs, the figure consequently quoted as the "cost" of a student on a particular course reflects, not only the resources devoted to that course but also the joint use by other courses of those same resources and the time during which they were not used at all. Any change in the extent to which other courses use joint-resources, thus affects the cost of the course in question.

9) A method of calculating economic cost per student on different courses is described in chapter 2. Costs are divided into:-

(I) Capital and maintenance costs of buildings and teaching equipment.

(II) teaching costs, comprising salaries of teaching and technical staff and expenditure on teaching equipment and materials.

(III) administrative expenditures.

(IV) library expenditures.

(V) student facility, general educational and miscellaneous expenditures.

No allowance is made for the foregone earnings of students as we are not attempting to measure social opportunity cost, nor for student maintenance grants.

10) Capital and maintenance costs comprise the annual interest and amortisation payments imputed to buildings at 7% over 50 years and the annual cost of maintenance. The cost of teaching accommodation is divided first between teaching and research and then between different courses in proportion to its timetabled use for these purposes. The cost of unused room-hours is allocated in the same proportion.

11) The cost of academic staff (and their office space) is divided between the undergraduate-orientated and other activities on the basis of a "diary" completed by staff during 1968. That proportion of time devoted to undergraduate-orientated activities is divided between courses in proportion to the amount of formal teaching timetabled for each course. The effect of extracting the cost of the time not devoted to undergraduates, is to reduce academic staff costs by between 39% and 53%.

12) Detailed figures of present costs per student on different courses are given in chapter 3, and in Appendix 2. They are briefly summarised below. Since all the data relates to 1969/70, figures of cost-per-student on a particular course formally comprise the cost of one first-year, one second-year and one third-year and, where applicable, one fourth-year student on that course in 1969/70. The costs quoted do not include the cost of that proportion of the time of courses, such as teaching space and staff, that is devoted to other activities, such as research.

13) Total economic cost per student varies between approximately £2,500. and £4,000. for laboratory-based courses (Science and Engineering) and between approximately £1,650. and £2,400. for classroom-based courses (the Humanities and Mathematics). As one would expect, laboratory-based courses are more expensive than classroom-based courses; in fact they are about one-and-a-half times as costly. There is no cost difference between engineering courses and pure science courses as such. (Table 3.1)

14) Capital and maintenance costs vary between approximately £850 and £1,900 (27% - 49% of total cost) for laboratory-based courses and £550 - £900 (31% - 39% of total cost) for classroom-based courses. Teaching costs vary between £950 and £1,850 (34% - 55% of total cost) for laboratory-based courses and £400 - £750 (22% - 35% of total cost) for classroom-based courses. The residual cost, made up of administrative, library, student facility, general and miscellaneous expenditures, varies between approximately £500 and £800. per student. This represents 13% - 22% of total cost of laboratory-based courses, but as much as 28% - 42% of classroom-based courses. (Table 3.1)

15) Although in general laboratory-based courses are approximately twice as costly as classroom-based courses in both their capital and teaching costs, there are very substantial defferences between apparently similar courses.

16) It is possible broadly to divide costs into "overheads" and "direct". Direct costs are those that are directly attributable to a particular course and comprise:-

(1) Capital and maintenance costs of classrooms and teaching laboratories.

(2) academic staff expenditures

(3) technical staff expenditures

(4) departmental secretarial staff expenditures, plus capital costs of all departmental offices.

(5) teaching equipment costs and expenditures on teaching materials.

17) Direct costs form only 66% to 80% of student cost in laboratory-based courses and as little as 35% to 56% for classroom-based courses. Overhead costs thus represent a high proportion of the total cost per student. In absolute terms the relative costliness of laboratory-based courses is more marked in terms of direct costs than of total costs. Direct costs of classroom-based courses range from approximately £650 - £1,250 per student, whereas those of laboratory-based courses vary between £1,650 and £3,200 , approximately two and a half times as much. (Table 3.3).

18) In laboratory-based courses, direct costs average £2,424 per student, of which the capital and maintenance cost of laboratories and classrooms constitutes 37%, the cost of academic staff 31%, of technical staff 15%, of equipment and materials 12% and of secretarial staff and non-teaching rooms 5%. For classroom-based courses, direct cost is £1,030 , of which academic staff costs amount to 48%, capital and maintenance costs of teaching space, 22%, secretarial staff and non-teaching rooms 14%, equipment and materials 13% and technical staff 3%. Although academic staff cost is only one-third of laboratory-based courses as against one-half of the classroom-based courses, in absolute terms it is half as much again (£740 per student as against £500) (Table 3.4)

19) The high cost of laboratory space is noted. On individual laboratory-based courses this varies between £339 per student (11% of total cost) and £1,338 per student (35% of total cost). (Appendix 2)

20) Thin-sandwich courses taking two entries of students per year cost on average approximately £3,250 per student, whereas those taking only one entry per year cost £3,800 per student. Care should be taken in the interpretation put upon this comparision due to the relatively small numbers of courses in each group. It cannot be deduced that the difference in cost is due to the fact of the second intake; it could be that those courses that have two intakes happen to be inherently cheaper for other reasons. (Table 3.6).

21) We have correlated for each laboratory-based course the total number of hours of formal teaching given to the course divided by the number of students registered for the course against each of the following items:-

(1) academic staff cost per student

(2) teaching accommodation cost per student

(3) total direct cost per student

(4) area of teaching accommodation per student.

There is no systematic relation with any of these items. Not only does the total teaching load per registered student vary greatly between courses (from 17 to 74 hours per year) reflecting differences in the contact-hours each student receives and the number present at each teaching meeting, but the allocation of staff and teaching accommodation to schools of study to meet this also varies greatly. This implies considerable differences in average staff teaching-loads and in the degree of utilisation of teaching accommodation between schools of study. (Table 3.7).

<u>ACADEMIC STAFF REQUIREMENTS</u> (Chapters 4 to 7)

22) Conventionally the number of academic staff required in a department is calculated using a staff:student ratio. We describe an alternative method which uses the teaching commitment generated by courses as a measure of the number and cost of staff required for a course. This method is then used to calculate the effects on staff costs of increasing enrolment, changing the teaching structure of courses (in terms of the number and size of lectures, classes, tutorials and laboratory sessions) and increasing the teaching load of staff.

23) The analysis used detailed descriptions of the teaching structure of nine courses given by the University of Bradford. It is hampered by the absence of either a clearly defined working week for academic staff, or detailed knowledge of the actual hours of teaching given by staff in different Schools of study. These problems have been alleviated by some averaging of teaching loads found in a survey carried out in the University of Bradford in 1968 and by the use of a nominal teaching load that would be borne by staff if staff:student ratios in the University of Bradford were equal to the average ratio of all U.K. universities in the appropriate subjects.

24) The method adopted is to analyse the teaching structures of existing courses in terms of the number of hours of lectures, classes, tutorials, laboratory sessions and project supervision given to each student ("contact hours") and the maximum number of students that may be taught in any one meeting of each of the different types of meeting ("group size"). These group size maxima are determined by the relevant professors and represent a control on the standard of education. Using this analysis of a course in terms of contact hours and group sizes for each component, we have calculated the total number of hours teaching that must be provided at each level of enrolment, or with alternative course structures. Next, given a standard annual teaching load per member of staff, we have calculated the number of full time equivalent staff required to teach the course, and their cost. Certain economies associated with expansion and alternative teaching methods are identified.

25) In order to overcome the lack of definite data on teaching loads of staff and staff:student ratios for individual courses (as opposed to Schools of Study) a Staff Cost Index is defined. This measures the number of hours teaching provided, divided by the number of students enrolled on the course, and is an index of changes in staff cost per student and in staff:student ratio resulting from changes in enrolment and the teaching structure of courses. It is strongly recommended that consideration be given to using this concept of the Staff Cost Index as an alternative to that of a Staff:Student ratio in assessing staff requirements for particular courses. The index is defined as

$$SCI_p = \frac{M_p . S_q . 100}{M_q . S_p}$$

where q relates to the original enrolment and course structure and p is any particular changed situation (either a different enrolment or a revised course structure). M represents the total number of meetings to be provided and S the number of students enrolled.

EXPANSION OF ENROLMENT

26) Here we hold constant the contact hours received by each student, the group size maxima and the average teaching load of staff, and consider the effects on staff requirements and cost of expanding enrolment on nine courses separately. It is assumed that work ancillary to actual teaching, such as preparation and marking, increases in direct proportion to the number of teaching meetings, although in practice it is unlikely that preparatory work will increase to this extent. To this degree, the results tend to underestimate the potential economies.

27) Study of nine courses indicates substantial economies in staff costs per student as enrolment expands. The Staff Cost Index falls as enrolment increases indicating economies of scale. A given increase in enrolment generates a less than proportionate increase in the total number of teaching meetings required to maintain the course structure unchanged. With a constant staff teaching load, the increase in staff numbers is less than proportionate to the increase in students, enabling a "deterioration" in the staff:student ratio

and a fall in staff cost per student, without either impairing the quality of education through altering the course structure, or increasing the average teaching load of staff.

28) The fall in the Staff Cost Index as enrolment increases is punctuated by sharp rises at regular intervals. These periodic jumps give the Index a characteristic "saw-edge" shape, and the enrolment levels at which they occur correspond to the points at which particular series of meetings must be repeated. In many courses several different elements of the course have the same maximum group size, causing very big increases in the number of meetings at these points. Often enrolment must be expanded a considerable way beyond one of these jump-points before the Index falls back to its value immediately before the jump.

29) The points at which these jumps occur differ between courses. In the nine courses studied they varied between multiples of six students and multiples of 50. In considering expansion of numbers it is therefore essential that each course be studied individually to identify the optimum point to which to expand - i.e. to a level of enrolment corresponding to a trough between the peaks on the Index curve. Expansion to other levels could well result in a greater staff cost per student than the present one. Thus a strict doubling of numbers on all courses would result in much smaller economies than approximate doublings to carefully selected points where the Staff Cost Index is in a trough. In considering in chapter 14 specific proposals made by professors for the next quinquennium we have found some cases where the enrolment postulated is less economic (in terms of staff cost per student) than the present, although in many cases the expansion chosen represented a relatively optimum point.

30) Over the nine courses studied the Staff Cost Index falls to between 52% and 82% of its present value, when enrolment is approximately doubled to an optimum point. This implies that similar percentage reductions in the staff:student ratio and in academic staff cost per student will occur.
The weighted average Staff Cost Index for the nine courses is 69%. Thus if the sample of courses chosen is typical of all university courses, then the overall weighted staff:student ratio for all U.K. universities and all subject groups, which in 1968/69 was 1:11.57, could, in association with the postulated expansion, "deteriorate" to 1:16.71 without impairing teaching standards or increasing staff teaching load.

31) This saving in staff cost means that the economic cost per student (excluding costs attributable to research but including annual cost of buildings and equipment) would decline with a doubling of students by between 5.0% and 13.1% for individual courses. The weighted average saving for the nine courses studied is 7.7%. Such savings are wholly in recurrent expenditure.

32) The total annual financial savings in academic staff expenditure (the full cost of staff including that attributable to research) to be obtained by the postulated expansion, may usefully be measured by comparing the total staff cost that would be incurred if expansion were backed by a constant staff:student ratio, with the cost incurred by expansion maintaining a constant teaching load per member of staff

and allowing the staff:student ratio to "deteriorate". The total annual saving for the nine courses at the increased level of enrolment would be £240,000 , or £520 per student over the full length of the course. (Table 5.6)

33) The expansion of student numbers envisaged during the next quinquennium can be met by a worsening of the staff:student ratio. Consideration should be given by the Department of Education and Science and the University Grants Committee to the use of a teaching load basis of assessing universities' requirements for academic staff, rather than a constant staff:student ratio. We are aware of the possibility of professors intensifying teaching in order to obtain more staff but insofar as the expansion is of existing courses taught in the same way as at present, this danger does not arise. Expanding existing courses on a teaching load basis rather than a staff:student ratio basis is a major source of economy.

CHANGING THE TEACHING STRUCTURE OF COURSES.

34) Any changes in the total number of contact hours incorporated in a course causes a directly proportionate change in the number of meetings and in the full academic staff cost per student. A 20% reduction in total contact hours causes economic cost per student on eight different courses to fall by between 3.7% and 6.2%, or on average by 5.1%. This is a substantial saving and is mainly in recurrent expenditure. It will, however, have implications on the quality of education offered and may not, therefore, be academically acceptable.

35) The range of optional subjects available has a substantial effect on cost per student. Reduction of the range of options by two, causes savings of between 1% and 4.8% of total economic cost per student. Conversely an increase in the number of options increases costs (by 4.3% in one case). Consequently care should be taken to avoid proliferation of optional subjects wherever possible.

36) Increasing the maximum size of teaching groups has in most cases relatively little effect on economic cost per student. On one course a 60% increase in group size maxima reduces economic cost by 5.7% but on no other course was the reduction greater than 1.7%. However economic cost is more sensitive to a reduction in group sizes and a 40% reduction in the size of teaching groups causes increases in economic costs per student of between 8.0% and 12.0%.

37) The effect of altering the balance of different types of teaching meeting within the existing total contact hours, varies considerably between courses. The replacement of lectures by more classes and tutorials of the same size and in the same proportion as with the existing course structure causes economic cost per student to rise by between 1.2% and 48.5%, or on average by 13.0%. Replacement of classes by lectures and tutorials causes economic cost to increase by 0.4% and 36.1%, or on average by 9.9%. Replacement of tutorials by lectures and classes shows savings in economic cost of between 0.4% and 3.5%, an average saving of 2.7%

INCREASING STAFF TEACHING LOAD

38) Here the average teaching load of staff is increased to various levels in excess of the present average of 210 hours per year (280 in Social Sciences). Course structure in terms of contact hours and group sizes, is held constant. Substantial savings are possible but would impose great burden on academic staff. Thus on nine courses considered, a 25% increase in load at the present level of enrolment (to 265 hours per year, and to 350 in Social Sciences) would give a total saving of 27 staff, or £93,000 per annum. A 75% increase in teaching load would save 58 staff or £201,000 per annum.

39) If associated with an approximate doubling of enrolment to an optimum point on the Staff Cost Index curve, a 25% increase in teaching load, would save a total of 41 staff over the nine courses (compared with expansion maintaining the teaching load constant) or £142,000 per annum. (Table 7.7). A 50% increase in teaching load associated with an approximate doubling of intake, reduces the full academic staff cost per student by between 46% and 65% on different courses. (Table 7.8) Against such savings must be set the loss of research output that the non-appointed staff would have produced.

40) In terms of economic sosts, an increase in teaching load will not in itself achieve any saving, because staff must be compensated for their extra teaching. This can be done either by increasing their remuneration by the same proportion as their teaching load, or by correspondingly reducing their research activities. In the first case the extra financial expenditure will maintain cost per student at the same level; in the second case the proportion of time devoted to the course as opposed to other activities (and therefore the proportion of staff cost allocated to the course) will increase, and maintain cost per student at the same level. Only if duties ancillary to actual teaching, such as preparation and marking, increase less than proportionately to the hours of teaching, will an increase in teaching load cause any reduction in economic cost per student.

41) If teaching load is increased at the expense of research activity there will be financial savings but no reduction in economic cost per student. Output-budgeting techniques highlight the transfer of resources from research to teaching. The actual resource-hours used for teaching each student do not fall. Insofar as the priority is to increase undergraduate numbers without equally increasing expenditure, then the loss of research effort may well be an acceptable price. There is no prima facie reason why because the output of graduates is to be doubled, research activity should also be doubled, yet the maintenance of a constant teaching load through a period of expansion, provides the resources necessary for this. Furthermore, keeping a constant staff:student ratio allows teaching load to fall, thus <u>increasing</u> the proportion of staff time available for research. The D.E.S. must answer the vital question of whether the nation, for every £1,000 spent on additional staff to teach the extra students it wants, also wants to spend a further £1,000 on research.

UTILISATION OF TEACHING ACCOMMODATION (Chapters 8 to 11).

42) General purpose teaching accommodation (lecture theatres, classrooms and drawing offices) are used on average only 19 hours per week. Out of a total of 3264 room-hours available in a standard teaching week of 32 hours, only 1915 (58.7%) are actually used. Even allowing for the practical timetabling problems, this appears to be a low level of utilisation. (Tables 8.1 and 8.2). Furthermore in most schools of study teaching continues for only 33 weeks of the year, although in some it is carried out for 42 weeks.

43) The eight drawing offices in the university are used for only 23% of the time. Otherwise there is no significant difference in utilisation between rooms of different types and sizes or in different buildings. (Table 8.2).

44) It has been difficult to obtain data on the utilisation of teaching laboratories as they are not timetabled centrally. In five schools of study for which data was obtained, the average utilisation was 41%. It is frequently asserted that because of the need to prepare experiments and the long time period over which some of them run, it is impossible to utilise laboratories more fully than at present. Against this, it must be noted that laboratories are highly expensive to construct, service and maintain. It is desirable, therefore, that they be used intensively to spread the cost over as many students as possible. (Table 8.3).

45) It has not proved possible to devise a measure of the "capacity" of laboratories, in the way that the number of seats measures the capacity of a lecture room. This is because in different years of different courses students may work alone, in pairs or in small groups. For this reason, and for that given in the previous paragraph, it is at present impossible to judge whether or not laboratories in different subjects are being used efficiently. Since the cost per student of laboratory space is so great, further research into the factors affecting its use, and the areas required in different subjects, would be invaluable. Comparative studies of particular subjects in several universities would be an essential element of such an investigation.

46) The university already has considerably more general purpose teaching space and laboratory space than its theoretical entitlement under existing U.G.C. norms with current student numbers. Taken with the low levels of utilisation found in practice, this throws doubt on the validity of some of the U.G.C. norms relating to teaching space. Indeed it questions the validity of the whole concept of norms relating space directly to student numbers. Space requirements (in terms of square foot-hours) can be calculated from the teaching structure of courses. It would therefore be possible to require individual universities and departments to justify their teaching accommodation requirements in terms of the teaching they will provide, instead of simply on the number of students.

47) At a time of expansion, economies can be obtained in cost per student by teaching the additional students in existing buildings, thus spreading the same total capital and maintenance cost more widely. The savings are realised through avoiding the capital cost of a new building and its associated maintenance costs. The maintenance cost of existing buildings will show little if any increase, even though more students are using them.

48) In the case of one school of study at present with the exclusive use of its own building, enrolment could be trebled without teaching accommodation exceeding 70% utilisation in the existing 32 hour week. The effect of this is to reduce the total economic cost per student by 16% (Table 9.3).

49) In five other schools of study we have calculated the number of students who could be taught using existing laboratories for 80% of a 32 hour week. This would require some additional classrooms if one assumes that other schools of study in the university are also expanding at the same rate. There would be sufficient rooms of under 20 seats and the demand for rooms between 20 and 80 seats could be met by a small amount of use outside the present range of 32 hours. It would, however, be necessary to construct new rooms of more than 80 seats. Assuming that the additional space is provided at the present cost per square foot and that all other items of cost increase pro-rata with the number of students, then the total cost per student will be reduced by between 7% and 19% (Table 9.10)

50) The 32 hour standard teaching week is not immutable. We have postulated successive extensions of it to 40, 50 and 60 hours per week. This does not mean that staff work longer hours, but that their formal teaching is spread over a longer period and laboratories and classrooms are in use for more hours per week. For each length of week we have calculated the number of students that could be taught in existing laboratories, the additional classroom requirements and the revised cost-per-student, assuming pro-rata increases in all other items of cost. At 80% utilisation of laboratories over a 60 hour week, the total economic cost-per-student is reduced by between 10% and 24%. (Table 10.4).

51) There would be practical problems in increasing the degree of utilisation and extending the length of the teaching week, such as timetabling difficulties and the need to induce staff to work outside the conventional hours. However the potential savings in cost per student and the high cost of new buildings, particularly laboratories, provide a major incentive substantially to increase the number of students using existing teaching accommodation. Further research is required into the organisation of teaching timetables and into the advantages and problems of extending the teaching week. With potential savings of 10% to 24% of existing unit costs, there is scope for adequate financial inducement to academic staff to teach outside conventional hours, and to increase technical staff establishment more than pro-rata with the increase in students in order to facilitate more intensive utilisation of laboratories.

52) At present most university teaching accommodation is in use for only 33 weeks of the year. We postulate an alternative arrangement of the academic year which involves using teaching accommodation for 45 weeks of the year and 44 hours per week. This permits two intakes of students per year, each of the same size as the present one, without extending the number of years required for a student to graduate. Doubling the throughput of students halves the cost per student of laboratories and classrooms. It is assumed that the number of academic staff will be doubled, thus maintaining the present staff:student ratio and teaching loads. It is recognised that there are many problems to any such re-arrangement of the academic year but it is emphasised that three undergraduate courses at the University of Bradford already have two intakes per year and several others overlap the second and third years of the course in a similar manner.

53) Alternative calculations of cost per student have been made. Under a pessimistic set of assumptions all costs, other than those of teaching accommodation are doubled, i.e. their cost per student is unchanged. This gives reductions in cost per student of 7% to 12% for laboratory-based courses and 4% to 7% for classroom-based courses. Under an optimistic set of assumptions (no increase in library and student social facility space and only 50% increases in technical staff expenditure and equipment and materials costs), cost per student falls between 18% and 24% for laboratory-based courses and 15% and 19% for classroom-based courses. (Table 10.5). Savings of this order justify further detailed investigation in individual universities of the scope for operating a double entry system.

54) When new buildings do become necessary, economies may be achieved in two ways - by reducing the original capital cost of the building and by matching the time of the construction of new buildings more closely with the growth of student numbers. There is limited scope for reduction of the original cost without severely impairing essential facilities. Even if a saving of 10% could be made in the capital cost of buildings and non-teaching equipment, the reduction in economic cost per student would be between only 1.7% and 3.1% of the present cost of different courses. Such savings are very small compared with those possible through expansion of student numbers to achieve greater utilisation of existing buildings. (Table 11.1).

55) There is scope for some economy by timing the introduction of new buildings to match more closely the growth of student numbers. It is difficult to avoid some under-utilisation in the first two or three years until the increased intakes have worked through to all years of the course. In practice this initial under-utilisation is aggravated by a stategy of gradual expansion of intake over the whole quinquennium. The use of pre-fabricated and easily extendable buildings could be useful but would not be applicable to laboratories. There is also a case during a time of expansion for a pool of rented accommodation on short lease, where available, suitable for general purpose teaching accommodation and offices. This could be transferred between departments as required and disposed of when no longer needed.

There is also a strong case for delaying new construction and deliberately overcrowding existing buildings temporarily (or temporarily extending the length of the teaching week) until there are sufficient students to achieve a reasonable level of utilisation in the new building.

TECHNICAL STAFF REQUIREMENTS (Chapter 12)

56) Technical staff are supposedly allocated to departments in accordance with norms relating their numbers to the number of academic staff. In practice wide variations from the normative numbers are observed in most departments. Even with a weighting for different grades of technical staff, there are still considerable differences from the norms. (Tables 12.1, 12.2).

57) No consistent relationship is found between technical staff numbers and student numbers (whether postgraduates are weighted or not) in different departments. The full financial cost of technical staff per weighted registered student varies substantially. For laboratory-based courses it ranged from £66 per student to £155 per student. (Table 12.4).

58) The number of technical staff is not consistently related to the number of hours of laboratory teaching given by departments.

59) A very close correlation (0.9537, significant to 1%) is found between technical staff, weighted according to grade, and laboratory area, when research laboratories are weighted 3 (in accordance with standard U.G.C. weighting of science postgraduates). The formula derived suggests that, on average, departments at the University of Bradford require one technical staff for each 1,600 sq. feet of teaching laboratory or for each 540 sq. feet of research laboratory. (Tables 12.5, 12.6).

60) Since research laboratories are more intensive in their use of technical staff, potential economies exist in increasing the proportion of teaching to research laboratories. Economies may also be obtained by increasing the area of laboratory space serviced by each technician. Provided there is under-utilised capacity of either teaching or research laboratories, it is likely that expansion of undergraduate numbers will not require additional technical staff. Further research into the workload of technical staff and its relationship to the degree of utilisation of laboratories would be valuable.

COSTING OF ACADEMIC DEVELOPMENT PROPOSALS (Chapters 13 and 14)

61. Studies have been made of a number of proposals made to the Academic Planning Committee for the expansion of existing courses during the next quinquennium. The incremental costs of these proposals were calculated on the basis of professors' own estimates of resource requirements for the expansion, which were not made with any deliberate aim of reducing costs.

62) A common factor in all these costings is that economies of scale arise through fuller utilisation of existing capacity. Overall an increase of 66% in the number of students on the six courses considered, can be met with an increase in total cost of only 14%. Average cost per student falls by between 15% and 71%: the average fall for the expansion proposals, weighted by student numbers, is 31%.

63) There is some evidence, though not conclusive because of the relatively small number of cases, that the greater the rate of increase in student numbers on any particular course, the greater will be the rate of fall in average cost.

64) The reductions in average cost result from the small size of incremental cost - zero for one course and varying up to £385 per student-year on others. Incremental cost broadly reflects the current degree of excess capacity of specialised resources within the relevant school of study. This degree of excess capacity is largely the result of past decisions on resource allocation. Thus a school of study which has been well provided for in the past and now has considerable excess capacity will be able to expand at little extra cost, whereas schools which have been only modestly provided for and are now operating at or near full capacity, will be costly to expand.

65) Further economies can be achieved by limiting the extra resources asked for. In most cases, additional academic staff formed the largest element in the incremental cost, and reduction of the marginal staff:student ratio (which in practice has a much smaller effect on the average staff:student ratio) results in considerable reductions in incremental costs.

<u>UNIVERSITY PLANNING MODELS</u> (Chapters 15 to 17)

66) Chapter 15 considers the potential role of computered models in university planning and the various forms these models take. The possibility of using one of these existing models to assist planning within the University of Bradford is rejected on the grounds that models are all based on the characteristics of particular institutions and are either too trivial to be of real use, or require such an enormous data base as to be impracticable without a computer-based management information system.

67) In chapter 16, two models, specially designed for use at the University of Bradford are described. One is a static model and the other a dynamic model relating to a quinquennial planning period. In each case it is possible to vary both absolute values of inputs, e.g. staff numbers, space, prices, etc. and the relationships between these factors, e.g. staff:student ratio, space per staff member, etc. It is thus possible to calculate staff and space requirements and costs for a number of alternative sizes and patterns of student population, under varying values of planning norms.

68) Chapter 17 contains prelinary results of using these models, demonstrating:-

(a) their use in calculating additional resource requirements for expansions of courses and introduction of new courses, retaining current values of norms,

(b) their use to trace the consequences of varying the norms.

It is hoped to continue this line of research in the future and to assess the practical use to which such models might be put in British universities.

EXISTING ECONOMIES OF SCALE (Chapter 18).

69) A cross-sectional study of the economic costs of all undergraduate courses in 1969/70 suggests that economies of scale do exist. In interpreting the results it must be remembered that some courses may by their nature be cheaper than others, regardless of size. The method of calculating economic cost per student (especially the capital cost and central university expenditures) makes it impossible to relate total economic cost to course size. Consequently the analysis is restricted to teaching cost per student.

70) Over all the undergraduate courses there is a negative relationship between teaching cost per student and course size but it is a weak one. If laboratory-based courses alone are considered, there is a much closer correlation, with three courses deviating substantially. There are special reasons for expecting these three courses to deviate and without them the correlation strengthens further.

71) The cost per student of teaching materials and equipment is not closely related to course size and if only academic and technical staff costs are included, the relation to course size becomes highly significant. These findings strengthen those of chapter 5 where it is asserted that expansion of existing courses could be accompanied by a worsening of the staff:student ratio and a fall in staff cost per student.

CONCLUSION

72) We are anxious to make the results of our research as widely available as possible and to ensure that it is of practical use in universities both in Britain and overseas. Anyone wishing to pursue the matter is invited to contact us at the Project Planning Centre of the University of Bradford.

APPENDICES

APPENDIX 1.

Computer program, specifications, listings and operating instructions

These will shortly be available and will be obtainable from the Project Planning Centre, University of Bradford.

APPENDIX 2

COSTS OF UNDERGRADUATE COURSES 1969-70

Board of Study: ENGINEERING Course: CHEMICAL ENGINEERING

TABLE 1

Item of Expenditure	1st Year Total Cost	1st Year Per Student	2nd Year Total Cost	2nd Year Per Student	3rd Year Total Cost	3rd Year Per Student	4th Year Total Cost	4th Year Per Student	Total Total Cost	Total Per Student	% of Total Cost
Number of Students	95		92		86		76				
1. Capital & Maintenance Costs											
a. Classrooms	5700	60	1840	20	1720	20	1520	20	10780	120	4.78
b. Teaching Laboratories	10925	115	10580	115	9890	115	8740	115	40135	460	17.79
c. Academic Staff Offices	1235	13	1196	13	1118	13	988	13	4537	52	2.01
d. Administrative Staff Offices	380	4	368	4	344	4	304	4	1396	16	0.62
e. Study Facility Space	1520	16	1472	16	1376	16	1216	16	5584	64	2.48
f. Student Facility Space	4560	48	4416	48	4128	48	3648	48	16752	192	7.43
g. Staff Facility Space	95	1	92	1	86	1	76	1	349	4	0.14
SUB-TOTAL	24415	257	19964	217	18662	217	16492	217	79533	908	35.27
2. Teaching Costs											
a. Academic Staff Salaries	23940	252	15364	167	13588	158	3040	40	55932	617	24.79
b. Technical Staff Salaries	4345	51	4692	51	4386	51	3876	51	17799	204	7.89
c. Expenditure on Teaching Equipment & Materials	6365	67	6164	67	5762	67	5092	67	23383	268	10.37
SUB-TOTAL	35150	370	26220	285	23736	276	12008	158	97114	1089	43.06
3. Administrative Expenditures											
a. Central University Expenditure	8265	87	8004	87	7482	87	6612	87	30363	348	13.46
b. School Expenditure	1710	18	1656	18	1548	18	1368	18	6282	72	2.78
SUB-TOTAL	9975	105	9660	105	9030	105	7980	105	36645	420	16.25
4. Library Expenditures	1425	15	1380	15	1290	15	1140	15	5235	60	2.32
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	1900	20	1840	20	1720	20	1520	20	6980	80	3.09
TOTAL COST	72865	767	59064	642	54438	633	39140	515	225507	2557	100.00

Board of Study: ENGINEERING   Course: CIVIL ENGINEERING   TABLE 2

	1st Year		2nd Year		3rd Year		4th Year		Total		
Number of Students	73		63		57		64				% of Total Cost
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	4380	60	2394	38			3392	53	10166	151	6.11
b. Teaching Laboratories	11242	154	9702	154			9856	154	30800	462	18.50
c. Academic Staff Offices	1387	19	1197	19			1216	19	3800	57	2.28
d. Administrative Staff Offices	292	4	252	4	228	4	256	4	1028	16	0.61
e. Study Facility Space	1168	16	1008	16			1024	16	3200	48	1.92
f. Student Facility Space	7008	96	6048	96			6144	96	19200	288	11.54
g. Staff Facility Space	146	2	126	2	114	2	128	2	514	8	0.30
SUB-TOTAL	25623	351	20727	329	342	6	22016	344	68708	1030	41.30
2. Teaching Costs											
a. Academic Staff Salaries	12337	169	9639	153	1596	28	6912	108	30484	458	18.32
b. Technical Staff Salaries	5840	80	5040	80			5120	80	16000	240	9.61
c. Expenditure on Teaching Equipment & Materials	6278	86	5418	86			5504	86	17200	258	10.33
SUB-TOTAL	24455	335	20097	319	1596	28	17536	274	63684	956	38.28
3. Administrative Expenditures											
a. Central University Expenditure	6351	87	5481	87	4959	87	5568	87	22359	348	13.44
b. School Expenditure	511	7	441	7	399	7	448	7	1799	28	1.08
SUB-TOTAL	6862	94	5922	94	5358	94	6016	94	24158	376	14.52
4. Library Expenditures	730	10	630	10			640	10	2000	30	1.20
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	2847	39	2457	39			2496	39	7800	117	4.68
TOTAL COST	60517	829	49833	791	7296	128	48704	761	166350	2509	100.00

Board of Study: ENGINEERING Course: ELECTRICAL ENGINEERING

TABLE 3

Number of Students	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
	67		61		65		54				
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	2144	32	1647	27	1820	28	2106	39	7717	126	3.50
b. Teaching Laboratories	12663	189	11529	189	12285	189	10206	189	46683	756	21.21
c. Academic Staff Offices	1005	15	915	15	975	15	810	15	3705	60	1.68
d. Administrative Staff Offices	268	4	244	4	260	4	216	4	988	16	0.44
e. Study Facility Space	1072	16	976	16	1040	16	864	16	3952	64	1.79
f. Student Facility Space	3216	48	2928	48	3120	48	5184	96	14448	240	6.56
g. Staff Facility Space	268	4	244	4	260	4	216	4	988	16	0.44
SUB-TOTAL	20636	308	18483	303	19760	304	19602	363	78481	1278	35.65
2. Teaching Costs											
a. Academic Staff Salaries	9045	135	16775	275	15795	243	22680	420	64295	1073	29.21
b. Technical Staff Salaries	5896	88	5368	88	5720	88	4752	88	21736	352	9.87
c. Expenditure on Teaching Equipment and Materials	5762	86	5246	86	5590	86	4644	86	21242	344	9.65
SUB-TOTAL	20703	309	27389	449	27105	417	32076	594	107273	1769	48.74
3. Administrative Expenditures											
a. Central University Expenditure	5829	87	5307	87	5655	87	4698	87	21489	348	9.76
b. School Expenditure	1139	17	1037	17	1105	17	918	17	4199	68	1.90
SUB-TOTAL	6968	104	6344	104	6760	104	5616	104	25688	416	11.67
4. Library Expenditures	1005	15	915	15	975	15	810	15	3705	60	1.68
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	1340	20	1220	20	1300	20	1080	20	4940	80	2.24
TOTAL COST	50652	756	54351	891	55900	860	59184	1096	220087	3603	100.00

Board of Study: ENGINEERING   Course: INDUSTRIAL TECHNOLOGY AND MANAGEMENT   TABLE 4

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	21		9								
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	651	31							651	31	2.07
b. Teaching Laboratories	7035	335							7035	335	22.43
c. Academic Staff Offices	378	18	162	18					540	36	1.72
d. Administrative Staff Offices	84	4							84	4	0.26
e. Study Facility Space	336	16							336	16	1.07
f. Student Facility Space	2016	96							2016	96	6.42
g. Staff Facility Space	231	11	99	11					330	22	1.05
SUB-TOTAL	10731	511	261	29					10992	540	33.05
2. Teaching Costs											
a. Academic Staff Salaries	10038	478	2646	294					12684	772	40.45
b. Technical Staff Salaries	1764	84							1764	84	5.62
c. Expenditure on Teaching Equipment & Materials	882	42							882	42	2.81
SUB-TOTAL	12684	604	2646	294					15330	898	48.89
3. Administrative Expenditures											
a. Central University Expenditure	1827	87	783	87					2610	174	8.32
b. School Expenditure	756	36	324	36					1080	72	3.44
SUB-TOTAL	2583	123	1107	123					3690	246	11.76
4. Library Expenditures	525	25							525	25	1.67
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	819	39							819	39	2.61
TOTAL COST	27342	1302	4014	446					31356	1748	100.00

Board of Study: ENGINEERING

Course: MECHANICAL ENGINEERING

TABLE 5

Item of Expenditure	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
	68		56		56		55				
	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	2108	31	1792	32	2576	46	2805	51	9281	160	3.98
b. Teaching Laboratories	20876	307	17192	307	17192	307	16885	307	72145	1228	30.97
c. Academic Staff Offices	816	12	672	12	672	12	660	12	2820	48	1.21
d. Administrative Staff Offices	272	4	224	4	224	4	220	4	940	16	0.40
e. Study Facility Space	1088	16	896	16	896	16	880	16	3760	64	1.61
f. Student Facility Space	3264	48	2688	48	2688	48	5280	96	13920	240	5.97
g. Staff Facility Space	204	3	168	3	168	3	165	3	705	12	0.30
SUB-TOTAL	28628	421	23632	422	24416	436	26895	489	103571	1768	44.46
2. Teaching Costs											
a. Academic Staff Salaries	9928	146	16296	291	15400	275	15125	275	56749	987	24.36
b. Technical Staff Salaries	7684	113	6328	113	6328	113	6215	113	26555	452	11.40
c. Expenditure on Teaching Equipment & Materials	4080	60	3360	60	3360	60	3300	60	14100	240	6.05
SUB-TOTAL	21692	319	25984	464	25088	448	24640	448	97404	1679	41.81
3. Administrative Expenditures											
a. Central University Expenditure	5916	87	4872	87	4872	87	4785	87	20445	348	8.77
b. School Expenditure	1020	15	840	15	840	15	825	15	3525	60	1.51
SUB-TOTAL	6936	102	5712	102	5712	102	5610	102	23970	408	10.29
4. Library Expenditures	952	14	784	14	784	14	770	14	3290	56	1.41
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	1360	20	1120	20	1120	20	1100	20	4700	80	2.01
TOTAL COST	59568	876	57232	1022	57120	1020	59015	1073	232935	3991	100.00

Board of Studies: LIFE SCIENCES Course: APPLIED BIOLOGY

TABLE 6

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	29		26		26		22				
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	957	33	546	21			506	23	2009	77	2.52
b. Teaching Laboratories	3277	113	2938	113			2486	113	8701	339	10.95
c. Academic Staff Offices	551	19	494	19			418	19	1463	57	1.84
d. Administrative Staff Offices	116	4	104	4	104	4	88	4	412	16	0.51
e. Study Facility Space	464	16	416	16			352	16	1232	48	1.55
f. Student Facility Space	2784	96	2496	96			2112	96	7392	288	9.30
g. Staff Facility Space	174	6	156	6	156	6	132	6	618	24	0.77
SUB-TOTAL	8323	287	7150	275	260	10	6094	277	21827	849	27.47
2. Teaching Costs											
a. Academic Staff Salaries	7105	245	7462	287	1066	41	8206	373	23839	946	30.00
b. Technical Staff Salaries	3277	113	2938	113			2486	113	8701	339	10.95
c. Expenditure on Teaching Equipment & Materials	3422	118	3068	118			2596	118	9086	354	11.43
SUB-TOTAL	13804	476	13468	518	1066	41	13288	604	41626	1639	52.39
3. Administrative Expenditures											
a. Central University Expenditure	2523	87	2262	87	2262	87	1914	87	8961	348	11.27
b. School Expenditure	464	16	416	16	416	16	352	16	1648	64	2.07
SUB-TOTAL	2987	103	2678	103	2678	103	2266	103	10609	412	13.35
4. Library Expenditures	899	31	806	31			682	31	2387	93	3.00
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditure	1131	39	1014	39			858	39	3003	117	3.77
TOTAL COST	27144	936	25116	966	4004	154	23188	1054	79452	3110	100.00

Board of Study: LIFE SCIENCES Course: PHARMACY (including PHARMACOLOGY) TABLE 7

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	93		78		59						
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	2976	32	1482	19	1770	30			6228	81	2.49
b. Teaching Laboratories	29295	315	24570	315	18585	315			72450	945	28.98
c. Academic Staff Offices	1767	19	1482	19	1121	19			4370	57	1.75
d. Administrative Staff Offices	372	4	312	4	236	4			920	12	0.37
e. Study Facility Space	1488	16	1248	16	944	16			3680	48	1.47
f. Student Facility Space	8928	96	7488	96	5664	96			22080	288	8.83
g. Staff Facility Space	465	5	390	5	295	5			1150	15	0.46
SUB-TOTAL	45291	487	36972	474	28615	485			110878	1446	44.34
2. Teaching Costs											
a. Academic Staff Salaries	11253	121	13572	174	14986	254			39811	549	16.00
b. Technical Staff Salaries	14694	158	12324	158	9322	158			36340	474	14.54
c. Expenditure on Teaching Equipment & Materials	9486	102	7956	102	6018	102			23460	306	9.39
SUB-TOTAL	35433	381	33852	434	30326	514			99611	1329	39.84
3. Administrative Expenditures											
a. Central University Expenditure	8091	87	6786	87	5133	87			20010	261	8.00
b. School Expenditure	1302	14	1092	14	826	14			3220	42	1.29
SUB-TOTAL	9393	101	7878	101	5959	101			23230	303	9.29
4. Library Expenditures	3069	33	2574	33	1947	33			7590	99	3.03
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditure	3627	39	3042	39	2301	39			8970	117	3.50
TOTAL COST	96813	1041	84318	1081	69148	1172			250279	3294	100.00

Board of Study: PHYSICAL SCIENCES Course: CHEMISTRY

TABLE 8

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	47		41		36		38				
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	1269	27	779	29	396	11	3002	79	5446	146	3.39
b. Teaching Laboratories	20962	446	18286	446			16948	446	56196	1338	34.98
c. Academic Staff Offices	987	21	861	21			798	21	2646	63	1.65
d. Administrative Staff Offices	188	4	164	4	144	4	152	4	648	16	0.40
e. Study Facility Space	752	16	656	16			608	16	2016	48	1.25
f. Student Facility Space	4512	96	3936	96			3648	96	12096	288	7.52
g. Staff Facility Space	188	4	164	4	144	4	152	4	648	16	0.40
SUB-TOTAL	28858	614	24846	616	684	19	25308	666	79 ,96	1915	49.59
2. Teaching Costs											
a. Academic Staff Salaries	6157	131	9635	235	1296	36	7524	198	24612	600	15.31
b. Technical Staff Salaries	6768	144	5904	144			5472	144	18144	432	11.29
c. Expenditure on Teaching Equipment & Materials	4700	100	4100	100			3800	100	12600	300	7.84
SUB-TOTAL	17625	375	19639	479	1296	36	16796	442	55356	1332	34.45
3. Administrative Expenditures											
a. Central University Expenditure	4089	87	3567	87	3132	87	3306	87	14094	348	8.76
b. School Expenditure	1269	27	1107	27	972	27	1026	27	4374	108	2.72
SUB-TOTAL	5358	114	4674	114	4104	114	4332	114	18468	456	11.49
4. Library Expenditure	846	18	738	18			684	18	2268	54	1.41
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	1833	39	1599	39			1482	39	4914	117	3.06
TOTAL COST	54520	1160	51496	1266	6084	169	48602	1279	160702	3874	100.00

Board of Study: PHYSICAL SCIENCES Course: COLOUR CHEMISTRY and COLOUR TECHNOLOGY TABLE 9

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	24		21		20						
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	1560	65	693	33	580	29			2833	127	3.33
b. Teaching Laboratories	10704	446	9366	446	8920	446			28990	1338	34.11
c. Academic Staff Offices	504	21	441	21	420	21			1365	63	1.61
d. Administrative Staff Offices	96	4	84	4	80	4			260	12	0.31
e. Study Facility Space	384	16	336	16	320	16			1040	48	1.22
f. Student Facility Space	2304	96	2016	96	1920	96			6240	288	7.34
g. Staff Facility Space	96	4	84	4	80	4			260	12	0.31
SUB-TOTAL	15648	652	13020	620	12320	616			40988	1888	48.22
2. Teaching Costs											
a. Academic Staff Salaries	7416	309	3885	185	5820	291			17121	785	20.14
b. Technical Staff Salaries	3456	144	3024	144	2880	144			9360	432	11.01
c. Expenditure on Teaching Equipment & Materials	2400	100	2100	100	2000	100			6500	300	7.65
SUB-TOTAL	13272	553	9009	429	10700	535			32981	1517	38.80
3. Administrative Expenditures											
a. Central University Expenditure	2088	87	1827	87	1740	87			5655	261	6.65
b. School Expenditure	648	27	567	27	540	27			1755	81	2.06
SUB-TOTAL	2736	114	2394	114	2280	114			7410	342	8.72
4. Library Expenditures	432	18	378	18	360	18			1170	54	1.38
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	936	39	819	39	780	39			2535	117	3.00
TOTAL COST	33024	1376	25620	1220	26440	1322			85084	3918	100.00

Board of Study: PHYSICAL SCIENCES Course: MATERIALS SCIENCE AND TECHNOLOGY TABLE 10

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	27		11		15		17				
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	540	20	770	70	675	45	527	31	2512	166	4.02
b. Teaching Laboratories	3051	113	1243	113	1695	113	1921	113	7910	452	12.67
c. Academic Staff Offices	270	10	110	10	150	10	170	10	700	40	1.12
d. Administrative Staff Offices	108	4	44	4	60	4	68	4	280	16	0.44
e. Study Facility Space	432	16	176	16	240	16	272	16	1120	64	1.79
f. Student Facility Space	2592	96	1056	96	1440	96	1632	96	6720	384	10.76
g. Staff Facility Space	81	3	33	3	45	3	51	3	210	12	0.33
SUB-TOTAL	7074	262	3432	312	4305	287	4641	273	19452	1134	31.13
2. Teaching Costs											
a. Academic Staff Salaries	3159	117	3036	276	4545	303	4862	286	15602	982	24.99
b. Technical Staff Salaries	3186	118	1298	118	1770	118	2006	118	8260	472	13.23
c. Expenditure on Teaching Equipment & Materials	2835	105	1155	105	1575	105	1785	105	7350	420	11.77
SUB-TOTAL	9180	340	5489	499	7890	526	8653	509	31212	1874	50.00
3. Administrative Expenditures											
a. Central University Expenditure	2349	87	957	87	1305	87	1479	87	6090	348	9.75
b. School Expenditure	756	28	308	28	420	28	476	28	1960	112	3.14
SUB-TOTAL	3105	115	1265	115	1725	115	1955	115	8050	460	12.89
4. Library Expenditures	378	14	154	14	210	14	238	14	980	56	1.56
5. Student Facility Expenditure: General Educational & Miscellaneous Expenditures	1053	39	429	39	585	39	[illegible]63	39	2730	156	4.37
TOTAL COST	20790	770	10769	979	14715	981	16150	950	62424	3680	100.00

Board of Study: PHYSICAL SCIENCES Course: MATHEMATICS (including MATHEMATICS & STATISTICS ORD.) TABLE 11

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	33		30		5		27				
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	1551	47	2220	74	215	43	2241	83	6227	247	10.92
b. Teaching Laboratories	759	23	690	23	115	23	621	23	2185	92	3.83
c. Academic Staff Offices	627	19	570	19	95	19	513	19	1805	76	3.17
d. Administrative Staff Offices	132	4	120	4	20	4	108	4	380	16	0.66
e. Study Facility Space	528	16	480	16	80	16	432	16	1520	64	2.66
f. Student Facility Space	3168	96	2880	96	560	96	2592	96	9200	384	16.14
g. Staff Facility Space	231	7	210	7	35	7	189	7	665	28	1.17
SUB-TOTAL	6996	212	7170	239	1120	208	6696	248	21982	907	38.48
2. Teaching Costs											
a. Academic Staff Salaries	4455	135	7020	234	395	79	5508	204	17378	652	30.49
b. Technical Staff Salaries											
c. Expenditure on Teaching Equipment & Materials	759	23	690	23	115	23	621	23	2185	92	3.83
SUB-TOTAL	5214	158	7710	257	510	102	6129	227	19563	744	34.32
3. Administrative Expenditures											
a. Central University Expenditure	2871	87	2610	87	435	87	2349	87	8265	348	14.49
b. School Expenditure	660	20	600	20	100	20	540	20	1900	80	3.33
SUB-TOTAL	3531	107	3210	107	535	107	2889	107	10165	428	17.82
4. Library Expenditures	594	18	540	18	90	18	486	18	1710	72	3.00
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	1287	39	1170	39	195	39	1053	39	3705	156	6.50
TOTAL COST	17622	534	19800	660	2450	474	17253	639	57125	2307	100.00

Board of Study: PHYSICAL SCIENCES Course: STATISTICS TABLE 12

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	9		17		12		9				
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	423	47	391	23	24	2	486	54	1324	126	6.72
b. Teaching Laboratories											
c. Academic Staff Offices	171	19	323	19			171	19	665	57	3.37
d. Administrative Staff Offices	36	4	68	4	48	4	36	4	188	16	0.95
e. Study Facility Space	144	16	272	16			144	16	560	48	2.84
f. Student Facility Space	864	96	1632	96			864	96	3360	288	17.06
g. Staff Facility Space	63	7	119	7	84	7	63	7	329	28	1.67
SUB-TOTAL	1701	189	2805	165	156	13	1764	196	6426	563	32.64
2. Teaching Costs											
a. Academic Staff Salaries	1215	135	1139	67			3078	342	5432	544	27.59
b. Technical Staff Salaries											
c. Expenditure on Teaching Equipment & Materials	207	23	391	23			207	23	805	69	4.09
SUB-TOTAL	1422	158	1530	90			3285	365	6237	613	31.68
3. Administrative Expenditure											
a. Central University Expenditure	783	87	1479	87	1044	87	783	87	4089	348	20.77
b. School Expenditure	180	20	340	20	240	20	180	20	940	80	4.77
SUB-TOTAL	963	107	1819	107	1284	107	963	107	5029	428	25.54
4. Library Expenditures	162	18	306	18			162	18	630	54	3.20
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	351	39	663	39			351	39	1365	117	6.93
TOTAL COST	4599	511	7123	419	1440	120	6525	725	19687	1775	100.00

Board of Study: PHYSICAL SCIENCES Course: OPTHALMIC OPTICS

TABLE 13

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	20		20		18						
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	520	26	600	30	558	31			1678	87	2.89
b. Teaching Laboratories	3580	179	3580	179	3222	179			10382	537	17.92
d. Academic Staff Offices	200	10	200	10	180	10			580	30	1.00
d. Administrative Staff Offices	80	4	80	4	72	4			232	12	0.40
e. Study Facility Space	320	16	320	16	288	16			928	48	1.60
f. Student Facility Space	1920	96	1920	96	1728	96			5568	288	9.61
g. Staff Facility Space	60	3	60	3	54	3			174	9	0.30
SUB-TOTAL	6680	334	6760	338	6102	339			19542	1011	33.73
2. Teaching Costs											
a. Academic Staff Salaries	4680	234	5680	284	5346	297			15706	815	27.11
b. Technical Staff Salaries	2360	118	2360	118	2124	118			6844	354	11.81
c. Expenditure on Teaching Equipment & Materials	2100	105	2100	105	1890	105			6090	315	10.51
SUB-TOTAL	9140	457	10140	507	9360	520			28640	1484	49.44
3. Administrative Expenditure											
a. Central University Expenditure	1740	87	1740	87	1566	87			5046	261	8.71
b. School Expenditure	560	28	560	28	504	28			1624	84	2.80
SUB-TOTAL	2300	115	2300	115	2070	115			6670	345	11.51
4. Library Expenditure	280	14	280	14	252	14			812	42	1.40
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	780	39	780	39	702	39			2262	117	3.90
TOTAL COST	19180	959	20260	1013	18486	1027			57926	2999	100.00

Board of Study: PHYSICAL SCIENCES Course: APPLIED PHYSICS TABLE 14

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	28		19		14		21				
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	1680	60	1349	71	1176	84	840	40	5045	255	6.77
b. Teaching Laboratories	4228	151	2869	151	2114	151	3171	151	12382	604	16.63
c. Academic Staff Offices	280	10	190	10	140	10	210	10	820	40	1.10
d. Administrative Staff Offices	112	4	76	4	56	4	84	4	328	16	0.44
e. Study Facility Space	448	16	304	16	224	16	336	16	1312	64	1.76
f. Student Facility Space	2688	96	1824	96	1344	96	2016	96	7872	384	10.57
g. Staff Facility Space	84	3	57	3	42	3	63	3	246	12	0.33
SUB-TOTAL	9520	340	6669	351	5096	364	5720	320	28005	1375	37.63
2. Teaching Costs											
a. Academic Staff Salaries	3052	109	2489	131	3514	251	5292	252	14347	743	19.27
b. Technical Staff Salaries	3304	118	2242	118	1652	118	2478	118	9676	472	13.00
c. Expenditure on Teaching Equipment & Materials	2940	105	1995	105	1470	105	2205	105	8610	420	11.57
SUB-TOTAL	9296	332	6726	354	6636	474	9975	475	32633	1635	43.85
3. Administrative Expenditure											
a. Central University Expenditure	2436	87	1653	87	1213	87	1827	87	7134	348	9.58
b. School Expenditure	784	28	532	28	392	28	588	28	2296	112	3.08
SUB-TOTAL	3220	115	2185	115	1610	115	2415	115	9430	460	12.67
4. Library Expenditure	392	14	266	14	196	14	294	14	1148	56	1.54
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	1092	39	741	39	546	39	819	39	3198	156	4.29
TOTAL COST	23520	840	16587	873	14084	1006	20223	963	74414	3682	100.00

Board of Study: PHYSICAL SCIENCE Course: TEXTILE SCIENCE AND TECHNOLOGY TABLE 15

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	24		13		19		29				
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	1056	44	1599	123			725	25	3380	192	5.10
b. Teaching Laboratories	4680	195	2535	195			5655	195	12870	585	19.43
c. Academic Staff Offices	432	18	234	18	342	18	522	18	1530	72	2.31
d. Administrative Staff Offices	96	4	52	4	76	4	116	4	340	12	0.51
e. Study Facility Space	384	16	208	16			464	16	1056	48	1.59
f. Student Facility Space	2304	96	1248	96			2784	96	6336	288	9.56
g. Staff Facility Space	264	11	143	11	209	11	319	11	935	44	1.41
SUB-TOTAL	9216	384	6019	463	627	33	10585	365	26447	1245	39.94
2. Teaching Costs											
a. Academic Staff Salaries	4512	188	4654	358	266	14	3944	136	13376	696	20.20
b. Technical Staff Salaries	3744	156	2028	156			4524	156	10296	468	15.55
c. Expenditure on Teaching Equipment & Materials	1008	42	546	42			1218	42	2772	126	4.18
SUB-TOTAL	9264	386	7228	556	266	14	9686	334	26444	1290	39.93
3. Administrative Expenditure											
a. Central University Expenditure	2088	87	1131	87	1653	87	2523	87	7395	348	11.16
b. School Expenditure	648	27	351	27	513	27	783	27	2295	108	3.46
SUB-TOTAL	2736	114	1482	114	2166	114	3306	114	9690	456	14.63
4. Library Expenditures	384	16	208	16			464	16	1056	48	1.59
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditure	936	39	507	39			1131	39	2574	117	3.88
TOTAL COST	22536	939	15444	1188	3059	161	25172	868	66211	3156	100.00

Board of Studies: SOCIAL SCIENCES   Course: Business and Administrative Studies   TABLE 16

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	37		40		32						
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	3663	99	2880	72	3424	107			9967	278	13.13
b. Teaching Laboratories	74	2	80	2	64	2			218	6	0.28
c. Academic Staff Offices	703	19	760	19	608	19			2071	57	2.72
d. Administrative Staff Offices	148	4	160	4	128	4			436	12	0.57
e. Study Facility Space	592	16	640	16	512	16			1744	48	2.29
f. Student Facility Space	3552	96	3840	96	3072	96			10464	288	13.78
g. Staff Facility Space	259	7	280	7	224	7			763	21	1.00
SUB-TOTAL	8991	243	8640	216	8032	251			25663	710	33.81
2. Teaching Costs											
a. Academic Staff Salaries	2627	71	4880	122	9376	293			16883	486	22.24
b. Technical Staff Salaries	518	14	560	14	448	14			1526	42	2.01
c. Expenditure on Teaching Equipment & Materials	2035	55	2200	55	1760	55			5995	165	7.89
SUB-TOTAL	5180	140	7640	191	11584	362			24404	693	32.15
3. Administrative Expenditures											
a. Central University Expenditure	3219	87	3480	87	2784	87			9483	261	12.49
b. School Expenditure	1554	42	1680	42	1344	42			4578	126	6.03
SUB-TOTAL	4773	129	5160	129	4128	129			14061	387	18.52
4. Library Expenditures	2553	69	2760	69	2208	69			7521	201	9.90
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditure	1443	39	1560	39	1248	39			4251	117	5.60
TOTAL COST	22940	620	25760	644	27200	850			75900	2114	100.00

Board of Study: SOCIAL SCIENCES Course: MODERN LANGUAGES

TABLE 17

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	68		61		65		46				
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	3128	46	1708	28	1625	25	2530	55	8991	154	6.32
b. Teaching Laboratories	1768	26	1586	26	1690	26	1196	26	6240	104	4.39
c. Academic Staff Offices	1360	20	1220	20	1300	20	920	20	4800	80	3.37
d. Administrative Staff Offices	272	4	244	4	260	4	184	4	960	16	0.67
e. Study Facility Space	1088	16	976	16	1040	16	736	16	3840	64	2.70
f. Student Facility Space	6528	96	5856	96	6240	96	4416	96	23040	384	16.22
g. Staff Facility Space	272	4	244	4	260	4	184	4	960	16	0.67
SUB-TOTAL	14416	212	11834	194	12415	191	10166	221	48831	818	34.37
2. Teaching Costs											
a. Academic Staff Salaries	13464	198	6710	110	6370	98	10028	218	36572	624	25.74
b. Technical Staff Salaries	1088	16	976	16	1040	16	736	16	3840	64	2.70
c. Expenditure on Teaching Equipment & Materials	1020	15	915	15	975	15	690	15	3600	60	2.53
SUB-TOTAL	15572	229	8601	141	8385	129	11454	249	44012	748	30.98
3. Administrative Expenditures											
a. Central University Expenditure	5916	87	5307	87	5655	87	4002	87	20880	348	14.69
b. School Expenditure	1360	20	1220	20	1300	20	920	20	4800	80	3.37
SUB-TOTAL	7276	107	6527	107	6955	107	4922	107	25680	428	18.07
4. Library Expenditures	4012	59	3599	59	3835	59	2714	59	14160	236	9.96
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	2652	39	2379	39	2535	39	1794	39	9360	156	6.58
TOTAL COST	43928	646	32940	540	34125	525	31050	675	142043	2386	100.00

Board of Study: SOCIAL SCIENCES Course: SOCIAL SCIENCES TABLE 18

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	113		110		80						
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	3390	30	4730	43	4400	55			12520	128	7.71
b. Teaching Laboratories											
c. Academic Staff Offices	2260	20	2200	20	1600	20			6060	60	3.73
d. Administrative Staff Offices	452	4	440	4	320	4			1212	12	0.74
e. Study Facility Space	1808	16	1760	16	1280	16			4848	48	2.98
f. Student Facility Space	10848	96	10560	96	7680	96			29088	288	17.91
g. Staff Facility Space	452	4	440	4	320	4			1212	12	0.74
SUB-TOTAL	19210	170	20130	183	15600	195			54940	548	33.84
2. Teaching Costs											
a. Academic Staff Salaries	8362	74	14630	133	15920	199			38912	406	23.97
b. Technical Staff Salaries	678	6	660	6	480	6			1818	18	1.11
c. Expenditure on Teaching Equipment & Materials	1921	17	1870	17	1360	17			5151	51	3.17
SUB-TOTAL	10961	97	17160	156	17760	222			45881	475	28.26
3. Administrative Expenditures											
a. Central University Expenditure	9831	87	9570	87	6960	87			26361	261	16.23
b. School Expenditure	1582	14	1540	14	1120	14			4242	42	2.61
SUB-TOTAL	11413	101	11110	101	8080	101			30603	303	18.85
4. Library Expenditures	7119	63	6930	63	5040	63			19089	189	11.75
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	4407	39	4290	39	3120	39			11817	117	7.27
TOTAL COST	53110	470	59620	542	49600	620			162330	1632	100.00

Board of Study: SOCIAL SCIENCES Course: APPLIED SOCIAL STIDIES TABLE 19

	1st Year		2nd Year		3rd Year		4th Year		Total		% of Total Cost
Number of Students	24		21		22		22				
Item of Expenditure	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	Total Cost	Per Student	
1. Capital & Maintenance Costs											
a. Classrooms	720	30	1008	48	682	31	154	7	2564	116	6.05
b. Teaching Laboratories											
c. Academic Staff Offices	480	20	420	20	440	20	440	20	1780	80	4.20
d. Administrative Staff Offices	96	4	84	4	88	4	88	4	356	16	0.84
e. Study Facility Space	384	16	336	16	352	16	352	16	1424	64	3.36
f. Student Facility Space	2304	96	2016	96	2112	96	2112	96	8544	384	20.16
g. Staff Facility Space	96	4	84	4	88	4	88	4	356	16	0.84
SUB-TOTAL	4080	170	3948	188	3762	171	3234	147	15024	676	35.49
2. Teaching Costs											
a. Academic Staff Salaries	1776	74	2310	110	2728	124	418	19	7232	327	17.06
b. Technical Staff Salaries	144	6	126	6	132	6	132	6	534	24	1.26
c. Expenditure on Teaching Equipment & Materials	408	17	357	17	374	17	374	17	1513	68	3.57
SUB-TOTAL	2328	97	2793	133	3234	147	924	42	9279	419	21.89
3. Administrative Expenditures											
a. Central University Expenditure	2088	87	1827	87	1914	87	1914	87	7743	348	18.27
b. School Expenditure	336	14	294	14	1218	14	1218	14	1246	56	2.94
SUB-TOTAL	2424	101	2121	101	3132	101	3132	101	8989	101	21.21
4. Library Expenditures	1512	63	1323	63	1386	63	1386	63	5607	252	13.23
5. Student Facility Expenditure; General Educational & Miscellaneous Expenditures	936	39	819	39	858	39	858	39	3471	156	8.19
TOTAL COST	11280	470	11004	524	11462	521	8624	392	42370	1907	100.00

APPENDIX 3

COSTS OF EXPANDING UNDERGRADUATE

COURSES 1969/70 - 1976/77

PPENDIX 3

Table 1 Applied Biology: Course Costs 1969/70 to 1976/77

Item of Expenditure	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
1. Capital and Maintenance Costs								
a. Classrooms	2,009	2,009	2,009	3,089	3,089	3,089	3,089	3,089
b. Teaching Laboratories	8,701	8,701	8,701	13,885	13,885	13,885	15,726	15,726
c. Academic Staff Offices	1,463	1,463	1,526	1,526	1,654	1,890	2,018	2,210
d. Administrative Staff Offices	412	412	412	412	412	524	524	524
e. Study Facility Space	1,232	1,232	1,232	1,232	1,232	1,232	1,232	1,232
f. Student Facility Space	7,392	7,392	7,392	7,392	7,392	7,392	7,392	7,392
g. Staff Facility Space	618	618	618	618	618	618	618	618
SUB-TOTAL	21,827	21,827	21,890	28,154	28,282	28,630	30,599	30,791
2. Teaching Costs								
a. Academic Staff Salaries	23,839	23,839	25,037	26,707	28,302	31,951	33,547	36,340
b. Technical Staff Salaries	8,701	8,701	10,333	11,804	12,873	12,873	14,217	16,067
c. Expenditure on Teaching Equipment and Materials	9,086	9,086	11,561	12,438	12,870	13,357	13,899	14,496
SUB-TOTAL	41,626	41,626	46,931	50,949	54,045	58,181	61,663	66,903
3. Administrative Expenditures								
a. Central University Expenditures	8,961	8,961	8,961	8,961	8,961	8,961	8,961	8,961
b. School Expenditure	1,648	1,648	1,648	1,648	1,648	2,442	2,442	2,442
SUB-TOTAL	10,609	10,609	10,609	10,609	10,609	11,403	11,403	11,403
4. Library Expenditures	2,387	2,387	2,387	2,387	2,387	2,387	2,387	2,387
5. General Expenditures	3,003	3,003	3,003	3,003	3,003	3,003	3,003	3,003
A. TOTAL COST	79,452	79,452	84,820	95,102	98,326	103,604	109,055	114,487
B. Total Student Numbers	103	112	126	138	152	164	174	194
C. Average Cost per Student Year (i.e. A ÷ B)	771	709	673	689	647	632	627	590
D. TOTAL VARIABLE COST	0	0	5,368	10,282	13,506	5,278	5,451	5,432
E. Incremental Student Numbers	0	9	14	12	14	12	10	20
F. Incremental Cost per Student Year (i.e. D ÷ E)	0	0	383	855	229	439	544	270

APPENDIX 3

Table 2 APPLIED BIOLOGY - Sensitivity Tests

		1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
Student Numbers	Total	126	138	152	164	174	194
	Incremental	0	12	14	12	10	20
Staff	TVC	£0	£ 3,141	£ 5,805	£10,248	£13,188	£17,831
	IC	0	261	190	370	294	232
Accommodation	TVC	0	6,264	6,392	6,740	8,709	8,901
	IC	0	522	9	29	196	9
Equipment	TVC	0	77	209	396	638	935
	IC	0	6	9	15	24	14
Materials	TVC	0	800	1,100	1,400	1,700	2,000
	IC	0	66	21	25	30	15
Aggregate	TVC	0	10,282	13,506	18,784	24,235	29,667
	IC	0	855	229	439	544	270
Aggregate LESS Accommodation	TVC	0	4,018	7,114	12,044	15,526	20,766
(See Figure 14.3a)	IC	0	333	220	410	348	263
Aggregate LESS Equipment & Materials	TVC	0	9,405	12,197	16,988	21,897	26,732
(See Figure 14.3b)	IC	0	783	199	399	480	241
REDUCING Technical Staff Requirements							
Staff	TVC	0	3,520	5,115	9,558	12,223	15,016
(See Figure 14.3c)	IC	0	293	113	370	266	139
Aggregate	TVC	0	10,661	12,816	18,094	23,270	26,852
	IC	0	887	152	439	516	177

Note: TVC = Total Variable Cost
IC = Incremental Cost per Student Year

Table 3: APPLIED BIOLOGY

Varying the Staff:Student Ratio

atio (1)	Total Increase in Student Numbers, 1972/73 to 1976/77 (2)	Annual Total Additional Academic Staff Cost (1976/77) (3)	Annual Total Additional Cost (1976/77) (4)	Incremental Cost per Student-Year ie (4)/(2) (5)	% Change in (4) and (5) from Planned Cost (6)
anned :10	68	11,303	29,667	436	---
:10	68	10,031	28,203	415	- 5%
:12	68	8,435	26,479	389	-11%
:15	68	6,381	24,317	358	-18%
:18	68	4,786	22,594	332	-24%
:22	68	4,786	22,594	332	-24%
:25	68	3,190	20,870	307	-30%

'ENDIX 3

Table 4 Electrical Engineering: Course Costs 1969/70 to 1976/77

Item of Expenditure	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
1. Capital and Maintenance Costs								
a. Classrooms	7,717							
b. Teaching Laboratories	46,683							
c. Academic Staff Offices	3,705							
d. Administrative Staff Offices	988							
e. Study Facility Space	3,952							
f. Student Facility Space	14,448							
g. Staff Facility Space	988							
SUB-TOTAL	78,481	78,481	78,481	78,481	78,481	78,481	78,481	78,481
2. Teaching Costs								
a. Academic Staff Salaries	64,295							
b. Technical Staff Salaries	21,736							
c. Expenditure on Teaching Equipment and Materials	21,242							
SUB-TOTAL	107,273	107,273	107,273	107,273	107,273	107,273	107,273	107,273
3. Administrative Expenditures								
a. Central University Expenditures	21,489							
b. School Expenditure	4,199							
SUB-TOTAL	25,688	25,688	25,688	25,688	25,688	25,688	25,688	25,688
4. Library Expenditures	3,705	3,705	3,705	3,705	3,705	3,705	3,705	3,705
5. General Expenditures	4,940	4,940	4,940	4,940	4,940	4,940	4,940	4,940
A. TOTAL COST	220,087	220,087	220,087	220,087	220,087	220,087	220,087	220,087
B. Total Student Numbers	247	264	266	273	284	290	300	311
C. Average Cost per Student Year (i.e. A ÷ B)	891	834	827	806	775	759	734	708
D. TOTAL VARIABLE COST	0	0	0	0	0	0	0	0
E. Incremental Student Numbers	0	17	2	7	11	6	10	11
F. Incremental Cost per Student Year (i.e. D ÷ E)	0	0	0	0	0	0	0	0

ENDIX 3 Table 5 Chemical Engineering: Course Costs 1969/70 to 1976/77 with an annual intake increasing to 120

Item of Expenditure	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
1. Capital and Maintenance Costs								
a. Classrooms	10,780	10,780	10,780	10,780	10,780	10,780	10,780	10,780
b. Teaching Laboratories	40,135	40,135	40,135	40,135	40,135	40,135	40,135	40,135
c. Academic Staff Offices	4,537	4,537	4,537	4,537	4,665	4,665	4,773	4,773
d. Administrative Staff Offices	1,396	1,396	1,396	1,396	1,396	1,396	1,396	1,396
e. Study Facility Space	5,584	5,584	5,584	5,584	5,584	5,584	5,584	5,584
f. Student Facility Space	16,752	16,752	16,752	16,752	16,752	16,752	16,752	16,752
g. Staff Facility Space	349	349	349	349	349	349	349	349
SUB-TOTAL	79,533	79,533	79,533	79,533	79,661	79.661	79,769	79,769
2. Teaching Costs								
a. Academic Staff Salaries	55,932	55,932	55,932	55,932	57,527	57,527	59,581	59,581
b. Technical Staff Salaries	17,799	17.799	17,799	17,799	17,799	17,799	17,799	17,799
c. Expenditure on Teaching Equipment and Materials	23,383	23,383	23,382	23,385	23,390	23,406	23,444	23,489
SUB-TOTAL	97,114	97,114	97,115	97,116	98,716	98,732	100,824	100,869
3. Administrative Expenditures								
a. Central University Expenditures	30,363	30,363	30,363	30,363	30,363	30,363	30,363	30,363
b. School Expenditures	6,282	6,282	6,282	6,282	6,282	6,282	6,282	6,282
SUB-TOTAL	36,645	36,645	36,645	36,645	36,645	36,645	36,645	36,645
4. Library Expenditures	5,235	5,235	5,235	5,235	5,235	5,235	5,235	5,235
5. General Expenditures	6,980	6,980	6,980	6,980	6,980	6,980	6,980	6,980
A. TOTAL COST	225,507	225,507	225,508	225,509	227,237	227,253	229,453	229,498
B. Total Student Numbers	349	346	341	340	350	365	395	420
C. Average Cost per Student-Year (i.e. A ÷ B)	646	652	661	663	649	622	580	546
D. TOTAL VARIABLE COST	0	0	0	2	1,728	1,746	3,946	3,991
E. Incremental Student Numbers	0	-3	-5	-1	10	15	30	25
F. Incremental Cost per Student-Year (i.e. D ÷ E)	0	0	0	-2	173	116	131	159

NDIX 3 Table 6 Chemical Engineering: Course Costs 1969/70 to 1976/77 with an annual intake increasing to 160

Item of Expenditure	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
1. Capital and Maintenance Costs								
a. Classrooms	10,780							
b. Teaching Laboratories	40,135							
c. Academic Staff Offices	4,537							
d. Administrative Staff Offices	1,396							
e. Study Facility Space	5,584							
f. Student Facility Space	16,752							
g. Staff Facility Space	349							
SUB-TOTAL	79,533							
2. Teaching Costs								
a. Academic Staff Salaries	55,932							
b. Technical Staff Salaries	17,799							
c. Expenditure on Teaching Equipment and Materials	23,383							
SUB-TOTAL	97,114							
3. Administrative Expenditures								
a. Central University Expenditures	30,363							
b. School Expenditure	6,282							
SUB-TOTAL	36,645							
4. Library Expenditures	5,235							
5. General Expenditures	6,980							
A. TOTAL COST	225,507	225,507	225,507	225,507	225,507	225,507	225,507	225,507
B. Total Student Numbers	349	346	341	342	355	380	435	500
C. Average Cost per Student-Year (i.e. A + B)	646	652	661	659	635	593	518	451
D. TOTAL VARIABLE COST	0	0	0	0	0	0	0	0
E. Incremental Student Numbers	0	-3	-5	1	13	25	55	65
F. Incremental Cost per Student-Year (i.e. D + E)	0	0	0	0	0	0	0	0

NDIX 3 Table 7 INDUSTRIAL TECHNOLOGY AND MANAGEMENT: Course Costs 1969/70 to 1976/77

Item of Expenditure	1969/70	1971/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
1. Capital and Maintenance Costs								
a. Classrooms	651	651	2,412	2,412	2,412	2,412	2,412	2,412
b. Teaching Laboratories	7,035	7,035	11,834	11,834	11,834	11,834	11,834	11,834
c. Academic Staff Offices	540	668	1,571	1,571	1,571	1,571	1,571	1,571
d. Administrative Staff Offices	84	84	232	232	232	232	232	232
e. Study Facility Space	336	336	2,097	2,097	2,097	2,097	2,097	2,097
f. Student Facility Space	2,016	2,016	2,871	2,871	2,871	2,871	2,871	2,871
g. Staff Facility Space	330	330	559	559	559	559	559	559
SUB-TOTAL	10,992	11,120	21,576	21,576	21,576	21,576	21,576	21,576
2. Teaching Costs								
a. Academic Staff Salaries	12,684	14,279	17,469	20,659	25,904	30,690	34,340	37,530
b. Technical Staff Salaries	1,764	1,764	1,764	3,108	3,108	3,108	4,452	4,452
c. Expenditure on Teaching Equipment and Materials	882	882	1,312	2,182	3,437	4,692	4,847	4,947
SUB-TOTAL	15,330	16,925	20,545	25,949	32,449	38,490	43,639	46,929
3. Administrative Expenditures								
a. Central University Expenditures	2,610	2,610	2,610	2,610	2,610	2,610	2,610	2,610
b. School Expenditure	1,080	1,080	1,080	1,080	2,794	2,794	2,794	2,794
SUB-TOTAL	3,690	3,690	3,690	3,690	5,404	5,404	5,404	5,404
4. Library Expenditure	525	525	525	525	525	525	525	525
5. General Expenditures	819	819	819	819	819	819	819	819
A. TOTAL COST	31,356	33,079	47,154	52,559	60,773	66,814	71,963	75,253
B. Total Student Numbers	30	57	96	130	159	192	222	252
C. Average Cost per Student-Year (i.e. A + B)	1,045	580	491	404	382	347	324	298
D. TOTAL VARIABLE COST	0	1,723	14,075	5,405	8,214	6,041	5,149	3,290
E. Incremental Student Numbers	0	27	39	34	29	33	30	30
F. Incremental Cost per Student-Year (i.e. D + D)	0	63	360	158	283	122	171	109

Table 8: INDUSTRIAL TECHNOLOGY AND MANAGEMENT
Sensitivity Tests

		1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
Student Numbers:	Total	96	130	159	192	222	252
	Incremental	0	34	29	33	30	30
Staff	TVC	£ 0	4,534	11,493	16,280	21,273	24,464
	IC	£ 0	133	239	145	166	106
Accommodation	TVC	£ 0	0	0	0	0	0
	IC	£ 0	0	0	0	0	0
Equipment	TVC	£ 0	440	1,265	2,090	2,090	2,090
	IC	£ 0	12	28	25	0	0
Materials	TVC	£ 0	100	200	300	400	500
	IC	£ 0	2	3	3	3	3
AGGREGATE	TVC	£ 0	5,074	12,958	18,670	23,763	27,054
	IC	£ 0	147	270	173	169	109
Aggregate LESS Equipment & Materials (see Figure 15.10 (a))	TVC	£ 0	4,534	11,493	16,280	21,273	24,464
	IC	£ 0	133	239	145	166	106
REMOVING Ancilliary Staff Requirements							
Staff	TVC	£ 0	3,190	8,435	13,222	16,871	20,060
	IC	£ 0	94	181	145	166	106
Aggregate	TVC	£ 0	3,730	9,900	15,612	19,361	22,650
See Figure 15.10(b)	IC	£ 0	108	212	173	169	109

Note: TVC = Total Variable Cost
IC = Incremental Cost per Student-year

APPENDIX 3

Table 9: INDUSTRIAL TECHNOLOGY AND MANAGEMENT
Varying the Staff:Student Ratios*

Ratio (1)	Total Increase in Student Nos 1972/3 to 1976/7 (2)	Annual Total Additional Academic Staff Cost (3)	Annual Total Additional Cost (4)	Incremental Cost per Student-Year ie (4)/(2) (5)	% Change in (4) and (5) from 1:10 ratio (6)
1:10	156	£27,247	£34,239	£219	----
1:12	156	25,537	32,529	209	- 5%
1:15	156	20,866	27,858	179	-18%
1:18	156	17,215	24,207	155	-29%
1:22	156	13,566	20,558	132	-40%
1:25	156	11,970	18,962	122	-44%

* Source of Figure 15.10(c)

APPENDIX 3

Table 10 MATHEMATICAL SCIENCES -- Course Costs 1969-70 to 1976-77

Item of Expenditure	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
1. Capital and Maintenance Costs								
a. Classrooms	7,551	7,551	7,551	7,551	8,301	8,301	8,301	8,301
b. Teaching Laboratories	2,185	2,185	2,185	2,779	2,779	2,779	2,779	2,779
c. Academic Staff Offices	2,470	2,470	2,470	2,962	3,327	3,724	3,853	3,861
d. Administrative Staff Offices	568	568	568	568	568	620	620	620
e. Study Facility Space	2,080	2,080	2,980	2,980	2,980	2,980	2,980	2,980
f. Student Facility Space	12,560	12,560	12,560	12,560	12,560	12,560	12,560	12,560
g. Staff Facility Space	994	994	994	994	994	994	994	994
SUB-TOTAL	28,408	28,408	29,308	30,394	31,509	31,958	32,087	32,195
2. Teaching Costs								
a. Academic Staff Salaries	22,810	22,810	22,810	29,650	34,395	41,032	42,627	44,682
b. Technical Staff Salaries	0	0	0	0	0	0	0	0
c. Expenditure on Teaching Equipment and Materials	2,990	2,990	3,045	4,288	5,336	5,561	5,636	5,711
SUB-TOTAL	25,800	25,800	25,855	33,938	40,231	46,593	48,263	50,393
3. Administrative Expenditure								
a. Central University Expenditure	12,354	12,354	12,354	12,354	12,354	12,354	12,354	12,354
b. School Expenditure	2,840	2,840	2,840	2,840	2,840	3,429	3,429	3,429
SUB-TOTAL	15,194	15,194	15,194	15,194	15,194	15,783	15,783	15,783
4. Library Expenditure	2,340	2,340	2,340	2,340	2,340	2,340	2,340	2,340
5. General Expenditure	5,070	5,070	5,070	5,070	5,070	5,070	5,070	5,070

A. TOTAL COST	76,812	76,812	77,767	86,936	94,344	101,744	103,543	105,781
B. Total Student Numbers	142	144	166	187	225	247	264	274
C. Average Cost per Student-Year (i.e. A ÷ B)	541	533	468	465	419	412	392	386
D. TOTAL VARIABLE COST	0	0	955	9,169	7,408	7,400	1,799	2,238
E. Incremental Student Numbers	0	2	22	21	38	22	17	10
F. Incremental Cost per Student Year (i.e. D ÷ E)	0	0	43	436	195	336	106	224

APPENDIX 3 Table 11: MATHEMATICS AND STATISTICS -- Sensitivity Tests

		1971/2	1972/3	1973/4	1974/5	1975/6	1976/7
Student Numbers:	Total	166	187	225	247	264	274
	Incremental	0	21	38	22	17	10
			£	£	£	£	£
Staff	TVC	0	6,840	12,085	18,811	20,406	22,461
	IC	0	325	138	305	93	205
Accommodation	TVC	0	1,086	2,201	2,650	2,779	2,887
	IC	0	51	29	20	7	10
Equipment	TVC	0	943	1,016	1,016	1,016	1,016
	IC	0	44	1	0	0	0
Materials	TVC	0	300	1,275	1,500	1,575	1,650
	IC	0	14	25	10	4	7
Aggregate	TVC	0	9,169	16,577	23,977	25,776	28,014
	IC	0	434	193	335	104	222
Aggregate LESS Accommodation (See Figure 14.10(a))	TVC	0	8,083	14,376	21,327	22,997	25,127
	IC	0	383	164	315	97	212
Aggregate LESS Equipment (See Figure 14.10(b))	TVC	0	8,226	15,561	22,961	24,760	26,998
	IC	0	390	192	335	104	222
Aggregate LESS Materials (See Figure 14.10(c))	TVC	0	8,869	15,302	22,477	24,201	26,364
	IC	0	420	168	325	100	215

Note: TVC = Total Variable Cost

IC = Incremental Cost

Table 12: MATHEMATICS AND STATISTICS -- Varying the Staff:Student Ratio

Ratio (1)	Total Increase in Student Numbers, 1972/73 to 1976/77 (2)	Annual Total Additional Academic Staff Cost (1976/77) (3)	Annual Total Additional Cost (1976/77) (4)	Incremental Cost per Student-Year ie (4)/(2) (5)	% Change in (4) and (5) from Planned Ratio (1:10) (6)
Planned 1:10	108	21,872	28,014	259	----
1:12	108	18,222	24,184	224	14%
1:15	108	13,680	19,316	179	31%
1:18	108	12,085	17,593	163	37%
1:22	108	10,031	15,431	143	45%
1:25	108	8,435	13,707	127	51%

APPENDIX 3 Table 13 PHARMACY - Course Costs 1969-70 to 1976-77

Item of Expenditure	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
1. Capital and Mainentance Costs								
a. Classrooms	6,228	6,228	6,228	6,228	6,228	6,228	6,228	6,228
b. Teaching Laboratories	72,450	72,450	72,450	72,450	72,450	72,450	72,450	72,450
c. Academic Staff Offices	4,370	4,370	4,370	4,498	4,606	4,734	4,862	4,970
d. Administrative Staff Offices	920	920	920	920	920	920	920	920
e. Study Facility Space	3,680	3,680	3,680	3,680	3,680	3,680	3,680	3,680
f. Student Facility Space	22,080	22,080	22,080	22,080	22,080	22,080	22,080	22,080
g. Staff Facility Space	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150
SUB-TOTAL	110,873	110,878	110,878	111,006	111,114	111,242	111,370	111,478
2. Teaching Costs								
a. Academic Staff Salaries	39,811	39,811	39,811	41,406	43,460	45,055	46,651	48,705
b. Technical Staff Salaries	36,340	36,340	36,340	36,340	36,340	36,340	36,340	36,340
c. Expenditure on Teaching Equipment & Materials	23,460	23,460	23,760	24,367	25,444	26,089	26,915	27,981
SUB-TOTAL	99,611	99,611	99,911	102,113	105,244	107,484	109,906	113,026
3. Administrative Expenditure								
a. Central University Expenditures	20,010	20,010	20,010	20,010	20,010	20,010	20,010	20,010
b. School Expenditure	3,220	3,220	3,220	3,220	3,220	3,220	3,220	3,220
SUB-TOTAL	23,230	23,230	23,230	23,230	23,230	23,230	23,230	23,230
4. Library Expenditure	7,590	7,590	7,590	7,590	7,590	7,590	7,590	7,590
5. General Expenditure	8,970	8,970	8,970	8,970	8,970	8,970	8,970	8,970
A. TOTAL COST	250,279	250,279	250,579	252,909	256,148	258,516	261,066	264,294
B. Total Student Numbers	230	255	266	280	310	329	365	377
C. Average Cost per Student-Year (i.e. A ÷ B)	1,088	981	942	[illegible]	826	786	715	701
D. TOTAL VARIABLE COST	0	0	300	2,330	3,239	2,368	2,550	3,228
E. Incremental Student Nos.	0	25	11	14	30	19	36	12
F. Incremental Cost per Student-Year (i.e. D ÷ E)	0	0	27	166	108	124	71	269

APPENDIX 3 Table 14 PHARMACY - Sensitivity Tests

		1971/2	1972/3	1973/4	1974/5	1975/6	1976/7
Student Numbers:	Total	266	280	310	329	365	377
	Incremental	0	14	30	19	36	12
		£	£	£	£	£	£
Staff:	TVC	0	1,595	3,649	5,244	6,840	8,894
	IC	0	113	68	83	44	171
Accommodation:	TVC	0	128	236	364	492	600
	IC	0	9	7	19	13	50
Equipment:	TVC	0	48	179	351	575	867
	IC	0	3	4	9	6	24
Materials:	TVC	0	559	1,505	1,978	2,580	3,354
	IC	0	39	31	24	16	64
Aggregate:	TVC	0	2,330	5,569	7,937	10,487	13,715
	IC	0	164	110	135	79	309
Aggregate LESS Staff and	TVC	0	607	1,684	2,329	3,155	4,221
Accommodation (See Figure 14.17(a))	IC	0	42	35	33	22	88
Aggregate LESS Equipment	TVC	0	2,282	5,390	7,586	9,912	12,848
(see Figure 14.17(b))	IC	0	161	106	126	73	285
Aggregate LESS Materials	TVC	0	1,771	4,064	5,959	7,907	10,361
(See Figure 14.17(c))	IC	0	125	79	111	63	245

Note: TVC = Total Variable Cost
IC = Incremental Cost

APPENDIX 4

CALCULATION OF NOMINAL TEACHING LOADS

Table 1 : Calculation of Notional Staff Entitlement at present Enrolment

Course	Number of Students		U.K. Staff	Notional Staff
	Annual Intake (1)	Weighted Total[1] (2)	Student Ratio[2] (3)	Entitlement (2) ÷ (3)
Pharmacology	9	27	1: 7.04	3.7
Chemical Engineering	40 x 2	320	1:12.38	25.8
Colour Chemistry	21	63	1:11.09	5.6
Civil Engineering	66	198	1:12.38	16.0
Computer Science(PG)	12	36	1:12.07	3.0
Social Sciences	120	360	1:13.47	26.7
Applied Physics	22	88	1:11.09	7.9
Applied Biology	30	90	1:10.71	8.4
Materials Science	20	80	1:11.09	7.2
All U.G.C. Subject Groups			1:11.57	

1 Annual Intake multiplied by length of course (students spending the whole year in industry not included); science-based postgraduates weighted 3 in accordance with U.G.C. practice.

2 Weighted Staff:Student ratio, 1968-69, averaged for all U.K. universities, for the appropriate U.G.C. subject group. The ratios are derived from numbers of staff and weighted students published in U.K. Department of Education and Science: Statistics of Education, Vol.6., 1969.

Table 2 : Calculation of Nominal Teaching Load

Course	Notional Staff Entitlement at Current Enrolment (1)	Number of Teaching Meetings Provided per Year at Current Enrolment (2)	Nominal Teaching Load (hours per year) (2) ÷ (1)
Pharmacology	3.7	1716	465
Chemical Engineering	25.8	1289 x 2	100
Colour Chemistry	5.6	2639	475
Civil Engineering	16.0	4496	281
Computer Science	3.0	851	284
Social Sciences	26.7	6009	225
Applied Physics	7.9	4495	569
Applied Biology	8.4	3689	439
Materials Science	7.2	3589	500