UNIVERSITY OF SOUTHAMPTON

QUANTITATIVE MODELS FOR THE ANALYSIS OF EDUCATIONAL POLICY

A THESIS SUBMITTED TO THE
FACULTY OF SOCIAL SCIENCES
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DEPARTMENT OF ACCOUNTING AND MANAGEMENT SCIENCE

by

CECILIO MAR MOLINERO

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ABSTRACT

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The subject matter of this thesis is the application of quantitative methods in the management of education. All levels of education are examined: special education, primary schools, secondary schools, post-compulsory education, and universities. The main body of the thesis is formed by a set of independent but related research papers.

A series of original contributions have been made, amongst them are:

1- A socio-demographic geographical study of children with Moderate Learning Difficulties. For the first time the number of children for whom separate special provision is made has been placed in the context of the relevant school age population of the area in which the children live. This makes it possible to separate, for the first time, demographic and policy effects.

2.- A population census based study of the demand for school places in a particular area. This made it possible to compare the number of children in a particular area with the number of children who attend the school. Social and demographic trends are identified and statements about the future of a particular school can be made.

3.- A new way of looking at out-of-catchment area transfers.

4.- A new measure of the attractiveness of a particular school.

5.- A comprehensive study of the relationship between the socio-economic geographical characteristics of an area, the attractiveness of a school, and academic results.

6.- A new methodology for clustering geographical areas based on MDS. This methodology makes statistical results accessible to a non-specialist, and makes it possible to explain in non-technical terms what members of a particular cluster have in common and in what way they differ from members of another cluster.

7.- The use of the 1981 population Census to calculate staying-on rates at the age of 16.

8.- A comprehensive study of the demand for school places in non-compulsory education from the different areas of a city, highlighting the link between educational policy, social structure, and demand for post-compulsory education.

9.- An econometric model for demand and supply of university places. This model incorporates a new interpretation for a partial adjustment mechanism. The model is no longer appropriate because of changes in the way in which university education is funded, but it was useful as a starting point for the analysis of the consequences of educational policy.

10.- The use of published UCCA information to explore university admissions policies. It was found that the 1981 cuts in university expenditure discriminated against applicants from poorer backgrounds and in favour of overseas applicants.

11.- A comprehensive analysis of the effect of the 1981 educational expenditure cuts in a particular university.

12.- A new way of looking at the popularity of a university or a university department.

13.- A new way of looking at academic differences between the entrants to different disciplines at a university.

14.- A MDS analysis of the 1986 research ratings of university departments which shows the way in which the perceived academic excellence is related to past funding policy.

15.- A system for administering undergraduate applications and gather marketing intelligence.

CONTENTS

FOREWORD

This is the second version of the thesis, after the corrections suggested by the examiners have been taken into account. It differs from the first version in several respects. All unpublished material has been removed and two new papers have been added. The new papers describe a decision support system for university undergraduate admissions; they are available in the form of proofs.

The introduction has been totally rewritten. It starts with a discussion of what is Operational Research. There has been a wide debate within the OR Society as to what is Operational Research, and this is reflected in the relevant section. The debate is necessary in order to introduce the concept of Community Operational Research, into which much of the work described here can be included. This is done in order to place the work presented here in the context of the relevant literature. Placing the work in the context of the literature is not easy for two reasons. First, because much work in educational systems OR is not published. Second, because it is very difficult to trace a frontier between Operational Research and other allied disciplines such as Statistics.

The work described here has evolved over a long period of time. The main concern has not been to develop the tools of theory, although it can be argued that several new tools have emerged, and others have been used in new ways, but to give new insights into particular problems as they appeared, and, occasionally, propose solutions. A section describes the way in which the work evolved and the reasons for limitations in its scope, when these existed.

Finally, there is a technical section which is aimed at showing the way in which some of the techniques used here, Multidimensional Scaling and Property Fitting, relate to other techniques, such as Principal Components Analysis and Multivariate Regression. The particular way in which the results for Property Fitting have been derived is my own.

INTRODUCTION

WHAT IS OPERATIONAL RESEARCH?

There is no clear answer to this question. The Journal of the Operational Research Society used to define it as follows:

> "Operational Research is the application of the methods of science to complex problems arising in the direction and management of large systems of men, machines, materials and money in industry, business, government, and defence. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to predict and compare the outcomes of alternative decisions, strategies or controls. The purpose is to help management determine its policy and actions scientifically."

Textbooks used to complement the above definition with a discussion of what is meant by "scientific method". Ackoff and Sasieni (1968) described it as a multistage process with the following steps:

1. Formulating the problem.
2. Constructing the model.
3. Deriving a solution.
4. Testing the model and evaluating the solution.
5. Implementing and maintaining the solution.

The remarkable thing about the definition is that there has been debate and disagreement about every statement that it contains and about many of its words. It was dropped, having died of natural causes, in 1984.

Dando and Sharp (1978) argue that the above definition reflects the mythical birth of the discipline during the second World War. It was then that a group of distinguished scientists, drawn from a variety of backgrounds, were assembled to think about tactical and strategic problems arising from the conduct of military operations.

The original OR groups had to use imaginative thinking to solve complex problems which involved men, machines, materials and money. Examples of the problems they approached are: how to make efficient use of the then new radar technology; how to reduce the number of boats sunk by German submarines; how to maximise the use of reconnaissance aeroplanes; how to improve bombing accuracy. They worked in close cooperation with the top decision makers and with their full support. Their approach was to collect data, analyse it, build a model, and make recommendations. They were surprised by the success of their approach. There is an often quoted note by Blackett (1962) in which he observes that chance events which affect particular operations average out when seen in large numbers, and the "aggregate results are often found to remain relatively constant". Accounts of the work done in this period can be found in Lovell (1988), Sawyer et al (1989), Falconer (1976).

At the end of the war, Operational Research groups were created in nationalised industries and in Government. The early attempt to introduce OR in Government met with considerable difficulties which have been extensively discussed by Rosenhead (1989a). The introduction of OR in industry benefited from the new advances in optimization theory with the discovery of an algorithm to solve Linear Programming problems. This was just the tool that was needed to plan production under post-war shortages. OR identified standard problems for which standard, specific tools were developed: stock control, queues, project planning, depot location.

During the 50's and 60's OR was accepted in a larger number of organisations, it found its way into the academic world, there was a feeling of optimism about the subject, OR Societies were created in developed countries, specialised publications describing the new technical advances were born. Yet, during the 60's the seeds of an identity crisis within the OR community were planted.

A CRISIS OF IDENTITY IN OPERATIONAL RESEARCH.

The crisis of identity suffered by the Operational Research community during the 1970's had various origins, but the main one was dissatisfaction, which was not founded on a lack of success but on a realisation that the dreams had not materialised. For example, Waddington (1948), one of the original Operational Research workers, discussing the success and promise of Operational Research and its use of the scientific method wrote:

> "I do believe that the scientific technique of handling events is the most effective yet invented by man, and that in consequence men trained in these methods will come to play a very large, and perhaps predominant, role in affairs". (Page 121)

And, later on in the same book he states:

> " (the) scientific method could be applied to the major problems of society. There are many difficulties to be overcome before such work is undertaken, and its results put into practice, on a scale commensurate with our needs. Not least is the difficulty of persuading sufficient mature and first-class scientists to leave their laboratories and launch out into this uncharted sea. But until the attempt is made, on a large scale, can we say that we are dealing with the social life of man (which is most of his life) in a fully responsible way?" (Page 130).

It is not only that OR had failed to approach the major problems of society, but by the 1970's OR was not even near the decision levels where such problems were being discussed.

A similar situation applied in industry. Although there is no agreement on how Corporate Planning should be defined, there is agreement on the fact that OR has been largely excluded from this strategic activity and that this has been caused by an identification of OR with narrow technical problems, Harris (1978).

Rather than approach problems and develop the tools to solve them, the situation had been reversed: techniques were developed and problem situations were identified in which the tools could be applied, exactly the opposite from what was originally intended. OR, and Management Science, Tinker and Lowe (1984) argued, had failed to reach beyond technical issues, and was failing to question the social pressures that set the technical agenda; the technocratic image was promoted by established journals, which helped to suppress the alternatives.

A further source of dissatisfaction was the divergence between OR, as done in the practical world, and OR as taught in academia and as reflected in journals. Academic OR was quickly becoming an homogeneous branch of Applied Mathematics. Mathematical models were being studied in isolation of the real world. Practitioners complained that academic teaching was of little relevance when applying the discipline.

OR, unlike the natural sciences, does not have an object of its own. The object of OR is "complex problems". The crisis of OR can be described as such a complex problem, it is not surprising to find that an extensive debate on what is, and should be, OR followed.

IS OPERATIONAL RESEARCH A SCIENCE?

This was one of the first questions to be addressed. It had to be, as the definition of the Operational Research Society has three sentences and each one of them contain a version of the world "science", as observed by Beer (1966). Do we, Beer asked, need to remind ourselves that we are doing science because we are not sure that this is the case?

Bevan (1976) argues that OR does not have the characteristics of a science, at least not a science as Popper describes it. Bevan observes that criticism does not play an important role in OR. Natural scientists write their research in a highly specialised language aimed at a monocultural peer group, and they are judged according to the standards set by the current paradigm. OR does not have general theories against which a current piece of work can be judged: each individual project has its own very determined characteristics and cannot be repeated. OR projects are not judged by a peer group: OR reports are written for sponsors and have to be written in a way that sponsors can understand if they are to be influential in affecting the way in which decisions are made. The influence of the sponsor has further consequences: it poses constraints on the methods used since complex abstract discussions are unlikely to result in implementation; and it limits the time scale in which the project can be carried out: research done after a deadline is time wasted. Bevan conjectures on the emphasis placed on the scientific approach and suggests that this is needed to give an aura of objectivity and optimality to decisions which are, in fact, only optimal for a group of people and may not be so for other groups. Inherent to the work of OR are conflict and the use of power. These are two issues which reappear in the crisis debate.

Does the use of scientific models raise OR to the status of science? Dando and Sharp (1978) take issue with the prominence given to the model. The importance of the model, they claim, is a myth which could be aimed at maintaining the status, or even the identity, of an OR worker who confronts difficult social problems. Unfortunately, myths have other consequences: they may be taken seriously by others. Because of its attachment to the myth of the mathematical model, OR may be attracting into the discipline the wrong type of person: convergent thinkers interested in narrowly defined, easily formulated problems, which can be isolated and solved using elegant mathematical methods and the solutions published in academic journals. These people then become the academics who give a false image of how OR is done and attract the wrong kind of student to their courses.

Practical OR should be reflected in papers in which the practicalities of obtaining consensus are described. Is this the case? Raiszadeh and Lingaraj (1986) carried out a survey of five "core" OR journals and found that too little attention was being paid to problem identification, that treatment of organisational issues was too light, that too many publications are straight technique applications, that too little was said about decision making and the political aspects of implementation. They emphasise the issue of conflict and recommend that we should produce transparent, user-friendly systems, rather than complex algorithms. As they stand, journals are not a reflection of the problems faced, they are unreadable by practitioners and of little value to them.

Keys (1989) argues that, although it is difficult to make a case for OR as a science, OR uses the scientific approach to problems: its methods "are based on measurement, analysis and validation rather than on guesses, intuition and judgement". A better description of OR is that it is a technology, technology being understood as the development of "new mechanisms and systems on the basis of existing devices". Interpreting OR as a technology gives new perspectives to its relationship with other disciplines and to its potential for creativity. It also explains how it can produce new theoretical discoveries when faced with new problems. This interpretation also explains the predominance of theory over applications in the literature: technicians do not want to divulge information of use to competitors, they have other rewards for success. Scientists need to show the success of their research in the form of publications.

Perhaps OR is not a science in the sense of traditional sciences, and the model is not as important as academics believe but, does OR work in practice proceed in a scientific, systematic way? Circumstancial evidence suggests that this is not the case. Pidd and Wooley (1980) visited several industrial OR groups in the Midlands and came to the conclusion that the five stages of the scientific method are not followed in practice. They did not observe a highly formalised approach at problem structuring, what they observed was a process of discovery by exploration. Exploration contains a cycle which involves questioning, trying to answer the questions, obtaining further information or insight in the light of the process followed to obtain the answers, and, after reflection, formulating new questions. It is an open-ended process which, they claim, requires skills not normally associated with the type of person who does mathematical modelling. What matters in OR is the process by which understanding is obtained about a particular problem, and the way in which a solution is agreed with those who are concerned.

The emphasis on the quantitative model has the consequence of limiting the range of problems that OR workers attempt to approach. The scientific approach becomes confused with quantification and analysis. There is more in life than quantification, Ackoff (1976) argues, solutions should include consideration to aesthetic values and to the quality of life. This cannot be done by taking a narrow view of OR. Ackoff (1979a) notes that in most OR process is based on analysis, the parts are looked at independently of the whole, and the fact that the whole is more than the sum of the parts is often ignored. An optimal solution to a partial problem can be a bad solution to the complete problem. He concluded that obsessed with optimality, looking at the parts, distant from real problems, no longer interdisciplinary, not taking into account ethics and aesthetics, OR is in a poor state.

SOFT AND HARD METHODS

The crisis of OR reflects the changes that are taking place in modern society, Sadler (1978). As society changes, the range of problems faced also changes, the techniques that served us well in the past are no longer appropriate. OR needs to be involved in the management of change, this cannot be done with the algorithmic approach, the hard methods: "obsolete social organisations cannot be regenerated by a sacred cow called algorithm".

The problems that OR has failed to solve are social problems, they are badly formulated, there is no clear set of objectives, there is conflict between the stakeholders. We need new approaches. Rosenhead (1989b) claims that traditional OR techniques have acted as straitjackets. Only those problems which are well defined in narrow technical terms can be dealt with by means of the hard techniques. It is only when the interesting problem has been solved that the technique approach can begin.

New problems require new approaches, a new way of thinking. Systems analysis has been proposed by Ackoff (1979b), amongst others, as a way out for OR. Systems thinking requires giving due consideration to the parts of a system, the way in which they are related to each other, the properties that emerge from the whole, and the relationship between the whole and other wholes. An important aspect of the systems methodology is that it is interactive, the principal benefit of systems planning comes, according to Ackoff (1979b), from engaging in it. The process, and not the model, becomes the central aspect of a piece of work. Systems thinkers are like teachers, they help their sponsors to think for themselves. Occasionally, there is a technical problem which requires the use of a technique but techniques are just tools to be used when needed. Systems planning reopens the door to multidisciplinarity. The OR worker is no longer a person trying to solve a problem for a sponsor, he/she is just one more person whose contribution is to impose structure to the way in which the problem is approached.

The systems approach by itself is not fundamentally different from OR, Checkland (1983). What it offers is a new paradigm, in the Kuhn (1962) sense, which can be used to explore complex problems. Checkland takes the systems theory one step further and argues that, in social problems, what should be modelled is the process of thinking about problems, the process by which different people arrive at different perceptions of reality. This leads to the conclusion that problem solving is related to conflict resolution.

Systems thinking by itself does not help to solve problems, but it permits the development of new methodologies which can be used to structure problems, what have been called "soft systems methods". Examples of such methodologies are Ackoff's futures design; Eden's cognitive mapping; Rosenhead's robustness analysis; Friend's strategic choice analysis; and metagame analysis. Most of these techniques are described in Rosenhead (1989c). Thus systems thinking is seen as a position "half way to infinity", which permits the management of complexity, Eden and Graham (1983). The emphasis can be on the meaning of things, not on relevance, objectivity, or optimality. Implementation can be treated as part of problem definition.

Eden and Jones (1980) give an example of soft systems methodology for problem structuring. This is a study without an objective, without a solution, and without a mathematical model that is solved. The methodology of cognitive planning is used to structure the problem and to create consensus as to how the sponsoring company should proceed in the future. The technique is transparent to the user, although its details involve sophisticated analysis based on the theory of networks. This paper drew an angry response from Machol (1980) who stated that it "did not say anything about anything", and that the work described was not OR. This is just the sort of debate between proposers of different paradigms, Kuhn (1962), where different groups talk across purposes.

Soft systems methods are not necessarily needed to structure problematic situations. It is possible to use hard techniques creatively in order to gain understanding of a problem. The technique is not the end in itself, but the excuse to negotiate a solution, to clarify a situation, and a tool that can be used to explore ideas. An example of the use of Linear Programming in this way is given by Bryant (1988).

POWER AND CONFLICT.

OR groups still thrive in business and Government, even if the scope of the problems they can solve is limited. For example, Biffen (1980) describes the type of work carried out by the OR group of the Treasury and emphasises the need to be conscious of the limitations of technical work, "there is no substitute for political judgement". Biffen is one of many politicians to praise the technique used for expenditure control in the UK, PESC, a technique based on the systems thinking approach. But Bevan (1983) comments that by the time Biffen was writing about PESC, it had already been discredited and places the blame on the failure of the technique on the absence of a feedback loop, on the refusal to incorporate decisions about taxation in a model which involves decisions about public expenditure, on the absence of politics in the model. He comments that "systems thinking cannot afford to ignore politics".

What, if any, is the value of OR to management? Bevan and Bryer (1978) ask a related question: how can the contribution of OR be measured? They considered the possibility of evaluating the contribution of OR to an organisation by means of a technique such as cost-benefit analysis but they concluded that such an approach is not totally appropriate. There are several reasons which make evaluation difficult. Benefits tend to accrue over a period of time. It is difficult to compare the results of a study which has resulted in implementation against what would have happened had the study not taken place since external conditions change all the time and an optimal solution, in whatever way optimality is measured, does not stay optimal for long. Furthermore, some of the outcomes of an OR project, like "better decision making", are intangible. The most important of the intangible outcomes may be the extra power that "scientific analysis" puts in the hands of the decision maker. Bevan and Bryer identify power with the possibility to bias outcomes in favour of certain interests. The sponsor chooses the issues to be analysed and can abort a study, it acts as a gatekeeper for issues. The OR worker may well be acting as the technocratic arm of management, having to reach the desired conclusions in order to gain implementation and continued employment.

Some practitioners, like Eden and Graham (1983) recognise the existence of conflict and observe that the technical apparatus does not help to solve the ethical problems derived from this. They conclude that the OR person has to take sides in a conflict and that this is a fact of life whether we like it or not. Ackoff (1974), was one of the first OR workers to discuss conflict and suggested that the OR person has to accept the responsibility of putting forward the views of those who are affected by an OR study. To do this it is necessary to understand the rationality and values of the other side, Ackoff (1983). The OR person is thus acting as a representative of all interested parties. Ackoff (1974) further suggested that OR professionals should make some of their time and skills available to those disadvantaged members of society who need them but cannot afford to pay.

Ackoff's attitude is based on the conviction that conflict can be resolved. This view was not shared by Rosenhead (1984) who points out that there is irresolvable conflict in the real world, and that the subordinate once they are outside the planning process must return to their role as subordinate, they are in a position of inferiority, they accept their role, and real conflict is often not observable. The disadvantaged are manipulated by the planning process. Rosenhead (1987) claims that Operational Research is not neutral, it is a technology used by management in order to extract surplus value from production processes. This explains the popular alternative description of OR as Management Science. The idea of OR as a manipulative tool in the hands of management is also explored in an alternative interpretation of the role of OR by Rosenhead and Thurnhurst (1982).

Views about conflict in social problems, Dando and Bennett (1981) observed, divide OR workers into three groups: (i) the positivist (official) group which claims that OR is a science which must play an apolitical role as the supplier of objective analysis; (ii) the reformist which believes that social problems require new methodologies aimed at negotiating consensus; (iii) the revolutionary, which claims that society is "riven by conflict, domination, power and exploitation" and that conflict cannot be resolved. For the official group social problems fall outside the scope of OR; for the reformist group social problems can be resolved through cooperation; for the revolutionary group social problems cannot be solved, the OR person has to take sides in order to make the disadvantaged aware of their position. This last view leads to the concept of Community Operational Research.

COMMUNITY OPERATIONAL RESEARCH

The acceptance of conflict in society as the underlying cause of social problems leads to the conclusion that both sides in a conflict are in need of problem structuring support. This is not a new idea. Legal aid is made available free to those who cannot afford to pay for it. Why is there not free OR advice? Perhaps is because it has never been sought. OR has always been associated with one of the sides, "the management of formally established and legally entrenched organisations disposing of substantial resources, including the labour power of their employees" according to Rosenhead (1986). There are alternative organisations that could benefit from OR support, but Rosenhead argues that OR has developed as a control tool in hierarchical organisations. Its methods reflect its birth, they favour control, centralisation, and deskilling. He identifies alternative organisations as loose coalitions, with no internal managerial hierarchy, committed to democratic procedures, and with no clear overall objectives. The methods of traditional OR are not appropriate to alternative groups. These require methods of problem structuring which allow for participation, for a sharing of power over their own operations, for self-management. Rosenhead suggests that these methods do exist, they are the methodologies developed by soft systems OR workers to deal with the sort of messy problems encountered at top management level. The two extremes of the social scale share the same dialectics. The methods developed for strategic problem solving can benefit disadvantaged social groups, and experiences in working within the community can benefit the OR profession by developing better methodologies to deal with a changing social reality.

Working with alternative sponsors limits both the role of the OR person, as one more voice in a group, and the methods used. Sophisticated mathematical approaches are unlikely to produce any impact on the alternative sponsor. The techniques to be used have to be transparent to the user, and are to be the basis for problem structuring rather than provide a "scientific objective solution".

There are as yet very few examples of Community OR in the literature. Jones and Eden (1981) comment that in the first 30 issues of the Journal of the Operational Research Society there are no case studies about the use of OR in the community. Leaving aside the paper by Jones and Eden (1981), a survey of the next ten issues of that journal, using the subject classification index, only identified two more papers which contain descriptions of case studies of community OR: Jackson (1988), Qing and Mar Molinero (1988). This is a remarkable paucity in the official journal of the British OR society where so much of the debate about community OR has taken place. In fact, actions have gone beyond words: in 1988 the OR society committed itself to community OR by sponsoring a community OR unit, CORU, at Northern College in Barnsley. The aim of CORU is to "provide community groups with more effective support in their decision-making". There is also a network of OR workers who are interested in community OR and who share expertise and make themselves available to community groups. Some interesting work is going on but these initiatives have not yet resulted in academic publications in journals although some working papers do exist.

Within community OR it is also possible to make a distinction between two types of situations. The first one is faced by community groups that try to make decisions under situations of uncertainty where several courses of action are open to them.

There may be conflict within the group, or between the group and an outside organisation, but the existence of conflict is not the dominant motivation for requiring OR skills. The role of the analyst is that of the expert in methodology who helps to structure "messes" in the words of Ackoff (1979a). The work of Jones and Eden (1981) provides a good example. Qing and Mar Molinero (1988) give an example of an alternative situation, in which a community group is expected to participate in a decision making process from a condition of inferiority. An opinion was sought by an outside body on a matter that affected the community, a school closure in this case. The outside body had committed considerable resources to the preparing the proposed plan, and the community group was ill-prepared to make a contribution, it needed expert advice on procedures, analyses, and the institutional framework. In this situation there is open conflict and the OR analysts use their expertise to the benefit of the community group.

The implications for OR are different in each case. The first case requires an OR person who is a specialist in problem structuring, as suggested by Rosenhead (1986). The second case requires a specialist in a particular topic who is able to make a case for the community group. Both types of community OR workers, however, face the same operational problem: how to make their services available to groups that have never heard of OR and are unaware of its availability. Both groups have to face the type of scepticism that Sims and Smithin (1982) find amongst those who are the recipients of voluntary professional work.

OVERVIEW OF THE WORK

Having discussed what is Operational Research, and the currents that have emerged within it, it is now possible to place the work submitted in this thesis within the context of Operational Research.

The work submitted in this thesis is only a subset of all the work that has been done, as the thesis only includes published papers in main journals. I have already discussed the difficulties faced when trying to define what is and what is not OR. If we accept the view that OR is the study of complex problems that arise in management, then the work described here can be defined as OR in education. In some cases it was done in order to generate systems for improved management of an educational system or subsystem. In other cases it was done in order to support community groups. Other pieces of work were undertaken in order to make a submission to a public enquiry with the aim to affect the outcome. Except for the community OR work described here, which was done for community pressure groups, there is no clear sponsor in the traditional management sense, unless it is considered that I was the sponsor for the work I did in order to analyse undergraduate admissions and to produce a decision support system to help with their management. Some work was done for more traditional sponsors but it has not been included here; examples include the design of optimal routes for busing in a special school, and a set of recommendations to a City Council on how to incorporate an education policy within its anti-poverty strategy. The ideas included in the papers have evolved over a period of time, which is reflected in the changing methodology and changing method of analysis. The papers have been presented in reverse chronological order.

Because of its very nature as a set of studies aimed to influence decision making, an effort was made to employ tools which are, as far as possible, transparent to the user. Furthermore, the papers were written in order to show how to influence a process of decision or how to contribute to the understanding of a system. An effort was made, in some of the papers, to remove mathematical analysis. The papers were constrained in yet another way: the Journal of the Operational Research Society imposes an upper limit of 5000 words (ten journal pages) on any article accepted for publication. For example, multidimensional scaling has been used in preference to principal component analysis, and property fitting techniques have been applied when regression would have done just as well. Scaling techniques have intuitive interpretation as they result in maps which convey sophisticated information in a visual form. That scaling methods and other more familiar statistical techniques are exactly equivalent is proved in a technical appendix.

Like in most practical work, many questions remain unanswered. Some issues could not be investigated because the data was not available and, either it would not have been possible to obtain it within the time available, or the extra effort was not considered to bring the type of benefit which would have justified it. Other issues were investigated but the work has not been reported here. Finally, other issues could have been investigated but, either I did not realise their importance at the time, or there was no time to do it. One thing that has to be taken into account is that often the work was done in a situation of conflict, and the data had to be obtained from "the other side", I did not obtain some information until it was too late, other I never obtained at all although it is known to exist. I will give a historical overview of how the work evolved in order to point out some of the limitations.

Most of the educational systems OR work that appears in the literature either describes the use of OR techniques at the service of the management of educational institutions, mainly in the US, or it is just of a technical nature in the sense that the interest of the author is in the technique, the model, and its mathematical solution. Very little has been published in the area of education systems from the point of view of non-policy makers and almost nothing in the area of community OR in education. I will attempt to give a summary literature review with signposts to papers where the interested person can proceed further in the search for references.

COMMUNITY OR AND SCHOOL CLOSURES

My involvement with school issues started in a traditional way as an academic providing conventional OR support to the headmaster of Netley Court special school in Southampton to cope with two well defined technical problems. The first problem arose from the fact that children had to be collected from their homes and taken to school by bus. The headmaster was in charge of transport arrangements and was concerned that some children had to travel very long distances and stay in the bus for a very long time. Would it be possible, I was asked, to construct better routes with the aim of minimising the maximum amount of time that a child spent in the bus while trying to reduce the overall distance travelled and keeping cost within reasonable limits? This is a standard OR problem which has been well studied in the literature; see, for example Sutcliffe and Board (1990). I set up a project, an algorithmic approach was appropriate, a microcomputer based algorithm was written, and improved schedules were proposed. The headmaster was also provided with a methodology to be used to generate schedules in the future. The most important benefit of the analysis was, however, the removal of an important psychological barrier: it was shown that it would be beneficial to use a toll bridge because this would reduce both travelling distance and travelling time. This is what the headmaster conjectured at the beginning of the project. An approach was made to the management of the toll bridge and they decided to waive the toll for the special school buses. The project was a complete success.

Simultaneously, another project was undertaken for the same school. There had been a fall in rolls in the school. A series of reasons could account for this fall. The simplest one was the fall in rolls reflected the fall in births. The second explanation could have been related to the changes in policy that had followed the 1981 Education Act with its emphasis on integrating handicapped children in mainstream schools. A further explanation could have been the changes in staffing that had taken place within the school psychological service of Hampshire LEA, the hypothesis being that assessments were being processed more slowly due to the disturbances in the system. At that time, in 1983, the Population Census had just become available through SASPAC. I suggested that it would be possible to look at the proportion of children with MLD (Moderate Learning Difficulties) needs in a series of subdivisions of the city of Southampton, assume no demographic movement in or out of the areas (an assumption that the LEA included in all its predictions), and produce forecasts for rolls in MLD schools.

This project involved the cooperation of the LEA, because there are several MLD schools in Southampton: two first schools and a middle school. I also wanted to familiarise myself with the LEA's methods for identifying and dealing with children who had been classified as potential MLD children. I had the full support of the Education Authority. I was allowed to collect the addresses of the children who attended MLD schools. I also discovered that no formal roll forecasting system was in existence, forecasts were being prepared using a cohort survival approach which included guesses for pre-school children. Joy Gard collected the data and obtained the relevant age group population from the Census. She observed that the proportions varied according to the area and applied different proportions to every area to produce the forecast. I conjectured that the reasons for the variation were related to the social characteristics of the area concerned. Further conversations with the LEA and headmasters of MLD schools confirmed the view that deprived sectors of the community are over-represented in special schools. I conducted the logit analysis which confirmed this. I used the results of the logit analysis to produce more refined forecasts. The forecast, assuming no change in the process that generates a need for separate MLD provision, was for a large fall in rolls. I used proportion of owner-occupier housing in each area as a measure of wealth. It would have been possible to look for more refined measures of wealth but the object of the project was not to study wealth and poverty in Southampton and their relevance to the incidence of special education needs. The aim of the project was to put a particular fall in rolls in perspective.

The result of the forecasting project was not good news for the MLD schools, the possibility of the school being closed down through falling rolls now appeared to be a real one. Part of any OR study is monitoring the system, and in 1984 I contacted the LEA again for a new count. My forecast had been wrong. Rolls had not declined as expected. The administrative problems arising from the reorganisation of the school psychological service had been solved, and children were being assessed in the same rate as they had been assessed in the past. There should have been a fall in numbers due to demographic movements but it did not happen. The conclusion had to be that the children were more likely than previously to be sent to segregated schools, against the spirit of the 1981 Education Act.

I conjectured that if the incidence of separate MLD needs is related to the wealth of the area concerned, the proportion of children in need of remedial provision, or special provision integrated in mainstream schools, would also depend on the wealth of the area concerned. I suggested that a study be set up to test this but my initiative was turned down by the LEA on the grounds of confidentiality of academic ability test results. It might be possible to carry out such a study if testing, and disclosure of test results, is introduced in primary schools as a result of the Education Reform Act.

During 1982 I had been approached by a member of Southampton Advisory Committee on Education, and asked if I could provide some advice on the proposed closure of a middle school, St. Dennis. School closures had taken place earlier on in the east of the city of Southampton, but the arguments had been mainly political. There had been no questioning of the models used to project rolls, or to identify the schools to be closed down. A tacit agreement had been reached between teacher unions, politicians of all parties, and officers that school closures were the only way to deal with falling rolls. Disagreements existed about the particular schools to be closed.

The process to be followed before a school can be closed requires consultation with interested bodies "while planning is at a formative stage". There has been some debate about what this means, but in Hampshire it is taken to mean that, when the planning process has been completed, a document is put for public debate and the opinion of interested parties is sought. The LEA is required by law to consult but is not required to act on the results of the consultation. There is further provision for a period of two months during which electors may object to plans to close a school. The amount of time available from the moment a document is issued proposing the closure of a school, to the end of the objection period can be relatively short, of the order of five months. Objectors have to put together a case within a complicated legal framework and with no access to data sources other than those released by the LEA. The LEA planners can be described as traditional OR workers putting together a strategy and some recommendations within a limited perspective, after all the important decisions have been taken at a higher level; they represent the "official" OR paradigm according to the Dando and Bennett (1981) classification.

When I was asked for an opinion about falling rolls in the St. Dennis area, I was not in a position to do it within the time scale available. I did, however, ask myself the question of whether the current arrangements made to allocate children to schools were, in one way or another, optimal. It is possible to allocate children to schools in such a way that some measure of distance is minimised. This is a standard OR problem which has been extensively studied in the literature, and is known as the p-median problem. A mathematical discussion of the p-median problem and its extensions can be found in Boffey and Karazakis (1984).

I set up two projects, one using primary school data and another one using secondary school data. The data was obtained from the 1981 Population Census and not from the LEA, although the LEA provided information about location and size of schools, as well as actual school catchment areas. The conclusions of both projects were similar: actual school catchment areas closely reflect the catchment areas generated by the algorithmic approach. The function to be optimised was taken to be, in each case, the total distance walked. Distance measurements were actual, taken from the map, and reflected geographical barriers such as rivers or main road crossings. The possibility of using other objective functions or introducing other constraints in the algorithm were considered and discarded. Other objective functions such as time travelled or difficulty of journey are closely associated with distance travelled in Southampton.

Other constraints, such as racial balance (a popular constraint in the American literature) required data that the LEA was not prepared to release. In any case, the importance of both studies is that it became possible to compare actual with theoretical rolls in each one of the schools under consideration. Wide differences were found between the various schools, the differences being apparently related to the wealth of the area in which the school was situated. This is how the idea of a social classification of school catchment areas was born. The actual work to develop it had to wait until a further piece of community OR had been completed. The Linear Programming approach had a further advantage: the algorithm generated values for dual variables, the so-called reduced costs. Dual variables are only meaningful in the case of constraints which hold in the form of equality. In other words, if the algorithm identified a school as operating to the limit of its capacity, it also identified the savings in distance travelled that would accrue from expanding the number of places by one. This allowed me to make a valuation of "social cost" of a place removed.

Early in 1984 Hampshire LEA proposed the closure of two secondary schools in Southampton, Hampton Park and Glen Eyre. I was invited to form part of one of the committees set up to oppose the closures. My role was to be that of a Community OR person, helping with the interpretation of quantitative data. The LEA proposal contained a set data analyses which were very difficult to understand and for which little explanation was provided. It was clear that the role of the data was not to prove a point but to show that the "optimal objective solution" to the expected fall in rolls was the one being proposed. In the words of Rosenhead and Thurnhurst (1982) "decisions which might formerly have been considered exercises of power, and hence political, were being presented as scientific or rational". There were analyses on school roll forecasts, transfers, and even pre-school population estimates. The issue of cost did not form part of the document.

The Linear Programming analysis of secondary schools had identified the school proposed for closure as the best situated school in Southampton in terms of reduced costs. I had also been able to generate relevant population estimates for every school catchment area.

The influence of parental choice became apparent when the number of children on roll in each one of the schools was divided by the relevant population in the catchment area. The question then arose of where did the children who did not go to their local school go to. I, again, required some data from the LEA. The data which was available was very limited. No information was available about children who did not go to state schools. Information about transfers was only available for transfers at the end of primary education. The LEA used a very crude model for transfers, and I developed an alternative one based on a Markovian process. I used my methodology to examine transfers during a period of five years, although the published paper only described the results for one of the years. The transfer analysis disclosed that the LEA had built an incorrect picture of inner-city dynamics, and that an inner city school used mainly by racial minorities was having severe problems because of the exercise of parental choice.

It, therefore, appeared to be the case that a crucial variable in falling rolls was the exercise of parental choice and its dynamics. In the time available all that it was possible to do was to develop an index of academic success for every school, based on success in O-level examinations (the only data available), to develop an index of how attractive a school is, and to confirm that schools that get good results are also the most attractive ones. The conjecture that both are related to the social characteristics of the catchment area had to wait to the study on social classification for an answer.

The issue of long-term demand for places also arose. The LEA used an Enhanced Electoral Register (EER) as a source of data. I was only allowed access to EER data for the school to be closed down, and agreement between Census figures and EER estimates was good. This was to be expected, if the results of Todd and Dodd (1982) and Todd and Butcher (1982) applied to Southampton. But EER estimates, for the same token could not have been good in other parts of the city, particularly in the inner-city immigrant area. The LEA did not disclose data on EER estimates for areas other than the school to be closed down.

Fortunately, there were alternative population projections which had been made by the Wessex Regional Health Authority (1983) using the method of components and 1981 Census data. These were used to argue that the decline in rolls was not to be as pronounced as the LEA claimed. Later events proved the WRHA figures to be nearer the truth than the LEA estimates.

I also attempted to approach the issue of cost. Unfortunately, my request for information from the LEA was met only partially and only just before the deadline for the presentation of objections.

Like in the Jones and Eden (1981) case study, my main contribution as a member of the group had been to structure quantitative information and to help to overcome the difficulties of debating complex technical points. The community group did not stop the school from being closed but, and this is another parallel with Jones and Eden (1981), the members of the group became active in state education; one member of the group became the chairperson of the governing body of the new school, and the new school was given a very substantial capital allocation which had not been originally planned for. A further benefit of this experience was the expertise gained on the technicalities of school management.

The expertise I had acquired was soon to be put to use when a proposal was made to reorganise special education in Southampton. I acted as an OR person for two community groups in two affected schools. This time it was possible to put a case much more quickly; to contribute to the education of members of the group on technicalities, strategies, and tactics; and to make them realise what were the important courses of action to taken and why. This is very much the sort of results that are obtained when using soft systems methodology. The strategy was successful and the schools remained open. This case study is still to be written.

During the summer of 1986 I set up a project to produce a social classification of school catchment areas. The technique to be used was Multidimensional Scaling. I favoured this technique because its transparency made it appropriate for community OR. I had developed experience on the use of Multidimensional Scaling for data analysis through my work on undergraduate admissions.

The data was collected by Alastair Leyland from the 1981 Census. He proceeded as he was instructed. The complete project had to be finished in three months because Alastair had to start a new job. The literature review was done quickly but we were able to benefit from a survey done by Thunhurst (1985). There were social classifications of Hampshire electoral wards made by the Research and Intelligence Group of Hampshire County Council (1985), but these were inappropriate for the study of school problems and had not been produced in a way that could be used to illustrate social points to a non-statistically educated audience; it lacked user transparency. I was concerned with the selection of indicators, but a more careful study of electoral wards in Hampshire did not find any major deficiencies in the choice of indicators, Modabber (1988). Furthermore, Modabber's study successfully explained the voting behaviour of electoral wards in Hampshire using the same set of indicators.

The work proceeded remarkably well despite the fact that the mainframe computer kept on breaking down. We were satisfied with the work, not only because summary statistics were good, but because the results closely reflected our knowledge of Southampton. Perhaps the most important test of a model is the ability to predict new events. I was able to predict that the secondary inner city school in the immigrant area would soon be closed down. This prediction materialised in 1988. I was also able to identify the schools at risk of being closed down. The next primary school to be proposed for closure, Aldermoor, was one of them.

The MDS study of the city of Southampton was used as the basis of a survey of attitudes towards the past amongst schoolchildren in Southampton, Emmot (1988). The methodology was used again to advise Southampton City Council on council housing, Mar Molinero and Mao Qing (1990). A grant from the Nuffield Fundation made it possible to extend the methodology and to apply it to schools in four major Hampshire cities; the results obtained were of very good quality in terms of summary statistics and the conclusions did not invalidate the conclusions reached in Southampton despite the fact that the technique used, Individual

Differences Scaling proposed by Carroll and Chang (1970), was not totally equivalent to MDS, Mar Molinero (1989). This last study has not been included in this thesis as it is still not published in a journal. Perhaps more time and effort would have made it possible to produce a more rigorous analysis of the set of indicators, but the analysis of the set of indicators was not the objective of the study, the intention was only to produce a way of presenting large amounts of complex information in a simple and intuitive form, this objective was achieved.

The next school to be proposed for closure was a sixth form college. Again, the time available to make a case was short although in this instance the LEA set up a working party to examine the issues. I was invited to advise a committee in the school proposed for closure although I did not join it.

The model used by the LEA was seriously deficient both in its structure and in the assumptions embedded in it. The procedure to be followed to prepare a case for the school was clear. Staying on rates had to be estimated for socially homogeneous areas; a cohort survival approach had to be taken to produce forecasts for every area; reasonable assumptions had to be made about future trends; and the possibility of policy changes, such as a youth wage, had to be investigated. I was able to benefit from the help of a Chinese visitor who had just arrived to the department, Mao Qing. She knew nothing about British education and had to be given very careful guidance on how to perform every step of the analysis. We met all the deadlines and submitted a report to the enquiry. The study would have benefited of better data on migration, but this did not exist. Another aspect of the study that could not be investigated was the issue of transfers between the state and the private sector, again there was no data available. Issues of cost and curriculum provision should have been important but we were not asked to investigate them and there was no possibility of carrying a thorough study within the time scale available.

My most recent case of Community OR in the area of school closures relates to Aldermoor school where I advised the parents' committee. The case was complicated by the absence of data. The LEA had put forward some figures which were little more than guesses. It was not possible to use the Population Census since it was too old in 1987 and the area in which the school was situated had a high population turnout. I had to advise the parents' committee on how to conduct surveys of the catchment area and surrounding areas. I have developed many ideas about conflict and power in community OR as a result of that experience but the study still remains to be written.

OR ANALYSES OF ISSUES RELATED TO HIGHER EDUCATION

In 1978 the Department of Education and Science produced projections of future demand for Higher Education. The projections were made in a very crude way and identified a large drop in the demand for places as a consequence of the fall in the number of births. I thought it appropriate to look at the figures to discover to what extent a more detailed analysis of the data supported the general conclusions. I set up a projet with Christine Hill.

The study took the form of an econometric model which used partial adjustment mechanisms. My inclination for econometric models derived from some work I had been doing in the area of Agricultural Economics: Mar Molinero (1979), Mar Molinero (1980), Mar Molinero (1986). The study was intended to test a series of hypotheses about the way in which changes in demand had affected the number of places in the past; about differences between home and overseas students; about the influence of the level of fees on the number of applications from overseas; about the trends that existed in Economics and Accounting; and about the way in which Southampton's share of applications had been evolving.

The aim of the study was to inform decision making within a "predict and prepare paradigm", Ackoff (1979a). The model was used for several simulation exercises although these were not discussed in the final paper, an absence which has been critisised by Fildes (1985). This absence has several explanations: first, we were asked to reduce the length of the paper as a condition for publication; second, forecasts were not the most important output derived from the exercise, the understanding of the dynamics of demand for places was, from my point of view, more important; third, discussing the forecasts would have needed a discussion of the assumptions made during the simulations, and would have meant a discussion about the social dynamics underlying the demand for university places, an issue which I did not yet feel confident to write about in a journal. The paper did, however, mention the fact that I identified different attitudes towards higher education amongst the different social classes as an important aspect in the dynamics of demand for places. This is, probably, the first mention to different social class participation rates in an academic paper concerned with prediction (the issue had been raised before in the national press).

At that time I had been developing a series of ideas on undergraduate admissions. I set up a series of projects related to undergraduate admissions. I explored the question of the relationship between A-level qualifications and final degree results. I found very little association between the two, which was not surprising given that observed A-level results are obtained from a censored sample, only those students who achieve a minimum standard are accepted, and any correlations tend to dissapear as observed by Akeman et al (1983). This study has not been published.

Another project was concerned with the possibility of using linear discriminant analysis in order to predict who would accept an offer based on A-levels for a given course. The results were reasonable but the model was difficult to use in practice and was discarded. I did not publish the study.

A further project looked at the possibility of using logit analysis rather than discriminant analysis. The results were good and they were incorporated in my admissions forecasting model, which was later published. The model considered whether an alternative way of weighting A-level scores could be more appropriate that the one recommended by UCCA. I considered the scheme proposed by Diamond (1980). The results obtained with Diamond's scheme were no better than the results obtained using the more traditional scheme. Despite this result, I used Diamond's scheme in practice for one admissions year. I made offers using points equivalent "à la Diamond". The new system created untold disturbances in the administration of admissions, as well as confusion with the applicants. This convinced me that there were advantages of staying with a scoring system which was well understood by applicants and administrators even if it had been discarded by research of PhD standard.

In 1981 the University of Southampton, in common with other universities, suffered a reduction in budget. A planning group, set up by the Vice-chancellor to propose a plan of action, recommended higher than average cuts for the Faculties of Arts and Social Sciences. The planning committee had used a series of statistics to compare faculties and gave such comparisons as a justification for differential treatment. Having acquired a fair degree of knowledge in the analysis of undergraduate applications, I produced several studies to attempt to show that direct comparisons, such as those being proposed by the committee, were misleading. My aim was to try to influence the decision making process at the University and my analyses were published in an internal magazine, Viewpoint. Issues raised were: class-related participation rates (perhaps the first time these were published); comparisons of demand for places in the different faculties; and the meaning of average A-level entry scores. The studies were also subject to deadlines which related to different stages in the planning process.

Average A-level scores are routinely calculated at Southampton and are used to make differential student quota, and budgetary, allocations to the different faculties. It is well known that the distribution of A-level scores depends on the subject mix, a topic which has been studied by Holt (1983). What is often overlooked is that offers are made before examinations take place, and that besides the probability of the applicant meeting the offer, the probability of the student declining the offer has to be taken into account. Average A-level scores combine both the uncertainty associated with predicting who is going to accept an offer and the uncertainty associated with meeting it. Both uncertainties are related to subject mix. I made a proposal to the Vice-chancellor that the calculation of average A-level scores should be discontinued in order not to use such misleading numbers in the resource allocation mechanism, but my proposal was not accepted despite my arguments, which the Vice-chancellor found convincing.

It can be argued that an important element that should be taken into account is the examining board. This may well be the case but undergraduate selectors do not make differences between examining boards when making offers, and an undergraduate entry forecasting system which was to make a prediction conditional on the examining board stands no chance of being implemented. The influence of the examining board is an interesting research question but to answer it requires a considerable amount of effort and time which I have not been able to find. Matters are complicated by the fact that many applicants take examinations in several examining boards, and some applicants take the same examination in several boards. UCCA, the principal source of statistics for undergraduate admissions, treats the marks from the different boards as being equivalent and does not collect data on examining board results.

By 1984 I had developed a complete computerised undergraduate admissions system which incorporated a market analysis based on Multidimensional Scaling, and a simple marketing intelligence survey based on cross-classifications.

I proposed to the University of Southampton that my system should be adopted for undergraduate admissions but my offer was not accepted. It was not until 1988 that a variant of the system was to be made operational in the Faculty of Social Sciences. The system and its implementation are described in two papers in the thesis. Mao Qing worked in 1988 on adapting my existing system to the new computer facilities, in this she was supported with a small grant from the Faculty of Social Sciences under my supervision.

In 1982, the DES asked the UGC for advice on the future of the University system. The UGC, in turn, asked for contributions from individuals and universities. My analysis of the social impact of the 1981 cuts was my contribution to the public enquiry. The time available for the study was limited because contributions to the enquiry had to be submitted by a certain date. The full study looked at individual subjects, but this aspect remains unpublished. The published version received a reply from the statistical advisor to the Minister in charge of Higher Education. An aspect which was not considered was sex differences in general and in the different subjects. The data was not available. I have, since then, obtained data from UCCA broken down by subject, sex, and level of qualification. I have now performed the analysis but the paper is still to be written.

The study on Multidimensional Analysis of research rankings was an obvious extension of the methodology which I had devised for undergraduate admissions. That study compared universities on the basis of subjects. I set up another project looking at the data from the point of view of comparing subjects on the basis of universities. The subject comparison approach confirmed the widely held view that university cuts have discriminated against technological universities, and suggests reasons why this is the case. The study has not yet been written in the form of a paper. The methodology could be used to analyse the 1989 research ratings of universities, but I have not been able to find the time to do it.

EDUCATIONAL SYSTEMS IN THE OR LITERATURE

Amongst recent OR review papers in the area of education management are: Steele (1979), Lancaster et al (1983), and White (1987). They comment that most of the work published is of a narrow technical nature.

There have been many studies of Linear Programming applications to the analysis of school catchment areas, but in many of them the interest has been on formulation and the models appear not to have been used in practice; examples are Bovet (1982), Nutson et al (1980), Schoepfle and Church (1989). There are cases when the problem has been formulated and solved using real data but this has been part of an academic rather than a managerial exercise; an example is the paper by Holloway et al (1975). There are few examples of cases of cooperation between planners and researchers, one of them is given by Jennergren and Obel (1980) who comment that the "study evolved in a gradual and iterative fashion, the relevant constraints and goals, and, in general, a relevant problem formulation only gradually became clear" and they conclude that "the process of gradual clarification of the problem was a useful one: ... it was a valuable learning process both for the investigators and for the members of the Planning Department". Ellis-Williams (1987) describes a model that combines costs with an algorithm to design school catchment areas, which was used for planning purposes by a LEA.

There are few published studies which address the issue of planning educational facilities under falling rolls situations. A formulation which uses Linear Programming is given in Bruno and Andersen (1982) who also give a survey of American literature on the subject. Their model uses real data for illustrative purposes but it is not a planning tool.

In the UK, Sutcliffe et al (1984), and Sutcliffe and Board (1988), discuss the application of Goal Programming to the allocation of children to schools in such a way that a series of social and educational objectives are taken into account. Their study stands alone in that the mathematical apparatus is used to show that the solution adopted by the Local Education Authority was difficult to justify on social and educational grounds. This has to be seen in the context of a very heated political and social context which has been described by Del Tufo et al (1982).

I am not aware of any other OR study in which the emphasis has been on the point of view of the community. Bondi (1987, 1988, 1989) has described a school closure programme from the point of view of the community, but her point of view is that of the independent observer, not the one of the academic consultant. A classical study of the managerial problems faced by falling rolls in schools in the UK is Briault and Smith (1980) but it would be difficult to describe this book as Operational Research except in that it studies falling rolls within an educational and managerial framework and makes recommendations to decision makers.

The issue of school closures is clearly related to the problem of forecasting school rolls. The careful work of the Local Government Operational Research Unit described by Groom (1971) was relevant to the planning of new schools, and did not survive the fall in the birth rate. More recent is the work by Simpson and Lancaster (1987) which produced a series of recommendations aimed at decision makers in Local Authorities. Simpson (1987) gives a review of the school roll forecasting literature, and discusses the statistical issues in detail, Simpson (1989). I am not aware of any OR paper describing the impact of school rolls forecasts from the point of view of the community, although the issues have been discussed in a general way from the point of view of management by Bailey (1982) and from the point of view of the community by Burchell (1989).

A particular form of a Linear Programming model, Data Envelopment Analysis (DEA), has arousen much interest because of its possible use in the analysis of the efficient use of educational resources. An example of the use of DEA to schools is given by Bessent et al (1982). DEA was seriously considered as a way to evaluate the performance of schools by the DES and at least one LEA but the approach was overtaken by the introduction of Local Management and formula funding in school education.

A set of models which should be mentioned are those used for financial planning. Ladley (1987) describes the models used by the DES to project education expenditure. The introduction of devolved financial management to schools can also be described as an OR application; the reasoning behind Local Management of Schools (LMS) can be found in Coopers and Lybrand (1988). Taylor (1989) discusses the formula used to fund special educational needs although his paper is the a starting point for an OR study rather than an OR study by itself.

Access to Higher Education in the UK has been extensively debated; most of the argument has centred on the models used to forecast demand. The issues are summarised in a Royal Statistical Society (1985) discussion. The original model used to make projections of student numbers had been described by Moore (1983). This model was criticised because it did not incorporate social trends in its formal structure. The criticism was slowly accepted and embedded in successive forecasts, DES (1980, 1984, 1986); the new forecasts were used as a basis for policy decisions; see white papers on the Development of Higher Education into the 1990's (1985) and on meeting the challenge in Higher Education (1987).

The financing of Higher Education in the UK is also done according to a model whose structure has been partially disclosed in the Review of the University Grants Committee report (1987). There are some published models used to fund Higher Education, mainly in the USA; they are reviewed by Steele (1979). There is very little in the literature about the general issues that arise when the models are implemented. An exception is the discussion of the Canadian case by Monahan (1988). There are some case studies of how formula financing has affected the management of particular universities in the UK; Ashworth (1982) describes the case of Aston University, and Hayward (1986) describes the impact of formula funding on the University of Hull. A more general paper on the same topic is the one by Shattock (1981). All these papers have in common the fact that they reflect experiences from the point of view of management.

The complete model for funding the Higher Education system in the UK has been much criticised, an example of such a criticism is AUT (1989). Criticisms of the assumptions underlying the system used to finance universities have been published; some examples are: Dolton and Makepeace (1983), Gee and Gray (1988), Gillet (1987 and 1989).

Published descriptions of financial models used to manage Higher Education institutions in the USA are not rare; see Steele (1979). They are rare in the UK; a survey is given by Gee (1986) who also proposes some guidelines to implement such a system although the discussion does not go beyond the hypothetical.

There is almost nothing published in the area of market analysis of applications for university courses. In the US, Stenberg and Davis (1978) used Multidimensional Scaling Analysis on the survey data, a one-off exercise because of the nature of the American admissions system. In the UK the only model for market analysis is the one proposed by Doyle and Lynch (1979) but this model is a good idea rather than a basis for analysis since the data that it requires does not exist.

An attempt to use multivariate statistical methods to predict enrolment in a university is given by Dambolena and Remaley (1980). The paper describes a linear discriminant analysis of applications data in an american university. The model appears to have been a simple statistical exercise rather than part of an admissions system; in any case, the American system of admissions is different from the British one and the experience cannot be easily translated although it is encouraging to see that the discriminant funtion behaved reasonably well at classifying applicants. In the UK there are examples of computerised systems to assist with admissions but they concentrate on selection rather than market analysis and administration; examples are Edwards and Bader (1988), Finlay and King (1989). Student selection by computer is full of dangers, as it was illustrated by the successful prosecution of St Georges Medical School by the Commission for Racial Equality (1988). The expert system developed by Edwards and Bader (1988) is not being used for admissions purposes, only as a training tool. Finlay and King (1989) do not mention implementation. Remus (1986) discusses the possibility of using a z-score procedure based on discriminant analysis for selection of MBA students at the University of Hawai'i but the results were not particularly good and the study did not result in implementation.

APPENDIX

This appendix attempts to show the relationship between Multidimensional Scaling (MDS) and other multivariate analysis techniques. MDS is used several times in this thesis in preference to other techniques because it is easily accessible to the non-statistician. It is a useful tool to represent data in an intuitive form, and to draw inferences from the data.

The appendix is organised as follows: first, an analytical solution is given to the problem of finding the position of a set of points in the space when the distances between them are known, this is the so-called classical scaling problem; second, an outline of the procedure to represent a set of points in the space using Principal Components Analysis is given; third, it is shown that the results obtained by PCA are identical to the results obtained through Classical Scaling; finally, it is shown that the Property Fitting technique to interpret the results of MDS is equivalent to Multiple Linear Regression Analysis; it follows from this that Property fitting is equivalent to Regression on Principal Components.

The appendix ends with a discussion of inference issues in a MDS context.

Classical scaling

The aim of this section is to present the analytical solution to the problem of deriving the coordinates of a set of points when the euclidean distance between any two points is known. The derivation follows the lines suggested by Torgenson (1958), and Chatfield and Collins (1980).

Let x_r be one of n points in a p-dimensional space,

$$x_r = (x_{r1}, x_{r2}, \ldots x_{rp})' \qquad r = 1, 2, \ldots n \qquad [1]$$

The set of points can be described in matrix form as,

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & & x_{2p} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix} = [x_1, x_2, \ldots x_n]' \qquad [2]$$

The euclidean distance between any two points, x_r and x_s, is a scalar, d_{rs}, which has been computed using

$$d_{rs} = [(x_r - x_s)' (x_r - x_s)]^{1/2} \qquad r = 1, 2 \ldots n$$

$$s = 1, 2 \ldots n \qquad [3]$$

Euclidean distances have a series of properties,

$$d_{rr} = 0 \quad \forall \; r = 1, 2, \ldots n$$

$$d_{rs} = d_{sr} \quad \forall \; r, s \qquad [4]$$

It is convenient to define a symmetric matrix of distances, D,

$$D = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{12} & d_{22} & & d_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ d_{1n} & d_{2n} & \cdots & d_{nn} \end{bmatrix} \qquad [5]$$

Equation [3] can be rearranged to read:

$$d^2_{rs} = x_r' x_r + x_s' x_s - 2 x_r' x_s \qquad r = 1, 2, ..n$$
$$s = 1, 2, ..n \qquad [6]$$

It is convenient to change notation

$$b_{rs} = x_r' x_s \qquad [7]$$

So that equation [6] becomes

$$d^2_{rs} = b_{rr} + b_{ss} - 2 b_{rs} \qquad r = 1, 2, ..n$$
$$s = 1, 2, ..n \qquad [8]$$

It is also convenient to define the symmetric matrix B as,

$$B = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{12} & b_{22} & & b_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ b_{1n} & b_{2n} & \cdots & b_{nn} \end{bmatrix} \qquad [9]$$

The matrix B is related to X in the form,

$$B = X X' \qquad [10]$$

The aim of the analysis is to obtain X when D is known. This is done in two steps. First, B is calculated from D using the set of equations defined by [8]; next, X is obtained from B using [10]. There is a problem to be resolved first. The left hand side of [8] consists of $\frac{n(n-1)}{2}$ known values. The number of unknowns is $n + \frac{n(n-1)}{2}$ since there are n terms of the form b_{rr} and $\frac{n(n-1)}{2}$ terms of the form b_{rs} ($r \neq s$) to be calculated.

The possible total number of solutions is unlimited. This is what should be expected since [8] indicates that the distance between any two points in the space can be obtained from the distance from each point to the center of coordinates and the angle formed by the lines that join the points and the centre of coordinates. The position of the centre of coordinates may, however, be changed without the distances between the points being altered. The ambiguity can be resolved by imposing constraints on the position of the centre of coordinates. It is customary to fix it in the centroid; i.e. for a given coordinate, j, the condition:

$$\sum_{r=1}^{n} x_{rj} = 0 \qquad j = 1, 2, \ldots p \qquad [11]$$

has to be satisfied.

The above conditions can be expressed in a more compact way. Let

$$1_n = (1, 1, \ldots 1)' \qquad [12]$$

be a unit vector of length n. Then [11] implies:

$$1_n' X = 0_p' \qquad [13]$$

where 0_p is a zero vector of length p.

Combine [10] and [13] to obtain:

$$1_n' B = 1_n' X X' = 0_n' \qquad [14]$$

which means that the sum of the elements in any column of B is zero. In the same way:

$$B 1_n = X X' 1_n = 0_n \qquad [15]$$

proves that the rows of B also add up to zero. These results can be exploited to solve the system of equations defined by [8]. First, add over s

$$\sum_{s=1}^{n} d^2_{rs} = \sum_{s=1}^{n} b_{rr} + \sum_{s=1}^{n} b_{ss} - 2 \sum_{s=1}^{n} b_{rs} \qquad [16]$$

The last term on the right hand side of [16] is the sum of the elements in row r of B and is, therefore, zero. The term $\sum_{s=1}^{n} b_{ss}$ is the trace of B. Changing notation,

$$\sum_{s=1}^{n} d^2_{rs} = n\, b_{rr} + \text{trace}\,(\,B\,) \qquad [17]$$

and adding over r,

$$\sum_{r=1}^{n} \sum_{s=1}^{n} d^2_{rs} = n \sum_{r=1}^{n} b_{rr} + \sum_{r=1}^{n} \text{trace}\,(\,B\,) \qquad [18]$$

which can be simplified to

$$\sum_{r=1}^{n} \sum_{s=1}^{n} d^2_{rs} = 2\, n\, \text{trace}\,(\,B\,) \qquad [19]$$

Equation [19] makes it possible to calculate trace(B) from the distance data. Then equation [17] can be used to calculate the diagonal elements of B. Finally, the off-diagonal elements of B can be derived from [8]. Having determined B, all that needs to be done is to decompose it in a product of two matrices, one being the transposed of the other one. There are infinitely many solutions to this problem, reflecting the fact that even when the centre of coordinates is situated in the centroid of the map, the distances between any two points are invariant to a rotation of the axes. A possible solution involves calculating the normalised eigenvectors of matrix B.

Let e_i be one such eigenvector, and let λ_i be its associated eigenvalue. The eigenvalue associated with some of the eigenvectors can be small enough to be ignored. Assume that there are k eigenvalues that cannot be approximated to zero, and that they have been ordered in order of magnitude:

$$\lambda_1 \geq \lambda_2 \geq \ldots\ldots \geq \lambda_k \qquad [20]$$

Then,

$$X = \left[\, \sqrt{\lambda_1}\; e_1 \;,\; \sqrt{\lambda_2}\; e_2 \;\ldots\ldots\; \sqrt{\lambda_k}\; e_k \right] \qquad [21]$$

See Chatfield and Collins (1980) for a proof.

This solution has the advantage that the variance associated with a particular coordinate, j, is equal to the eigenvalue, λ_j, and that the different coordinates are uncorrelated. The coordinates are rotated to their principal components.

Thus, the above analysis has shown that is is possible to find a set of points in the space, a configuration, when the euclidean distance between any pair of points is known. Any set of positive numbers could have been treated as distances, including a set of positive correlation coefficients. It is possible to relax this positivity condition, but the discussion here will not contemplate such a possibility in order to simplify the arguments. If correlation coefficients between variables had been used to generate the configuration, then a point will correspond to a variable and the distance between any two variables will be proportional to their correlation. The question now arises of how is the solution that has been found through classical scaling related to the solution that would have been found if Principal Components Analysis had been used, and not MDS. This will be the object of the next section.

Principal components analysis

Principal components is a technique used to explore the structure of multivariate data. For example, we could be describing a school catchment area by means of a series of measurements such as the proportion of owner-occupied households, the average age of the population, the number of cars per household, and so on. For a particular area, r , there will be a series of measurements which can be organised in the form of a vector, u_r .

$$u_r = \left[u_{r1}, u_{r2}, \ldots\ldots u_{rp} \right]' \qquad [22]$$

In some cases the variables are standardised prior to analysis, when that is the case we define a new variable

$$Z_k = \frac{U_k - \bar{U}_k}{S_{U_K}} \qquad [23]$$

Where $\bar{U}_k$ is the mean of the variable U_k and S_{u_k} is its standard deviation. After standardisation, observation u_r becomes z_r , where,

$$z_r = \left[z_{r1}, z_{r2}, \ldots\ldots z_{rp} \right]' \qquad [24]$$

Thus, an observation is a point in a p-dimensional space. Principal Components analysis aims at describing this space through a set of coordinates which are not the original ones. In general there will be n observations, which can be organised in the form of a matrix Z ,

$$Z = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1p} \\ z_{21} & z_{22} & \cdots & z_{2p} \\ \cdots & \cdots & \cdots & \cdots \\ z_{n1} & z_{n2} & \cdots & z_{np} \end{bmatrix} \qquad [25]$$

The variance covariance matrix associated with the variables Z_k is proportional to the matrix $Z'Z$. Because of the standardisation transformation, it will be a correlation matrix, **R**.

Principal components analysis involves applying an orthonormal rotation to the coordinate space in which **R** is defined in such a way that **R** becomes a diagonal matrix. To do this, the p normalised eigenvectors of R, and their associated eigenvalues, have to be calculated. We can order eigenvectors according to the size of the associated eigenvalues

$$\lambda_1 > \lambda_2 > \cdots\cdots > \lambda_p \qquad [26]$$

Let $\mathbf{a}_j$ be the jth normalised eigenvector,

$$\mathbf{a}_j = \begin{bmatrix} a_{1j} & a_{2j} & \cdots\cdots & a_{pj} \end{bmatrix}' \qquad [27]$$

Eigenvectors may be grouped together in a matrix, **A**,

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1p} \\ a_{21} & a_{22} & \cdots & a_{2p} \\ \cdots & \cdots & \cdots & \cdots \\ a_{p1} & a_{p2} & \cdots & a_{pp} \end{bmatrix} \qquad [28]$$

The eigenvectors become the new basis of coordinates, the change of coordinates is regulated by the matrix **A**. For example, the point $\mathbf{z}_r$ (equation [24]) chages its coordinates and becomes $\mathbf{x}_r$. The relationship between the new and the old coordinates is:

$$\mathbf{x}_r = \mathbf{A}'\mathbf{z}_r \qquad [29]$$

The projections on the new j axis of all the data points are easily calculated by means of

$$Z\, a_j = e_j \qquad [30]$$

where the first component of e_j is the projection of the first point on the new j axis, and so on. The vector e_j has the property that its sum of squares is equal to λ_j, i.e.

$$e_j' e_j = \lambda_j \qquad [31]$$

It is possible to group all the x_r points in a matrix,

$$\left[\, x_1 \;\; x_2 \;\; \ldots\ldots x_n \,\right] = A' \left[\, z_1 \;\; z_2 \;\; \ldots . z_n \,\right] \qquad [32]$$

Or, in a more compact form,

$$X' = A'\, Z' \qquad [33]$$

Which can also be written,

$$X = Z\, A \qquad [34]$$

Relationship between multidimensional scaling and Principal Component analysis.

This section is based on Gower (1966) as described by Chatfield and Collins (1980).

Multidimensional scaling involves calculating the eigenvalues of the matrix $Z\,Z'$, while principal components analysis is related to the eigenvalues of the matrix $Z'Z$. To explore the relationship between the two techniques it is sufficient to explore the relationship between the two sets of eigenvectors. Consider the eigenvectors of $Z'Z$,

$$(\, Z'Z\,)\, a_j = \lambda_j\, a_j \qquad [35]$$

Multiplying by Z on the left,

$$(Z Z') Z a_j = \lambda_j Z a_j \qquad [36]$$

Thus, the eigenvalues of $Z Z'$ are $Z a_j$. These are the vectors e_j in equation [30]. The sum of squares of e_j is, by equation [31], λ_j. In the description of classical scaling, the eigenvectors were required to have unit length. Let e_j^* be the unit length eigenvector of $Z Z'$, then:

$$Z a_j = (\lambda_j)^{1/2} e_j^* \qquad [37]$$

If all the eigenvectors are grouped in a matrix equation, this becomes,

$$Z A = \left[(\lambda_1)^{0.5} e_1^* \quad (\lambda_2)^{0.5} e_2^* \; \ldots\ldots (\lambda_p)^{0.5} \; e_p^* \right] \qquad [38]$$

The left hand side of equation [38] is, by equation [34], the set of points X as obtained when using Principal Components analysis. The right hand side of equation [38] is, by equation [21], the set of points X as obtained when using Multidimensional Scaling. Both techniques produce exactly the same results when distances are euclidean.

A criticism of the above methodology is that Classical Scaling can only be used when the distances are all positive while correlations can be either positive or negative, but this limitation can be easily overcome by using ordinal scaling, as described by Kruskal (1964). Ordinal scaling has the further advantage of making it possible to relax the definition of distance. Maps can be constructed from a wide class of measures of similarity. See Coxon (1982) for a discussion of this topic.

Property fitting

This section describes the mathematical basis for property fitting and its relationship to multiple regression analysis.

The aim of the analysis is to draw a line through a multidimensional scaling configuration in such a way that a property of the configuration is reflected by the position of the line. It is common practice to draw the line through the centre of the configuration. Any line drawn through a point in the space is totally described by a directional vector, v. Any point on the line, x_k , satisfies the equation:

$$x_k = \nu_k \, v \qquad [39]$$

where ν_k is a scalar.

Let x_r be a point which is not on the line. We are interested in finding the point on the line which is nearest to x_r . This requires projecting x_r orthogonally on the line. Let **q** be the nearest point to x_r on the line. **q** satisfies the equation of the line

$$q = \nu_q \, v \qquad [40]$$

The orthogonality of the projection can be written in vector form,

$$v' \; (\; q - x_r \;) = 0 \qquad [41]$$

using equation [40],

$$v' \; (\; \nu_q \, v - x_r \;) = 0 \qquad [42]$$

which can be rearranged

$$\nu_q \, v' \, v - v' \, x_r = 0 \qquad [43]$$

From here it is possible to work out the value of ν_q

$$\nu_q = \frac{v' x_r}{v' v} \qquad [44]$$

The nearest point on the line is,

$$q = \left(\frac{v' x_r}{v' v} \right) v \qquad [45]$$

The distance from the origin to the point q is:

$$d_r^2 = q'q = \left(\frac{v' x_r}{v' v} \right)^2 v'v = \frac{(v' x_r)^2}{v' v} \qquad [46]$$

The notion of directionality can be introduced by attaching a positive sign to distances to points situated on the right hand side of the origin and a negative sign to points situated to the left hand side of the origin. This can be achieved by means of:

$$d_r = \frac{v' x_r}{(v' v)^{0.5}} \qquad [47]$$

Assume now that every point x_r has associated with it a property which can be measured, and let the value of such measurement be m_r. Property fitting aims at drawing a line through the configuration in such a way that the correlation between the value of the property, m_r , and the distances d_r is maximised.

$$\rho = \frac{\sum_{r=1}^{n} \left[\frac{v' x_r}{(v' v)^{0.5}} + d_0 \right] m_r}{\left[\sum_{r=1}^{n} \left[\frac{v' x_r}{(v' v)^{0.5}} + d_0 \right]^2 \sum_{r=1}^{n} m_r^2 \right]^{0.5}} \qquad [48]$$

where d_0 is just a constant which will not affect the value of the correlation. It is convenient to write it in a different way

$$d_0 = \frac{v_0}{(v' v)^{1/2}} \qquad [49]$$

This has the advantage that the term $(v'v)^{0.5}$ can be simplified out of the equation. This way the correlation can be written,

$$\rho = \frac{\sum_{r=1}^{n} m_r \left[\sum_{s=1}^{p} v_s x_{rs} + v_0 \right]}{\left[\sum_{r=1}^{n} \left(v_0 + \sum_{s=1}^{p} v_s x_{rs} \right)^2 \sum_{r=1}^{n} m_r^2 \right]^{1/2}} \qquad [50]$$

The decision variables are the components of the directional vector v, v_s, and they are unconstrained. We can give them values in such a way that ρ is maximised. To do this, all that needs to be done is to set the partial derivatives of ρ with respect to v_s equal to zero. This is easily done, but notation is simplified if we define

$$x_{r0} = 1 \qquad [51]$$

Setting

$$\frac{\partial \rho}{\partial v_j} = 0 \qquad [52]$$

and simplifying, the following expression is obtained

$$\left[\sum_{r=1}^{n} \left(\sum_{s=0}^{p} v_s x_{rs} \right)^2 \right] \left[\sum_{r=1}^{n} m_r x_{rj} \right] -$$

$$- \left[\sum_{r=1}^{n} \left(\sum_{s=0}^{p} v_s x_{rs} \right) m_r \right] \left[\sum_{r=1}^{n} x_{rj} \left(\sum_{s=0}^{p} v_s x_{rs} \right) \right] = 0 \qquad [53]$$

This can be rearranged in a different way,

$$\left[\sum_{r=1}^{n}\left(\sum_{s=0}^{p} v_s\, x_{rs}\right)^2\right]\left[\sum_{r=1}^{n} m_r\, x_{rj}\right] -$$

$$- \left[\sum_{r=1}^{n}\left(\sum_{s=0}^{p} v_s\, x_{rs}\right) m_r\right]\left[\sum_{s=0}^{p} v_s \left(\sum_{r=1}^{n} x_{rj}\, x_{rs}\right)\right] = 0 \qquad [54]$$

This equation can be written in a simpler way if we notice that $\sum_{r=1}^{n} x_{rj}\, x_{rs}$ is the element in row j, column s of the matrix $X'X$ where matrix **X** is defined as in equation 2. However, the introduction of notation in equation [51] makes it desirable to define an extended matrix X^* as follows;

$$X^* = \begin{bmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1p} \\ 1 & x_{21} & x_{22} & \cdots & x_{2p} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix} \qquad [55]$$

and an extended vector v^* as follows;

$$v^{*\,\prime} = \left[\, v_0 \;\; v_1 \;\; v_2 \cdots\cdots v_p \,\right]' \qquad [56]$$

The expression $\sum_{s=0}^{p} v_s \left(\sum_{r=1}^{n} x_{rj}\, x_{rs}\right)$ is element j of the vector $(X^{*\prime}X^*)\, v^*$ which can be written $\left[(X^{*\prime}X^*)\, v^*\right]_j$. In the same way, $\sum_{r=1}^{n} m_r\, x_{rj}$ is element j of the vector $X^{*\prime} m$, and this can also be written as $\left[X^{*\prime} m\right]_j$. The notation can be used to write equation [54] in the form,

$$\left[\sum_{r=1}^{n} \left(\sum_{s=0}^{p} v_s \, x_{rs} \right)^2 \right] \left[X^{*'} m \right]_j =$$

$$= \left[\sum_{r=1}^{n} \left(\sum_{s=0}^{p} v_s \, x_{rs} \right) m_r \right] \quad \left[(\; X^{*'} X^{*} \;) \; v^{*} \right]_j \qquad [57]$$

To proceed any further we need further assumptions. We can assume that the value of the projection on the line, d_r , is related to the measurement at point x_r , m_r , in a linear form,

$$m_r = v_0 + \sum_{s=1}^{p} v_s \, x_{rs} + \varepsilon_r \qquad [58]$$

Substituting in equation [57],

$$\left[\sum_{r=1}^{n} \left(\sum_{s=0}^{p} v_s \, x_{rs} \right)^2 \right] \left[X^{*'} m \right]_j =$$

$$= \left[\sum_{r=1}^{n} \left(\sum_{s=0}^{p} v_s \, x_{rs} \right) \left[\sum_{s=0}^{p} v_s \, x_{rs} + \varepsilon_r \right] \right] \left[(\; X^{*'} X^{*} \;) \; v^{*} \right]_j \qquad [59]$$

Provided that the average value of the errors is zero ; i.e.

$$\sum_{r=1}^{n} \varepsilon_r = 0 \qquad [60]$$

and that the errors are independent of the x_{rs} terms; i.e.

$$\sum_{r=1}^{n} x_{rs} \, \varepsilon_r = 0 \qquad [61]$$

equation [59] simplifies to

$$\left[X^{*'} m \right]_j = \left[(\; X^{*'} X^{*} \;) \; v^{*} \right]_j \; \ldots\ldots\ldots\ldots [62]$$

There will be one such equation for each dimension, j = 1,2,....p
These equations can be collected in matrix form

$$X^{*'}m = (X^{*'}X^{*}) v^{*} \qquad [63]$$

If the inverse matrix exists, this can be solved to obtain the vector v^{*}

$$v^{*} = (X^{*'}X^{*})^{-1} X^{*'}m \qquad [64]$$

This is the usual multiple regression least squares result and it automatically ensures that condition [60] is satisfied. Property fitting is, therefore, equivalent to multiple regression analysis. If, as it was discussed earlier on, the axes of the configuration are the eigenvalues, then property fitting is equivalent to regression with principal components with all the advantages that the orthogonality of the regressors bring to the analysis.

Discussion

Existing packages to perform MDS analysis give very few summary statistics. This, on first sight, appears to be remarkable since many statistical results are available for PCA and for regression with principal components; an overview of the literature on these last two topics can be found in Seber (1984) who also comments that "little has been done in the way of inference in MDS". However, the MDS algorithm does not require similarities to be euclidean distances, and packages do not rely on the classical scaling approach but on the Monotone Regression approach, Kruskal (1964), which is often called Non-metric MDS (NMDS). The use of NMDS makes it possible to find the position of a set of points from a set of distances even when some of the distances are negative, since the results of monotone regression are invariant to the addition of a constant to the original set of distances. Any measure of proximity or association can be used as the basis for NMDS. There has been some discussion on the advantages and disadvantages of MDS as compared with PCA; see Shepard (1972), Lingoes (1971), MacCallum (1974). The two approaches were compared by Balloun and Oumlil (1988) who found the solutions to be not very different under various measures of similarity.

Monotone Regression is an algorithmic approach and does not lend itself easily to the sort of perturbation analysis which is so productive in other branches of Statistics. An alternative to

NMDS which is model based and permits hypothesis testing has been developed by Ramsay (1982) but I did not have access to relevant software and could not use the technique.

The parallel between MDS and PCA can be exploited by first performing PCA on a set of data in order to evaluate its dimensionality and then carry out NMDS. This was done in several of the cases reported in this thesis although it is not mentioned in the published papers.

The question "how sensitive is a configuration in NMDS to perturbations?" is relevant to the degree of confidence that can be attached to the results. This question is normally approached by trying to find out the answer to another question: "what is the goodness of fit that can be obtained by chance from random noise?". Spence and Graef (1974) used simulation to derive some tables which are incorporated into standard MDS packages. Comparisons with Spence and Graef tables was made, and in each case the hypothesis that the results of a MDS analysis could have been the result of chance was rejected.

The possibility of using the jacknife method as described in Mosteller and Tuckey (1977) is discussed by Kruskal and Wish (1978). Kruskal and Wish (1978) recommed that data should be collected from different subjects and the results compared using a three-way approach to Multidimensional Scaling such as the Individual Differences Scaling approach of Carroll and Chang (1970). This was done with good results in the analysis of the social structure of a city , Mar Molinero (1988), but the study has not been included here as it has not been published in a main journal.

Kruskal (1977) comments that the results of MDS are remarkably robust to perturbation, an observation which is confirmed by Mardia (1978).

In the case of similarities between school catchment areas the question of the number of indicators to be used can be raised. In this particular case adding an extra indicator to the MDS analysis is equivalent to adding an extra observation to the data set and asking how influential this observation can be. To proceed any further, two things have to be realised: first, that an extra observation will cause a distortion in the variance-covariance matrix associated with the school catchment areas; second, that this disturbance will affect the position of the axes. An axis is, by the geometrical interpretation of profit analysis, the graphical representation of a regression line which has all the coefficients except one constrained to be zero. In this way examining the influence of an extra indicator is equivalent to studying the influence of an extra observation on the results of regression analysis. The Theil and Goldberger (1961) results could be applied in the manner described by Harvey (1981, page 106) to explore this. There is, of course, no reason to concentrate on the axes since the results of MDS are invariant to rotation and any line can be used as an axis.

Theil-Goldberger can be the basis on a sensitivity analysis on any property vector. I did not do it because this idea has only recently come to my mind.

This argument can be reversed. The influence of an observation on a MDS configuration is not addressed in the literature. The general attitude is that if a configuration can be interpreted then the result is reasonable. This implies a theory of how the data is generated, a paradigm. In the particular case of the university research rankings it is not surprising to find Oxford and Cambridge at one extreme of the configuration because there is general preconception that they are seen as "good" research universities. In the same way, in the study of school catchment areas, the finding that professional workers tend to live in the areas where managers concentrate and not in the areas where manual workers have their residence is also consistent with prior expectations about the way in which society is organised. Had something different been found, the motivation to do further statistical analysis would have been stronger. Because the findings were consistent with the theory, the possibility that the theory could be wrong was not even contemplated. In this it must be pointed out that the MDS model was only a small part of a large attempt to structure a system rather than an objective by itself.

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CHAPTER 1

Understanding university undergraduate applications

Cecilio Mar Molinero

Two things are remarkable about the process which is followed by British universities to admit students for their undergraduate courses: the amount of easily available information that it generates, and the little use that is made of it.

The availability of information is a by-product of the admissions system, which is centralised. Candidates for university admissions do not apply for a place to the university of their choice, as in many other countries, but to a central computer centre, UCCA. Candidates fill in a form on which they express up to five choices of university and course. The form requires the candidate to give personal information such as address, age, family background, personal interests, schools attended, and previous academic results. A confidential reference is entered on the form by a headteacher or other person in a position of responsibility. When the candidate is still at school or other similar academic institution, the referee enters some statistical information on the form. Most of the contents of the UCCA form are coded and stored in magnetic form in the UCCA computer. Universities have on-line access to the UCCA data-base.

In the UK, the number of candidates for university places is about double the number of places available, although there are large differences between universities, and between courses within a given university. Up to now, the number of places available for a particular course has kept only a distant relationship with demand. This number is often determined by historical accident, internal bargaining within the institution, or as a consequence of external pressure, such as from the University Grants Committee.

The task of accepting exactly the right number of students with the appropriate qualifications for a given course is entrusted to university selectors. Selectors have a very difficult job to do. Most candidates apply for a place before they have taken their examinations. A possible mechanism for matching demand and supply, and one which is often used, is to ask applicants to obtain a minimum number of marks in their forthcoming examinations. In this way examination marks take the role of price in clearing the market. Selectors do not only have to find the exact number of students for each course, they would prefer to find the best students to join their course, and they have to do this without other bias or discrimination.

Applicants have choices too. If, in the process of trying to get the best possible applicants, a selector asks for very high grades, an applicant may accept the offer made by another university. An offer can be accepted as firm, or as insurance. Firm acceptance means that if the student meets the entry conditions he has to go to the relevant course and the university has to offer him a place. If the student does not meet the entry conditions the university whose offer he has accepted firmly does not have to give him a place, and may well reject him. In this case the insurance system enters into action. The student is guaranteed a place in the course accepted as insurance, provided that its conditions have been met. It is, therefore, in the interest of the applicant to accept as insurance an offer which is easier than the

This system of conditional offers hinges on the ability to forecast examination results, but this is very difficult. Many UCCA forms, in the confidential reference, contain a judgement of the marks that an applicant is expected to obtain, but Murphy[1] argues that such forecasts still leave a great deal of unexplained variation. Applicants are not expected to know their expected performance, and even if they know it they may think that the forecast does not properly reflect their ability. If selectors ask for high marks, good applicants may decline the offer of a place. If selectors give offers which are easier than those made by competing courses, these offers may be accepted as insurance.

The difficulty of meeting an offer is only one of the factors that an applicant takes into account when making a decision. A substantial number of applicants firmly accept offers which are easier than the ones they accept as insurance.

When making offers, selectors would like to know what is attractive about their particular course. They need to know what courses they are competing with: what is the selection policy followed by other courses: what conditions do the competitors normally impose: and what degree of success do their competitors have in filling their places with the best applicants. Finally, selectors would like the right number of students to enrol in the first year of the degree, and they would welcome a decision support system to help them make the right number of offers at the right level of difficulty.

There are a number of strategies that a selector may follow. A selector aware that a course is not particularly attractive to applicants can make low offers to ensure that many applicants will take them as insurance, and that some of these will be faced with the choice of going to that course or not going to university at all. When dealing with high demand a selector has two alternatives. The first one is to give very high offers, although this would put off some particularly good students.[2] The second is to make lower offers to a small number of applicants and reject the rest. The choice of policy and how best to carry it out is the responsibility of the selector.

The problem faced by a university selector is, in essence, no different from any other marketing problem. When examining demand for a product, managers would like to know what is it that makes the product attractive; what segment of the population finds it attractive; what are the reasons for the interest in the product; how the product is perceived when compared with competitors' alternatives; what success are the competitors having at selling the alternatives; what is the correct price for the product; what is the correct level of production; what trends are emerging in the market; and how these trends can be influenced. Firms devote a considerable amount of effort and energy to marketing to provide answers to some of these questions. They advertise, commission surveys, and analyse trends in order to keep abreast of their competitors.

How do university selectors carry out market analysis? It appears that they rely on experience and intuition. Many of them behave as if information was unavailable or very difficult to obtain. This is not the case; the UCCA form can be seen as an ideal marketing analysis tool, but to extract the information it contains requires an important initial effort. A system implemented in the Faculty of Social Sciences at the University of Southampton, which attempts to use UCCA forms as a source of marketing information is described here.

Computerised admissions management models

The system is based on relational database, SQL, with associated FORTRAN routines. A relational database is best seen as a large two dimensional matrix. Each row of the matrix, or record, corresponds to an applicant. In the case of the Faculty of Social Sciences, there were about 6500 records by the end of the 1988 – 89 admissions year. Each column, or field, contains an item of information such as the fee status of the applicant. There are about seventy fields, a total of 294 bytes, per applicant. The database is held in a mainframe computer, an IBM 3090, and can be interrogated using the SQL language.

Information is entered into the database at intervals depending on the time of the year. Around the end of the calendar year, when decisions are being made, the database is updated every two weeks. When the selection process is over, but information is still required to monitor progress, the database is updated every month. The mainframe database is used as a source of data to update departmental databases held in microcomputers. In this way each department has its own admissions system which is used for administrative purposes.

Information to guide selectors, and the selection process, involves running a specially written set of programs, CAMM, written in FORTRAN, which communicate with the SQL mainframe database. CAMM is run in a conversational manner, through a series of questions and answers. In 1988 the UCCA procedure changed, applicants not having to rank courses in order of preference. To accommodate this, the CAMM programs had to be modified. The examples assume the pre-1988 UCCA system. An example of a question and answer session can be seen in Table 1.

Table 1 here

The CAMM program can select from the database students who qualify for home fee status, or those who are expected to pay overseas fees. It can disregard applicants who have applied to certain universities, such as Oxford or Cambridge, on the grounds that they behave differently from the rest of the applicant population and they have to be treated as a different segment for analysis purposes. It is possible to run the program for all the applicants to a particular university, irrespective of course. The chosen university does not have to be the one in which the selector is employed; thus, the selector can draw inferences about alternative universities. The condition that all applicants included in any analysis must have applied for a particular course can also be imposed. Preferences can also be taken into account by, for example, ignoring those applicants for whom a particular university and course appears low on the UCCA form (this relates to the pre-1988 UCCA rules). Finally, there is the option of disregarding those applicants who have been rejected, or those who have declined an offer, or include only those who have firmly accepted an offer. In its present form, the CAMM program ignores sex and racial origin information, if available.

Analysis

The first step in a marketing analysis of a particular course must be at the macro level; examining market potential and market share. This involves comparing total demand for a course, or discipline, with national figures, as published by UCCA. I have described a methodology to carry out this analysis elsewhere.[3]

It is at the micro level that the CAMM program is particularly useful. A simple exercise such as listing the names of alternative universities or alternative courses mentioned in the UCCA form may throw light on why applicants choose this particular course. Lists can be produced for both home and overseas applicants. The ordering of universities can reflect different preconceptions: for example, the list for overseas applicants may reflect the international reputation of the university, or the impact that any marketing effort may have had on demand. It is up to the individual selector to interpret the information.

A list of the courses mentioned on the UCCA form, with no reference to the university where the course is run, gives information about the disciplines in which the applicants are interested. This information is of interest when considering whether a particular course is aimed at the wrong market, or whether the emphasis of a particular course should be changed in order to meet more closely applicants' expectations.

The CAMM program can be run for two different types of analyses: competitor analysis and similarity mapping.

Competitor analysis

The information available from UCCA for a particular segment of the applicant population can be reorganised to obtain evidence about every course mentioned in an UCCA form. An example of the output produced can be seen in Table 2. For every course, CAMM gives the total number of times it has been mentioned in the forms. The courses mentioned most often should be considered to be in direct competition with the course under the responsibility of the selector. In the pre-1988 version, CAMM shows the number of times that a course has been mentioned as first choice, second choice, and so on up to fifth choice.

Table 2 here

It is important to know what policy is followed by selectors in charge of the competitor courses. For every level of choice, the computer gives the offers that the relevant selector has made, and the number of times that such an offer has been made. If a selector has a policy of giving offers only to those applicants who rank the course as first or second choice, and rejecting the rest, this will appear clearly in the output.

It is wise to run the competitor analysis section of the program several times for the same segment of the applicant's population. The first time all applicants should be included, irrespective of their response to any offer they might have received; the second time only those applicants who have firmly accepted an offer should be included. This makes it possible to discover how successful a course is by working out which proportion of the applicants who have received a particular offer have firmly accepted it. The ratio of offers to firm acceptances can be used for forecasting purposes.

Similarity mapping

The CAMM program allows multidimensional scaling (MDS) maps to be constructed from the information contained in the UCCA forms.[4] Two measures of similarity between universities can be calculated. The simplest way of finding out how similar any two universities are from the point of view of applicants is to count the number of times that the same universities appear together on an UCCA form (co-occurrences). However, such a measure ignores the fact that, for the applicant, some universities are genuine alternatives while others may have been listed for insurance purposes. The degree of indifference can be taken into account by counting the number of times that a university appears mentioned next to another one on the same UCCA form (adjacencies): counting adjacencies is, of course, not valid after 1988 since universities no longer appear listed in order of preference but in alphabetical order. Adjacency measurement has been found to be much more useful at providing marketing information than co-occurrences. The change in the UCCA rules can only be described as unfortunate from the point of view of marketing information.

The matrix of similarities calculated as above has some important characteristics. The university to which the selector belongs is always mentioned, hence much information is available about the similarity between it and its direct competitors. Much less information is available about perceived similarity between any two competitor universities. This results in many zero entries in the similarity table. An example of a similarity table based on co-occurrences can be seen in Table 3.

Table 3 here

A map can be constructed from a similarity table so that those universities for which the measure of similarity takes a high value are plotted next to each other, and those with a low value are plotted far apart. A MDS solution can be obtained in any number of dimensions. Experience suggests that three dimensional solutions are appropriate for marketing analysis purposes. In general, the first dimension has been found to be associated with academic characteristics; the second with difficulty of entry in a given course; and the third with socio-geograhical features or the location of the university. MDS maps are produced for most courses in the Faculty of Social Services of the University of Southampton. Since geography is outside the control of universities, only plots in the first two dimensions are distributed to selectors.

The first two dimensions of the map that was derived from the data shown in Table 3 can bee seen in Figure 1. Southampton's central position is a consequence of the fact that all applicants mentioned this university on the UCCA form.

Fig 1 here

A case study

The way in which information derived from UCCA can be used to analyse the market for a particular course can be illustrated by means of an example. This example relates to an existing course, but its name and the name of the department concerned have been changed to preserve confidentiality; the names of related courses had to be changed for consistency.

The Department of Euskara offers only one course: combined honours Euskara with Welsh. The department has been concerned at the difficulty of filling its first year student quota. There is no shortage of good applicants, many of whom also mention Oxford or Cambridge on the UCCA form. A possible reason for the low take up rate might be that applicants who are interested in Euskara do not want to study a second language, and the possibility of offering a single honours course in Euskara should be investigated. Can any advice be given on the basis of the information available from UCCA as processed by means of CAMM?

The first step taken to advise the Department of Euskara was to collect information for a complete admissions year, so that all the decisions made by selectors and applicants could be observed and summarised. A first run of CAMM was made asking for a competitor analysis, without excluding any of the applicants for the course. The list of universities and courses which were mentioned most often is summarised in Table 4. As each applicant can mention up to five courses on the UCCA form, the total number of mentions is of the order of five times the number of applicants. Both the list of universities and courses have been truncated in Table 4. The only Southampton course mentioned in the UCCA forms was Euskara with Welsh, hence the total number of Southampton mentions is equal to the total number of applicants.

Table 4 here

Only one mention to either Oxford or Cambridge may appear in an UCCA form; such mention always being the first choice. The ratio of Oxford or Cambridge applicants to the total is high at 18 per cent. An examination of Table 4 shows that applicants are not interested in single honours courses. The courses which are mentioned most often are 'Welsh with Euskara' and 'Euskara with Welsh'; the courses 'Combined Languages', 'Modern Languages', and 'Minority Languages' may also reflect an interest in Euskara with Welsh. The hypothesis that applicants are interested in coming to Southampton because of the high reputation of its Euskara studies, and would prefer to study single honours Euskara, which is not available, is not supported by the data.

The standard conditional offer made to Southampton applicants was, during the year under examination, BCD in three Advanced Level examinations. This was low compared with the offers made by competing courses. CAMM disclosed that Nottingham's standard offer was BB; Exeter's BBC or BCC; Leed's BBC; Sheffield's BCC; Bristol's BBC; Bath's BBB: London Westfield asked for BC; Birmingham's offer [illegible] and Cambridge [illegible] examinations.

In recent years the total number of students who want to study minority languages such as Welsh and Euskara has been declining, for reasons still unclear. The consequence of this decline is that departments have been reluctant to reject applicants who have failed to meet the condition of the offer. Under these circumstances, the Southampton policy of making a low offer which can be accepted as insurance is not wise except, perhaps, in the case of Oxford and Cambridge applicants. The department of Euskara should consider increasing the level of its standard offer in line with the offers made by its main competitors. The need to increase the level of the offer at a time of decreasing demand for places is a paradoxical consequence of UCCA rules.

CAMM was used to obtain information about those applicants who had not included Oxford and Cambridge in their UCCA forms. The results are summarised in Table 5. There were 91 such applicants, of whom 78 were made some kind of offer, 12 were rejected, and one withdrew. If Southampton had been placed at random on the form one would have expected to have seen about 18 candidates at each level of choice. Southampton only appeared 12 times as first choice, which is a low number under a binomial probability model. The course often appeared as second, third, or fourth choice; it is suspected that the image of the course is in need of enhancement.

The program was run again excluding Oxford and Cambridge applicants, and including only applicants who had not declined a Southampton offer; and it was run, yet again, including only applicants who had firmly accepted an offer from Southampton. This made it possible to construct Table 6, which summarises firm acceptances, and Table 7, which summarises insurance acceptances.

Tables 5,6,7 here

Tables 6 and 7 show that the probability of an offer being firmly accepted increases, as would be expected, as the level of preference increases. The reverse occurs with the probability of an offer being accepted as insurance. The probability of an offer being accepted as firm, or as insurance, depends on the level of the offer. It is possible to pool all the data for all universities and estimate these probabilities as a function of the level of the offer and the level of preference,[5] but selectors feel much more confident if they see the probabilities relating to their own courses. Probabilities of acceptance can be estimated by dividing the number of accepted offers by the number of offers made at every level of offer. The main difficulty is that when the numbers of offers and acceptances are small, the proportions are not very good estimators of the underlying probabilities. In the case of Euskara with Welsh, the probability of an offer being accepted as firm, when the offer is the standard one (BCD) was estimated to be 0.625 for the first choice, 0.333 for the second choice, 0.20 for the third choice, 0.133 for the fourth choice, and 0.143 for the fifth choice.

The probability of an offer being firmly accepted is only the first step towards the prediction of the number of students who will enrol in the course. This requires an estimate of the probability than an offer has of being met, which depends on the level of the offer, and an estimate of the probability that an applicant who has met a firmly accepted offer will withdraw at the last minute. These last two probabilities can be easily estimated from past experience. Despite all the uncertainties built into the admissions process, predictions made in this way are remarkably accurate.

The facility built into the CAMM program of only analysing the behaviour of those applicants who had applied to a particular university was used to obtain information about Oxford and Cambridge applicants. Table 8 summarises the offers made by the selector for Euskara with Welsh to Oxford or Cambridge applicants.

Table 8 here

The department of Euskara has a policy of giving 'easy' offers to Oxford and Cambridge applicants. Out of 20 applicants, eight were given unconditional offers: eight were given CCC offers, which are lower than the standard offer, two were given non-standard offers (mainly conditions to meet matriculation requirements); and two withdrew before receiving an offer from Southampton. The offers that Oxford and Cambridge gave these 20 applicants were: five unconditional offers; five conditional offers; nine rejections.

Southampton appears low on the list of priorities of Oxford and Cambridge applicants. Applicants who feei confident enough to apply to these two universities would not normally find the standard offer made by Southampton's competitors as 'difficult', and little would be gained by making them an 'easy' offer. A possible policy for the Department of Euskara with respect to Oxford or Cambridge applicants is as follows:

i) Wait until the result of entrance examinations is known.
ii) Applicants that are rejected by Oxford or Cambridge should be given offers which are no easier than those given by competitor courses.
iii) If the applicant is given an offer from Oxford or Cambridge which is conditional on the results of exams still to be taken, make sure that Southampton's offer is accepted as insurance. A possible policy is to be make an unconditional offer, or an offer which is so low that it can be considered to be unconditional, for example two E's at A level.

Recommendation (iii) runs counter Southampton's established rules for university selectors. The Department of Euskara needs to decide whether it is willing to continue receiving applications from candidates who expect to obtain very high marks, and see all of them enrol in alternative universities, as in the past, or it is prepared to take the risk of occasionally having to accept badly qualified applicants.

Finally, the program CAMM was also run in the similarity matrix mode to find out how Southampton is perceived by applicants before they apply. The program was run several times to explore the perceptions of those applicants who accepted a Southampton offer as well as those who just applied. The level of preference was also changed to exclude universities which were listed at a low level of choice, presumably as insurance. The definition of similarity was also changed. Figure 1 shows the map which was produced when all applicants and all choices were included, similarity between universities being measured through co-occurrences.

Interpreting the maps required detailed knowledge of the courses available at alternative universities. The discussion of the maps was an exercise of interest in itself, since many questions had to be asked about the type of course offered by alternative universities and how applicants perceive any differences. In Figure 1 Southampton appears at the centre of the map; this is reasonable since all applicants have listed Southampton in their UCCA form. Geography appears to play a part in the minds of the applicants, with London colleges at the top left hand corner of the map and universities situated in the Midlands in the bottom right hand corner. The division between literature based courses and applied courses was evident to the Euskara selector. Academic reputation was also found to play a part when filling in an UCCA form. All this information was found to be useful for future marketing strategy.

Conclusion

Much marketing information can be obtained about admissions from existing data sources. It is possible to explore how a course is perceived by applicants; what are the main competing courses; what are the admissions policies of competing courses. This knowledge can be used to design an admissions policy which maximises the qualifications of entrants to a given course. A by-product of this information system is that reasonably accurate forecasting systems can be devised for admissions purposes.

Universities have not been particularly motivated to understand the dynamics of student demand. The proposals to shift the balance of student finance to fees are an attempt to introduce market forces into the admissions system. There will be a need for better information and careful marketing. A system like the one described here may become an important tool for university undergraduate selection.

The methods described are easy to modify to incorporate changes in admissions processes, such as the removal of the order of preference in the UCCA form. This makes it easy to review marketing indexes, and to assess the influence of change. Such changes have been incorporated in the current version of the system. Some selectors will argue that they receive good information from UCCA on each candidate, the offers made to them, and their decisions; that they talk to them; and that they are aware of the reasons for those decisions. These selectors would also argue that selection is an art rather than a science. These views ignore the important administrative advantages to be derived from a computer based system for admissions, and the difficulties of obtaining insight from a very large amount of data, specially at a time of change.

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[5] Mar Molinero, *op cit.*

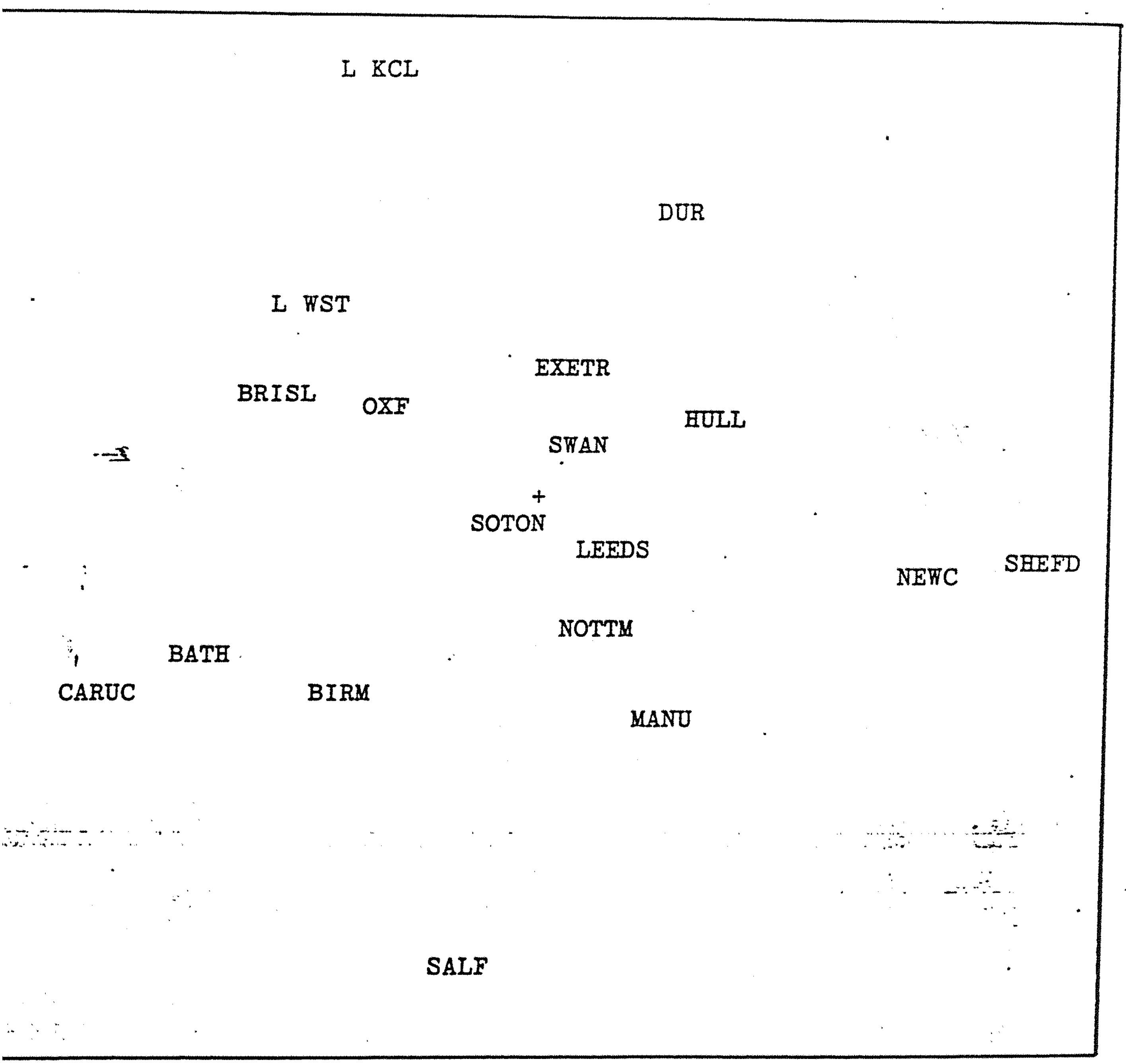

Figure 1. Example of MDS map derived from UCCA information.

```
O YOU WANT COMPETITOR ANALYSIS OR SIMILARITY MATRIX ? COMP OR SIMI
    COMP
LEASE TYPE IN SHORT NAME FOR UNIVERSITY
    SOTON
O YOU HAVE A PARTICULAR COURSE IN MIND?YES OR NO
    YES
LEASE INPUT UCCA SHORTNAME FOR COURSE
   ESWS
TUDENTS WHO HAVE NOT APPLIED FOR THIS
OURSE AT THIS UNIVERSITY WILL BE IGNORED
LEASE INPUT LOWEST POSITION FOR COURSE
   5
O YOU WANT HOME, OVERSEAS, OR ALL STUDENTS?HOME,OVER,ALL
   OVER
O YOU WANT TO EXCLUDE REJECTIONS? YES OR NO
   NO
O YOU WANT TO EXCLUDE DECLINED OFFERS? YES OR NO
   NO
EASE INPUT LOWEST CHOICE YOU WANT INCLUDED IN STATISTICS
   5
```

Table 1. Example of CAMM dialogue

```
NOTTM        38  MENTIONS

              3 CHOICE 1  BB  (  3)
              8 CHOICE 2  BB  (  4)   R   (  3)   BC  (  1)
             11 CHOICE 3  BB  (  8)   R   (  2)   BC  (  1)
              6 CHOICE 4  R   (  4)   B   (  1)   BB  (  1)
              3 CHOICE 5  BB  (  2)   R   (  1)
   WSES      31 APPLICATIONS


              1 CHOICE 2  BC  (  1)
              2 CHOICE 3  BC  (  2)
   WSSH       3 APPLICATIONS


              1 CHOICE 2  BCC (  1)
              1 CHOICE 3  R   (  1)
   ESSH       2 APPLICATIONS


              1 CHOICE 3  BB  (  1)
   ESWS       1 APPLICATIONS


              1 CHOICE 2  R   (  1)
   OTHR       1 APPLICATIONS
```

Table 2. Example of CAMM competitor analysis output

UNIVERSITY		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SOTON	1	-																	
NOTTM	2	41	-																
EXETR	3	39	12	-															
LEEDS	4	31	8	11	-														
SHEFD	5	26	15	5	9	-													
BRISL	6	25	4	11	8	2	-												
BATH	7	24	11	6	6	1	6	-											
L WST	8	20	6	13	3	1	2	3	-										
BIRM	9	17	4	5	4	2	2	2	5	-									
L KCL	10	17	1	5	2	1	6	1	7	2	-								
MANU	11	17	6	3	4	4	3	2	0	3	1	-							
DUR	12	16	3	9	5	2	3	1	3	1	3	2	-						
HULL	13	16	10	4	6	6	2	3	1	1	2	0	1	-					
NEWC	14	15	9	3	1	8	0	0	0	1	1	2	2	2	-				
OXF	15	15	1	7	2	0	9	2	0	1	2	4	4	2	0	-			
SWAN	16	13	4	3	3	2	1	2	4	3	3	2	1	0	2	1	-		
SALF	17	12	2	1	6	1	1	6	1	3	0	3	1	1	1	0	1	-	
CARUC	18	10	3	2	0	0	2	3	2	2	0	1	0	0	0	3	2	1	-

Table 3. Similarity table generated by CAMM using co-occurrences as measure of similarity

UNIVERSITY	TIMES MENTIONED
Southampton	111
Nottingham	41
Exeter	39
Leeds	31
Sheffield	26
Bristol	25
Bath	24
London Westfield	20
Oxford or Cambridge	20
Birmingham	17
London Kings College	17
Manchester University	17
Durham	16
Hull	16
Newcastle	15
Swansea	13
Salford	12
Cardiff	10
London Queen Mary	10
Bradford	8
Essex	8
London University Col.	7

COURSE	TIMES MENTIONED
Welsh with Euskara	315
Euskara with Welsh	128
Combined languages	35
Modern languages	19
Euskara	13
Welsh	11
Euskara and linguistics	4
Euskara. european stud.	4
Minority languages	3

TABLE 4. Universities and courses mentioned in UCCA forms.

Preference in UCCA form	Total number	Offers						With
		U/O	BCD	CCC	BC	other	Reject	
1	12	1	8	0	0	0	3	0
2	21	1	18	0	0	1	1	0
3	22	1	15	0	0	1	4	1
4	21	0	15	2	0	2	2	0
5	15	0	7	3	2	1	2	0

TABLE 5. Offers made to applicants who did not mention Oxford or Cambridge.

Preference in UCCA form	Total number	Offers				
		U/O	BCD	CCC	BC	other
1	6	1	5	0	0	0
2	7	1	6	0	0	0
3	3	0	3	0	0	0
4	2	0	2	0	0	0
5	3	0	1	0	1	1

TABLE 6. Firm acceptances from applicants who did not mention Oxford or Cambridge.

Preference in UCCA form	Total number	Offers				
		U/O	BCD	CCC	BC	other
1	2	0	2	0	0	0
2	6	0	6	0	0	0
3	7	0	6	0	0	1
4	13	0	11	1	0	1
5	5	0	2	2	1	0

TABLE 7. Insurance acceptances by applicants who did not mention Oxford or Cambridge.

Preference in UCCA form	Total number	Offers						With
		U/O	BCD	CCC	BC	other	Reject	
1	0	0	0	0	0	0	0	0
2	1	1	0	0	0	0	0	0
3	4	1	0	1	0	1	0	1
4	10	3	0	6	0	0	0	1
5	5	3	0	1	0	1	0	0

TABLE 8. Offers made to applicants who mentioned Oxford or Cambridge.

CHAPTER 2

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Decision Support Systems for University Undergraduate Admissions

CECILIO MAR MOLINERO[1] and MAO QING[2]

[1]Department of Accounting and Management Science, University of Southampton and [2]Institute for Post and Telecommunications, University of Beijing

Undergraduate admissions to British universities are computerized through a central clearing house, UCCA. A by-product of this arrangement is that information on each applicant is easily available in computer-readable form. The paper describes a system used to administer undergraduate applications, forecast enrolment and do market analysis which was implemented in the faculty of Social Sciences of Southampton University.

Key words: decision support systems, education, forecasting

INTRODUCTION

Every year about 175,000 individuals apply for admission as undergraduates at a British university. The process by which available places are matched with individuals wanting to take them is computerized through a central clearing house, UCCA. Applicants do not write direct to universities; they fill in an UCCA form. The rules that regulate the admissions process are very clear, with clear procedures and deadlines.

Obtaining a place in a British university institution is not easy. Only about 7% of the 18-year-old age group go to university, a very low proportion by the standards of developed countries. Nearly all British undergraduate students receive some support from the state, which, in turn, takes an important role in the supply of places. The number of places available every year is limited, in the last instance, by the budget allocated for university expenditure. Until 1989 this general budget was divided between institutions by the University Grants Committee (UGC). One of the roles of the UGC has been to indicate to every university institution how many undergraduate students it should take in every discipline. Final responsibility for the allocation of student places to faculties and courses rests, however, with individual institutions, although significant departures from UGC directives may be met with financial penalties in later years. The UGC ceased to exist in 1989, and a new body, the Universities Funding Council (UFC), has taken over its duties.

A consequence of this planning mechanism is that the number of undergraduate places available in a particular course within a given university is the result of national discussions and internal bargaining, and is only indirectly related to student demand.

University selectors are under a great deal of pressure to accept neither more nor fewer students than planned for the courses under their responsibility. The pressures on the selectors are, in the last instance, financial ones. Students bring funding both directly, in the form of fees, and indirectly, through the block grant for the university. The consequences for a department of failing to accept enough students can be very serious: funding may be reduced for the university and the department. It is also possible for the number of acceptances to exceed planned numbers, but the block grant does not increase on account of the extra costs that may be incurred, while the student fees are set at a level which is below marginal cost. Exceeding quotas is a bad strategy in the short term, and departments that do so may be penalized. The ability to predict how many students will enrol in a course is a crucial skill that a university selector is expected to possess.

Meeting a quota is not the only objective of the selection task. Selectors are expected to find the best possible students. They are also expected to be able to justify their actions. This is particularly important in the context of equal opportunity policies.

It is possible to base undergraduate selection on a structured interview system aimed at assessing the academic potential of every applicant. It is not clear, however, whether a selector can identify the most promising individuals as a result of a short interview. It can also be claimed that the decision to make an offer to an applicant after an interview can be tainted by prejudice. Besides, in institutions where demand far exceeds supply as in the case of Southampton, interviewing applicants is not a practical proposition. A possible way forward is to select applicants on the basis of a criterion which can be quantitatively evaluated. Examination results provide such a criterion. Most university selectors would argue that the results of examinations taken at the age of 17 or 18 do not necessarily reflect academic ability; that there are many uncertainties associated with examination results; that school and personal background can be very important factors to be taken into account; and that a selection system based on examinations may be denying opportunities to many very able individuals. However, an investigation into admissions to higher education carried out for the Training Agency found that many insititutions selected applicants on the basis of A-level scores; i.e. they used the result of a public examination as a rationing device.[1] It was also found that many institutions justify some of their resource-allocation decisions on the basis of average A-level results. Southampton is no exception in this respect.

When the whole selection system hinges on examination performance, it is easy to fall into the temptation of associating quality with examination results. Selecting the best students then becomes equivalent to identifying those who will achieve the highest grades at A-level. However, individuals apply for university places before the result of their examinations are known. It is common practice to make the offer of a place conditional on the applicant obtaining minimum grades in their A-levels. But applicants may decline the offer if they see it as too difficult, or accept it only as an insurance if they consider it to be too easy.

Most British undergraduates choose to go to a university which is far away from home. When applying for a university place, each individual is allowed up to five choices. Individuals would like to read the subject of their choice at their preferred university. There is no guarantee, however, that they will be offered a place since, for most courses, demand exceeds supply.

Under these circumstances, mistakes can be very expensive. An individual who applies to the wrong courses may find himself/herself without a university place. A selector who fails to make offers at the right level may be imposing financial burdens on his/her department. Any information which may be used to remove uncertainty will be welcome by either party.

Applicants are helped by school careers advisory services, and by specialized publications such as univeristy prospectuses and commercially available publications. Selectors benefit from the fact that the admissions system is centralized and computerized. Selectors face, however, a problem of data overload. They have to deal with many applicants, for which much data is available, and more is obtained as the admissions process evolves. There is a need to transform data into information, and to design a decision support system to help in the admissions process. The system that was developed for the Faculty of Social Sciences of the University of Southampton will be described here, and it will be illustrated with reference to a particular course, Accounting with Statistics.

DATA

The main source of information at the beginning of the admissions process is the UCCA form. It contains personal details, academic results, information about the school that the applicant attends and a confidential reference. Some of this is coded and stored in a database in the UCCA computer. The UCCA form is photocopied and sent to the universities that are mentioned in it. UCCA also makes available the relevant database records through a remote computer link.

Until 1988, the ordering of courses on the UCCA form reflected the applicant's preferences, with the most preferred course at the top of the form and the least preferred course at the bottom of the form. This system was very useful from the point of view of market analysis of admissions, as will be discussed later, but, given the excess demand on some courses, some selectors used to reject all those applicants who did not list their course at the top of the form. To avoid this behaviour, the statement of preferences on the UCCA form was done away with. As from 1988/89, universities are listed in alphabetical order, although there is provision for a 'star' system to indicate which course, if any, is preferred above all others. The examples given here refer to the old procedures.

As the admissions process evolves, applicants are made offers by university selectors. Applicants then decide which offer to accept and whether the acceptance is on a firm or on an insurance basis. All this information is entered in the UCCA database and made available to all selectors in charge of courses mentioned in the UCCA form.

THE ADMISSIONS SYSTEM

An overview of the structure of the admissions system implemented in the Faculty of Social Sciences of the University of Southampton is given in Figure 1.

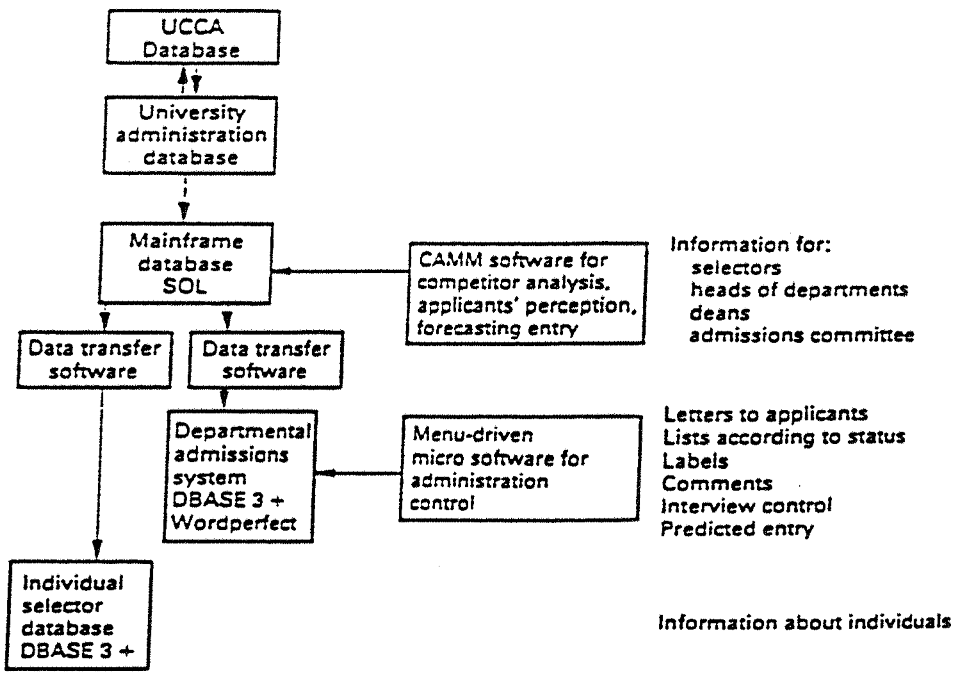

FIG. 1. *Overview of the admissions system.*

The University of Southampton communicates with UCCA through a remote terminal located at the administration. For security reasons there is a clear separation between administration and academic computing. Course selectors are academics, and are not allowed direct access to the administration computer. As a compromise, a database was set up for admissions purposes in the academic mainframe, an IBM 3090. The mainframe admissions database uses standard relational database management software, SQL, which is capable of communicating with FORTRAN programs.

The need to use the mainframe was dictated by practical considerations. First, communication between the administrative computer and the mainframe is easily established. Second, the datafile obtained from the administrative computer contains all applicants to the faculty, independently of the department applied for. Indeed, some individuals apply to more than one course within the faculty, and this creates a potential source of data-processing headaches, which are avoided through the use of the SQL database. Third, the mainframe is an ideal environment in which to run the FORTRAN modules on which the analysis of applications relies. Fourth, the mainframe can be described as 'neutral territory' in which the data for different departments which compete for resources within the faculty can reside.

The mainframe database contains a record for every applicant, with 78 fields per record—a total of 294 bytes per applicant. At the end of the admissions year 1988/89 there were about 6400 records. These include applicants to any of the 32 courses under the responsibility of one of the six departments in the faculty. The mainframe database was used for market analysis purposes, using a series of specially written programs, Computerised Admissions Management Models (CAMM).

The frequency with which the database was updated was also dictated by practical considerations. If the database is updated very frequently, the information that it contains closely reflects demand for places in every course. There are costs associated with a high updating frequency:

programs have to be run in the administration computer; data files have to be transferred through the communications network; the mainframe database has to be updated; programs have to be run to segregate the data that is to be transferred to each department; and the database that resides in every department has to be updated. The benefits from frequent updating are, however, not all that important. The computerized admissions system is not a tool for selection, but an instrument of market analysis and an aid to administration. A decision was made not to change existing selection procedures; they still rely on members of the academic staff carefully considering all the information in the UCCA form, in particular the confidential reference, which is not available in the computer file. There is little point in designing and implementing an expensive procedure that makes information about applicants available before the UCCA form arrives, particularly when a selector may take several weeks to process an UCCA form.

The admissions system does not assist admissions tutors in the selection of students, except in so far as it provides relevant information. The main selection tool continues to be the UCCA form. For an example of an expert system designed to help admissions tutors, see Edwards and Bader.[2] Selection by computer can create many problems, as was illustrated by the successful prosecution of St George's Medical School.[3] All this taken into consideration, it was decided to make the updating frequency dependent on the time of the year. During the winter months, when decisions were being made, it was updated once every 2 weeks. When decisions had already been made and all that was required was to monitor progress, updating took place about once a month.

It would have been possible to design an admissions system centered around the mainframe database, but this would have required a centralized faculty admissions system. A system based on a central admissions office run by a well-qualified administrator has much to commend itself. Unfortunately, individual departments wanted to keep control of their own admissions administration, and six different subsystems had to be set up. Data is segregated from the mainframe and distributed to relevant departments. These smaller databases were made to reside in microcomputers situated in departmental offices being used by secretarial staff. Only a small subset of the fields available in the mainframe database were transferred to departments. There was also provision to create databases for admissions tutors to use, although this was not implemented. It was left to individual admissions selectors to ask for this facility, but no-one did.

MARKET ANALYSIS WITH CAMM

Admissions tutors are no different from product managers in industry. Admissions tutors are in charge of a product whose market has to be understood; product price has to be set at the correct level; they need to know who their competitors are, how successful these competitors are, and what policies and pricing strategies are being followed by these competitors. Companies carry out market surveys, study the image of their product and advertise. Universities do not behave in the same way. Undergraduate courses are not advertised. Little market research is undertaken. Most is left to the experience and intuition of admissions tutors who behave as if information was very difficult to obtain. This is, however, not the case. The computerization of the admissions system makes it possible to extract much marketing intelligence from UCCA forms.

The computer program CAMM attempts to explore how a particular course is perceived by applicants, what it is that attracts applicants, what other courses are seen by applicants as alternatives, what the admissions policies followed by the selectors for these competing courses are, and what success competitors have at filling their quota.

There is always the possibility that different segments of the applicant population will behave in different ways; for example, overseas applicants and home applicants may have different preconceptions about a particular university. To take this into account, the first step in running CAMM involves a conversation with the program to establish the conditions to be met by the segment of applicants to be analysed. This makes it possible, for example, to analyse the behaviour of home students who did not apply for a place at Oxford or Cambridge, and who did not decline an offer from Southampton. An example of a CAMM conversation is given in Figure 2.

The way in which applicants perceive a particular course is explored by means of multidimensional scaling techniques (MDS). MDS has been found to be a very powerful tool for decision

```
QUESTIONS TO DETERMINE IF APPLICANT IS TO BE INCLUDED IN ANALYSIS
PLEASE TYPE IN SHORT NAME FOR UNIVERSITY
    SOTON
DO YOU HAVE A PARTICULAR COURSE IN MIND? YES OR NO
    YES
PLEASE INPUT UCCA SHORTNAME FOR COURSE
    43KQ
STUDENTS WHO HAVE NOT APPLIED FOR THIS COURSE AT THIS UNIVERSITY WILL BE IGNORED

PLEASE INPUT LOWEST POSITION FOR COURSE
    5
DO YOU WANT TO EXCLUDE APPLICANTS IF THEY MENTION CERTAIN UNIVERSITIES? YES OR NO
    NO
DO YOU WANT HOME, OVERSEAS, OR ALL STUDENTS? HOME, OVER, ALL
    HOME
DO YOU WANT FIRM ACCEPTANCES ONLY? YES OR NO
    NO
PLEASE INPUT LOWEST CHOICE YOU WANT INCLUDED IN STATISTICS
    3
CHOICES IN UCCA FORM BELOW 3 WILL BE IGNORED
```

FIG. 2. *Example of CAMM conversation.*

analysis. An example of the use of MDS as a market research tool in the area of universities is given by Sternberg and Davis.[4] Crucial to the use of MDS is a measure of similarity. A possible measure of similarity between two institutions can be obtained by counting the number of times that they are named in the same UCCA form (co-occurrences). Under the old admissions system, the ordering of universities was important; to take this into account, the program offered the possibility of defining similarity by the number of times two institutions appeared next to each other in an UCCA form (adjacencies). The measure of similarity based on adjacencies was found to be much more effective in gathering market intelligence for university selection than the measure based on co-occurrences. The change in the UCCA rules is, therefore, to be deplored from the point of view of understanding the wishes of applicants.

Having obtained a measure of similarity between pairs of institutions, it becomes possible to produce maps in such a way that universities for which similarity counts are high are plotted next to each other, and universities with low similarity counts are plotted far apart. It has been found through experience that maps in three dimensions are appropriate, that the first two dimensions are, in general, associated with academic structure and difficulty of entry, and that the third dimension is normally associated with the geographical characteristics of the city in which universities are situated. During the academic year 1987/88, the program CAMM was run to produce MDS maps for all the courses in the Faculty of Social Sciences. The complete computer output was made available to those selectors who wanted to have it, but, in general, only the plot in the first two dimensions was distributed to all course selectors. Figure 3 shows the first two dimensions of the map produced for Accounting with Statistics, home students only, similarity being defined through co-occurrences; in order to ignore insurance stragegies, only those universities that had been mentioned in one of the first three positions in the UCCA form were counted; the data is for the admissions year ending in August 1984. Figure 3 shows the map as it is produced by the computer. No attempt is made to label the axes or to interpret the map. This is left to the judgement and experience of the individual selector.

In Figure 3, Southampton appears at the centre of the map. This is not surprising since all applicants mentioned Southampton in their UCCA forms. There is a central cluster of universities which, besides Southampton, includes Kent, Lancaster, Hull and Aberstwyth. These four universities can be described as Southampton's direct competitors in the area of Accounting with Statistics. The courses that they offer are similar to the course at Southampton and are perceived as such by home UCCA applicants. It is therefore wise to attempt to obtain further information about them. When the map was carefully examined, and the knowledge of the relevant admissions tutor was taken into account, it became possible to discern two main directions, which are not the axes: one of them is associated with high or low emphasis on mathematical content; the other direction is associated with difficulty of entry. Thus, when choosing alternatives to Accounting

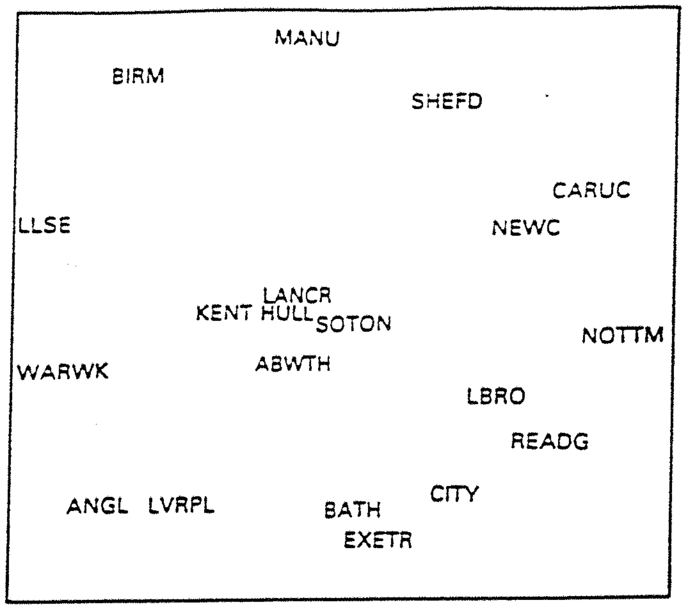

FIG. 3. *Multidimensional scaling representation of applications from home students to Accounting with Statistics: similarities measured through co-occurrences.*

with Statistics at Southampton, applicants take into account how difficult it is to be accepted, and whether the courses on offer lean towards statistics or toward accounting.

Further information about competing universities is easy to obtain from the database. CAMM makes it possible to examine applications and decisions for every course mentioned by the particular segment of the applicant population which is being analysed. Competitor analysis does not require any sophisticated technique: a simple list of the universities and courses mentioned is of great interest. Table 1 shows such a list for the 1984 entry, home students only.

TABLE 1. *Universities and courses mentioned by home applicants to According with Statistics at Southampton, 1984 entry*

University	Mentions	Course	Mentions
Soton	104	Accounting	194
Kent	35	Accntg statistics	100
Shefd	29	Mathematics accntg	43
Lancr	27	Accntg mathematics	26
Warwc	23	Economics	22
Abwth	22	Economics accntg	21
Hull	21	Bus admin	11
Manu	19	Morse	7
Lbro	18	Accntg finance	7
Angl	16	Maths management	6
Caruc	15	Accntg economics	6
Newc	15	Banking finance	5
Exetr	14	Management science	5
Salf	13	Mathematics accntg	4
Birm	12	Economics stats	3
Essex	11		
L Lse	11		
Bangr	9		

There were 100 applicants to Accounting with Statistics at Southampton by the time of the year when the program was run, but Southampton was mentioned 104 times in UCCA forms. This is because some applicants mentioned Southampton more than once. Southampton does not offer single honours Accounting, but this course was found to be the most often quoted of all. That single honours Accounting is perceived to be distinct from Accounting with Statistics is easily seen from the peripheral position that Warick takes in Figure 3. Single honours Accounting at

Warwick was listed as an alternative to Accounting with Statistics at Southampton by 18 applicants out of the 23 that mentioned both universities.

The above analysis suggests that if single honours Accounting was to be introduced at Southampton, the number of applications for Accounting with Statistics would suffer a large drop. Undergraduate Statistics at Southampton is seen, at least within Southampton, as a high-quality product. A decision to introduce single honours Accounting may result in Statistics joint degrees becoming too expensive to run. The expansion of a popular subject may, therefore, result in contraction in an area where the faculty thinks there is a element of excellence. This is just an example of the hard decisions that would have to be made if demand, rather academic planning, was to become the driving force behind the supply of undergraduate places. The fact that almost all the students concerned choose to follow a career in Accounting rather than Statistics confirms the view that Statistics is only their second interest.

It is possible to produce evidence for each individual course named by applicants. Figure 4 shows how Southampton applicants were treated by Warwick University. Five Warwick courses were mentioned, the most popular one being 4300 (Accounting), which was mentioned 18 times. The course 4300 was mentioned as first choice by six applicants. This is more than would have been expected if the course had been placed at random on the UCCA form. This may indicate either that Accounting at Warwick has a good reputation and is the first choice for many applicants, or that the word has gone round that applicants who do not put this course high on the form are likely to receive a rejection. There is evidence to support both hypotheses: rejections concentrate on the lower levels of choice, and the standard offer, BBC, is relatively high when compared with offers made by other similar courses in 1984. Another example of how this type of analysis can be of help to design an admissions policy can be found in Mar Molinero.[5]

WARWK		23 MENTIONS			
		6 CHOICE 1 BBB (3)	(1)	BBC (1)	B (1)
		2 CHOICE 2 R (1)	BBC (1)		
		1 CHOICE 3 BBC (1)			
		4 CHOICE 4 R (3)	BBC (1)		
		5 CHOICE 5 R (3)	BBC (2)		
	4300	18 APPLICATIONS			
		1 CHOICE 1 BBD (1)			
	3120	1 APPLICATIONS			
		1 CHOICE 4 BBC (1)			
		1 CHOICE 5 BBC (1)			
	4000	2 APPLICATIONS			
		1 CHOICE 2 R (1)			
	3100	1 APPLICATIONS			
		1 CHOICE 3 BC (1)			
	3130	1 APPLICATIONS			

FIG. 4. *Offers made by Warwick University to Southampton applicants.*

FORECASTING ENROLMENT

A by-product of an admissions system based on a database is that it can be made to incorporate a forecasting system. Each individual can be allocated a probability of enrolling as a first-year student. This probability changes as the admissions process evolves. The expected number of students who will enrol in the course is the sum of the probabilities attached to all the applicants to the course. Some probabilities are subjective. This would happen in the case of non-standard applicants, such as those who are following an access course.

In the case of standard applicants, the probability of enrolling will be zero if the applicant is rejected. If an offer is made, then the probability of enrolling will have to take into account that the offer may be declined, that the offer may not be met, or that the applicant may drop out at the last minute. More formally,

$$P(\text{enrolling}) = P(\text{accept offer})\ P(\text{meet offer})\ P(\text{no drop out}).$$

The probability that the offer has of being accepted depends on the level of the offer, on the level of choice, and on the subject. Offers that are considered to be too difficult in some subjects would be easy in others. Thus, these probabilities have to be estimated for every course. It is possible to pool all the data for a particular type of course, ignoring the university where the course is offered, and use a technique such as logit analysis to estimate probabilities, as done by Mar Molinero.[6] Selectros and administrators are defensive about sophisticated statistical methods, and would prefer simple proportions between offers and acceptances for a particular course for every level of choice. It is easy to derive such proportions using CAMM. All that is required is to produce Figure 4 for all applicants, and to produce it again only for those applicants who have accepted an offer. However, some offers might have been made to very few individuals, and the proportions obtained may not be representative of the underlying population. If this is the case, the proportions have to be adjusted in a subjective way.

The probability that an offer will be met depends on the difficulty of the offer and on the particular combination of subjects that the applicant is studying. At the end of the admissions year, UCCA discloses to every university the marks obtained in A-level examinations by all applicants. This makes it possible to estimate, for every level of offer, the proportion of applicants that would have met it. For example, the standard offer for Accounting with Statistics in 1984 was BBC, with one of the Bs in mathematics. On average, about 15% of the applicants meet this offer; if the offer had been BCC, with one of the Bs in mathematics, this proportion would have increased to 31%.

Applicants drop out at the last minute for personal reasons, unrelated to courses or difficulty of offer. The probability of dropping out is, therefore, best estimated at faculty level, pooling information from all courses in the faculty. At Southampton the quota for the faculty is increased by the expected drop-out number. Thus, if there were no drop-outs in a particular year and forecasts were perfect, then the faculty would be oversubscribed.

If an applicant declines an offer, or fails to obtain the required grades, the probability of enrolment becomes automatically zero. If an applicant accepts the offer, then the relevant element in the formula becomes one. This allows continuous monitoring of the admissions process.

Considering the uncertainties associated with the admissions process, forecasts made in the above away are surprisingly accurate. The home-student quota for Accounting with Statistics is 10. During the admissions years ending in August 1988, 1987 and 1986, the number of applicants who qualified as entrants was the same as the quota for the course.

ADMINISTRATION OF THE ADMISSIONS PROCESS

Admissions creates a large amount of repetitive clerical work. Letters have to be sent to applicants; visits and interviews have to be arranged; lists have to be produced; questions need to be answered. Many of these tasks can be made simple with the help of a computer.

To help with these tasks, a database, which was made to reside in a personal computer dedicated to administrative tasks, was created in every department. The databases used standard software, DBASE3+. Communication with the database was made user-friendly through specially written menus. Mail-merge facilities were taken advantage of, by incorporating calls to a word-processing package, Wordperfect. This particular word-processing package has been chosen as standard at the University of Southampton, and most clerical staff are familiar with it. A set of mailing letters, standard to each department, was made to reside in each departmental computer.

Not all the fields available in the mainframe are transferred to the departmental database. Only those fields that relate to Southampton are available to the secretary. The secretarial database can recall on the screen information about a particular applicant. The software incorporates a query system to make it possible to produce management information at the touch of a button. For example, the system offers the possibility of listing all those overseas applicants who have firmly accepted an offer from Southampton.

The change from manual to computerized operation was very well received by departments. Furthermore, departments valued the decentralized structure, which allowed them control over their own admissions.

IMPLEMENTATION

An early version of this admissions system was operational during the admissions year ending in August 1984. At that time, the University of Southampton did not have on-line access to UCCA. Data had to be entered by hand. This was a daunting task, and the system was only used for the course Accounting with Statistics. The original version relied on an early piece of relational database software, RAPPORT.

In 1986 the Faculty of Social Sciences decided to move towards computerized admissions, and requested that admissions data be made available in magnetic form. It was not, however, until 1988, 2 years later, that the request was granted. By that time the University had decided to change its mainframe computer, and the original database management software was not replaced. Programs had to be rewritten and adapted to available software. By the time the admissions system was fully operational, in 1988, UCCA rules changed, and the programs had to be modified to accomodate these changes.

The Faculty of Social Sciences of the University of Southampton has seen the number of applicants increase year after year for many years. Although admissions tutors were interested to know who their competitors were and what offers they were making, they were not particularly interexted in market intelligence. Their main concern was how to be fair to applicants while not exceeding their quotas. This attitude may change if universities become more market-oriented. On the other hand, the administrative burden was increasing all the time, and a system which helped to reduce it was welcome. As time evolved, it was realized that the database approach offers enormous potential, and those who used it most frequently, departmental clerical staff, suggested many sensible improvements.

There were implementation problems of a different nature. A user-friendly computer approach has the disadvantage of making an important clerical task appear to be easy to perform. In the past, admissions had been the responsibility of relatively senior clerical staff, but as they left or changed jobs, the task was in every case passed on to a junior individual. In one case, a secretary who had been hired on a temporary basis was required to do admissions. Rosenhead[7] argues that scientific management tools often contribute to de-skilling; if an example was needed, this experience offers it.

CONCLUSION

Undergraduate admissions is one of the most important tasks performed at a university. There are well organized and efficient procedures that those who want to go to a university in the UK have to follow. The central admissions clearing house, UCCA, provides frequent and good-quality data to be used by universities in the selection and admissions process, but the potential of this data is normally not realized. Undergraduate selection is in the hands of academics who have many other demands on their time. Selectors operate in a very uncertain world. They are required exactly to meet a student quota with the best possible applicants. They have a series of tools at their disposal, but the one that is used most often is a conditional offer based on the results of some examinations yet to be taken. Thus, selectors have to predict how applicants will react to a given offer and whether the offer will be met. This is complicated by the existence of a competitive market. Selectors compete against other selectors for a fixed pool of good applicants. Obviously, those who can collect the best information are at an advantage.

This paper has described now UCCA data is being processed in the Faculty of Social Sciences of the University of Southampton. The procedures have been illustrated by means of some data relating to the 1984 admissions year. This has been done in order to try to preserve confidentiality (course codes have changed since then) and not to disclose information of value to universities that compete with Southampton.

A further advantage of a computer-based admissions system is that it can substantially increase the productivity of clerical staff. This was an important factor that contributed to the success of the procedures described here. Secretaries had more spare time which could be used for other tasks, such as typing research papers. Furthermore, computer software was written in such a way that no complicated training was required to perform clerical tasks. It became possible for some departments to assign the admissions task to the most junior members of the secretarial staff.

Setting up the system described here required a great deal of skill and sophistication. Several computer systems are involved. It was necessary to create a database in the mainframe, to write a series of FORTRAN computer programs, to create microcomputer-based software, and to interface various kinds of hardware and software. The effort involved was quite substantial, but once all the problems have been solved, routine operation presents no particular difficulty. The admissions system had to be upgraded to incorporate various changes in data definition and various suggestions that had been made by those who used it; this, again, was easily done.

The admissions system demonstrated how useful databases can be for administrative purposes. The Faculty of Social Sciences is currently investigating other areas which could benefit from a similar approach.

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CHAPTER 3

A multidimensional scaling analysis of the 1986 ratings of universities in the UK

C Mar Molinero

In May 1986 every university in the UK received a letter giving detailed target student numbers for the academic year 1986-87, and outline target student numbers for the academic year 1989-90. In this letter the University Grants Committee (UGC) announced the amount of money that would be made available to each institution and described the procedure by which the allocation had been arrived at. The procedure by which the UGC allocates budgets to individual institutions had not been disclosed before, and this had been the source of controversy in the past.[1]

The UGC stated that in future the allocation of grant is to be based 'partly on teaching and research criteria to be applied uniformly to all institutions and partly on selective judgements on research'. For budgeting purposes university departments are grouped into cost centres. Cost centres are accounting artifacts sometimes covering very different activities; for example, Sociology, Politics and Economics form part of the cost centre described as 'other Social Studies'. The reverse is also true; very similar areas of activity are sometimes split into two different cost centres; the best example is given by Accountancy and Business Studies that in many universities form part of the same department but for UGC purposes are seen as being two different cost centres.

Under the new procedure the cost of teaching a student in a particular cost centre is to be independent of the institution concerned, thus part of the grant calculation involves knowledge of planned student numbers and a set of weights. These weights are not made public by the UGC. The actual grant received by an institution will contain also an extra element based on the UGC's assessment of the research strengths of the institution. To give guidance to 'institutions in taking their own decisions on resource allocations', the UGC gave to each university information about 'the rating of research which the Committee used in its selective distribution of resources'.

This article presents an attempt to analyse the research ratings of cost centres in UK universities. Information was collected about research ratings for 45 universities. The University of London was excluded from the analysis because of its large size. Other institutions that were excluded from the analysis are: University of Belfast, London Graduate School of Business Studies, Manchester Business School, Lampeter College, and University of Wales College of Medicine. The analysis is based on Multidimensional Scaling (MDS) analysis.

Multidimensional Scaling Analysis

Given the position of a set of points it is easy to find the distance between any two of them. MDS addresses the inverse problem: given that the distances between a set of points are known, where are they situated? The solution to this problem has been available for some time,[2] and there is a close relationship between MDS and other multivariate techniques such as Principal Component Analysis (PCA). It is still possible to recover the position of the points when the definition of distance is relaxed and replaced with a measure of proximity or similarity.[3] The algorithm needed to solve this more general problem is due to Kruskal,[4] and is implemented in the package MDS (X).

The use of MDS to analyse management decisions has been advocated by, amongst others, Rivett[5] and Stewart[6], who suggested that statements of indifference between two subjects or two policies can be of use when evaluating preferences. This approach was used in the area of education by Sternberg and Davies who examined how the University of Yale compares with its competitors in the opinion of those who applied for a place to study there.[7]

This article does, however, differ from previous research in the area of policy evaluation by means of MDS in the sense that decision makers are not asked to produce statements of indifference or similarity; the measures of similarity that form the basis of the analysis are derived from statements of perceived quality. Thus, instead of deriving orderings from statements of indifference, statements of indifference are derived from statements of ordering.

Similarity measures

In the letters sent to every university individual cost centres were rated in the nominal scale 'below average', 'average', and 'above average'. More detailed information was provided about individual departments on areas of activity, the rating 'outstanding' being used to describe the perceived quality of some of them.

For the purpose of this study a numerical variable r_{ij} was defined to described the UGC's rating of every cost centre (i) at every university (j). This variable was given the value 1 when the cost centre had been described to be 'below average', 2 when it was rated 'average', and 3 for 'above average' ratings. The numerical variable r_{ij} was further given the value 4 when the rating 'outstanding' was used to describe a large part of the activities of the cost centre. Judgement had to be employed in order to evaluate how 'large' a section of a cost centre had to be in order to describe the whole cost centre as 'outstanding'. In many cases the problem did not arise since a single department covered the whole of the cost centre, in others a decision had to be made as to the correct value of r_{ij}. In case of doubt it was assumed that the presence of an 'outstanding' department would bring extra support to the cost centre concerned unless another department in the cost centre acted as a disincentive. Thus evidence of 'outstanding' quality in a department would qualify the cost centre for a rating of 'outstanding', unless there was evidence to the contrary. This rule is similar to the rule used at some universities to classify students at the end of their degree.

Having allocated a numerical value to every cost centre at every university it is possible to compare universities on the basis of the ratings that similar cost centres have received in pairs of universities, and cost centres on the basis of the ratings that the same cost centres have received in different universities. A great deal of care has to be taken since not every cost centre is present at every university, and the matrix of values r_{ij} has many missing entries.

A first attempt to define a measure of similarity between universities was based on correlation coefficient. Let r_{iu} be the ranking that cost centre i has received at university u, and r_{iv} the ranking that the same cost centre as received at university v, and let

$$\mathrm{corr}(u, v) = \frac{\sum_c (r_{iu} - r_{.u})(r_{iv} - r_{.v})}{[\sum_c (r_{iu} - r_{.u})^2 \sum_c (r_{iv} - r_{.v})^2]^{1/2}}$$

where the summations extend only over common values of r_{iu} and r_{iv}, ie only if cost centre i has received a rating at both universities are the relevant terms incorporated in the sum. The means relate only to terms incorporated in the sums.

This definition of correlation is attractive in the sense that the results obtained by means of MDS are directly comparable with the results using other multivariate techniques such as PCA. But when an attempt is made at computing corr(u, v) it is found that many such terms are undefined and others have counter intuitive signs. The fact that some terms of corr(u, v) are undefined arises from the use of a limited number of values for r_{ij}; if, in a particular university, all the cost centres relevant to a particular summation have received the same rating both the numerator and the denominator of the fraction are zero, and the correlation is undefined. Counter intuitive signs are a consequence of comparing ratings for individual cost centres in a given university with a mean for that particular university. Thus if u is a 'good' university the mean $r_{.u}$ will be high, and if v is a 'bad' university the mean $r_{.v}$ will be low. Since cost centres are compared with the mean of their university, it is possible for corr(u, v) to have a high positive value while most $r_{iu} > r_{iv}$. This only indicates that cost centres which are rated higher than the average for university u, are also rated higher than the average for university v.

A more satisfactory measure of association is obtained if ratings of cost centres are compared with some 'absolute' measure of average. The value 2.5 was chosen because it partitions the sample space of the variable r_{iu} into two equal subsets. Thus the chosen measure was

$$c(u, v) = \frac{1}{n_c} \sum_{c} (r_{iu} - 2.5)(r_{iv} - 2.5)$$

where the sum is defined in the same way as before, n_c being the number of cost centres that universities u and v have in common.

The measure c (u, v) can take positive or negative values. The computer package that was used to perform the calculations, MDS (X) does not accept negative values as measures of similarity, thus the measure c (u, v) had to be transformed in order to make it possible to use it as a measure of similarity.

It was noticed that if many cost centres at universities u and v are given high ratings, then both universities are very similar, in this case c (u, v) takes a high positive value. A high positive value for c(u, v) is also obtained if both universities have many cost centres that have received poor ratings, and both universities are, again, very similar. If the two universities are very different in the sense that cost centres that have received high ratings at university u have received low ratings at university v, and vice versa, then c(u, v) will have a strong negative value. Any function that transforms c(u, v) into a measure of similarity s(u, v) in such a way that negative values of c(u, v) correspond to low positive similarities, and positive values c(u, v) corresponds to high positive similarities will result in a map that will preserve the relative ranking of universities.

In the most extreme situation every cost centre at university u would have been rated as 'outstanding', $r_{iu} = 4$, while every corresponding cost centre at university v would have been rated 'below average', $r_{iv} = 1$; in this case c(u, v) would have taken the value −2.25. If, on the other hand, every cost centre at university u had been rated as 'outstanding' and the same cost centres at university v had received identical ranking, the value of c(u, v) would have been 2.25.

When the calculated values c(u, v) were examined no value below −2 was found. It was, therefore, considered appropriate to define a similarity measure between universities u, and v as

$$s(u, v) = c(u, v) + 2$$

Analysis

The object of the analysis is to obtain a set of points in the space, one for each university, in such a way that points that correspond to very similar universities are close to each other, and points that correspond to very different universities are far apart. The Euclidean definition of distance was used to assess how near to each other two points are.

The similarity measures s(u, v) were used as input for the program MINISSA, a member of the MDS (X) package. This program calculates, for every university, a point in the space in such a way that long distances in the space correspond to low similarities and short distances in the space correspond to high similarities. The algorithm that MINISSA uses is described by Kruskal.[8] Let x_u be the point that corresponds to University u and let there be t dimensions in the space, then the position of the point x_u is defined by a set of t coordinates $x_{u1}, x_{u2}, \ldots x_{ut}$.

The map is presented in such a way that the origin of coordinates is the centroid of the points, and the variable that defines a coordinate is orthogonal to the variables that define the remaining coordinates; ie if x_{ul} is the lth coordinate of the point then

$$\sum_u x_{ul} = 0$$

and

$$\sum_u \sum_v x_{ul} \, x_{vt} = 0$$

In other words, MINISSA rotates the map to its principal components.

The first decision to be made when using MDS relates to the dimensionality of the space in which the map has to be constructed. The choice of the number of dimensions in MDS is equivalent to the choice of the number of components in PCA. Several rules exist to be used to determine the dimensionality of the solution but they were not used. An important characteristic of any map produced must be its interpretability and its usefulness to explain policy decisions. Thus maps were produced in a seven dimensional space and an attempt was made to interpret the meaning of the dimensions. Those dimensions to which meaning could not be attached were treated as 'residual variation'.

It is useful to see in which way the dimensionality of the space in which the map is produced affects the 'quality' of the map. Several measures of 'quality' are available, but they all point in a similar direction. The results for STRESS 1[9] are:

Dimensions	STRESS 1
1	0.35
2	0.23
3	0.18
4	0.14
5	0.11
6	0.09
7	0.07

According to Kruskal's nominal scale for a map to be described as a 'good' representation of a similarity matrix STRESS 1 should be less than 0.10. This suggests that at least five dimensions are relevant to the present case. There is nothing surprising about this; different cost centres were rated by different committees, there are important differences between disciplines and between universities, and there is no simple way of describing a university, let alone compare two of them; the complexity of the mathematical representation simply reflects the complexity that is found in real life. It is to be remembered however, that the map that has been produced is based on the UGC's rating of the cost centres; if the decision processes that the UGC uses to decide student numbers or allocate budgets are unrelated to the processes by which cost centres are rated, then the maps produced by means of MDS will be of little use for policy evaluation.

An initial assessment of how near to each other are any two points in the space can be obtained by means of cluster analysis. This is what was done in the present study. Johnson's hierarchical cluster analysis was applied to the matrix of similarities.[10] The computer program CLUSTAN, also a member of the MDS (X) package, was run to perform the calculations. The diameter method, which maximises the compactness of the clusters, was found to be more relevant to this case. The dendonogram that shows the linkages between universities has been

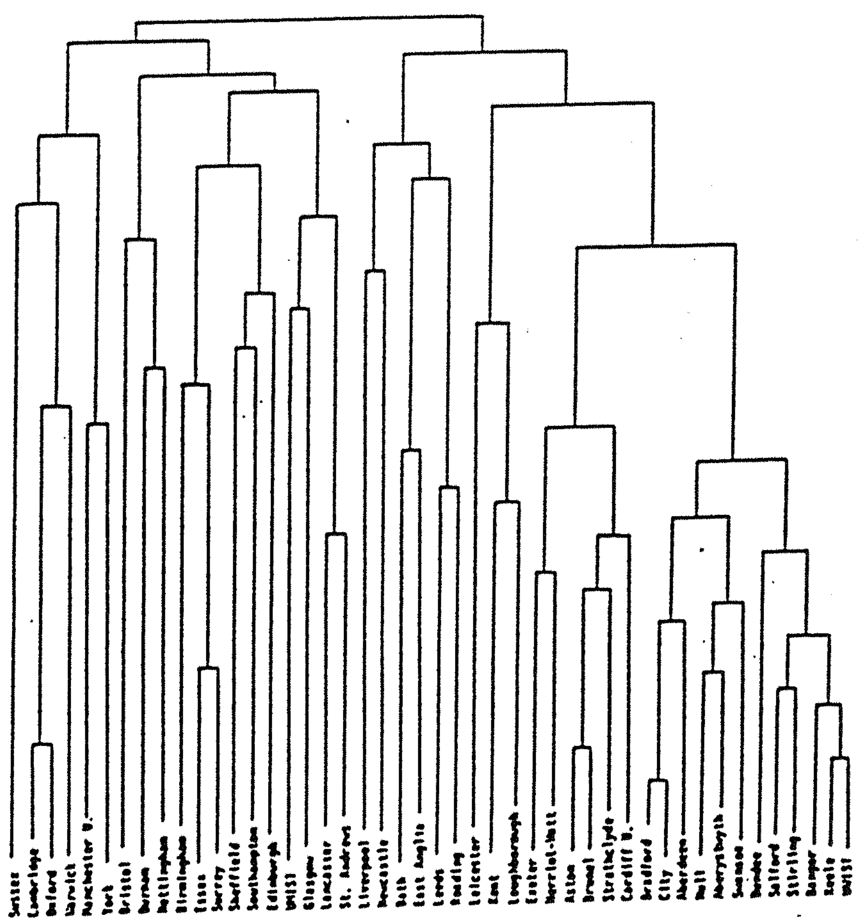

Figure 1. Results of Jonson's cluster analysis

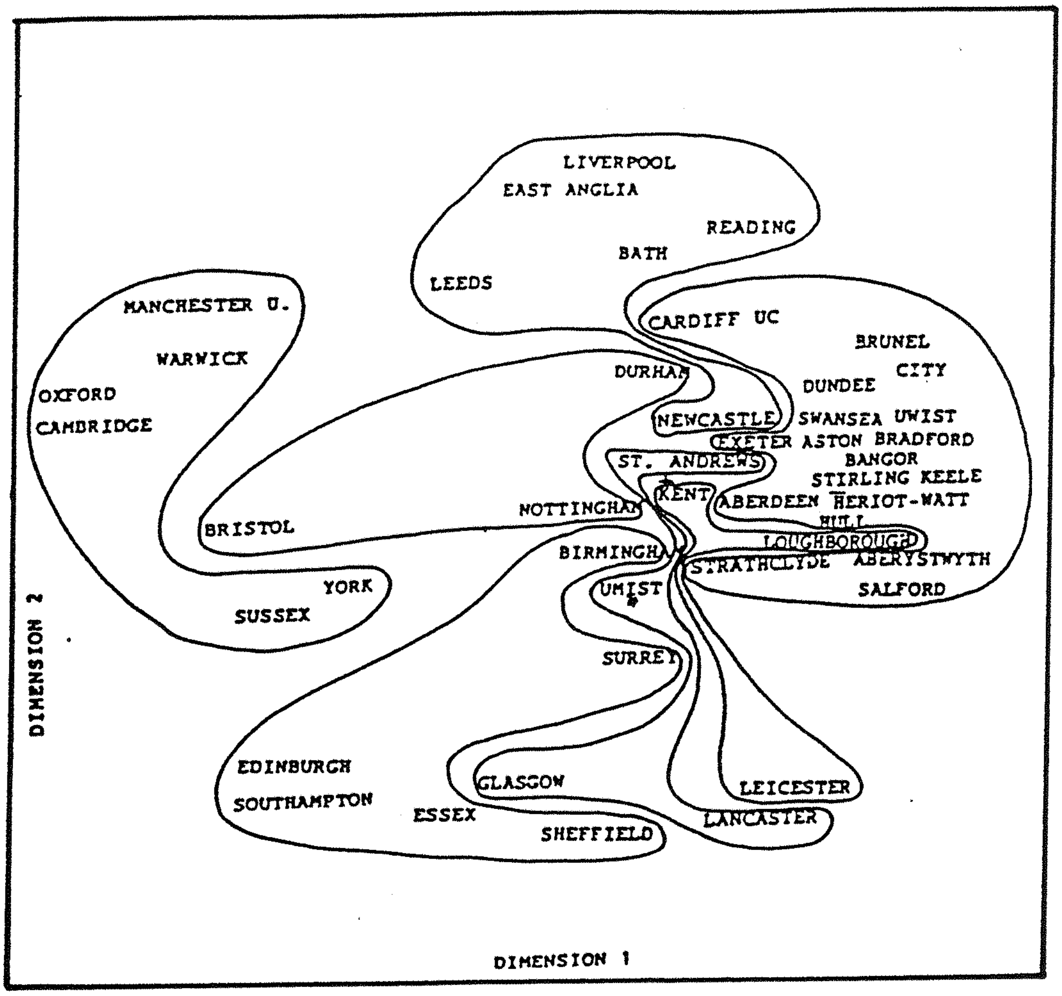

Figure 2. Final configuration and cluster analysis

reproduced in Figure 1. It is interesting to compare Figure 1 in this paper with Figure 2 in Dolton and Makepeace's 1982 study,[11] and to notice the small degree of overlap between the two clustering exercises.

Cluster analysis can be used to assist in the interpretation of the map produced by MINISSA. The map has been calculated in a seven dimensional space, and this makes it impossible to give a simple representation other than a set of coordinates for every point. It is common practice to project the points perpendicularly into the planes formed by sets of two coordinates, but then it is possible for two points that are very far apart in the space to project close to each other on the plane. When looking at the projection on a plane of the map, it is possible to highlight the relative position of the points in the space by means of contours drawn at several levels of clustering. The projection of the map into the first two dimensions can be seen in Figure 2 together with the contours that correspond to an intermediate level of clustering.

Interpretation

The first attempt that was made to interpret the results of the MDA analysis was based on visual inspection. Given the parallel that exists between PCA and MDS it was expected that Dimension 1, which is equivalent to the first component in PCA, would turn up to be a general measure of quality, and that the ordering of universities along this dimension would be as near to a UGC's 'league table' as it is possible to produce. This is exactly what was found. It can be seen in Figure 2 that on the negative extreme of Dimension 1 are the points that correspond to Oxford and Cambridge, where many cost centres were rated as outstanding; these two universities are followed by Manchester, Warwick, and Bristol, where many cost centres received high ratings. At the other extreme of Dimension 1 are universities such as Keele, Bradford, Stirling, and Salford which have suffered heavily from past cuts in university budgets.

Visual inspection gives few clues as to the meaning of the remaining dimensions, but since the maps have been produced using the ratings allocated to cost centres, it is reasonable to expect that the ordering of universities along the remaining dimensions would reflect some special characteristics of cost centres. To explore this possibility used was made of Property Fitting techniques.[12] A property, in this context, corresponds to a given characteristic of a particular university such as, for example, the rating that a particular cost centre has received.

The program PROFIT, another member of the MDS (X) package, was used to perform the calculations. On output this program gives the position of a straight line through the centre of the map. The points that correspond to each university are projected on to this line, and the distance from the centre of the map to the position of the projection is noted. The line is such that the correlation between this distance and the value of the selected property is maximised.

The calculation of the position of the line is based on multiple regression analysis. The value of the property acts as dependent variable, while the coordinates of the points that represent the universities act as independent variables. It has to be remembered that these coordinates form an orthogonal set, therefore the contribution that each coordinate makes to the regression is independent from the contribution made by the other coordinates. Unfortunately, the program PROFIT does not give test statistics for the coefficients in the regression equation. The only test statistic is RHO, the maximum correlation between the dependent variables and the linear combination of the independent variables. In order to assess the contribution of extra

Cost Centre		Direction cosines of fitted vectors in normalized space						Correlation between property and projections		
no.	Description	Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5	Dimension 6	2 Dimensions RHO_2	4 Dimensions RHO_4	6 Dimensions RHO_6
1	Clinical Medicine	-0.63	-0.18	0.27	0.15	-0.55	0.41	0.60	0.63	0.72
4	Anatomy and Physiology	-0.43	0.43	-0.46	0.52	0.01	0.39	0.65	0.78	0.80
9	Biochemistry	-0.26	-0.12	-0.40	0.54	0.59	-0.34	0.38	0.68	0.82
10	Psychology	-0.63	-0.13	0.49	0.49	0.29	0.13	0.55	0.64	0.66
11	Other Biological Sciences	-0.49	-0.32	-0.52	0.33	-0.31	-0.42	0.59	0.69	0.75
14	Chemistry	-0.72	0.09	0.36	-0.45	-0.09	-0.34	0.74	0.82	0.84
15	Physics	-0.72	-0.14	-0.12	-0.07	-0.31	0.59	0.76	0.77	0.85
16	Other Physical Sciences	-0.21	0.10	-0.62	-0.65	-0.32	0.16	0.38	0.81	0.85
17	Mathematics	-0.49	0.74	0.37	-0.07	-0.09	-0.23	0.84	0.88	0.90
18	Computer Science	-0.69	0.12	-0.17	0.09	-0.37	-0.57	0.63	0.63	0.71
20	Chemical Engineering	-0.34	0.26	-0.16	0.59	-0.65	0.03	0.47	0.78	0.94
21	Civil Engineering	-0.66	0.37	0.14	0.40	0.48	0.10	0.52	0.63	0.69
22	Electrical and Electronic Eng.	-0.06	-0.73	0.50	-0.07	-0.42	0.14	0.75	0.83	0.88
23	Mechanical, Aero, and Production Eng.	-0.54	-0.18	0.32	-0.53	0.32	-0.44	0.62	0.73	0.78
25	Metallurgy and Materials	-0.53	-0.04	-0.53	0.42	-0.14	0.50	0.62	0.77	0.81
29	Geography	-0.38	0.63	-0.11	0.04	0.36	0.56	0.79	0.79	0.89
30	Law	-0.50	-0.35	0.17	0.60	0.10	0.48	0.66	0.77	0.82
31	Other Social Studies	-0.82	-0.32	-0.42	0.16	-0.16	-0.02	0.83	0.87	0.88
32	Business and Management Studies	-0.15	0.38	0.20	0.88	0.02	-0.07	0.32	0.75	0.75
33	Accountancy	-0.87	-0.20	-0.35	0.07	0.20	-0.20	0.61	0.64	0.65
34	Language-Based Studies	-0.59	0.19	-0.25	-0.27	0.59	0.36	0.62	0.66	0.77
35	Humanities	-0.47	-0.22	0.44	-0.02	0.21	0.70	0.55	0.63	0.76
36	Creative Arts	-0.78	0.08	0.38	-0.45	0.04	0.19	0.84	0.90	0.91
37	Education	-0.16	-0.39	-0.17	-0.46	0.76	0.01	0.46	0.62	0.86

Table 1. Results of property fitting analysis: cost centres

dimensions to the explanatory power of the equation PROFIT was run with two, four, and six dimensions as explanatory variables.

Cost centres were taken in turn as properties. It was, however, decided to exclude those cost centres that were present at less than 16 universities in order not to base the regression results on too few points since this would have biased the value of RHO upwards and, in the absence of estimates of the variability of the regression coefficients, would have given a false sense of confidence on the results. Care was taken to exclude from the analysis any universities that did not contain the relevant cost centre, although the lines given by PROFIT were drawn on the map that contains all the universities. The results can be seen in Table 1, and the lines in Figure 3.

Cost Centre		Direction cosines of fitted vectors in normalized space						Correlation between property and projections		
No.	Description	Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5	Dimension 6	2 Dimensions RHO_2	4 Dimensions RHO_4	6 Dimensions RHO_6
1	Clinical Medicine	-0.63	-0.18	0.27	0.15	-0.35	0.41	0.60	0.63	0.72
[illegible]	Anatomy and Physiology	-0.43	0.43	-0.46	0.52	0.01	0.39	0.65	0.78	0.80
9	Biochemistry	-0.26	-0.12	-0.40	0.54	0.59	-0.34	0.38	0.68	0.82
10	Psychology	-0.63	-0.13	0.49	0.49	0.29	0.13	0.55	0.64	0.66
11	Other Biological Sciences	-0.49	-0.32	-0.52	0.33	-0.31	-0.42	0.59	0.69	0.75
14	Chemistry	-0.72	0.09	0.36	-0.45	-0.09	-0.34	0.74	0.82	0.84
15	Physics	-0.72	-0.14	-0.12	-0.07	-0.31	0.39	0.76	0.77	0.85
16	Other Physical Sciences	-0.21	0.10	-0.62	-0.65	-0.32	0.16	0.38	0.81	0.85
17	Mathematics	-0.49	0.74	0.37	-0.07	-0.09	-0.23	0.84	0.88	0.90
18	Computer Science	-0.69	0.12	-0.17	0.09	-0.37	-0.57	0.63	0.63	0.71
20	Chemical Engineering	-0.34	0.26	-0.16	0.59	-0.65	0.03	0.47	0.78	0.94
21	Civil Engineering	-0.64	0.37	0.14	0.60	0.48	0.10	0.52	0.63	0.69
22	Electrical and Electronic Eng.	-0.06	-0.73	0.50	-0.07	-0.42	0.14	0.75	0.83	0.86
23	Mechanical, Aero, and Production Eng.	-0.54	-0.18	0.32	-0.33	0.32	-0.44	0.62	0.73	0.78
25	Metallurgy and Materials	-0.53	-0.06	-0.55	0.42	-0.14	0.50	0.62	0.77	0.81
29	Geography	-0.38	0.63	-0.11	0.06	0.36	0.56	0.79	0.79	0.89
30	Law	-0.50	-0.35	0.17	0.60	0.10	0.48	0.66	0.77	0.82
31	Other Social Studies	-0.82	-0.32	-0.42	0.16	-0.16	-0.02	0.83	0.87	0.88
32	Business and Management Studies	-0.15	0.38	0.20	0.88	0.02	-0.07	0.32	0.75	0.75
33	Accountancy	-0.87	-0.20	-0.35	0.07	0.20	-0.20	0.61	0.64	0.65
34	Language-Based Studies	-0.59	0.19	-0.25	-0.27	0.59	0.36	0.62	0.66	0.77
35	Humanities	-0.47	-0.22	0.44	-0.02	0.21	0.70	0.55	0.63	0.76
36	Creative Arts	-0.78	[illegible]	0.36	-0.45	0.06	0.19	0.84	0.90	0.91
37	Education	-0.16	-0.39	-0.17	-0.66	0.78	0.01	0.66	0.62	0.86

Table 1. Results of property fitting analysis: cost centres

It has to be taken into account when interpreting the results of PROFIT, that the rating of cost centres is only a crude measure of quality. Much has been said about the accuracy of the methodology that was employed by the UGC to rate cost centres and there is no need to emphasise here the fact that these ratings are subject to a large margin of error. For the same reasons, the position on the MDS map of the points that represent the universities are also

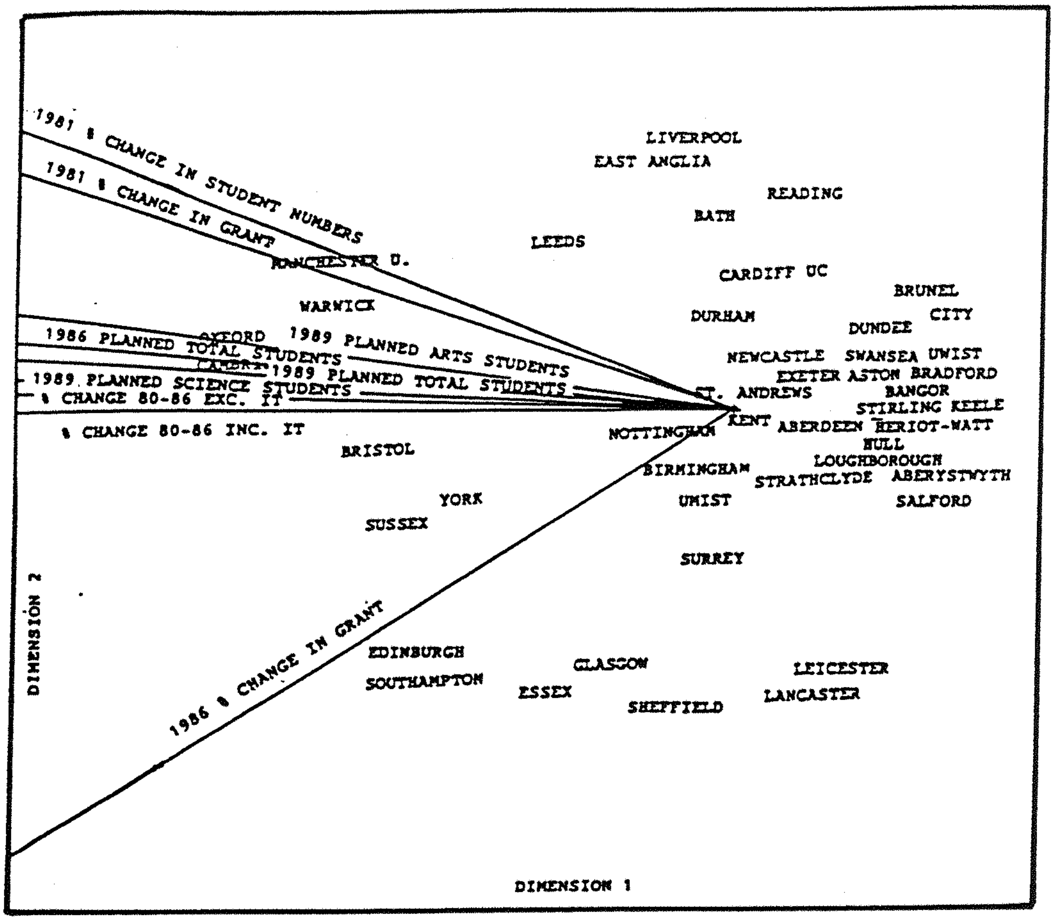

Figure 3. Results of property fitting analysis: cost centres

subject to some uncertainty. Thus the regression on which PROFIT results are based suffers from the 'error in variables' problem, which results in correlations being biassed downwards. Further bias downwards will be produced by the use of a simple four point scale for ratings. Nevertheless, when Table 1 is examined it is found that the values of RHO are, in general, remarkably high.

An examination of Table 1 and Figure 3 confirms the initial assessment of the meaning of Dimension 1. All the properties take increasing values as one moves towards the left hand side of Dimension 1. As the comparison of the test statistics RHO_2, RHO_4, and RHO_6 indicates, the first two dimensions account for a large proportion of the variation in the data in most cases, with the exception of Biochemistry, other Physical Sciences, Chemical Engineering, Law, Business and Management, and Education.

The cost centre 'Creative Arts' is of particular interest since excellence in this cost centre seems to be related to the perceived quality of the university and nothing else; this is supported by the high value of RHO_2, high loading on Dimension 1, and the low loading in Dimension 2. It is to be noticed that similar comments apply to the cost centres 'Physics', 'Chemistry', 'Accountancy', and to a lesser extent to 'Other Social Studies', 'Computer Studies', and 'Clinical Medicine'.

If the order in which the lines that represent cost centres is taken into account, no clear pattern appears. It is possible to think of reasons why some ordering could be present; for example, if universities had to make a choice between achieving excellence in the arts, or the social sciences, or the sciences, or engineering, then cost centres that can be grouped within each one of the above categories would correspond to a set of lines that would be close to each other, and the groups of lines that correspond to the different categories would be disjoint. The fact that lines seem to appear without any clear ordering seems to indicate that no such choices have been made in the past with respect to most disciplines; or that, if they have been made, they have not been successful.

Dimension 2 appears to be strongly related with 'Electrical and Electronic Engineering', thus achieving excellence in this discipline seems to be unrelated (in the eyes of the UGC) to the general quality of the university. This could have been the result of chance, because excellence in this discipline depends on events that are unrelated to the general characteristics of the university, or the result of design, because certain cost centres involved in 'Electrical and Electronical Engineering' have been supported independently of the characteristics of the university in which they are situated.

No clear meaning can be attached to Dimension 3 by looking only at the loadings, but if the changes in the values of RHO are also taken into account it appears to be related to 'Other Physical Sciences', 'Anatomy', 'Biochemistry', and 'Chemical Engineering'. Using similar considerations it is possible to identify Dimension 4 with 'Business Studies', and Dimension 5 with 'Education'.

Policy analysis

During the period from 1980 to 1986 the total amount of resources available to the UGC to distribute amongst universities declined in real terms. The UGC decided not to spread the consequent cuts uniformly amongst universities, but to engage in a policy of selective funding. The principles behind this policy have been outlined in a series of circular letters, the most recent one being dated on the 20 May 1986. This last letter explains how funding decisions for the period 1986-1989 has been based on the UGC's estimates of the cost of providing education in a

Decision variable	Direction cosines of fitted vectors in normalized space						Correlation between property and projections		
	Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5	Dimension 6	Dimensions RHO_2	4 Dimensions RHO_4	6 Dimensions RHO_6
Real terms % change in funding 1980/81 - 1986/87 including "new blood" and I.T.	-0.73	0.00	0.13	-0.24	-0.54	-0.31	0.50	0.51	0.56
Real terms % change in funding 1980/81 - 1986/87 excluding "new blood" and I.T.	-0.69	0.01	0.15	-0.27	-0.58	-0.30	0.47	0.48	0.54
1981 % change in student numbers	-0.52	0.26	0.17	0.76	-0.14	-0.18	0.29	0.36	0.38
1981 % change in grant	-0.58	0.25	0.15	-0.43	-0.53	-0.33	0.46	0.50	0.56
1986 % change in grant	-0.66	-0.47	-0.12	0.30	0.34	-0.36	0.46	0.48	0.51
1986 Ratio of arts to science students	0.01	-0.01	-0.45	0.42	0.45	-0.64	0.01	0.28	0.42
1986 Planned total number of students	-0.74	0.11	0.15	-0.53	-0.31	0.19	0.69	0.75	0.77
1989 Planned total number of students	-0.74	0.09	0.17	-0.51	-0.33	0.21	0.70	0.76	0.79
1989 Planned number of arts students	-0.89	0.17	-0.09	-0.36	-0.16	0.07	0.71	0.73	0.73
1989 Planned number of science students	-0.57	0.04	0.30	-0.58	-0.39	0.29	0.60	0.69	0.75

Table 2. Results of property fitting analysis; decision variables

particular discipline and on its own judgement of the quality of cost centres in every university.

Although the MDS map had been derived using only 1986 information it was considered to be appropriate to analyse up to what point it could explain policy decisions that had been made in 1981, and changes that had resulted from an accumulation of decisions between 1980 and 1986. Use was made of percentages in order to exclude any change that was only due to size. Data about the percentage cut in student numbers and percentage cut in grant in 1981 for every university were obtained from the national press[13] in order to use the figures as they were originally announced. Figures about percentage change in funding in real terms between the academic years 1980-81 and 1986-87 were made available to the House of Commons;[14] these figures were produced both including and excluding funding additions made under the 'New Technology' and the 'New Blood' programmes.

Details about percentage change in grant in 1986 were obtained from the UGC's circular letter 4/86. To explore the suggestion that the 1986 rating of cost centres was influenced by their size, [15] and that large universities were treated in a more favourable way than small ones, data were also collected from UGC circular letter 4/86 about planned total number of students, planned number of science students, and planned number of arts

Decision variable	Direction cosines of fitted vectors in normalised space						Correlation between property and projections		
	Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5	Dimension 6	Dimensions [illegible]	4 Dimensions	6 Dimensions
Real terms % change in funding 1980/81 - 1986/87 including "new blood" and I.T.	-0.73	0.00	0.13	-0.26	-0.54	-0.31	0.50	0.51	0.54
Real terms % change in funding 1980/81 - 1986/87 excluding "new blood" and I.T.	-0.69	0.01	0.13	-0.27	-0.58	-0.30	0.47	0.48	0.54
1981 % change in student numbers	-0.32	0.26	0.17	0.76	-0.14	-0.18	0.29	0.36	0.30
1981 % change in grant	-0.38	0.33	0.15	-0.43	-0.53	-0.33	0.46	0.50	0.56
1986 % change in grant	-0.66	-0.47	-0.12	0.30	0.34	-0.36	0.46	0.48	0.51
1986 Ratio of arts to science students	0.01	-0.01	-0.43	0.42	0.45	-0.66	0.01	0.38	0.42
1986 Planned total number of students	-0.76	0.11	0.15	-0.33	-0.31	0.19	0.69	0.75	0.77
1989 Planned total number of students	-0.76	0.09	0.17	-0.31	-0.33	0.21	0.70	0.76	0.79
1989 Planned number of arts students	-0.89	0.17	-0.09	-0.34	-0.16	0.07	0.71	0.73	0.73
1989 Planned number of science students	-0.37	0.04	0.39	-0.38	-0.39	0.29	-0.60	0.69	0.75

Table 2. Results of property fitting analysis: decision variables

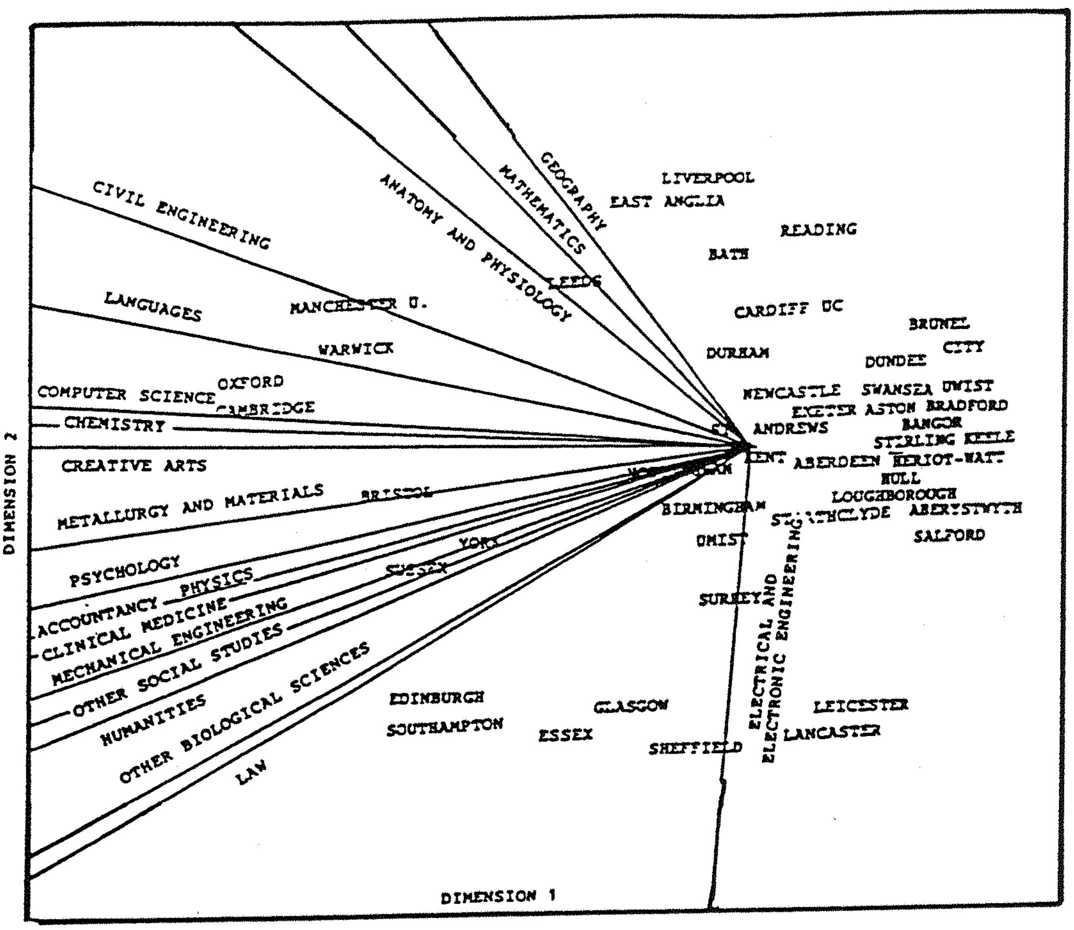

Figure 4. Results of property fitting analysis: decision variables

students for 1986 and 1989. The last two variables were also used to calculate the ratio of arts to science students in universities to establish whether the character of the university, in terms of 'technological' or not, had had any influence on the rating of cost centres and, therefore on policy decisions. The analysis was, again, based on property fitting techniques. The results are summarised in Table 2 and graphically displayed in Figure 4.

An examination of Table 2 suggest that the UGC's perceived quality of universities, as represented by the position on Dimension 1, has been an important factor when differential planning decisions have been made. Universities that map to the left of Dimension 1 have received smaller percentage cuts in funds and student numbers than universities that map to the right of this dimension. The correlations between these variables and the lines that have been fitted through the map are not very high. This is not very surprising since important changes took place as a result of the 1981 cuts, and these might have resulted in changes in the perceived quality of cost centres between 1981 and 1986, thus 1986 data may not be appropriate to describe decisions made in 1981.

The association between quality judgements that were made in 1986 and the accumulation of cuts between 1981 and 1986 is also evident. The level of correlation is, again, not very high. The same is true of the change in budget for the 1986-87 academic year although the UGC did indicate that changes in budget had not only taken into account the rating of cost centres, but also the relative cost of the discipline in different universities. It was also mentioned that cuts, and preferential treatment had been limited by a 'safety net' so that no institution would suffer a cut of more than 1.5 per cent in real terms. The inclusion in the decision process that led to differential treatment of variables other than the quality judgements of cost centres would have increased uncertainty and would have resulted, therefore, in a lower value of RHO. The 'safety net' would have introduced non-linearities in the relationship between planning decisions and quality judgements and would also have resulted in a lower RHO value.

In its letters to individual universities, the UGC gave an indication of the role that research evaluations had played in the resource allocation process. The universities of Oxford, Cambridge, Warwick, Bristol, Sussex, Southampton, UMIST and, to a certain extent, Birmingham were told that their research strength had worked in their favour in the resource allocation process. All of these universities, except Birmingham and UMIST are situated on the lower left hand side of the MDS map; UMIST scores higher than any other university on dimension 4; the support given to Birmingham was based on the research strength of a few specialised subjects. All the universities that were told to have suffered from the selective allocation of resources because of their research profiles concentrate at the right hand side of the MDS map; these were: Cardiff, Brunel, City, Dundee, UWIST, Swansea, Aston, Bradford, Bangor, Keele, Stirling, Aberdeen, Herriot-Watt, Hull, Aberystwyth, and Salford.

When factor loadings are examined it is found that the change in budget for 1986-87 took into account, not only the general perceived quality of the university as measured by the position of points in Dimension 1, but also the perceived quality in Electrical and Electronical Engineering. This is indicated by the loading in Dimension 2, and can be seen clearly in Figure 4.

The association between the results of the MDS analysis and planned number of students for 1986 and 1989 is particularly interesting. All the variables that relate to student numbers are associated with Dimension 1 only. This can be inferred from the low loading in Dimension 2, and the very small contribution that the addition of extra dimensions make towards the value of RHO.

Thus Diamond's suggestion that perceived quality is associated with size is confirmed by the data. This implies that in the view of the UGC either 'big is good' or 'good must be big'. It is not difficult to see how the association between size and perceived quality might have arisen. In 1981 those universities that were perceived to be 'below average' received large cuts in budgets and student numbers. In order to survive they had to sacrifice academic initiatives, thus not having an opportunity to build up their academic strengths.[17] Further differential cuts again discriminated against them. The UGC associates resources and student numbers, thus decreased funding means decreased student numbers. If there was no association between size and perceived quality in 1981, policy decisions would have brought it about.

Conclusions

Use has been made in this article of the 1986 UGC ratings of cost centres in order to obtain a multidimensional picture of the UGC's perceived research rankings of universities. Universities have been compared on the basis of the cost centres that they have in common. It has been shown that the information disclosed by the UGC does not make it possible to produce a simple league table of universities. When describing a university at least five dimensions are involved. These have been identified as: a general view of the quality of a university based on an heterogeneous set of disciplines, strength in Electrical and Electronic Engineering, strength in Biochemistry, strength in Business Studies, and strength in Education.

A graphical representation of the way in which universities compare on the basis of their research strengths has been produced with the help of Multidimensional Scaling techniques. Whether this representation correctly reflects reality or is only the result of a distorted view of how universities in the UK work is, to a large extent, of limited importance. The real question is whether this graphical representation can be of use when explaining the way in which the UGC has arrived at its differential resource and student allocations. The answer seems to be, despite the limitations of the data, a qualified yes.

It has been observed that, despite the complexity of the graphical representation of the data set, only two dimensions are involved when explaining policy decisions. The ordering along Dimension 1 is clearly associated with differential resource allocations, and, for this reason, can be interpreted as an ordering of universities in terms of prestige as seen from the UGC. All the universities that had received a more favourable treatment in the

1986 budgetary allocation because of the strength of their research concentrate on the left hand side of dimension 1; all the universities that had been penalised because of their research ratings concentrate on the right hand side of dimension 1.

Differential resource allocations from 1981 until 1986 have favoured universities situated on the left hand side of dimension 1; this is surprising, and implies that some sort of ordering of universities existed in 1981 as far as the UGC is concerned, and that the ordering was not very different from the one that the 1986 exercise produced. The association between percentage changes in resources and research strengths (as disclosed in 1986) is, however, not very high, although many other things have been taken into account when allocating resources like the so called 'safety net' in 1986. In 1986-87 strength in Electrical and Electronic Engineering seems to have played an important role; it is not possible to say if this has been intended, in order to promote these subjects, or if it has come about indirectly because the cost centres that are strong in this discipline attract large research contracts, and this has been taken into account in the resource allocation procedure.

The UGC disclosed its research rankings of cost centres in order to motivate institutions to mirror its procedures; ie. individual universities were given a block grant but were expected to protect excellence where it existed. Differential resource allocations may be possible under expanding budgets, but when real resources decline many other mechanisms enter. For an organisation which cannot balance its books the first priority will be survival; the need to support existing courses and to protect current staff will also be an important consideration; the protection and promotion of excellence may be seen as a luxury when the whole organisation is under stress.

The policy of supporting more generously those universities that are seen to be doing well and cutting the budget of those that are seen not to be so strong can have important consequences; it may widen differences where they already exist and create them where they do not exist. Universities that are short of resources may encourage staff to leave voluntarily, and are unlikely to replace those who leave, or may replace them with junior, cheaper, academics. Those who remain behind will see their teaching and administrative loads increase, the resources available for research decrease, the funds made available to attend conferences vanish, and their opportunities for promotion become non-existent; they will naturally look for alternatives either in other, better treated universities, or outside the academic world; in either case the 'best' staff will be in a better position to find alternative employment and with them may go the expertise that gave a particular cost centre the rating of 'excellent'.

From the point of view of the students similar dynamics may arise. The rating of 'excellent' may act as good publicity for a department and result in an increased number of applications per place to the courses that it gives. Since academic institutions select students on the basis of academic results,[18] universities that have received favourable budgetry treatment will require higher qualifications for entry than less favoured universities and will end up with a better qualified intake. Both the number of applications per place and average intake qualifications are seen as performance indicators in planning, inside and outside the university concerned. Increased demand and better qualified students will act as strong arguments when asking for increased resources. With a fixed budget for the whole system, the expansion of part of it can only take place at the expense of the contraction of another part. Having received poor research rankings will eventually result in further cuts in budget.

Is this a reasonable state of affairs? It can be argued that good quality universities with good quality students are being protected. There are, however, other ways of looking at the same data. There is evidence of association between school results and social background amongst university undergraduate applicants.[19] Rationing entry by price is, to a certain extent, equivalent to selecting by class. The ranking of universities in terms of quality of research may produce student bodies that are also socially different, with the most prestigious universities being also the most middle class ones. The redistribution of resources to protect excellence may result in discrimination against the students who are most in need of support because of their unsatisfactory school and parental background. A policy aimed at giving everyone equality of opportunity would increase the resources available to those universities that are seen not to be doing so well, both in order to take into account the special difficulties that their student bodies may have, and to give them the chance to build on their strengths.

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CHAPTER 4

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Provision for Non-Compulsory Education in Southampton

MAO QING and C. MAR MOLINERO
Department of Accounting and Management Science, University of Southampton

In 1986, Hampshire Local Education Authority reviewed its provision of non-compulsory education in Southampton and proposed the closure of a sixth-form college. The reason given for the closure was an expected fall in rolls, but the review appears to have been motivated primarily by financial pressures. This paper re-examines the evidence put forward by the LEA to forecast rolls. It is found that outdated methods, inadequate data sources and superficial analyses were used to produce the forecast. An alternative analysis shows that the proposed closure, if implemented, would run counter to the objectives of the reorganization. It is argued that the LEA chose to consult on the wrong problem, and that the real issue was a lack of funds in the education budget.

Key words: community OR, education

INTRODUCTION

This paper is an example of community OR. The main subject of the paper is education—an issue that concerns not only those who manage it, but the whole of the community. The research described here was thought to be desirable by the governors, parents and teachers of a school which had been proposed for closure. There is a legal requirement to consult with the above groups before approving a closure proposal. An important part of the evidence put forward to justify the closure of this particular school was statistical; its examination required statistical expertise and access to data sources not normally available to community groups. The authors were contacted because of their experience in analysing statistical data in other school-closure proposals.[1]

Between 1965 and 1976 the number of children born in the UK declined by about one-third. The fall was due to class-related changes in fertility rates. Werner[2] shows that the number of children born to 1000 women, when standardized for age, fell most amongst manual workers and least for individuals in professional occupations. The implications of changes in the number of births are evident in the case of compulsory education, since all children have to go to school until the age of 16, irrespective of their parental background.

The impact of the fall in the birth rate on non-compulsory education is more difficult to predict. The demand for non-compulsory education is class-related. Models that are based on a constant percentage of the age group staying on after school-leaving age are no longer appropriate when the social distribution of the children born in a particular year changes. This is not a new situation. Similar considerations apply to the demand for places in universities and other higher education institutions, where, after extensive debate, models based on constant participation rates have been unanimously condemned as inadequate.[3]

Successive governments have taken an interest in falls in school rolls: they have been seen as an opportunity to save money. A series of circulars to Local Education Authorities (LEAs) issued by the Department of Education and Science (DES) gave advice on how to approach falling rolls in schools.[4–6] Other official bodies, such as the Audit Commission for Local Authorities,[7] have also examined this issue.

Falling rolls have resulted in school closures. School closures are, in theory, administrative decisions aimed at making better use of scarce resources, but in practice social dynamics and political decisions have important social consequences.[8,9]

In 1986, Hampshire LEA, reacting to falling rolls in compulsory education, decided to examine the future of non-compulsory education in Southampton. A document was put forward for discussion which effectively argued that since the number of children in compulsory education had fallen by one-third, it would be appropriate to reduce provision in non-compulsory education by the same amount.[10]

This paper starts with a background section which gives details of the planning process as implemented in Southampton, and in which the objectives of the proposed reorganization are discussed. The roll-forecasting model used by the LEA is examined next. Since the LEA model is population-led, the following two sections discuss population trends in Southampton. The 1981 Census is used to estimate, for the first time, school staying-on rates at 16 for the different areas of a city. This leads to an alternative forecasting methodology which allows for the effects of policy changes to be explored. As an example of a policy change, the impact on staying-on rates of the introduction of educational allowances is discussed. The availability of data on a geographical basis makes it possible to explore the geographical consequences of the closure of a college. This research was not accepted by the LEA. The reasons for the rejection are also examined.

BACKGROUND

After a reorganization of schools that took place at the end of the 1960s, post-compulsory education in Southampton has been provided by three sixth-form colleges and a technical college. A policy of 'open access', which ensures that children can enrol with minimal qualifications, has been followed.

The proposal to review the provision of non-compulsory education was prompted by accommodation problems and by the fall in the size of the relevant age group. In a paper to the Schools Sub-Committe of the County Council,[10] it was pointed out that the accommodation available to the technical college was inadequate, and that an extensive capital programme would be necessary to improve it, but that 'given the uncertainties that inevitably surround capital expenditure', it had never been possible to proceed with the replacement of inadequate accommodation. The LEA observed that the size of the 16-year-old age group was to decline by 30% between 1982 and 1993, predicted that rolls in sixth-form colleges would decline by 35% during this same period, and concluded that accommodation problems would be solved if one of the sixth-form colleges was closed down and the technical college was to move to the redundant building.

Despite the importance of the financial arguments, public consultation about the proposal to close the school was limited to educational and statistical issues. The document issued by the LEA contained extensive statistical information but no cost data; this is consistent with the procedure followed in previous school reorganizations. A possible explanation for this is that the statistical argument was thought to be so convincing that discussion of financial issues had become irrelevant. Another, more cynical explanation is that, by providing statistical evidence about rolls, attention was being diverted from the real, financial problem.

The LEA convened a working party composed of professional educators, which included the principals of the affected institutions, in order to consider the issues raised by the expected fall in rolls. This working party never questioned the statistical analysis put forward by the LEA, and worked on the assumption that rolls forecasts were correct, although some of the information that the working party was given ran counter to the assumptions in the original document. The working party did not have, and did not seek, statistical expertise. It only considered the educational consequences of falling rolls under educational policies based on constant ratios of pupils to teachers.

This professional working party set some educational objectives that any reorganization of provision should achieve. It took the view 'that any reorganisation of 16–19 education must lead to improved provision, not just in accommodation, but in the opportunities offered to students'. It also stated that 'it is important that the open access policy is maintained and indeed made explicit', in order to give opportunities to students that would not have been accepted if examination results had been the only selection criterion. The importance of improving access to non-compulsory education for girls, for children from working class background, and for racial minorities was recognized. The likely increase in demand resulting from the possible introduction of state support for students in the 16–19 age group was mentioned. The working party recognized the danger of creating 'centres of elitism rather than centres of excellence' since 'the students hit hardest would be those we wish to encourage the most'.[11] These objectives were accepted as desirable by the Schools Sub-Committee of the County Council.

THE LEA PLANNING MODEL

It was at this stage that the LEA recommended that consultations should take place on the possible closure of a sixth-form college. No particular college was recommended for closure but, as an example, it was shown how provision could be reorganized if the college situated in the most central position was to close. The parents, teachers and governors of the named college promptly formed a committee to prepare a reply to the reorganization proposal, and asked for help from the authors of this paper in order to examine the statistical evidence that had been put forward.

Our first step was to contact the LEA in order to obtain more information on how pupil forecasts had been prepared. The LEA had not disclosed this in any of the documents put forward for discussion, although it was made clear that the model was based on rolls in state schools and past staying-on rates at 16. The most recent data used to produce the forecast corresponds to 1984. The LEA replied in writing, and described the model as follows:

> 'Forecast figures are put together essentially by ageing forward the existing school age population. By working out an average over time it is possible to forecast what percentage of the 14 year old secondary school cohort are likely to go on in two years' time to the first year of post-16 education, and similarly for the second and third year (the age of 14 is used since the model predates the raising of the school leaving age). For 1986/87 for Southampton a percentage of 33.1%, from 16 to 17 71.2%, and 17 to 18 26.1% are being used.'

This is a far from clear description, but several points have to be noted. The school-leaving age was raised to 16 years in 1973, so the model was at least 13 years old when it was used to propose the closure of a college. Thus this model was developed before the onset of changes in the fertility rate, and ignores its dynamics. It attempts to capture fluctuations in the size of the age group but ignores changes in its social structure; this is further aggravated by the use of averages over several time-periods to estimate proportions.

The LEA did not keep information on the number of Southampton children who receive compulsory education in private schools; it did not have, or did not use, information on the number of children who transfer to state sixth-form colleges from private schools. Thus, the proportion of the age group that remains in the first year of non-compulsory education was obtained by dividing the number of entrants to non-compulsory education (which includes transfers from private schools) by the number of children of the relevant age in state schools (excluding children in private schools). It is not clear how wastage rates were calculated either, but it is possible to estimate that if the age group was to remain unchanged, the average staying-on rate for the 2 years of non-compulsory education would be between 31% and 32%. The model makes the crucial assumption that 1986 staying-on rates are to remain unchanged in the future.

The lack of sensitivity analysis in this model is worrying. Staying-on rates, as calculated by the LEA, had suffered ample fluctuations in recent years; the data made available to the professional working party pointed towards a sustained increase in this percentage, and it is to be noted that a 1% increase in the staying-on rate is equivalent to 1% of the relevant age group, not 1% of the role of the relevant institutions.

DATA SOURCES

To investigate the issues raised by the 16+ reorganization we made extensive use of the 1981 Population Census, which was accessed by means of the computer program SASPAC. Southampton was divided into primary-school catchment areas and relevant information collected for each one of them. This arrangement made it possible to benefit from the experience obtained from earlier studies.[1] Areas from outside the city of Southampton were excluded, in line with the LEA model.

POPULATION TRENDS

Population counts, for every age group from 0 to 16, were obtained from the 1981 Census for every primary-school catchment area, and for the whole of Southampton. Estimates of the 15-year-old age group for successive years after 1981 were obtained by 'ageing forward' children counted in the Census. The LEA obtained estimates of the 15-year-old population by ageing forward children in state schools; thus, the LEA equated the size of the age group with the number of children in state schools. The two sets of figures do not have to be equal since some children go to private schools, and there are children who live outside the city of Southampton and go to school within it. These two flows seem to be of equal magnitude, since the total number of pupils in non-compulsory education in Southampton is not very different from the number that was estimated using the methods described in this paper. Figure 1 shows the graph of the evolution of the number of 15 year olds, both as estimated from the Census and as estimated by the LEA. It can be seen that there is close agreement between LEA and Census figures, except for 1985 and 1986, and the last part of the plot, 1991–1996. The differences could be due to a temporary shift towards private education in 1986 as a result of the teachers' industrial action, which could distort the actual LEA figures for 1986 but not the Census-based estimates; no data was available to test this conjecture.

The Census figures suggest that the lowest point in the 15-year-old age group is reached during the period 1991–1993, numbers increasing in subsequent years. It is to be noticed that the lowest point in the age group, when the Census is used, is higher than the figure predicted by the LEA. If the method used by the LEA to predict rolls is used with Census numbers, the lowest point in the sixth-form school population has to be increased by about 8%. If the LEA has used Census data to forecast rolls beyond 1990, the closure of a sixth-form college would have been unjustified on statistical grounds alone.

STAYING-ON RATES

The 1981 Census contains information about the occupation of 16, 17 and 18 year olds. People of that age were classified in the Census into three categories: full-time education, employment and unemployed. The Census was taken on 5th April 1981. This is an awkward time of the year when it comes to eduation. Some 16 year olds, all those who had birthdays before 31st August of the previous year (1980), would have been taken out of compulsory education by the time the Census was taken.

Let n_{16} be the number of 16 year olds in a particular primary-school catchment area as counted in the 1981 Census, and let p be the proportion of these children who had their birthday before 31st August 1980 (see Figure 2). This proportion was estimated using national data for 1965, the year when the children were born. An estimate of the number of children over compulsory school

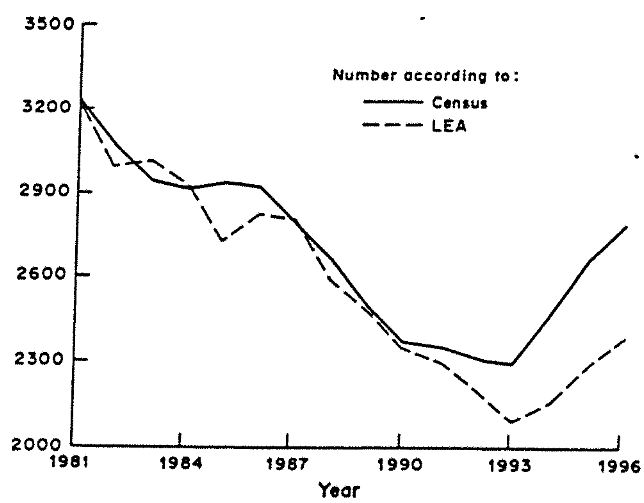

FIG. 1. *Population of 15 year olds in Southampton according to the Census and according to the LEA.*

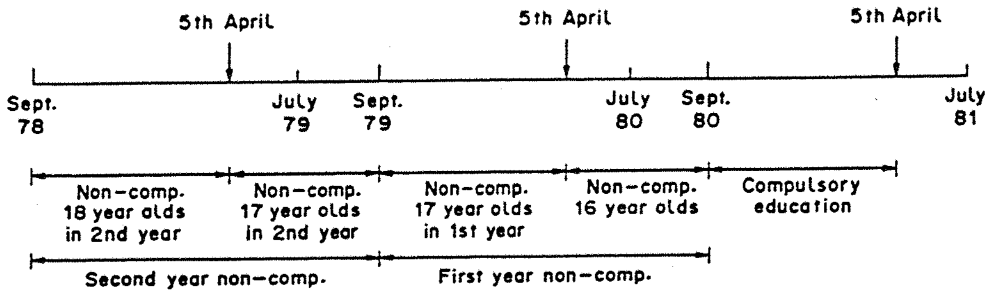

FIG. 2. *Relationship between age structure and school population.*

age is, therefore, pn_{16}. Let s_{16} be the number of 16 year olds who were counted in this particular primary-school catchment area as being full-time students. The number of 16-year-old students in non-compulsory education can be estimated to be: s_{16}-$(1-p)n_{16}$. The estimated staying-on rate at 16 for this area would be

$$r_{16} = \frac{s_{16} - (1-p)n_{16}}{pn_{16}}.$$

Some of the 17 year olds counted in the Census would have been in the first year of non-compulsory education and some in the second year. Let n_{17} be the number of 17 year olds counted in the Census, then $(1-p)n_{17}$ is the number of 17 year olds in the area who would qualify by age to be in the first year of non-compulsory education. It is now assumed that all the wastage occurs at the end of the academic year; i.e. that the staying-on rate for 17 year olds in the first year of compulsory education is the same as the staying-on rate for 16 year olds. The estimated number of 17 year olds in the first year of non-compulsory education is then $r_{16}(1-p)n_{17}$. The number of 17 year olds in the second year of non-compulsory education can now be estimated to be $s_{17} - r_{16}(1-p)n_{17}$. The staying-on rate at 17 would be

$$r_{17} = \frac{s_{17} - r_{16}(1-p)n_{17}}{pn_{17}}.$$

The average staying-on rate for the first year of non-compulsory education is then

$$r_{1nc} = \frac{s_{16} - (1-p)n_{16} + r_{16}(1-p)n_{17}}{pn_{16} + (1-p)n_{17}}.$$

To calculate the average staying-on rate for the second year of non-compulsory education, further assumptions are made. The staying-on rate for 18 year olds in the second year of non-compulsory education is assumed to be the same as the staying-on rate for 17 year olds in the same academic year. The model avoids having to use the number of 18 year olds as obtained from the Census, since some 18 year olds would have been university students and it is not possible to use the Census to establish whether an 18 year old in full-time education is at sixth-form college or at university. The number of 18 year olds, excluding university students, was assumed to be the same as the number of 17 year olds. The estimated number of 18 year olds in the second year of non-compulsory education is

$$s_{18} = \frac{[s_{17} - r_{16}(1-p)n_{17}](1-p)}{p}.$$

The estimated staying-on rate for the second year of non-compulsory education is simply the estimated staying-on rate for 17 year olds.

This procedure was followed for males and females for every primary-school catchment area. In this way, area- and sex-specific staying-on rates were calculated. The number of 16 year olds in non-compulsory education was found to be very small in some areas. Small errors in counts of full-time students could, therefore, have resulted in large percentage errors in staying-on rates. For this reason it was assumed that non-compulsory education covered 2 academic years, and participation rates were found for the whole of the 2 years with respect to the whole potential qualifying (by age) population. Thus it was preferred to estimate the percentage of youngsters in non-compulsory education to the total size of their peer group. The equation used was

$$r = \frac{s_{16} - (1-p)\,n_{16} + s_{17} + [s_{17} - r_{16}(1-p)\,n_{17}]\,\dfrac{1-p}{p}}{pn_{16} + n_{17} + (1-p)\,n_{17}}.$$

There are several potential sources of error in this analysis. Some figures were artificially altered in the Census in order to maintain its confidentiality. The assumption that national birth patterns apply throughout the city is also a potential source of error. Migration is, as is usual in this type of work, one of the biggest problems. If families move near a sixth-form college when their children reach non-compulsory school age, as anecdotal evidence suggests, then staying on rates are biased upwards for the area that contains the sixth-form college and downwards for the area where the children originally came from. Methodologically there is nothing wrong with very high staying-on rates, even 100% or more, when they are accounting for an omitted variable such as internal migration, but it was decided to limit rates to the 0–100% range.

The estimated staying-on rates for the 46 areas into which Southampton was divided, and the average for the entire city, can be seen in Table 1. Staying-on rates for girls were

TABLE 1. *Average staying-on rates for 2 years of non-compulsory education. See text for method of calculation*

	Staying-on rates		
Area	Male	Female	Area average
1	15	22	18
2	16	23	19
3	0	11	6
4	4	25	15
5	21	8	15
6	4	36	19
7	19	13	16
8	15	40	27
9	13	43	28
10	40	52	46
11	11	27	19
12	22	42	33
13	28	44	35
14	53	53	53
15	52	71	62
16	56	42	48
17	16	29	22
18	18	23	21
19	19	26	23
20	30	37	33
21	10	41	28
22	55	34	43
23	53	100	93
24	24	30	27
25	68	63	66
26	39	45	42
27	26	39	32
28	22	26	24
29	8	67	39
30	32	69	48
31	34	43	38
32	19	20	20
33	24	39	31
34	20	12	16
35	28	28	28
36	15	33	24
37	19	36	26
38	21	40	31
39	44	48	46
40	27	32	29
41	17	24	20
42	31	28	30
43	23	28	26
44	30	24	27
45	20	36	27
46	19	40	30
Average	27	37	32

found to be higher than for boys, in line with national results. The average for the whole of Southampton is 32%, in line with the figures released by the professional working party. The agreement between the staying-on rate calculated by the LEA and the one estimated using the above methods is reassuring, and suggests that the assumptions made in the calculations were reasonable.

Careful examination of Table 1, together with local knowledge, makes it possible to establish a link between the wealth of an area and participation in non-compulsory education. The average staying-on rate conceals important variations. Middle class areas have high participation rates, while working class areas have low participation rates. The staying-on rates shown in Table 1 are, apart from any errors that the analysis may have introduced, true rates for every primary-school catchment area. All children were counted in the Census, independently of whether they were attending private or state schools, or whether the schools that they were attending were near to or far from their neighbourhood.

FORECASTING

Once population counts and staying-on rates are known, it is possible to produce forecasts for future rolls in non-compulsory education. To do this it was assumed that the staying-on rates that were calculated for 1981 remained unchanged until 1996. It was also assumed that children do not move in or out of the city. These same assumptions were made by the LEA. The assumption of constant staying-on rates ignores, however, a trend towards higher participation in non-compulsory education; this implies that roll forecasts will be on the conservative side.

The forecasting model is a static one, based on population counts. It is of limited use because it ignores population dynamics. Population dynamics are very difficult to model, but main trends can be identified with the help of local knowledge, and this made it possible to assess the direction of the bias inherent in the forecasts. New estates in areas where participation rates in non-compulsory education was low, council housing policies, and house prices were considered to be relevant in this context; for example, the relatively small number of young children in middle class areas may simply reflect the fact that young professional people with small children cannot afford to move to middle class areas until later in life because of the prices of the houses involved. It is clear that a forecast based only on geographical considerations is not totally adequate. Forecasts of numbers in non-compulsory education are probably adequate only as a lower limit.

The professional working party claimed that the staying-on rate in Southampton in 1986 was 39.8%. The difference between this rate and the one used for planning purposes (about 32%) is higher than the full roll of a sixth-form college in 1993, the year used as an indication of the long-term need/demand for non-compulsory education. It is likely that the staying-on rate given by the professional working party for 1986 does not correspond to reality, and that the increase reflects only the move towards private education as a result of the teachers' industrial action. If the proportion of the age group in state schools decreases but the proportion of the age group that goes to college at 16 does not, calculated staying-on rates for state schools will appear to increase; this is likely to have happened in 1986. Nevertheless, it is not unlikely that staying-on rates will increase to 40% by 1993 as a result of the changing structure of society. This would make the number of students in 1993–1994, the years when rolls had been predicted by the LEA to be at their lowest, exactly the same as the number of students in non-compulsory education in 1986.

Forecasts of future rolls are compared in Figure 3. The forecasts that have been produced by means of the Census are above those produced by the LEA for the three sixth-form colleges. This is what should be expected since the Census forecasts include students that would have enrolled in the technical college. The graph of the forecasts obtained from the Census follows approximately the same path as the graph of the forecasts given by the LEA. It seems reasonable, as it was argued above, to consider the forecasts obtained from the Census as a lower limit. The fact that LEA forecasts are approximately proportional to the forecasts produced by means of the Census implies that the LEA figures are also to be seen as a lower limit.

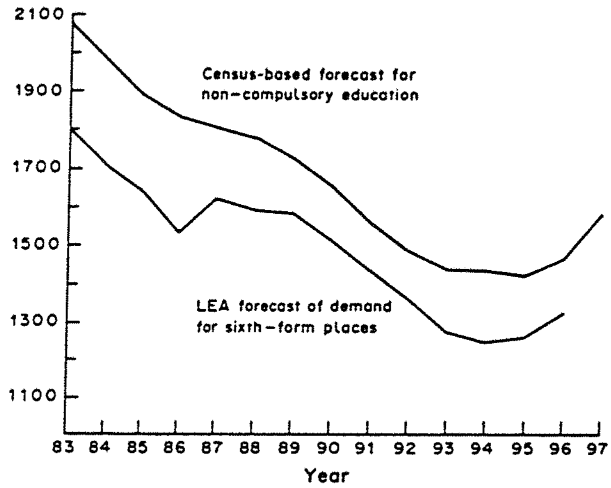

FIG. 3. *Demand forecasts for non-compulsory education.*

YOUTH WAGE

The availability of demographic data and staying-on rates for different areas made it possible to explore the likely impact of policy decisions on the demand for education. As an example, the subject of a youth wage is examined here. There is a current argument that there should be a 'youth wage' to be paid to youngsters, whether in education or unemployed or in some work experience programme;[12] such a policy would have an effect on staying-on rates. It is therefore appropriate to consider what would happen if all students in non-compulsory education were given the support given to those who are unemployed.

Although the debate on the effect of educational maintenance allowances has been going on for a long time, little work has been done on the impact that these allowances would have on participation rates in non-compulsory education. Rice[13] used a sample of 575 single persons aged 16 or 17, taken from the 1976 family expenditure survey, to explore the economics of the decision to stay in non-compulsory education. The choice of the 1976 survey was not an arbitrary one; it was used because 'it corresponds more closely than later surveys to a period of "normal" conditions in the juvenile labour market'.

Rice explored the way in which a change in household income would change the probability of a youngster staying in education after school-leaving age. This is not exactly the same as the choice faced by a youngster who qualifies for educational maintenance allowance, since in the latter case the extra income is allocated to the school-leaving youngster, not to the family. In other words, Rice estimates the 'income effect' of the allowance, while there are also 'substitution effects' to be taken into account. Thus the actual impact of the educational maintenance allowance is likely to be higher than predicted. Rice discovered that the decision to stay in education is influenced by the local unemployment rate: as unemployment increases, staying-on rates also increase, other things being equal. She also found that females were more responsive than males to changes in income. She gave some typical staying-on rates for standard families in different occupations, and estimated the way in which 'the introduction of an educational maintenance allowance equivalent to the supplementary benefit rate paid to school leavers' would change staying-on rates.

It is not claimed here that the conclusions reached by Rice for individual households using national data for 1976 apply necessarily to areas of Southampton in 1986 and beyond. Unemployment rates are much higher in 1986 than in 1976, and there are new training schemes, but in the absence of any local information, it was considered reasonable to find out what would happen in Southampton if the findings of Rice's study were translated to the Southampton situation. To do this, use was made of the table that predicts how the introduction of an allowance would change staying-on rates.

For every area of Southampton, the estimated staying-on rate was taken to be the pre-educational allowance rate, and the post-allowance rate was used to predict numbers in non-compulsory education. When figures had not been tabulated, simple interpolation was used. This was done for males and females and for all the relevant age-group population. The impact of introducing the allowance was higher for females than for males, because females have higher participation rates in the first place, and high participation rates increase most after the introduction of the allowance. The difference between the original prediction and the prediction that corresponds to the change in staying-on rates for both males and females was found to be equivalent to a 30% increase in students in non-compulsory education.

Taking into account the general trends towards higher participation in non-compulsory education, the fact that Rice's estimates consider only income effects, and the increase in youth unemployment rate that has taken place since 1976, it is reasonable to say that the impact of the introduction of a 'youth wage' in Southampton would be equivalent to the full roll of a sixth-form college. It would not be sensible to reduce provision for non-compulsory education for as long as a change in the support given to non-compulsory education remains a possibility.

GEOGRAPHY

Having identified, by means of the Census, the expected demand for non-compulsory education from every primary-school catchment area, and the way in which this demand is likely to evolve over time, it becomes possible to allocate students to colleges in some 'optimal' way. Although geographical considerations tend not to be of prime importance when looking at non-compulsory education, because students are able to travel relatively long distances, the minimization of total travelling distances was taken as the objective to be optimized. The LEA bases its catchment-area policy on numbers on roll in secondary schools. This ignores the fact that many children who do not go to their local comprehensive school may go to their local sixth-form college; and also some children who go to the local comprehensive school may not go to the local sixth-form college.

The estimates obtained by means of the Census correspond to the whole of non-compulsory education. Demand for places in the three local colleges being considered for rationalization represents only a proportion of the total demand for non-compulsory education. It is likely that this proportion changes from area to area, demand for sixth-form college places being proportionally higher in the wealthier areas, but since no data could be found to explore the way in which this proportion is distributed, it was assumed to be constant throughout the city. It would have been appropriate to relax this assumption of constant proportionality, but the result would have been increased demand for sixth-form college places from the centre of the city, and this would have reinforced, rather than invalidated, the conclusions arrived at in this section.

The allocation of children to schools in such a way that every child goes to some school, that no school operates beyond its capacity, and that the overall distance travelled is minimized is an appropriate application of linear programming. The computer package Sciconic was used on an ICL computer to perform the calculations. Only the solution is discussed here.

The computer program was run several times under different conditions: using 1986 and 1990 student-demand estimates, without restricting the capacity of the colleges, restricting the capacity of the colleges, with three colleges, and with only two colleges in order to explore the effect that the closure of a college may have on the expected rolls of the other two. The estimates used in all the runs assumed 1981 staying-on rates. The lowest number of children on roll in sixth-form colleges is to be reached in 1993–1994, but since rolls had been forecast by the LEA to continue at around the 1990 level in the long term this date was chosen as indicative of the structure of sixth-form education demand in the future.

The optimal solution for 1986, with three colleges and unlimited capacity, can be seen in Figure 4. This allocation is reassuring in the sense that it closely reflects current arrangements. It has the advantage of ensuring socially mixed catchment areas in every one of the colleges (see Mar Molinero[1]), thus avoiding as far as possible the development of academic differences between the colleges—something that could result in a 'league table' developing, with consequences on rolls, staffing levels and subject provision.

The consequences of closing one sixth-form college and imposing no capacity constraints were also explored. It became apparent that the college situated in the centre of the city had an important role to play: when either of the other two colleges was assumed to have closed down, its catchment area was allocated almost in its entirety to the central college; when the central college was assumed

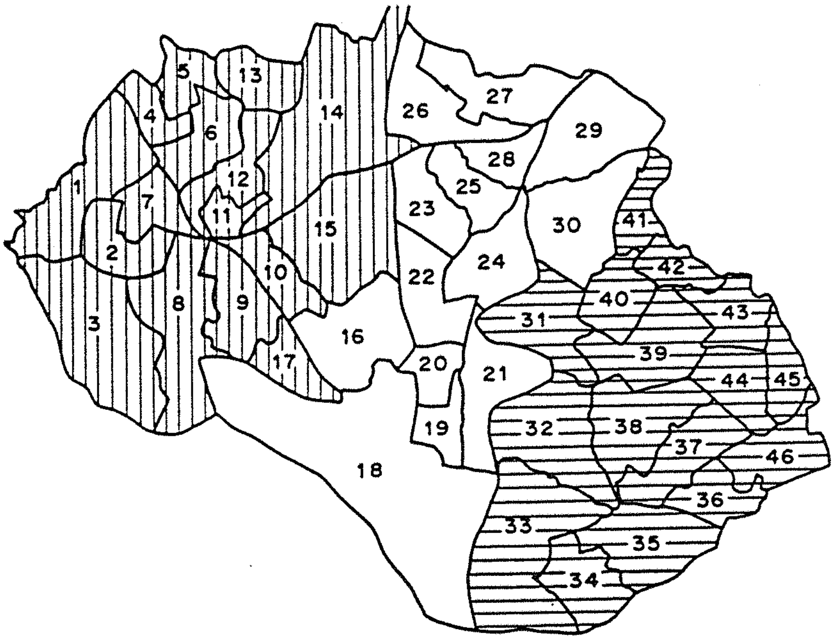

FIG. 4. *Allocation of primary-school catchment areas to sixth-form colleges.*

to have closed down, its catchment area was allocated almost in its entirety to the college that remained open in the west of the city. This was true for the 1986 and for the 1990 data sets, and is due to the demand for non-compulsory education being higher in the west of Southampton than in the east. The clear lack of balance between the two sides of the city is evident from the results of the linear programming model. Furthermore, given that the west of the city has higher proportions of individuals in non-manual occupations, any social trends, such as an increase in participation in non-compulsory education, will only reinforce this situation.

The LP was also solved for sets of two colleges after capacity constraints had been imposed. The LP demonstrated that if any college had been closed down in 1986, the remaining capacity would have been insufficient to house all the children. Feasible solutions were obtained for the 1990 data set when the central college was assumed to remain open. The closure of the central college in 1990 produced an infeasible solution; feasibility could only be restored by increasing the capacity of the college situated in the west of the city, which became significantly larger than the college situated in the east.

The data provided by the LEA and the professional working party makes it possible to demonstrate that during the period 1980–1986, the student/staff ratio has oscillated around 12 for all three colleges. If this policy of constant student/staff ratio is continued but colleges are allowed to be dissimilar in size, then the number of staff per college will also be different. It is possible to conjecture that the number of subjects on offer will be different, the possible number of subject combinations will be different, the smaller colleges will become less attractive, and the differences will widen.

The LEA decided to recommend that the central college be closed down and that the college situated in the west of the city be expanded.

BEYOND 1996

The research that led to the proposal to close a sixth-form college was done by the LEA using rolls up to 1984. Since LEA forecasts are based on numbers on roll in state schools, special attention has to be given to the size of the first year in primary schools. Numbers on roll in the first year of primary schools in 1985, the most recent figures known to the authors, have already proved wrong the assumption of the age group stabilizing around the 1994 level. If the number of children in the first year of primary schools in 1985 is 'aged forward' and plotted as an extra point, a clear trend towards increasing rolls is established. There is nothing surprising about it;

the number of pre-school children in Southampton has long been predicted to increase as a consequence of the changing age-structure of the population of the City.[14]

CONCLUSION

The governing body objected to the reorganization proposal, and incorporated the above analyses in its objections. It was argued:

(i) that the methods used by Hampshire LEA when forecasting future rolls for non-compulsory education had been inappropriate;
(ii) that the methodology employed was based on an old model that no longer reflected the structure of the system it was intended to explain: it assumed constant staying-on rates at a time when structural changes had made this assumption invalid;
(iii) that the data set that the model used was incomplete: no account had been taken of rolls in private schools and how they had been influenced by external conditions such as the changing social structure of society and the long industrial dispute that disrupted the work of state schools;
(iv) that the analysis was simplistic and superficial: it was based on the secondary schools children went to, and did not take into account where they lived;
(v) that trends towards higher participation in non-compulsory education had been ignored;
(vi) that the latest available information had not been incorporated into the forecasts;
(vii) that no allowance had been made for error, especially since the predictions produced by the LEA were probably valid only as a lower limit.

Closure of the central college is likely to result in an unbalanced system of two colleges, one of them larger and more attractive than the other, operating to the limit of its capacity. A free-access policy would mean that the largest college would have to be expanded and the smallest one would have to contract. This is unrealistic. A more likely outcome would be the introduction of selection. The introduction of selection would work against the most disadvantaged groups in society, against the stated objectives of the LEA.

The strategy followed by the LEA has been to accept, as the basis for policy-making, forecasts that do not provide for changing attitudes nor for changing policies, and do not leave room for error. This has resulted in a system which may have to be expanded as soon as it is contracted. It would be more sensitive to plan for a robust and flexible system that can adapt to needs at the end of the century. Such a plan would describe as unwise a proposal to reduce provision by more than one-third.

The LEA is under a legal obligation to consult when a major reorganization is taking place, but it does not have to act upon the results of the consultation. It chose to ignore the research presented in this paper. It would be unfair to say that the LEA is unaware of the limitations of its analysis, the inadequacies of its data and the need to allow for the uncertainties. A more likely explanation is that the stated objectives of the LEA are different from its true ones. The motivation for the reorganization of non-compulsory education was not educational but financial. The LEA could not afford, on the current budget, the cost of improving the technical college.

The LEA had argued the case for the closure of a sixth-form college on the grounds of future rolls. The analysis described here did not solve any problems; it only exposed the complexities of decision-making under uncertainty. It can be argued that the issue of future rolls is, to a certain extent, a peripheral one. Educational disadvantages does not need to follow from a reduction in pupil numbers; it is possible to keep the number of teachers unchanged when rolls fall in order to try to improve the quality of the education provided. The number of teachers allocated to an educational institution is not dictated by a law of nature, but is the result of an administrative decision. The central issue of cost had been missing from the debate. The debate was not only about better data, improved analysis and a more sophisticated forecasting methodology, but about the budget available for education, and this is a political issue. This explains why the LEA, and the professional working party that the LEA set up, did not ask for external statistical and modelling expertise where they did not have it: external advice might have recommended increased expenditure—a politically unacceptable choice.

Yet, in 1988, there were new developments: a secondary school that adjoins the technical college was proposed for closure, and its buildings allocated to the technical college to solve its accommodation problem; the original financial problem had disappeared. In the meeting of Southampton's Advisory Committee on Education, which took place on 23rd March 1988, the Area Education Officer reported that the staying-on rate at 16, as computed by the LEA, was 39.2%. The prediction that the staying-on rate at 16 was to remain at 32% had, again, proved to be wrong. It was also reported that the staying-on rate at 16 in Southampton was the lowest in the Education Authority, and that there was a need to increase it. Despite all this, the LEA did not withdraw its plans to reduce provision for non-compulsory education in Southampton.

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CHAPTER 5

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Schools in Southampton: A Quantitative Approach to School Location, Closure and Staffing

C. MAR MOLINERO
Department of Accounting and Management Science, University of Southampton

Between 1965 and 1976 the number of children born in the UK decreased by about one third. The fall in the number of births was followed by a fall in the number of children on roll in compulsory education, which resulted in many schools being closed. This paper examines the dynamics of falling rolls in the city of Southampton. Multidimensional scaling techniques are used to explore the social characteristics of the schools proposed for closure. The paper examines also the consequences of the exercise of parental choice of school. It is shown that social dynamics and staffing rules based on constant pupil/teacher ratios remove resources from the schools that are most in need of them.

Key word: education

INTRODUCTION

This paper summarizes the author's experiences during a period of school closures in Southampton. It is argued that a school should not be seen in isolation but as a part of a complex system. It is also argued that the objectives of those who administer school education are not always the same as the objectives of those who use the system. There are management problems, educational problems and social problems. Under these conditions the effect of management decisions is not neutral but depends on the social structure of the area in which the school is situated.

The problems faced by schools in the United Kingdom, especially at a time of falling rolls, are many, deep rooted and complex. Responsibility for their solution rests with a bureaucratic organization, the local education authority (LEA), under the supervision of elected politicians. The individuals who are most concerned about the running of schools—teachers, parents and the local community—have few opportunities to influence the management of state education. It is only when a school is proposed for closure that they are asked to give a view on the matter. To give an opinion under conditions of limited knowledge of management arrangements and practice, without easy access to the data, and without an overall view of the structure of the system, is very difficult. Even when some detailed knowledge is acquired in the process of preparing a case against a school closure, this is lost when the final decision is made.

The methods and analyses presented in this paper were developed while the author was a member of, or an adviser to, community bodies, such as action groups or parents' committees, in the Southampton area. Community bodies, as suggested by Rosenhead,[1] have 'limited tangible resources', have no 'internal management hierarchy', and have an 'ideological commitment to democratic procedures with ultimate power located at the base'. Rosenhead suggests that what is needed under these circumstances is an OR methodology 'capable of structuring issues rather than solving problems'. No solutions are given in this paper, only a methodology to structure the problems in order to highlight the difficult choices faced in the administration of school resources.

The paper begins with a background section that describes the institutional framework, the reasons for the reorganization of education provision and the procedures that are to be followed before a school can be closed. The paper deals only with compulsory education; the analysis of non-compulsory education provision raises a number of important issues that are discussed at length elsewhere.[2] Rolls in primary schools are first examined; it is found that a simple allocation of children to primary schools on the basis of geographical proximity makes it possible to discern some social patterns about the exercise of parental choice. It becomes apparent that any analysis of rolls in primary schools will benefit from a description of the social characteristics of the area in which the school is situated; a new methodology to do this is described in the next section. The implications for secondary schools are next examined; it is found that primary schools are allocated to secondary schools in Southampton in such a way that the social differences that exist between primary schools are reinforced. The consequences of the social differences between secondary schools in their attractiveness and in their academic performance are the basis of the next two sections. The paper concludes with a summary of the consequences of the educational policy followed by the LEA.

BACKGROUND

During the peak year of 1965, 950,000 children were born in the UK; in 1976 the number of births was one third lower, about 630,000. The fall in the birth rate has not been uniform across the social classes. It has been more accentuated amongst manual workers than amongst those who are in non-manual occupations.[3]

Population changes of this magnitude have important consequences for the management of schools. Successive governments have taken an interest in these demographic movements. The first circular to local education authorities (LEAs) on the subject of management of falling school rolls was issued in 1977 by the Department of Education and Science (DES). At this early stage claims were made that 'the quality of education provision' would be protected and that full consideration would be given 'to any social or other problems that may arise', but it was also stated that if it could be shown 'that there will be significant financial savings, and that the problems appear to be outweighed by the educational and financial benefits, the general policy of the Secretary of State will be to approve proposals to cease to maintain under-used schools'.[4]

The arrival of a new government in 1979 resulted in a change of emphasis in the management of falling rolls. To motivate LEAs towards school closures, the money that county councils receive from the central government to pay for local services, the Rate Support Grant, was made to depend, for the first time, on the number of school-age children in the area; thus lower school rolls meant reduced funding whether or not there had been a reduction in education expenditure. At the same time a new Education Act (1980) provided the legal framework for the management of school closures. The 1980 Act dealt also with the delicate issue of choice of school. The new Act made it possible for parents to choose to send their children to a school other than their assigned one provided that the chosen school had the necessary spare capacity to take the child.

When the number of teachers that a school is allocated is based on a simple management rule such as 'keep the ratio of pupils to teachers as near as possible to a given number', the exercise of parental choice may have important consequences for staffing and for the curriculum. For this reason small schools are sometimes staffed according to curricular needs.

The procedure under which schools are closed allows for a 'consultation' period. The case for closure is put in a paper issued by the LEA. This paper usually contains statistical information about past and projected school rolls. Views about the paper are sought from staff, parents and the local community. It is at this stage that these groups are in need of statistical and educational advice, to be able to make a considered response to the proposal to close the school. The decision to go ahead with the closure is taken by a committee of the county council, although provision exists for objections to the Secretary of State for Education, whose decision is final. For a full discussion of the issues involved see Meredith[5] and Mar Molinero.[6]

ROLLS IN PRIMARY SCHOOLS

Southampton operates a three-tier system of education. Children aged between 5 and 12 attend primary schools. These incorporate two stages: first schools educate the smaller children, up to the age of 8, and middle schools the older ones. Secondary schools cater for the 12 to 16 age group. Non-compulsory education between the ages of 16 and 18 is provided by sixth form colleges and by a technical college.

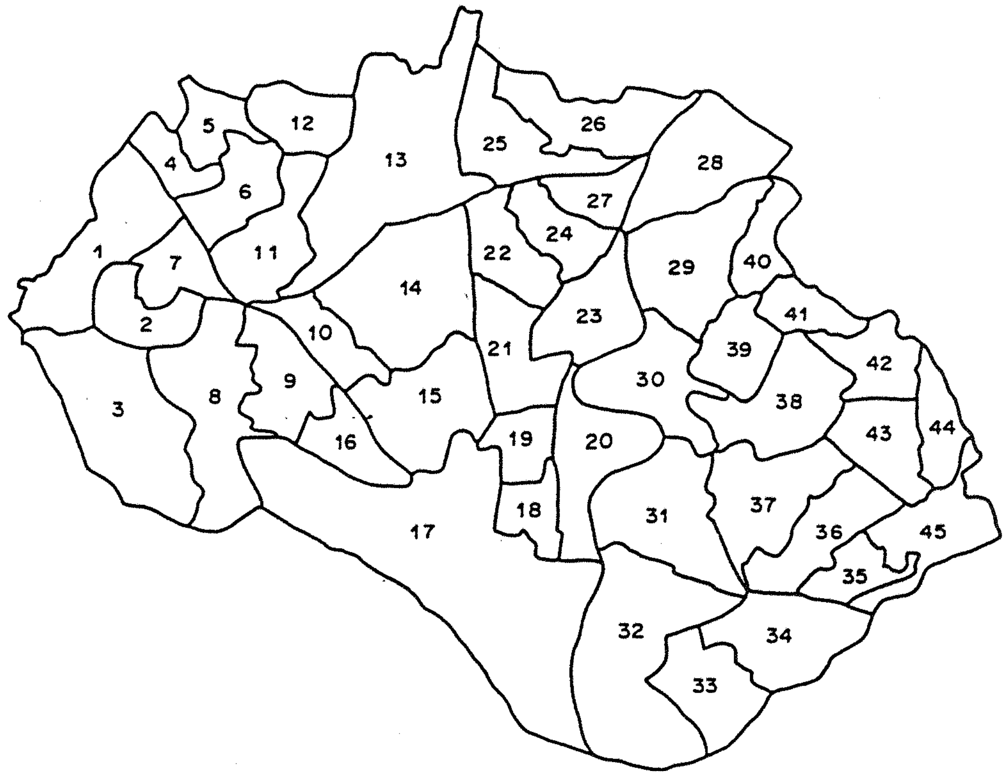


FIG. 1. *Primary school catchment areas in Southampton.*

The allocation of children to primary schools in Southampton is made, in the first instance, on geographical grounds. Each school is allocated a catchment area. Children who live within the catchment area of a given school are expected to go to that school. Although catchment areas are seldom modified, they were originally designed with the aim of producing schools of roughly equal size. The catchment areas of primary schools in Southampton are outlined in Figure 1.

The LEA derives its knowledge about the school-age population from school rolls and known out-of-school-catchment-area transfers, and about pre-school population from an enhanced electoral register (EER).

EER techniques have proven to be very useful in certain cases but only after a great deal of effort has been directed to data collection.[7] The limitations of the EER are, at least, the same as the limitations of the electoral register. According to Todd and Dodd,[8] electoral registers are known to contain large errors in areas with large immigrant populations, areas with a high proportion of unemployed workers, areas where new housing is taking place, and areas with a high proportion of rented accommodation. In Southampton many primary schools have catchment areas that fall into some of the above categories. It is, of course, possible to use past experience to make allowances for error, but when important class-related changes are taking place, as is the case with changing birth-rate dynamics, the past may be a very poor guide to the future.

An important source of information that is more appropriate than the electoral register for educational planning is the decennial population census, the last one being undertaken in 1981. The census provides an opportunity to compare the number of children in a school with the relevant population in the catchment area; it also makes it possible, by assuming no migration, to make some tentative statements about future rolls in schools.

The smallest data-collection unit in the 1981 census, the enumeration district (ED), contains only about 200 households. No great error is made if it is assumed that all the relevant population in the ED resides in a central point within the ED. An 'optimal' allocation of children to schools can then be made. In the case of primary schools it is sensible to assume that geographical distance from home to school is an important factor to be taken into account when making the allocation. It is, therefore, appropriate to examine the consequences of allocating children to schools in such a way that no school operates beyond its capacity and that the total distance travelled is minimized. There are, of course, other objectives to be taken into account when making any allocation, but an allocation based on distance alone provides both a starting point and a yardstick against which to compare other allocations.

For primary education purposes the central corridor of Southampton can be treated as a single, independent unit. It is delimited by the River Itchen on one side and by Southampton Common and a commercial area on the other side. Although these are not barriers that cannot be overcome, they are important enough to make it reasonable to assume that children who live in this area will go to school within it unless some other strong force is in operation. The primary schools concerned correspond to areas 18 to 28 in Figure 1. There were 11 primary schools and 94 EDs within this corridor in 1981.

The linear programming model was used to allocate children to first and middle schools in 1981 and 1983. The relevant school populations were directly available for 1981 but had to be estimated for 1983. To do this it was assumed that all the children who were registered as living in a particular ED in 1981 would still be there in 1983 but would be two years older (ageing forward). The results for first schools for 1983 can be seen in Table 1. The full set of results is available in Poon.[9]

The catchment areas that the LEA had been operating were compared with the geographical allocation of EDs to schools as produced by the model, and found to be nearly optimal. This coincidence between optimal and actual catchment areas has been observed elsewhere.[10] It is to be noticed, however, that 23% of all the children who live in the central corridor of Southampton choose not to go to their neighbourhood school. There are wide variations with respect to the average; schools 22, 24 and 26 attract more children than there are in their catchment area, while some schools, such as 18, 19 and 21, appear to be very unattractive. The reasons for this difference are evident to anyone with some local knowledge of Southampton. Schools 18, 19 and 21 are situated in an inner-city area, while schools 22, 24 and 26 are in a pleasant position near the University. Schools cannot be seen in isolation: differences between the percentage of children who attend their local school are a consequence of differences between the social structure of the catchment areas of schools that are not very far apart. It is important, therefore, to understand the social characteristics of school catchment areas. This will form the basis of the next section.

SOCIAL CHARACTERISTICS

The allocation of children to schools is only a particular case of allocation of resources. Some other examples of resources to be allocated are urban aid, social services and health. Allocations can be made according to demand or according to need. The two approaches are not necessarily equivalent. Some sectors of the community may be more aware of the value of a particular resource or service and place more pressure upon the allocation mechanism, and this may result in an allocation that reflects awareness or political power rather than need.

Attempts to allocate resources according to need have met in the past with the difficult problem of describing need. The normal approach has been to develop indicators, often in the form of

TABLE 1. *Rolls in primary schools: actual versus model predicted*

School	Capacity	Roll in 1983 Actual	Roll in 1983 Model	Actual/model
18	140	63	140	0.44
19	280	177	234	0.50
20	140	62	97	0.64
21	280	90	229	0.39
22	140	119	103	1.15
23	280	74	130	0.57
24	140	143	139	1.03
25	420	218	247	0.88
26	280	266	204	1.30
27	280	82	159	0.57
28	140	87	117	0.74
Total		1380	1799	0.77

indices, based on statistical information. A full discussion of the issues involved can be found in Thunhurst.[11] An index of need for particular EDs based on census variables was prepared by the Planning Department of Southampton City Council.[12] The approach taken by Southampton City Council was to look at certain important variables, and identify the areas of the city that did worst in terms of the selected variables. However, the fact that there are, for example, few cars per household in a particular ED does not necessarily mean that the ED is a deprived one. Conversely, if an ED is badly off in terms of many variables but not very badly off with respect to any of them, it will not be identified as being deprived. Besides, need is a complex concept that is not properly described by means of a single number.

An alternative approach is to produce groupings of areas by means of cluster analysis. Cluster analysis is not without problems either. It is not easy to decide what the right number of clusters should be. There is also the problem of explaining what the members of a particular cluster have in common and in what way they differ from the members of another cluster. An up-to-date account of this methodology can be found in Jolliffe *et al.*[13] and the references therein. A study of the different areas of Hampshire was done by the Research and Intelligence Group of Hampshire County Council[14] using cluster analysis.

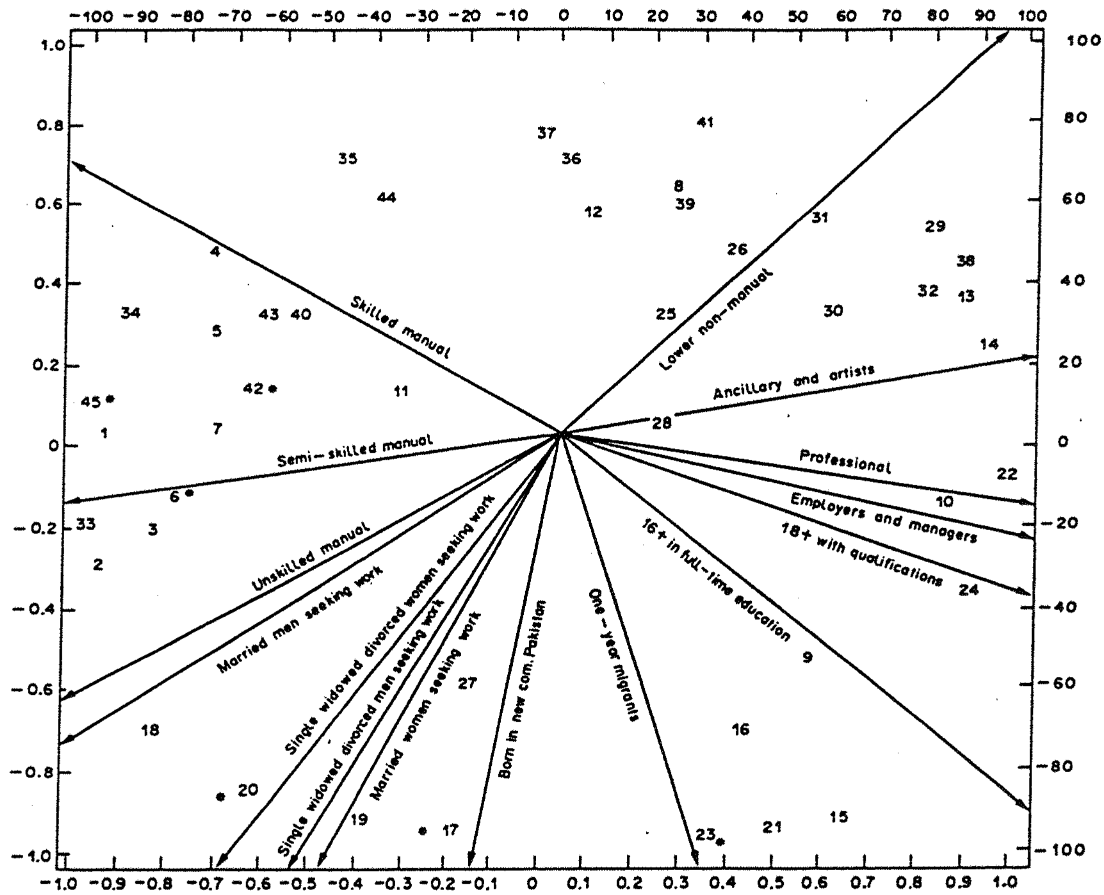
A new method of describing the social characteristics of an area, based on multidimensional scaling (MDS), was developed by Mar Molinero and Leyland.[15] Given a map and a definition of distance it is easy to find the distance between any two points on the map; MDS addresses the inverse problem: given that the distances between any two points are known, where should the points be situated on the map?[16,17]

Information was collected from the 1981 Population Census, for every primary school catchment area, on a total of 53 variables. The choice of variables was based on previous studies, such as the one by Skrimshire.[18] Care was taken to collect information on the age structure of the population, its social composition, ethnicity, characteristics of housing stock, type of housing tenure, as well as other variables that had been traditionally taken to be measures of need. All the variables were expressed as ratios of the total relevant population in the area in order to control for size.

An important part of the modelling process was the development of an index of similarity between any two areas. Two areas can be said to be similar if they score both higher than average values on some variables, such as, for example, percentage of people who are unemployed, and lower than average values on others, like, for example, average number of cars per household. The index of similarity between any two areas can be seen as a measure of social distance between them (see Appendix A).

The indexes of similarity between primary-school catchment areas were used as input for an MDS analysis. MDS ensures that areas that are highly similar are mapped close to each other while areas that are different are mapped far apart. The number of dimensions of the space in which the map is to be drawn is both an important and a difficult choice to be made. It was found that Southampton can be adequately described in a three-dimensional space, although only the first two dimensions are relevant to the topic discussed here. The projection of the three-dimensional map onto the first two dimensions can be seen in Figure 2.

Geographical maps often incorporate a vector that indicates the direction north. This makes it possible to tell if a point on the map is further to the north than another point on the map. MDS maps can be interpreted in a similar way: a vector can be incorporated on the MDS map in such a way that some characteristic (property) of the data grows in the direction of the vector. For further details on property-fitting techniques see Schiffman *et al.*[19] Two sets of variables were used as properties. The first set included information about the social and employment structure of the population. The results were good in terms of test statistics, and allowed the directional lines to be drawn with confidence; these can be seen in Figure 2. The order in which the different social and employment categories appear on the map is remarkable, highlighting the extent to which people fail to integrate in society. Starting with high proportions of professional people, and moving in an anticlockwise direction, one finds the vectors that indicate concentration of managers, non-manual workers in intermediate managerial professions, skilled non-manual workers, skilled manual workers, non-skilled manual workers, the various categories of unemployed, immigrants and students.



* Areas where primary school closures are proposed or have taken place

FIG. 2. *Results of multidimensional scaling analysis.*

The second set of variables that were treated as properties attempted to measure quality of life. The results cannot be described as surprising. Overcrowding, bad-quality housing, sick people and rented accommodation tend to be characteristics of the inner city, which is where unskilled, unemployed and immigrant individuals tend to concentrate, while large, owner-occupied housing is more common in the areas where non-manual workers and professional people tend to live.

If the primary schools situated in the central corridor of Southampton are located on the MDS map, the 'attractive' schools are found in the areas with high proportions of professional people, employers and managers, while the 'unattractive' schools are situated in deprived inner-city areas with a high level of unemployment. The availability of the MDS maps makes it possible to place into context the social and educational problems of primary schools. The problems faced by secondary schools result, to a large extent, from the allocation of primary to secondary schools. The use of MDS maps in the context of secondary schools is discussed in the next section.

SECONDARY SCHOOLS: CATCHMENT AREAS

A pyramidal structure is used in Southampton to group together the different types of schools. One or more first schools are assigned to a middle school, a group of middle schools is assigned to a secondary school, and a group of secondary schools is assigned to a sixth form college. Thus, with minor exceptions, the catchment areas of the lower levels of the pyramid are partitions of the catchment areas of the higher levels. Special schools and Roman Catholic schools have no defined catchment areas.

There is a reluctance, on the part of the LEA, to modify catchment areas unless it is as a consequence of a major reorganization exercise, but this has the disadvantage that, owing to the changes in the birth rate that have taken place in recent years, the original objective of producing schools of roughly equal size is no longer being met.

Geography and size are not the only possible considerations to be taken into account when defining school catchment areas. Sutcliffe *et al.*[20] give a model based on goal programming that can be used to assign primary to secondary schools in such a way that many objectives, not all of them attainable at the same time, are taken into account.

A factor that has been ignored in the past when defining the catchment areas of secondary schools is social mix; yet this may have important implications. The case of Reading[21] is particularly relevant in this context. Primary schools were assigned to secondary schools in Reading in such a way that the catchment areas of two single-sex secondary schools covered the most deprived area of the city. These were areas with a large racial minority population. It was claimed that these two secondary schools would contain so many children with remedial needs that teachers would have to spend most of their time looking after them, and the education of the children from the racial minorities would suffer. Berkshire LEA was accused of indirect racial discrimination. The Commission for Racial Equality (CRE) made a formal investigation and cleared Berkshire County Council of malpractice.[22] The report of the CRE contained an important series of recommendations and suggestions. The CRE invited LEAs to collect 'the right sort of data ... on any factors that may affect the opportunities available to pupils in each of the schools considered in a reorganization so that due consideration can be given to promoting equal opportunity'. This view is shared by Hausner and Robson,[23] who studied the problems of inner cities; they recommended 'the strengthening of the capacity of public, private, and non-statutory bodies to identify and address economic and social problems'.

The MDS map of Southampton reproduced in Figure 2 can be used to identify and address social problems. The way in which primary schools were assigned to secondary schools in Western Southampton until 1986 can be seen in Figure 3. The linkages that correspond to Eastern Southampton are not shown; the analysis described here was repeated using data from the east of the city, and similar conclusions were arrived at.

An examination of Figure 3 shows that, in general, the catchment areas of the primary schools that have been assigned to a particular secondary school have very similar social characteristics. There are two exceptions. School 8 is different from the other schools in its group, 1, 2, 3 and 7. The same thing is true of school 11 and the remainder of its group, 9, 10, 14, 15 and 16. The surprising fact is that there are not many more exceptions. Primary schools in Western Southampton are linked as if it had been intended to keep the different social groups apart, although there is no suggestion that this has been done intentionally. In particular, the group 17, 18, 19 and 20 should be noticed. All these schools have, at one time or another, been described as 'educational priority schools', and their catchment areas as 'social priority areas', and have received extra support from urban aid grants because of the level of deprivation. The catchment area of the resulting secondary school contains a high immigrant population. The Reading experience appears to be of prime interest to Southampton.

It can be conjectured at this stage that transfers will take place from the areas that are situated on the left-hand side of the MDS map to the areas that are situated on the right-hand side of the map; that the schools that benefit from these transfers will also show good academic results; and that school closures will take place in deprived areas. These conjectures are confirmed by the analyses that follow.

SCHOOL DYNAMICS

The analysis of primary school areas in the central corridor suggests that as spare capacity appears in primary schools situated in middle-class areas, the slack is taken by children who would normally go to schools in working-class areas. Thus primary schools in working-class areas face a much more severe falling-roll situation than demographic considerations alone would suggest. If, as is the case in Southampton, the number of teachers allocated to a school is a function only of the number of pupils, as rolls fall so does the number of teachers, the range of expertise

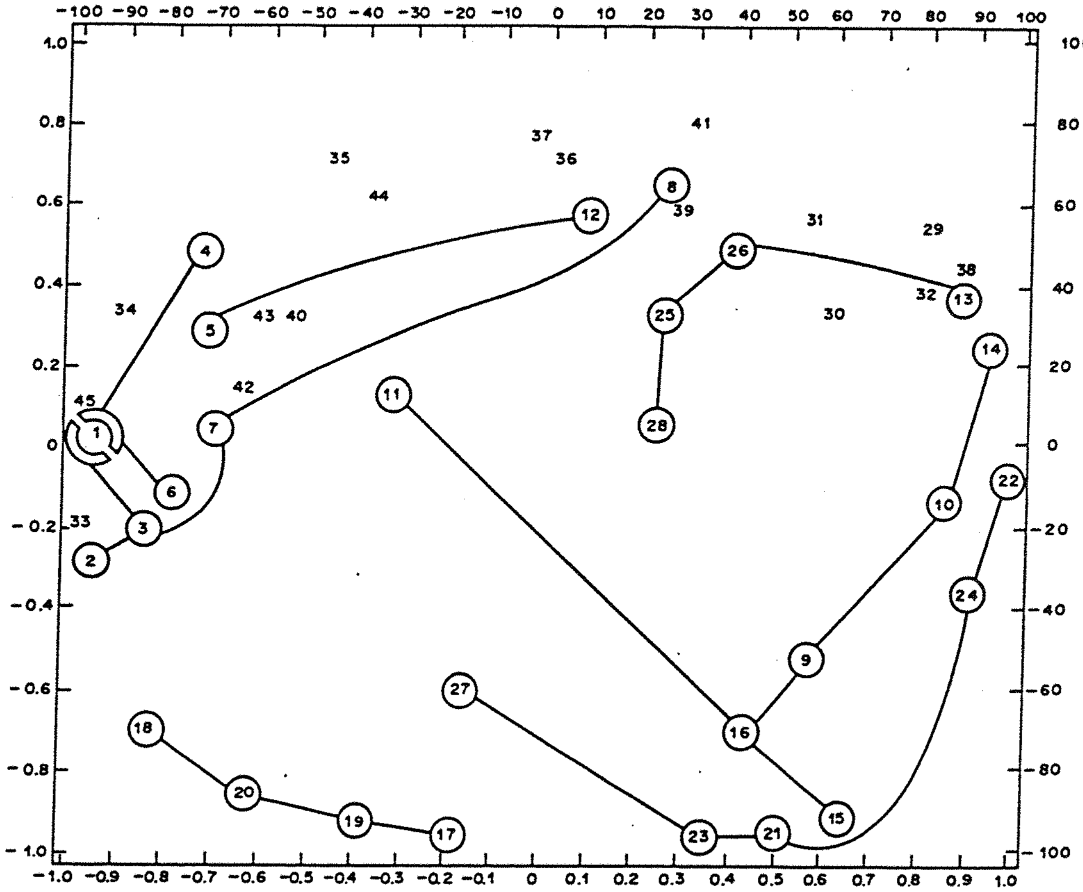


FIG. 3. *Secondary school catchment areas.*

available declines, and the school becomes less attractive. Areas where primary schools have been closed down or are threatened with closure have been marked with an asterisk in Figure 2; they concentrate on the left-hand side of the MDS map.

The LEA predicts rolls in secondary schools on the basis of rolls in feeder primary schools. In practice the LEA expects most of the children in the relevant feeder schools to transfer to the secondary school attached to the primary school, wherever their home address is. Other transfers have to be approved by the LEA.

Data about approved transfers is used for planning purposes. Unfortunately, the model used by the LEA to forecast rolls relies on the absolute number of children who transfer, and does not take into account how high or low this number is when compared with the total number of children who are expected to move to the next stage of their education.

The move from primary to secondary school can be seen as a stage in a Markov process, and the associated transition matrix can be estimated. Mar Molinero[6] shows how an index of attractiveness can be computed for a secondary school. It is first assumed that numbers about to transfer to secondary school are such that under a 'no transfer' situation, all secondary schools would end up with a roll of 100 in the first year, but that transfers take place according to the estimated transition matrix; the resulting roll in every secondary school is taken as a measure of attractiveness. It is to be noticed, however, that some children may have transferred at primary-school level and may not be counted in the index; it is also possible that some transfers may have been rejected. Thus it is likely that attractive schools are more attractive than the index suggests, the reverse also being true of unattractive schools.

The index of attractiveness was calculated for all Southampton schools for several years. Children who transferred to private schools or to schools that fall outside the city boundary were excluded since these children transfer one year before the rest of the population, at 11 and not at 12. The 1983 values that correspond to the secondary schools shown in Figure 3 are

TABLE 2. *Secondary schools in Western Southampton: attractiveness and academic results*

Secondary school group	Index of attractiveness	Average pass rate at O-level
9, 10, 11, 14, 15, 16 (F)	129.1	1.46
9, 10, 11, 14, 15, 16 (M)	119.1	1.50
5, 12	119.1	—
13, 25, 26, 28	89.5	1.14
1, 4, 6	84.6	1.04
21, 22, 23, 24, 27	83.7	1.38
17, 18, 19, 20	75.6	0.63
1, 2, 3, 7, 8	73.6	0.50

summarized in Table 2. Two single-sex schools share the same catchment area. The catchment area of primary school 1 is divided into two parts, and each of the parts is allocated to a different secondary school.

The results summarized in Table 2 confirm the conjecture that schools situated in middle-class areas are more attractive than schools situated in working-class areas. The apparent anomalous situation of the school that groups areas 21, 22, 23, 24 and 27 can be explained by the threat of closure under which that school had been operating for several years. It is also to be noticed that the most unattractive school is not the one situated in the most deprived area of the city, which has received substantial support from urban aid grants and is staffed according to curricular needs, but the one that groups areas 1, 2, 3, 7 and 8; this is a school situated in a part of the city that cannot be described as badly off with respect to most measures of deprivation, but it scores badly in many of them. Of particular interest is the school that groups areas 5 and 12. This is a new school, in pleasant grounds, in a strategic geographical area; it is more attractive than the social characteristics of its catchment area would suggest.

Birth-rate dynamics, transfers at primary-school level, exercise of parental choice at the age of transfer into secondary education, and staffing policies based on constant pupil/teacher ratios work against schools situated on the left-hand side of the MDS maps, and it is there that secondary-school closures should be expected. This is what happened on the east of Southampton. The situation on the west was more complicated. The obvious candidate for closure was the school that groups the deprived areas, but that closure would have met with strong political opposition since it would have been perceived as an attack on the racial minorities, the main users of that school. The next unattractive school was too large to be closed down and too far away from the alternatives. The final choice was to close the school that covers areas 21, 22, 23, 24 and 27. A linear programming analysis (see Thick[24]) proved that this was the best located school in the whole of Western Southampton, in the sense that allocations based on minimizing distance always produced a school full to the limit of its capacity, and its closure would increase the average amount of travelling per child more than the closure of any other school. But the main argument against that closure was that the LEA had failed to dentify, and address, the educational problems faced by Southampton, and that the closure of that particular school would do nothing to solve them. Subsequent events supported this view: in 1987 the LEA decided to reconsider the future of the inner-city secondary school since the fall of the number of children on roll had been much higher than the LEA had anticipated.

EDUCATIONAL ISSUES

Most school closures in Hampshire are justified on the basis of rolls forecasts. Educational issues are seldom discussed or mentioned. It has long been known that there is association between academic results and parental background;[25] but how far is this reflected in Southampton schools?

Any attempt to answer the above question finds important data limitations. These are particularly severe in the case of primary schools. A proxy for academic success would be the ability to perform certain tasks (like reading) at a given level of skill. In 1985 a standardized reading-ability test was given to every child at the end of first school education in Southampton; but the results of the test were kept confidential.

At the lower extreme of the ability range is the child with 'moderate learning difficulties (MLD)', who needs special, segregated, educational provision. A study by Mar Molinero and Gard[26] found that the proportion of primary-school-age children who required segregated MLD provision in 1983 greatly changed between the different areas of Southampton, and that this proportion was related to the wealth of the area concerned. Wealth was measured by the proportion of owner-occupied housing in the area, a 'property' that maps along dimension 1 in Figure 2. LEA officers confirmed that the percentage of children who were found to be in need of remedial provision was highest in the schools situated in the areas that contained the highest percentages of MLD children. This suggests that some schools face particularly difficult educational problems, that these are the same schools that have been most affected by the fall in the birth rate, and the schools that some parents choose not to send their children to. The use of staffing rules based on pupil/teacher ratios removes teachers from where they are most needed. It should not come as a surprise to discover that the proportion of children for whom separate MLD provision is made in Southampton has been increasing despite a general fall in rolls and a policy of integrating such children in mainstream schools. This, in turn, suggests that teachers who can hardly cope with 'normal' children find it increasingly difficult to cope with children who require special attention.

Although it is suspected, it is not possible to show that the children who choose not to go to their local school are also the most able. If this was the case, an appropriate policy for the management of falling rolls might be to keep the number of teachers unchanged in schools affected by falling rolls, in order to give an advantage by policy to children who have a disadvantage by birth.

Measures of success exist for secondary schools since some children take public examinations. If both academic success and transfer out of catchment area are related to parental background, it makes sense to take a prejudiced view of what constitutes success. The highest qualification available at the end of secondary education in Southampton is O-level; hence a pass at grades A, B or C at O-level was considered to be a prejudiced measure of academic success. It is to be expected that attractive secondary schools will score high on the average number of such results per relevant age group. The results, which can be seen in Table 2, show that there is association between results and attractiveness. Results were not available for one of the schools since this was a new school and none of its pupils had had the opportunity to sit public examinations.

The dynamics of secondary school rolls are now clear: schools that group areas situated at the left of the MDS maps have falling rolls, because of the falling-roll problem in their feeder primary schools, and staffing rules are such that teaching resources are removed from those schools, although the children that they receive may require more careful attention because of their educational background. These schools operate below their capacity, are expensive to run on a *per capita* basis, and have bad academic results. On the other hand, schools that group areas that map towards the right of the MDS maps have easier children to teach, are more attractive, receive extra teaching resources, have good academic results, and, because they operate at or near full capacity, they are cheap to run on a *per capita* basis. This explains the perverse findings of Darlington and Cullen,[27] who found that academic results are negatively correlated with expenditure.

CONCLUSION

Management rules interfere with social conditions to produce some paradoxical consequences. Children with educational problems tend to concentrate in particular schools, and these are the schools from which resources are removed. Some schools have to limit entry despite a general fall in rolls. The percentage of children in need of special education provision (MLD) increases despite a policy of integration and spare capacity in schools. It is cheap, on a *per capita* basis, for a school to obtain good academic results while it is expensive to obtain bad ones. It has been shown that the operational research approach can be of help to understand the structure of educational problems.

Administrators often emphasize that the management of school closures is not politically motivated but designed to make efficient use of limited resources (see Mallen[28]). This view is not shared by the community, whose objectives are educational. As long as the community is concerned with the quality of the education provided by a school, and education administrators with its cost, school closures will meet with strong opposition. The conflict of objectives is matched by a difference in the quality of the means available to both groups. This paper has shown that an alternative analysis that highlights educational and social problems is both relevant and important in order to inform the decision-making process. Unfortunately this analysis is beyond the means of most community groups.

APPENDIX A

Index of Similarity

This appendix describes the way in which an index of similarity between any two areas was computed.

Let x_{ij} be the value that variable j takes for area i. The units of measurement change from variable to variable. To overcome this difficulty all variables were standardized to zero mean and unit variance. Then

$$Z_{ij} = \frac{X_{ij} - X_{.j}}{S_{.j}} \quad \begin{array}{l} i = 1, \ldots 45 \\ j = 1, \ldots 53, \end{array}$$

where

$$X_{.j} = \frac{\sum_{i=1}^{45} (X_{ij} - X_{.j})^2}{45}$$

and

$$S_{.j}^2 = \frac{\sum_{i=1}^{45} (X_{ij} - X_{.j})^2}{44}.$$

A correlation coefficient between two zones was computed next by treating standardized variables as observations:

$$r_{mn} = \frac{\sum_{j=1}^{53} (Z_{mj} - Z_{m.})(Z_{nj} - Z_{n.})}{\left[\sum_{j=1}^{53} (Z_{mj} - Z_{m.})^2 \sum_{j=1}^{53} (Z_{nj} - Z_{n.})^2\right]^{1/2}} \quad \begin{array}{l} m = 1, \ldots 45 \\ n = 1, \ldots 45, \end{array}$$

where

$$Z_{m.} = \frac{\sum_{j=1}^{53} Z_{mj}}{53}.$$

The value of this correlation coefficient could be used directly as a measure of similarity. Unfortunately the computer package used, MDS(X),[29] did not accept negative numbers as measures of similarity, and some of the r_{mn} took negative values. To overcome this problem the correlation coefficients were linearly transformed into similarities by adding one and dividing by two.

The matrix of similarities between areas was used as input to the computer program MINISSA, a member of the MDS(X) package.

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CHAPTER 6

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The Distribution of Special Education (Moderate) Needs in Southampton

C. MAR MOLINERO & J. F. GARD, *University of Southampton*

ABSTRACT *This paper examines the demand for special education (moderate) in the City of Southampton. It is shown that the number of children that require special education (moderate) in a particular area depends on the characteristics of the area concerned. A forecast of future demand for special education is produced. A comparison with the actual 1984 figures makes it possible to assess the influence of educational policies.*

Introduction

In recent years the number of children born in the UK has been subject to large fluctuations, as has been their social distribution (see Werner, 1985). Important changes have also taken place in the institutional framework that regulates education in the UK. The provision of main stream education was the object of the 1980 Education Act, while Special Education was the object of the 1981 Education Act.

Little is known about the relative demand for Special Education, and this makes it difficult to assess the impact of changes in social trends and changes in policies. This paper reports an investigation into the need for Special Education (moderate) in the Southampton District using data from both the 1981 Census and local education authority files. It attempts to analyse the geographical distribution of children between the ages of five and 15+ who are receiving Special Education in Southampton and to offer a possible explanation for this distribution.

This study shows a link between external and environmental factors and the numbers of children with moderate learning difficulties, which would be of use in the planning of future special educational provision. Although the analysis, and its results, are limited to Southampton it is felt that it is of general interest, and that studies similar to this one should be carried out in order to discover whether its conclusions are generally valid.

Background

"Special education is the education of handicapped children" (Chazan *et al.*, 1972). This broad definition illustrates the historical attitude to special education provision. At the end of the eighteenth century provision was made only for the physically handicapped, the blind and deaf, but when the 1870 Education Act came into being it became apparent that a group of children existed for whom, though they were physically normal, learning presented great difficulties. They were labelled the 'intellectually handicapped' and provision was made for them to be educated separately beginning in the last decade of the nineteenth century. Another group of children requiring special attention was recognised, in the mid-twentieth century as those who were emotionally disturbed or maladjusted, and special schools were set up to deal with their particular problems.

The education of handicapped children and young people was reviewed in 1977–78 by a Committee of Enquiry, chaired by Mrs H. M. Warnock (*Special Education Needs*, 1977–78). In the light of the committee's findings the Government published a White Paper, *Special Needs in Education*, in August 1980 setting out the law reforms that they wished to implement. At that time local education authorities' obligations to provide schooling for all 5–18 year olds in their areas were supplemented by specific legal provisions for the handicapped. The categories of handicap provided for were listed as the blind, partially-sighted, deaf, partially-hearing, educationally sub-normal, epileptic, maladjusted, physically handicapped, speech-defective and the delicate. The local education authority were obliged to identify and provide opportunities in special education for all these groups. The Warnock Committee suggested that a new and wider concept of special education should be considered in which the educational needs of the children concerned, and not the physical, mental or emotional causes of their handicap, were the deciding factors. In addition to this new definition the Government recognised the shift in the attitude of society towards integration of handicapped and normal pupils within the ordinary school system. The Government stated its intent to pursue a process of "Planned and sensible integration" of handicapped children into ordinary schools whilst still providing for those whose serious difficulties required separate provision (White paper, para. 37, 1980).

In 1981 the Education Act was passed, "An Act to make provision with respect to children with special education needs". The Act contained the new definition of children requiring special education as those who have learning difficulties which mean that special educational provision must be made. It classified a child as having a learning difficulty if,

> (a) he has a significantly greater difficulty in learning than the majority of children of his age; or
> (b) he has a disability which either prevents or hinders him from making use of educational facilities of a kind generally provided in school, within the area of the local authority concerned, for children of his age; or
> (c) he is under the age of five years and is, or would be if special educational provision were not made for him, likely to fall within paragraph (a) or (b) when over that age. (Education Act, 1981)

In the future, for economic reasons as well as for reasons of principle, integration may become accepted as an important goal. It has advantages in that 'normal' children learn to accept and work with those who are different to them in some way, but it also has disadvantages. For example, it cannot provide the same kind of opportunities for the use of special techniques and specially-trained teachers as exist in the segregated schools. The provision of separate facilities for those children whose needs are too great to be met within the ordinary school system will have to be maintained.

This policy of integration has important implications for planning. If implemented it may make many special schools redundant, unless the general demand for Special Education increases. The current study was undertaken in order to assess what the demand for Special Education in Southampton would have been if changes in policy and legislation had not taken place. A comparison between actual and predicted numbers can then be used to evaluate the influence of these changes.

Children with Moderate Learning Difficulties

The schools for which information was available were those concerned with educating the group labelled 'children with moderate learning difficulties'. This study concentrates on this group.

There are three schools which provide for the needs of children with moderate learning difficulties from the area. Two of them lie within the area boundary and the other is situated just outside it. All children, between the ages of five and 15+, resident in Southampton, and requiring special education attend one of these schools. They do not attend schools outside the area. Some pupils are, however, transported into the schools by minibus or taxi from outside Southampton, and they were eliminated from the study. It is possible for parents to send their children to private schools dealing specifically with special education needs but no information about such children was found during data collection and so this possibility was ignored. If there were any such privately-educated children the number would probably have been too small to significantly affect the results, even though the fee-paying pupils would have been more likely to come from the wealthier areas. The proportions of specially educated children in the wealthy areas may therefore have been slightly understated and the gap between figures for lower and middle class zones may not be as great as it appeared to be.

The Census

To put the incidence of demand for special education services into perspective it is necessary to know the characteristics of the general population. It was possible to do this using data available in the 1981 census.

The 1981 Census was based on a subdivision of England and Wales into district electoral wards as amended in the Local Government Act 1972 (which came into operation on the 1st April 1974). These wards are each subdivided into enumeration districts (EDs) which are the smallest areas for which census statistics are published.

The Census was taken on the night of 5–6 April 1981 (OPCS, 1982). The computer program SASPAC was used to obtain information from the Census. The SASPAC program allows not only access to the data but also extraction, analysis and tabulation of any particular subset of it (UMRCC, 1982).

Cell numbers from SASPAC Tables II and XLIX were used for this study. Table II sets out the numbers of all residents of particular age groups. Table

XLIX contains 10% sample figures for the social status of private households and all the residents of those households. Families are allocated to a particular socio-economic group (SEG). This was evolved with the intention of forming categories of people with similar 'social, cultural and recreational standards' and is as follows:

SEG 1 Employers and managers in central and local government, industry, commerce, etc.—large establishments (employing 25 people or more).
2 Employers and managers in industry, commerce, etc.—small establishments.
3 Professional workers—self-employed.
4 Professional workers—employees.
5 Intermediate non-manual workers
5.1 Ancillary workers and artists
5.2 Foreman and supervisors non-manual
6 Junior non-manual workers.
7 Personal service workers.
8 Foreman and supervisors manual.
9 Skilled manual workers.
10 Semi-skilled manual workers.
11 Unskilled manual workers.
12 Own account workers (other than professional).
13 Farmers—employers and managers.
14 Farmers—own account.
15 Agricultural workers.
16 Members of the armed forces.
17 Inadequately described or not stated occupation.

The Data

Southampton education area was subdivided into 15 electoral wards for the purpose of the 1981 Census. Each of these was further subdivided into between 25 and 32 enumeration districts, giving approximately 400 in total.

It was found that the wards were few and each contained areas widely differing in, for example, the average income per household or the social class of the majority of residents. Therefore, since the aim of the study was to investigate any links between external factors, such as the above, and the proportion of children needing Special Education for each area, the wards were unsatisfactory for use as data areas. The enumeration districts, on the other hand, were too numerous to allow a sensible analysis of the data and so it was necessary to create new zones.

Reference was made to Ordnance Survey maps of Southampton (scale 1:10,560), issued by HM Stationery Office, on which all 1981 EDs were marked. These were aggregated into two or three groups within each ward. The objective was to obtain zones containing approximately the same numbers of EDs and at the same time to group together those EDs which had similar characteristics (i.e. council estate, working class areas, wealthy areas, etc.).

The final result of this procedure was a set of 31 new zones, for which tables of Census data could be produced. Figure 1 shows the position of these zones and of the original 15 wards. It was assumed that the characteristics of each area (e.g.

proportion of owner-occupied housing, SEG classifications) had remained at a constant level since the census was taken. Data was obtained from the Census for these new areas.

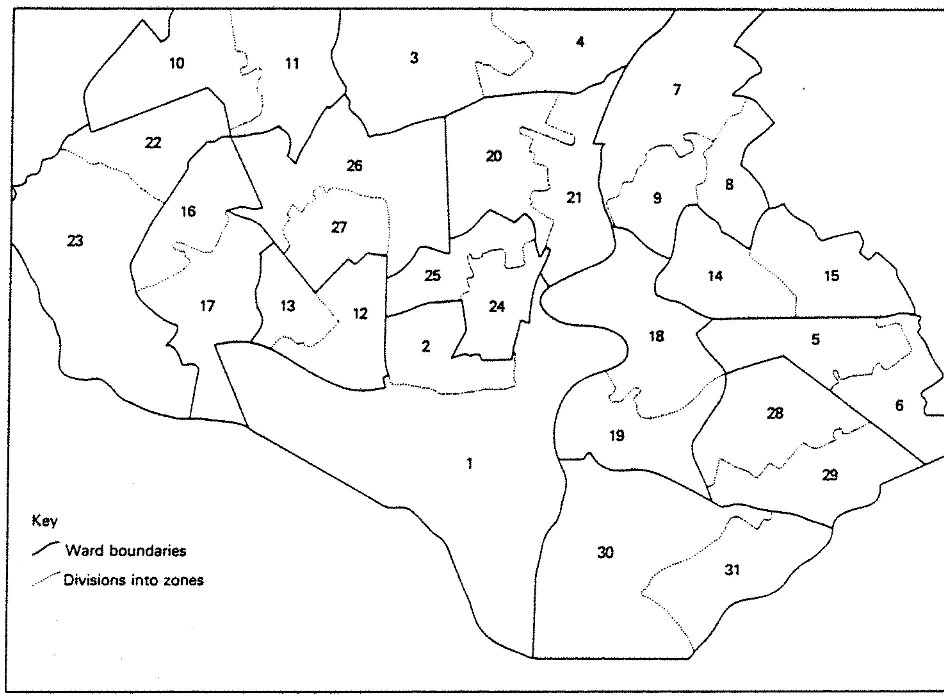

FIG. 1. Southampton District: wards and numbered zones.

Education Department Information

With the permission of the Southampton Area Education Office, information was gathered from their files concerning all children undergoing special education at the three schools in the area. Details of the addresses and dates of birth of all these children were recorded but their names were not, in order to maintain confidentiality. Care was taken to exclude any children not resident in the Southampton Area and it was also confirmed that no children from the area received special education in schools other than the three named above, i.e. they did not travel to a school outside the area.

The resulting list of 229 addresses and dates of birth was analysed to enable total numbers of children in special education (moderate) to be calculated for each of the census zones. This involved marking the addresses on a street map of the district, deciding in which ED they appeared by reference to the Ordnance Survey maps and thus placing them in the relevant zone.

This method was subject to possible errors. The street map contained only occasional references to house numbers and thus it was difficult to pinpoint exactly the specific address. The EDs contain only about 200 houses each and so an error of positioning of an address might have meant placement of it in the wrong ED and therefore perhaps in the wrong zone. Fortunately, however, these errors did not often affect placement of an address in a zone and so the errors in the data as presented for further analysis are small and should not have affected the overall results of the study.

The ages of the children were calculated from their birth dates, as at 1 September 1983 the beginning of the current school year. Then the total numbers for each of the 31 zones were broken down into sub-totals for the 5–9–, 10–14– and 10–15– year old groups to enable comparison with the census figures. After this process, only one child of 16 years remained unclassified and was eliminated from the rest of the analysis.

Analysis

On a first analysis it was assumed that the total number of children in the 5–9– and 10–15– age groups as given in the Census had remained unchanged between 1981 and 1983 for every zone (Gard, 1984). Although the conclusions of this study are largely unchanged it was felt that it would be more appropriate to estimate the number of children in the 5–9– age group in 1983 by aggregating 40% of the children in the 0–4– age group in 1981 with 60% of the children in the 5–9– age group in 1981. In the same way, estimates for the number of children in the 10–15– age group in 1983 were obtained by aggregating 40% of the numbers in the 5–9– age group in 1981 and 80% of the numbers in the 10–14-age group in 1981. The resulting figures, together with the number of children with moderate learning difficulties in every zone are given in Table I.

The socio-economic group data were used to calculate a 'weighted average' SEG figure for each zone. This was intended to give an overall picture of the district and was done by multiplying the number of households in each SEG by the SEG figure, adding the totals produced and then dividing by the number of households. It was calculated separately for each zone and the resulting figures were corrected to one decimal place. Socio-economic group 5, which is normally split into two groups 5.1 and 5.2, was treated as one class labelled '5' for this calculation. Obviously the SEG classification is not a continuous one and the figures produced as weighted averages are only useful as a very rough guide to the characteristics of each zone. Besides, this procedure scores the S.E.G.s as if they were on a linear scale, but this is far from being the case. Another source of error arises from the fact that households falling in SEG 17 were ignored. SEG 17 is simply a category for any households in which the Census form was incorrectly completed or for which no suitable classification exists.

Although there is no single variable that adequately describes the relative wealth of a zone, the proportion of owner-occupied housing that a zone contained was used as a proxy for its wealth. This figure was calculated for each zone. The resulting average SEG and proportion of owner occupiers can be seen in Table I.

The proportion of children with moderate learning difficulties in each zone varies greatly in the range .0015 to .0203. These outer points of the range are in the ratio of 1:15 which indicate important differences between the zones. The overall proportion of children with moderate learning difficulties in the education area is .0076 and the proportions for individual zones would be expected to approach this figure if the distribution of needy children was uniform throughout the education area. To test whether this is the case an χ^2 test was performed. This test is not

TABLE I

Zone	Average SEG	Proportion owner-occ.	No. special 5–9–	No. special 10–15–	Pop. '81 5–9–	Pop. '81 10–15–	Est. pop. '83 5–9–	Est. pop. '83 10–15–
1	8.4	.1529	4	3	285	429	326	384
2	6.9	.5236	1	7	207	308	231	280
3	5.0	.8565	0	1	286	477	258	422
4	7.4	.4457	10	12	614	975	534	897
5	7.2	.7345	2	2	400	614	363	554
6	8.3	.2529	0	5	413	623	485	570
7	7.8	.4625	2	0	202	368	185	321
8	7.9	.4205	1	2	266	433	301	372
9	7.5	.8036	0	1	233	398	227	348
10	8.7	.1497	9	20	1613	1344	1275	1584
11	7.5	.5986	4	5	731	660	770	743
12	7.0	.6007	2	1	307	430	323	405
13	8.0	.6445	1	6	255	379	273	355
14	7.2	.6763	3	0	308	501	310	437
15	7.5	.5367	3	2	469	764	445	681
16	8.1	.3271	3	5	419	632	423	571
17	7.5	.6285	0	2	337	483	326	452
18	7.5	.6761	3	4	545	719	519	683
19	7.4	.6471	0	8	405	615	372	572
20	5.8	.5833	1	1	302	467	303	424
21	7.6	.6166	1	6	377	593	353	541
22	8.0	.4762	6	7	433	682	433	623
23	8.0	.2364	6	14	384	658	398	589
24	7.8	.5342	0	5	299	453	330	432
25	6.6	.4484	3	3	186	230	196	222
26	6.9	.6420	2	5	267	484	270	420
27	6.9	.6583	1	2	339	552	338	496
28	7.3	.8140	3	4	456	712	454	641
29	8.2	.5654	1	8	539	813	544	752
30	7.4	.7510	1	3	414	578	394	550
31	8.4	.3022	6	4	647	837	713	820

totally adequate given the small numbers in some of the cells, but the null hypothesis was rejected strongly at the 95% significance level, this suggesting that the proportions of children with moderate learning difficulties in the zones are not uniform over the area; or, in other words, that the chances of the differences in the proportions being the result of chance alone are smaller than 5%. Similar results were obtained for the individual age groups. Full details of these tests can be found in Gard (1984).

These χ^2 analyses show that there are important differences in the proportions of needy children occurring in each of the 31 zones. The result almost certainly could not have occurred by chance alone.

It is interesting to note that the highest proportion of owner occupied housing occurs in zone 3, which also has the lowest proportion of children with learning difficulties. The same zone has a weighted socio-economic group figure of 5.0—the lowest of all the 31 zones—and therefore can be regarded as being on average of a higher social grouping than the other zones. The lowest proportion of owner occupiers occurs in zone 10 together with the highest numerical value of weighted SEG. Although zone 10 does not contain the highest proportion of children with learning difficulties, it does contain a proportion of .0101, which is higher than the average, and significantly larger than that for zone 3. The highest proportion (.0202) occurs in zone 23 and that zone yields a weighted SEG of 8.0 (one of the highest values) and a proportion of owner occupiers which is one of the lowest at .2364. Overall then, there seems to be a link between the proportion of educationally subnormal children in an area and the proportion of owner occupied housing in that area.

It was decided to explore the possibility that the proportion of educationally subnormal children in an area depends on the wealth of the area concerned, the proportion of owner occupied housing in the area being used as a proxy for wealth. Although the probability of finding that a randomly selected child belongs to the special group can, in theory, take any value between zero and one, what is observed in practice is the fact that a child belongs or does not belong to the special group. An appropriate way of modelling this type of situation (see, for example, Pindyck & Rubinfeld, 1981) is by means of a logit function of the form

$$\frac{P_i}{1-P_i} = \exp\,(\beta_0 + \beta_1\, x_i + \varepsilon_i) \qquad (1)$$

where P_i is the probability that a child that lives in zone i belongs to the special group.

x_i is the proportion of owner-occupier housing in area i.

ε_i is an error term

β_0, β_1 are coefficients to be estimated from the data

It should be noted that $P_i/(1-P_i)$ is the odds of belonging to the special group when living in area *i*.

Equation (1) was first estimated under the assumption that the probability of belonging to the special group was the same for all the children in a particular area irrespective of their age. The computer package GLIM (Baker & Nelder, 1978) was used to perform the calculations. The following results were obtained.

$$\frac{P_i}{1-P_i} = \exp\,(\underset{(0.159)}{-4.239} \underset{(0.320)}{-1.317}\, x_i) \qquad (2)$$

Deviance = 49.88 Degrees of freedom = 29

Figures in brackets as asymptotic standard errors.

The deviance, a χ^2 statistic, is a measure of goodness of fit appropriate for hypothesis testing in this context. For details see Dobson (1983).

The coefficient of the explanatory variable, χ_i, is significantly different from zero. thus supporting the view that the proportion of children with moderate learning difficulties depends on the wealth of the area being considered. The value of the deviance is, however, higher than one would expect for the equation to be considered acceptable (the 5% cut off value for 29 degrees of freedom is 42.56).

It was noticed that the proportion of 5–9– children who belong to the special group, 0.0062, is lower than the corresponding proportion for the 10–15– age group, 0.0086. This might be explained by the fact that some children start school in main stream education and are later transferred to special schools. Taking this into account equation (1) was first estimated for the 5–9– age group with the result

$$\frac{P_i}{1-P_i} = \exp\underset{(0.265)(0.541)}{(-4.114-1.397x_i)} \qquad (3)$$

Deviance = 45.56 Degrees of freedom = 29

The equivalent result for the 10–15– age group was

$$\frac{P_i}{1-P_i} = \exp\underset{(0.200)(0.397)}{(-4.114-1.297x'_i)} \qquad (4)$$

Deviance = 52.48 Degrees of freedom = 29

The value of the deviance is, again, higher than one would expect both in equation (3) and in equation (4).

Consider the 5–9– group first. On close examination it was found that there was a very large residual associated with zone 4. This is a zone that includes a large council estate with more than its fair share of social problems. When this zone was removed from the data set and equation (3) was reestimated the following was found

$$\frac{P_i}{1-P_i} = \exp\underset{(0.278)(0.565)}{(-4.499-1.403x_i)} \qquad (5)$$

Deviance = 37.73 Degrees of freedom = 28

The value of the deviance is now within the acceptable range.

When the 10–15– age group is considered it is found that there are two large residuals that can be held responsible for the large value of the deviance. These correspond to zones 2 and 23. Zone 23 contains another large council estate while zone 2 is an inner city area with severe deprivation problems, as identified by a planning document produced by the City Planning Department (1985). It can be argued that both zones should be treated as special cases and removed from the data set. When this was done equation (4) became

$$\frac{P_i}{1-P_i} = \exp\underset{(0.224)(0.429)}{(-4.321-1.048x_i)} \qquad (6)$$

Deviance = 39.37 Degrees of freedom = 27

The value of the deviance is now within the acceptable range.

The above analysis confirms the widely held view that immigrant and low income communities are overrepresented in special schools. It is interesting to notice that the above mentioned study of population characteristics in Southampton (City Planning Department, 1985) after defining a series of measures of deprivation identifies areas 4, 2, and 23 as suffering from 'multiple deprivation', scoring high in almost every measure of deprivation.

Forecasting Future Rolls

The 1981 census was used to produce population estimates for every Southampton zone for 1986. To do this it was assumed that all the children in the 0–4– age group in 1981 would be 5–9– in 1986, that all the children aged 5–9– in 1981 would be 10–14– in 1986, and that 20% of those aged 10–14– in 1981 would be 15– in 1986. This assumes that children born in a particular zone remain in the zone, or that population movements in and out of a particular zone cancel each other out.

The proportion of children in a particular zone that may fall within the special education category is given by equations (5) and (6), although reasonable corrections have to be made to take into account the characteristics of areas 2, 4, and 23. By applying expected proportions to the estimated population figures it is possible to produce forecasts for rolls in the relevant special schools in 1986. Given all the uncertainties associated with data collection, estimation, projection of future population figures, and corrections to be made for discordant zones the forecasts have to be seen only as an indication of what rolls would be in 1986 if past policies continued unchanged, and provide a yardstick against which to measure the effects of the policy of integration that has resulted from the implementation of the recommendations contained in the 1981 education act.

As it can be deduced from Table I the special school population in Southampton was 227 in 1983. The methods described in this paper produce a forecast of about 215 in 1986. This change is roughly in line with the percentage change in the total 5–15-age old population although its geographic distribution is different. The actual number will, of course, not be the same as the forecast; although the forecast provides a yardstick against which to assess the impact of falling rolls and the implementation of the 1981 Education Act. It would seem reasonable a priori to expect the actual number to be lower than the forecast. The first reason is connected with the 1981 Act; since it not only defines a new policy of integration but also, by introducing extra administrative procedures and safeguards, makes entry into special schools more of a traumatic experience for the parents; who may, in turn, think twice before sending their children to special schools. The second reason for the expected shortfall in numbers is related to the temporary fall in the birth rate; school rolls have been declining and are expected to continue to decline in the near future in most schools; but since the fall in the birth rate has been more accentuated amongst the working classes—the ones that are most represented in special schools—the problem of falling rolls should be particularly acute in special schools; furthermore, falling rolls in 'normal' schools should free staff time and make integration easier to achieve. Yet, against all the odds, the number of children with Southampton addresses who were receiving special education (moderate) in Southampton had gone up to 278 by the 1 October 1984.

It is difficult to speculate about the reasons for this increase but we suspect that it is related to the staffing policies of Hampshire's Education Authority (HEA); HEA follows a policy of equalisation of teacher/pupil ratios in schools; as the number of children in a school declines so does the number of teachers; the teachers that remain face an increased workload and may find it harder to cope with disruptive or difficult children; they are then more likely to suggest that these children should be sent to special schools. Consultations with some of the headmasters of Southampton special school confirms an increase in applications from children with behavioural problems. Thus the decline in the birth rate may have the paradoxical consequence of making the integration objective harder to achieve.

Conclusion

It has been shown that the need for special education (moderate) differs greatly between the 31 zones of Southampton Education Area. This is true for the two age groups investigated. This variation seems to correspond with the variation in the characteristics of those zones so that a smaller proportion of upper/middle class children attend special schools than lower class children.

The consequence for the provision of special education in the future are significant since the occurrence of special need, instead of being regarded as a random or chance event, could perhaps be predicted by reference to the characteristics of an area.

In the long term, the ability to forecast the areas from which the highest proportions of children with special needs will come could be very useful in the positioning of new schools or the repositioning of established ones. The problem of transport for pupils to and from special schools is often a serious and expensive one for the local education authority and is a significant drain on its resources. A sensible placement of the special schools allowing easy access to them from those areas producing higher proportions of children with learning difficulties might save a large amount of money.

Correspondence: C. Mar Molinero, Department of Accounting and Management Science, University of Southampton, Southampton SO9 5NH, England.

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CHAPTER 7

The Social Impact of the 1981 Cuts in British University Expenditure

C. MAR MOLINERO
Department of Accounting & Management Science, University of Southampton, Southampton, SO9 5NH, England

Introduction

In the summer of 1981 a Conservative government committed to reductions in public expenditure imposed large reductions in university budgets and university student intake. It was accepted at the time that access to courses would be made more difficult but it was then said that "quality would probably improve".

This paper examines the way in which the cuts were felt by the candidates to university entry. It will be shown that the cuts had different impact on applicants from different social backgrounds, and that they greatly improved the chances that an overseas student has of being accepted to study in a British university. It is shown that university selectors would like to accept 'well qualified' applicants if there were no constraints in student numbers. This only happens in the case of overseas students. If there are restrictions in the number of university places, selectors accept the 'best qualified' applicants. A combination of institutional characteristics means that the 'best qualified' applicants are more likely to have a middle class than a working class background.

Applications for entry into United Kingdom universities are computerised and centrally coordinated through the Universities' Central Council for Admissions (UCCA). UCCA includes all the U.K. universities except the Open University and the private University of Buckingham. Any applicant has to fill in an UCCA form where information is requested about the courses applied for (five choices), personal background, general interests, and academic background. The UCCA form contains also a confidential statement by a referee. UCCA provides data concerning applicants and entrants through its regular publications: the Reports and the Statistical Supplements.

The terms 'applicant', 'accepted', 'home', 'overseas', and 'social class', are used in this paper as defined in the UCCA reports and Statistical Supplements (UCCA, 1977–1983).

An applicant is a person who submits an application for entry through UCCA. It includes all those who apply for entry in a subsequent year and all those who withdraw during the selection process. An applicant is classified as 'accepted' if he/she holds a firmly accepted unconditional offer by the 30 September of the relevant year. It includes applicants accepted for entry in a subsequent year but excludes withdrawals. Deferred entry and last minute drop-outs make the number of entrants into universities different from the number of acceptances. For the purposes of this paper acceptances is the variable of interest since it reflects planned changes in behaviour during the admissions process.

The definition of 'home' and 'overseas' students changed in 1981. Until that year an attempt was made by UCCA to guess the level of fees that a particular student would be expected to pay on registration. Thus, applicants whose home was abroad but had been living in the U.K. for a qualifying period were classified as 'home'. EEC applicants were sometimes classified as 'home' and sometimes as 'overseas'. Under the new system all those applicants whose permanent home is outside the U.K. are classified as 'overseas'. To indicate the criteria used UCCA uses the words 'Fees' and 'Domicile' in the relevant tables; that convention will be retained in this paper.

Most applicants give their parent's occupation as requested by the UCCA form. This information is used to classify them into social classes. The DPCS definitions are used for this purpose. The social class categories are as follows.

class I	Professional
class II	Managerial
class IIIN	Skilled (non-manual)
class IIIM	Skilled (manual)
class IV	Partly skilled
class V	Unskilled

A detailed description of the problems that this process entails is given in the Statistical Supplement to the 17th Report (UCCA, 1979). About 10% of the applicants cannot be classified. There is always the risk of mis-classification; the example given by UCCA is illuminating in this respect: if the son of a chartered engineer had written 'engineer' as his father's occupation he would have been classified as being class III instead of class I. The OPCS definitions changed in 1980, and the new definitions were used in the 18th UCCA Report, hence the figures that relate to admission in October 1980 and after are not directly comparable with the ones produced in previous years.

Home Students

Table I shows the total number of home students that were accepted through UCCA from 1977 until 1982, it also shows the total number of home applicants. The row labelled 'average' gives the ratio of acceptances to applications, i.e. the probability that a randomly chosen applicant had of being accepted in that particular year. To indicate the fact that figures prior to 1981 used 'Fees' as a classificatory device instead of 'Domicile', as was done from that date onwards, the letters F and D have been added to the corresponding years.

Table I. Home students

Social class	Proportion accepted for entry in year					
	1977(F)	1978(F)	1979(F)	1980(F)	1981(D)	1982(D)
I	0.584 (7.7)	0.588 (6.4)	0.581 (7.9)	0.567 (5.7)	0.592 (6.1)	0.511 (10.1)
II	0.549 (1.2)	0.558 (1.0)	0.548 (1.7)	0.544 (1.4)	0.505 (1.1)	0.475 (2.5)
IIIN	0.535 (−1.3)	0.552 (0)	0.520 (−3.6)	0.526 (−1.9)	0.468 (−6.2)	0.439 (−5.2)
IIIM	0.508 (−6.2)	0.520 (−5.8)	0.505 (−6.3)	0.497 (−7.3)	0.455 (−8.9)	0.407 (−12.2)
IV	0.486 (−10.3)	0.495 (−10.3)	0.481 (−10.7)	0.481 (−10.2)	0.437 (−12.5)	0.385 (−17.0)
V	0.465 (−14.3)	0.510 (−7.7)	0.449 (−16.7)	0.447 (−16.7)	0.454 (−9.1)	0.379 (−18.2)
Average	0.542	0.552	0.539	0.536	0.499	0.464
Home applicants	132047	134588	142228	149330	153283	156675
Acceptances	71578	74339	76631	78939	74514	72634

Source: *UCCA Statistical Supplements.*

Throughout this period the total number of home applicants increased from one year to the next. It is to be noted that if the old definition of home student had been retained, the increase in applications during the last two years would have been even larger than that shown in the table.

It was shown by Hill & Mar Molinero (1981) that even in the days when an attempt was being made to provide university places for all those who were qualified and willing to go to university (the Robbins principle), universities did not react immediately to changes in applications. The long run proportion of applicants accepted was estimated as being 0.55, data for the period 1964–1977 was used to obtain such an estimate. There had been an increase in applications in years prior to 1977, so it is not surprising to find a relatively low value of 0.54 for this proportion for that year. Things returned to normal in 1978 when the proportion of applicants accepted returned to 0.55. After this moment the influence of government policies can be felt on the data. The lowering of this proportion to 0.539 in 1979 can be attributed to the decision of a Labour government not to expand the provision of places in line with the demand for them. In 1980 there was a change of policy that related to overseas students. As from this moment the level of fees charged to them was raised "to cover the full economic cost of tuition", and overseas students were excluded from education planning. This had the paradoxical consequence of expanding the number of places available to home students since in previous years target student numbers included both home and overseas students. Despite this expansion in the number of places the proportion of applicants accepted fell again to 0.536 due to a large increase in the number of applicants. In the summer of 1981, just after a year of expansion, a Conservative government decided to reduce the amount of money available to universities, and this resulted in a decrease in the number of places available despite a new large increase in the number of applications. It is unfortunate that UCCA decided to change the definition of home/overseas students during this particular year. It is, however, possible to assess the impact of the 1981 cuts on access to university education since figures for applications and acceptances in 1981 were produced under both the 'Fees' and 'Domicile' system. The proportion accepted, measured in the old way, fell from 0.536 to 0.494. There was a further drop in this proportion rate between 1981 and 1982 due to further reduction in places, and the proportion of applicants accepted, now measured under the new system, fell again from 0.499 to 0.464. No alternative set of figures was produced in 1982 but one can guess that if it had been provided the corresponding figure for 1982 would have been around 0.46. Thus from 1978 until 1982, the proportion of applicants accepted fell from about 0.55 to about 0.46, a 9% drop in absolute terms, or 16% in relative ones. If this proportion had remained at the 1978 level it can be estimated that between 25,000 and 30,000 more home students would have been accepted for entry by universities in the United Kingdom during the four-year period up to September 1982. This has to be compared with the 72,600 actually accepted in 1982.

The distribution of applicants and acceptances by social class has been published by UCCA in its present form since 1977, as part of its regular Statistical Supplements. This information has received a great deal of attention since it is possible to use it to work out the proportion of individuals in the age group who go to university for each one of the social classes. This proportion is known as Age Participation Rate (APR). It is well known that APRs for social classes I and II is very high, while the corresponding figures for classes IV and V are very low. As a result of these differences the social class structure of the student population is very different from the social class structure of the general population of 18-year-olds (Holt, 1983; Mar Molinero, 1984; AUT, 1983).

Using the distribution of applications and acceptances by social class it is possible to work out the proportion of applicants accepted for every social class. This was done for the years for which the data was available. The results are shown in Table I. It can be seen that there are social class differences, for example in 1977 0.584 of the applicants from social class I were accepted while the corresponding figure for social class V was 0.465. Since the average proportion of applicants for that year was 0.542 it follows that applicants from social classes I and II stood a better than average chance of being accepted, while the opposite was true of the remaining social classes. This pattern repeats itself every year both before and after the 1981 cuts and before and after the 1980 redefinition of social class. It can be seen that the increase in the difficulty of acceptance has been felt by all social classes. The differences in acceptance rates between the years 1979 and 1980 have to be interpreted with care due to the effects of the changes in the classification system.

The figures shown in brackets are the percentage differences between the proportion of applicants accepted for a particular social class and the average for that year thus in 1977 those applicants that belonged to social class I had a 7.7% better chance of being accepted than the average for the year, while applicants from social class V had a 14.3% disadvantage over the average. The dividing line that seems to exist between the 'middle classes' and the 'working classes' is to be noted. A middle class youngster is more likely to apply for university admission than a working class one, and is more likely to be accepted once he/she has applied for entry. The two apparently anomalous figures for social class V for the years 1978 and 1981 are almost certainly due to the effect of rounding, since both the number of applications and the number of acceptances are rounded by UCCA.

During the first four years shown in Table I there was a remarkable degree of stability in the relative differentials between the proportion of accepted applicants, as shown by the figures in brackets. This situation did, however, change dramatically after the 1981 cuts. The cuts were announced during the summer, hence admissions policies for entry in 1981 were not affected by them, although applicants who marginally failed to meet the conditions they had to meet in order to be accepted might have been treated in a less generous way as a result of the cuts. The cuts did influence the way in which empty places were matched with uncommitted applicants (the clearing system); there was a large reduction in the number of students accepted in this way. Applicants from social classes IIIN, IIIM, IV and (perhaps) V seem to have suffered most from this late decision. The full effect of the cuts was felt during 1982 when universities modified their admissions policies to adjust to the new student number targets. A comparison between the figures for

1981 and 1982 shows the worsening of the relative positions for classes IIIM (from −8.9 to −12.2), IV (from −12.5 to −17), and V (to −18.2), and an improvement in the relative positions of classes I (from 6.1 to 10.1), II (from 1.1 to 2.5) and IIIN (from −6.2 to −5.2). These changes cannot be attributed to a change in the pattern of applications since the social class distribution of the applicants changed very little during the years 1980, 1981 and 1982. The conclusion has to be that the 'working classes' felt the impact of the cuts to a much larger extent than the 'middle classes'.

Overseas Students

Table II shows applications, acceptances, and the proportion accepted of overseas students for the period 1977–1982. For the year 1981 two sets of figures are given, corresponding to the 'Fees' and the 'Domicile' basis for classification. No data on social class distribution is available for this group of students. Table II also shows the minimum level of fees in pounds sterling charged to overses students.

TABLE II. Overseas students

	Year of entry						
	1977(F)	1978(F)	1979(F)	1980(F)	1981(F)	1981(D)	1982(D)
Applications	21569	22918	24134	21105	13813	17766	14821
Acceptances	6277	6191	5767	5756	4618	5827	5118
Proportion accepted	0.291	0.270	0.239	0.273	0.334	0.328	0.345
Fees (£s)							
Arts	650	705	940	2000	2500	2500	2900
Science	650	705	940	3000	3600	3600	3800
Clinical	650	705	940	5000	6000	6000	7000

Source: *UCCA Statistical Supplements.*

Using data for the period 1950–1978, Hill & Mar Molinero (1981) showed that, when a trend had been removed, the number of overseas applications was sensitive to the level of fees measured in US dollars. The level of fees charged to overseas students increased every year, although increases during 1977, 1978 and 1979 were relatively small when compared with the changes that took place during 1980. As from this year the government decided not to make any money available to universities in relation to overseas students, and fixed the minimum fee to what was considered to be the real cost of teaching them. Since teaching costs depend on the particular discipline being taught different levels of fees were established for arts based courses, science based courses, and clinical courses. This large increase and the others that followed it made university courses in the U.K. less attractive to overseas applicants, and there was a large decline in the number of overseas applications. Between 1979 and 1981 the number of overseas applications decreased by 43%. The availability of two sets of data for 1981 makes it possible to estimate that in that year there were about 3950 home fee paying applicants that were domiciled abroad, thus suggesting that between 1981 and 1982 there was a further decline in the number of applications from overseas fee paying applicants. The increase in fees, on the other hand, made fee paying overseas applicants more attractive to universities since income derived from them was, as from 1980, outside government control.

The proportion of overseas applications that are accepted by universities is smaller than the corresponding figure for home applications, as can be seen comparing Table I and Table II. This was noted by Hill & Mar Molinero (1981) who, using data for the period 1964–1977 found that the long run value of this proportion was 0.33. They also found that universities reacted less to changes in overseas applications than they did to changes in home applications. It is not possible to know if the difference in acceptance rates for home and overseas students is due to different withdrawal or different rejection rates since data is not available to answer this question.

Whatever the reason for the low proportion accepted its value fell from an already low value of 0.291 in 1977 to 0.270 in 1978 and further to 0.239 in 1979. This may be explained by the general increases in the number of applications during this period, together with the slow reaction to changes in overseas applications that has just been mentioned. The sharp rise in fees in 1980 accounts for the smaller number of applications, whilst the higher proportion may be only a sign of things returning to normal. Until this moment there was no particular advantage from the point of view of the universities of accepting overseas rather than home students; hence no discrimination is suspected either way. The 1981 cuts changed this situation dramatically. Suddenly overseas students became very attractive as a source of independent finance. The new large increase in fees produced a further fall in overseas applications which was ssociated with a large increase in the proportion accepted that rose now to 0.334. Using the two sets of figures for 1981 it can be found that the proportion of home fee paying students domiciled abroad accepted is 0.306. Since this group of students are likely to have been in the U.K. for their secondary school education, it is surprising to find that their chances of being accepted are lower than those of overseas fee paying students. The new increase in the proportion of overseas students accepted in 1982 contrasts with the decline in the chances of being accepted suffered by home students. It seems as if the 1981 cuts had the effect of substantially improving the chances that an overseas fees applicant had of being accepted by some university.

Home Students: qualifications

It has been noted before that the social class distribution of applicants is different from the social class distribution of accepted candidates. UCCA comments that there is no evidence of social class bias by university selectors and that a possible explanation for the observed differences is the different examination performance of the various social groups. This is a subject that has important implications in assessing the impact of the cuts and will be analysed next.

The usual minimum standard for acceptance to study in a British University is two passes in the Advanced Level General Certificate of Education (A-level), although, in theory, all applicants are seriously considered irrespective of their qualifications; special procedures apply for non-standard applicants. Most candidates do, however, apply before they have taken their A-levels, and they receive an offer for entry which is conditional on their achieving a minimum number of points in the subjects they are taking. The A-level results are graded on a nominal scale from A to F, A being the highest level of achievement.

Tables showing examination performance by social class both for applicants and entrants have been published by UCCA for some time. The tables are based on a 10% sample of all applicants. This may seem a large number of data points, but, given the low participation rates for the 'working classes', especially class V the numbers of such individuals that appear in the table can be very small at times and therefore subject to large percentage variation.

The data provided by UCCA can be processed in several ways depending on the characteristic of interest to be examined. From the point of view of the universities it is interesting to know up to what point applicants with different social backgrounds achieve different levels of qualification. Table III was prepared to throw light on this matter. This table shows the percentage of all applicants belonging to a certain social group that achieved a certain number of points at A level. (The figures show the number of A level passes gained and counted in the scoring—not the number of subjects attempted. Some of those scored on three subjects may have attempted, or even passed, four or more, but only the best three are counted. Many of those with two or fewer passes will have attempted three or more subjects, but failed one or more.) Points have been computed using the standard scale A=5, B=4, C=3, D=2, E=1, F=0. This scale is unsatisfactory in many respects but is simple and generally adopted (Diamond, 1980). Point scores were aggregated by UCCA into groups, for example the first group covers results obtained with three A levels in the range 15–13, i.e. AAA, AAB, ABB, AAC. Different levels of aggregation were used in 1980 from those in subsequent years, hence the missing figures in the table. It can be seen that the 1981 sample contained 2703 applicants that belonged to class I, 19.1% of them achieved total scores in the range 15–13 points with three A levels, and also that 12.2% of them achieved less than two A levels. The last two columns in the table give the proportion of the total number of applicants in a particular class that achieved two and three A levels. It can be seen, for example, that in 1981 69.7% of all class I applicants achieved three A levels.

When a particular social class is examined it is found that there is very little variation in the distribution of qualifications from year to year. If one takes, for example, class II, it is found that the proportion of the applicants in the sample that achieved 12–9 points on three A levels was 25.6% for 1980, 25.9% in 1981 and 26.2% in 1982. The same is true of the remaining social classes. It is remarkable the small degree of variation to be found in the figures that relate to class V despite the small numbers in the sample. The table does, therefore, support the view that the qualification structure of the applicants has remained unaffected by the cuts. This

TABLE III. Home students

Social class	Year of entry	Proportion of all applicants with: 3 A levels 15–13	12–11	10–9	12–9	8–6	5–3	2 A levels 8–3	10–8	7–5	4–2	Less than 2	Total applications	Proportion with 3 A levels	Proportion with 2 A levels
I	1980	0.184	–	–	0.274	–	–	0.233	0.017	0.059	0.099	0.133	2405	0.691	0.175
	1981	0.191	0.131	0.130	0.261	0.171	0.074	0.245	0.015	0.067	0.098	0.122	2703	0.697	0.180
	1982	0.204	0.131	0.130	0.261	0.181	0.060	0.241	0.012	0.060	0.092	0.128	2646	0.706	0.164
II	1980	0.146	–	–	0.256	–	–	0.244	0.017	0.079	0.106	0.152	5286	0.646	0.202
	1981	0.164	0.124	0.135	0.259	0.174	0.067	0.241	0.017	0.076	0.107	0.137	5498	0.664	0.200
	1982	0.171	0.121	0.141	0.262	0.156	0.070	0.226	0.017	0.076	0.107	0.140	5835	0.659	0.200
IIIN	1980	0.151	–	–	0.248	–	–	0.233	0.022	0.076	0.121	0.148	1219	0.632	0.219
	1981	0.118	0.128	0.116	0.244	0.188	0.071	0.259	0.024	0.070	0.119	0.166	1037	0.621	0.213
	1982	0.132	0.115	0.146	0.261	0.186	0.080	0.266	0.018	0.059	0.109	0.153	1139	0.659	0.186
IIIM	1980	0.095	–	–	0.242	–	–	0.236	0.012	0.080	0.136	0.199	1717	0.573	0.228
	1981	0.115	0.104	0.121	0.225	0.178	0.072	0.250	0.015	0.086	0.127	0.182	1538	0.590	0.228
	1982	0.116	0.102	0.130	0.232	0.166	0.079	0.245	0.022	0.072	0.139	0.174	1628	0.593	0.233
IV	1980	0.110	–	–	0.188	–	–	0.241	0.024*	0.079	0.143	0.214	543	0.539	0.246
	1981	0.084	0.096	0.114	0.210	0.188	0.082	0.270	0.016*	0.092	0.127	0.200	510	0.564	0.235
	1982	0.096	0.087	0.133	0.220	0.141	0.098	0.239	0.021	0.084	0.141	0.201	633	0.555	0.246
V	1980	0.064*	–	–	0.250*	–	–	0.241*	0.007*	0.078*	0.164*	0.221	140	0.528*	0.249*
	1981	0.081*	0.089*	0.104*	0.193*	0.163*	0.089*	0.252*	0.022*	0.067*	0.133*	0.252	135	0.526*	0.222*
	1982	0.085*	0.085*	0.148*	0.232*	0.127*	0.092*	0.218*	0.014*	0.092*	0.134*	0.225*	142	0.535*	0.240*
Not class.	1980	0.110	–	–	0.197	–	–	0.208	0.033	0.102	0.143	0.206	941	0.515	0.278
	1981	0.116	0.100	0.105	0.205	0.141	0.051	0.192	0.021	0.105	0.141	0.220	1117	0.513	0.267
	1982	0.099	0.095	0.119	0.214	0.169	0.057	0.225	0.018	0.101	0.123	0.219	1264	0.538	0.242
Average	1980	0.142	–	–	0.249	–	–	0.236	0.018	0.077	0.115	0.162	12251	0.627	0.210
	1981	0.151	0.120	0.127	0.247	0.172	0.069	0.241	0.017	0.078	0.113	0.153	12538	0.639	0.208
	1982	0.156	0.116	0.136	0.252	0.165	0.070	0.235	0.017	0.074	0.112	0.155	13287	0.643	0.203

Source: *UCCA Statistical Supplements.*
* Based on small number of individuals.

is, in any case, what should be expected since most candidates apply for entry into university before they take their examinations. It has to be noted, however, that the proportion of applicants that achieve three A levels is higher in 1982 than in 1980 for every social group although the variation is small.

If different social groups are compared it is found that class I applicants are, on average, better qualified than class II applicants. A randomly chosen class I applicant is more likely to achieve three A levels and more likely to achieve a high point score than a similarly chosen class II applicant. It is also true that class II applicants are, on average, better qualified than class III applicants, and so on. One extreme around 70% of all class I applicants achieve three A levels while the corresponding figure for class V applicants is only about 53%.

To find out if there are differences in the examination performance of the different social groups the proportion of all three A level applicants that achieved a particular point score was computed for every social group. The same was done with two A level applicants. Since, as said above, it is reasonable to assume no change between 1981 and 1982 for a particular group, data for these two years was pooled. The results are presented in Table IV. There it can be seen that 28.1% of all three A level class I applicants achieve between 15 and 13 points, 18.7% achieve 12 or 11, 18.6% achieve 10 to 9, 25.1% achieve between 8 and 6, and 9.6% achieve between 5 and 3 points. It is clear from the examination of Table IV that there are important differences between the social groups. The patterns that appear in the two A level section of the table are complex and open to conjecture, but those that appear in the three A level side are beyond argument. It is clear that class I applicants do better than class II applicants in their examinations, and that class II applicants do better than class III applicants, and so on. The differences become very striking between the top and the bottom of the table: class I applicants are nearly twice as likely to obtain 15–13 points as class V applicants.

TABLE IV. Home students

Social class	Proportion of three A level applicants with					Of two A level applicants with		
	15–13	12–11	10–9	8–6	5–3	10–8	7–5	4–2
I	0.281	0.187	0.186	0.251	0.096	0.080	0.369	0.551
II	0.253	0.185	0.209	0.249	0.104	0.084	0.381	0.535
IIIN	0.195	0.189	0.205	0.292	0.118	0.106	0.323	0.570
IIIM	0.195	0.174	0.213	0.291	0.127	0.081	0.342	0.577
IV	0.163	0.163	0.222	0.290	0.163	0.076	0.364	0.560
V	0.156	0.163	0.238	0.272	0.170	0.078*	0.344*	0.578*

Source: *UCCA Statistical Supplements.*
* Based on a small number of individuals.

It follows that a middle class applicant is more likely to obtain three A levels than a working class applicant, and even if the two obtain three A levels the middle class applicant is likely to achieve a better point score. If selectors do not make any allowance for social class, a middle class applicant stands a better chance of being accepted to study at university than a working class applicant.

To construct Tables III and IV only information about applicants was used. By also using information about acceptances it is possible to calculate, for every social group, the proportion of applicants with given qualifications that were accepted. This information is shown in Table V. The table shows that in 1980 88.7% of all class I applicants that achieved between 15 and 13 points in three A levels were accepted. The equivalent figures for classes II, IIIN, IIIM, IV and V are 89.1%, 90.2%, 91.4%, 98.3% and 100%. The last two figures have to be interpreted with care since only 60 class IV students and 9 class V students with this level of qualification were included in the sample. This slow change in the probabilities of acceptance for this particular qualification group, which reappears in 1981 and 1982, may reflect the fact that some high scoring candidates turn down the offer of a place in order to enter for Oxford or Cambridge the following year; one would expect the proportion doing this to be linked to social class. Apart from this pattern nothing on Table V suggests that selectors take social class considerations into account. This is what one would expect since selectors tend to give standard offers which often reflect departmental selection policy. Selectors exercise their flexibility by giving either a standard offer or a rejection to the applicant concerned. This does not mean, however, that the level of the offer does not change from year to year or that a student that does not meet the offer is automatically rejected. Indeed, the opposite is often true, offers change from year to year in the light of experience, and may have been set at a level which is slightly 'too high', i.e. not enough students are expected to obtain the required grades to fill the student quota for the course, the department, or the faculty. If after the results are known it is found that not enough applicants have met their offers, universities may choose between accepting the 'best' amongst those that have failed to meet the offer, but are still qualified at an acceptable level (marginal candidates), or to make use of the 'clearing house' system to try to find the 'best' available students.

It is unfortunate that none of the years for which information was available to construct Table V can be described as 'normal'. During 1980 there was an expansion in the number of places available to home students due to the change in policy towards overseas students. It is reasonable to assume that selection plans for 1981 entry were made in the light of the 1980 experience, hence when the cuts were announced universities could only change the number of students accepted by changing the treatment of marginal applicants, i.e. enforcing the condition of the offer, a subject which was much debated in the national press. Admission policies for 1982 entry on the other hand, reflect the reaction of the university system to the change in student places, all the tools available to selectors could be used to ration places. Higher rejection rates, higher level of offers, and a less sympathetic treatment of marginal cases are suspected for 1982 than for previous years.

An examination of Table V shows that the proportion of applicants accepted changed very little during these three years for the 15–13 points qualification group. This means that applicants who achieved high qualifications found their way to study at university in one way or another both before and after the cuts. The same

TABLE V.

Social class	Year of entry	Proportion accepted: Score on three A-levels 15–13	12–11	10–9	12–9	8–6	5–3	8–3	Score on two A-levels 10–8	7–5	4–2
I	1980	0.887	–	–	0.860	–	–	0.561	0.775	0.582	0.159
	1981	0.891	0.901	0.807	0.854	0.575	0.165	0.452	0.780	0.401	0.068
	1982	0.880	0.919	0.846	0.863	0.480	0.113	0.388	0.727	0.277	0.041
II	1980	0.891	–	–	0.865	–	–	0.597	0.837	0.566	0.143
	1981	0.918	0.870	0.849	0.859	0.585	0.187	0.474	0.674	0.408	0.087
	1982	0.893	0.913	0.775	0.839	0.445	0.093	0.336	0.616	0.368	0.061
IIIN	1980	0.902	–	–	0.861	–	–	0.574	0.815	0.516	0.155
	1981	0.934	0.872	0.825	0.850	0.513	0.270	0.446	0.720	0.438	0.049
	1982	0.920	0.878	0.783	0.825	0.424	0.066	0.317	0.809	0.267	0.024
IIIM	1980	0.914	–	–	0.913	–	–	0.571	0.905*	0.587	0.180
	1981	0.949	0.894	0.828	0.858	0.555	0.200	0.453	0.783	0.432	0.117
	1982	0.931	0.964	0.792	0.868	0.467	0.070	0.339	0.750	0.322	0.044
IV	1980	0.983*	–	–	0.892	–	–	0.511	0.692*	0.558	0.218*
	1981	1.000*	0.857	0.897	0.878	0.594	0.190	0.471	0.375*	0.511*	0.046
	1982	0.912*	0.891	0.774	0.820	0.449	0.097	0.305	0.615*	0.377	0.079*
V	1980	1.000*	–	–	0.943*	–	–	0.500*	1.000*	0.455*	0.174*
	1981	1.000*	0.917*	0.928*	0.923*	0.545*	0.417*	0.500*	1.000*	0.555*	0.056*
	1982	0.833*	1.000*	0.714*	0.818	0.444*	0.077*	0.290*	1.000*	0.538*	0.053*
Not classified	1980	0.856	–	–	0.827	–	–	0.571	0.839*	0.615	0.244
	1981	0.885	0.848	0.829	0.838	0.548	0.228	0.463	0.667*	0.436	0.134
	1982	0.872	0.842	0.753	0.792	0.460	0.014*	0.368	0.826*	0.344	0.044
Average	1980	0.895	–	–	0.876	–	–	0.578	0.822	0.570	0.167
	1981	0.915	0.878	0.836	0.857	0.570	0.197	0.463	0.704	0.422	0.087
	1982	0.894	0.911	0.789	0.845	0.455	0.091	0.346	0.696	0.340	0.053
Total accepted	1980	1553	–	–	2673	–	–	1673	185	535	237
	1981	1737	1320	1327	2647	1232	170	1402	152	413	123
	1982	1856	1400	1422	2822	997	85	1082	158	334	79
Total applied	1980	1735	–	–	3052	–	–	2896	225	939	1416
	1981	1899	1503	1587	3090	2161	864	3025	216	979	1412
	1982	2077	1536	1803	3339	2191	936	3127	227	981	1482

Source: *UCCA Statistical Supplements.*
* Based on a small number of individuals.

seems to be true for the 12–11 group despite the lack of data for 1980. Applicants in the 12–9 group seem to have suffered a small reduction in their chances of being accepted as a result of the cuts, except for class I applicants. There are, however, important differences in the acceptance rates of those applicants that achieve less than 9 points at A level. In 1980 around 57% of the applicants in the 8–3 point group were accepted. This figure dropped to 46% in 1981 probably because of the treatment of marginals and the reduction in the use of the clearing house system. In 1982 the figure drops yet again to 35%. It seems as if the qualification that is required to secure a place at university is 9 points at A level, i.e. CCC or equivalent, and students that achieve less than this number of points see their chances of going to university greatly reduced. This seems to be also true for two A level students. The chances of being accepted with less than two A levels are minimal.

Evidence to support the view that the universities have reacted to cuts in student places (at a time of rising demand for them) by raising the qualifications required for entry is given in an indirect way by UCCA. UCCA publishes the average A level scores of accepted home candidates for larger subjects. The 1982 table, which contains information about 1981 and 1980 shows that this average has increased for all the subjects for which information is available.

The Government accepted after the 1981 cuts that the Robbins principle of availability of places for all those who are qualified and willing to go to university should be 'redefined'. It is not clear how far the Robbins principle ever applied because no explicit definition exists on what it means to be qualified 'by ability and attainment'. It has just been seen that applicants with less than 9 points at A level found it difficult to be accepted to study at university even before the cuts took place. The cuts only made it even more difficult for them to secure a place as a result of selectors' aims of accepting the 'best qualified' applicants. It is paradoxical to reflect that while many well qualified home students are turned away because there is no room for them, fee paying overseas students have seen their chances of acceptance greatly improved. The removal of implicit restrictions on the number of overseas students to be accepted means that universities are prepared to take them provided that they are qualified. The Robbins principle applies only to them.

Conclusion

It has been shown that not all home applicants stand the same chance of being accepted to study at university. There are social class differences in admission rates. It has also been shown that although all applicants have suffered in their chances of being accepted as a result of the 1981 cuts, class differences have been widened by the cuts.

A very different picture emerges when overseas applicants are considered. Although traditionally these applicants have been less successful at securing university places than home applicants they continued to apply in increasing numbers until 1980 when large fee increases took place. As from this year they were excluded from the planning process, universities taking the sole responsibility for their acceptance. Fee increases have produced large drops in overseas applications in subsequent years. On the other hand, overseas students have become more attractive as a source of independent finance and this has had the effect of considerably improving their chances of acceptance. It can be argued that after the 1981 cuts the Robbins principle applies only to them.

No evidence of social class bias by university selectors was found, as suggested by UCCA. Differences in acceptance rates are to be attributed to differences in examination performance. Middle class applicants are more likely to offer three A levels and achieve higher grades than working class applicants. University selectors give standard offers as a means of matching demand to supply (Mar Molinero, 1984). The combination of social class differences with university policies results in 'institutional' discrimination against working class applicants.

It is not suggested here that univesity selectors should treat a B in Mathematics A level obtained by an applicant from a prestigious, and expensive, private school as being in any way different from the same result obtained by a student from a free inner city state school, but selectors should be aware of the fact that by rationing by price, they are selecting by class, and politicians should realise that reductions in university places discriminate against those that have already suffered from other cuts in public expenditure.

Summary

This paper examines the impact that the 1981 cuts in university expenditure had on the social class structure of the students accepted by universities in Great Britain. It is found that the cuts were felt to a larger extent by students from working class backgrounds than by students from middle class backgrounds, and that they improved the chances of acceptance for overseas students. The reasons for this institutional discrimination are explored.

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CHAPTER 8

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University Cuts and Statistical Information

C. MAR MOLINERO
Department of Accounting and Management Science, University of Southampton

As a result of reductions in government spending brought about for political reasons, the budgetary allocation to the University of Southampton, in common with other universities, was reduced. Some decisions had to be made on how to adapt to the new, lower level of funding. In the course of the discussion, figures were produced to justify decisions. It was shown that on closer examination those figures indicated a situation very different from the one presented by the decision makers.

INTRODUCTION

"OPERATIONAL RESEARCH is the application of the methods of science to complex problems", according to the definition. Operational researchers are concerned with the interpretation and analysis of complex data sets in order to clarify issues, improve understanding and, hopefully, influence decision making. Operational research is normally sponsored by management but this does not always have to be the case. The analysis of complex data, the clarification of the issues involved, the improved understanding of a situation can serve a useful purpose when used to evaluate proposals or criticize decisions that have already been made.

The recent turmoil that has shaken the British university system has provided many examples of decisions being made on political grounds with little regard for a scientific analysis of the real facts. It has been noted that, despite the fact that some universities have very prestigious operational research departments, these have not been consulted when preparing management plans for the universities concerned. Southampton University was no exception. A management plan prepared by a central committee gave rise to much discussion. It was soon clear that such a plan was based on qualitative opinions, reinforced by superficially examined quantitative data. This paper concentrates on the way in which a reinterpretation of the data presented to support a proposal for a large cut in the budget of the Social Sciences Faculty found such harsh treatment unjustifiable.

The paper examines first what the future of the University would have been had things remained constant, and draws some conclusions about the future of the Social Sciences Faculty. Demand for places for the Faculty of Social Sciences is analyzed next; it is argued that the quality of student intake in the Faculty cannot be compared with the quality of student intake in other faculties within the same university. An examination of what a typical applicant for admission does, reveals some interesting facts for admissions policy.

Although the paper concentrates on the Faculty of Social Sciences at the University of Southampton, the issues raised are more general. It is hoped that this paper will make a positive contribution to the understanding of the university system.

BACKGROUND

In 1980 a British government committed to reducing public expenditure decided to decrease the amount of funding made available to universities.[1] The reduction in the level of funding was "subject to many uncertainties but probably laid in the range of 11–15%"[2] and was to take place from the beginning of the 1981/82 academic year.

Budgetary cuts in university education reversed previous policy, since 1963 education policy had been assumed to be based on the principle that "courses in Higher Education should be available for all those who are qualified by ability and attainment to pursue them and wished to do so", as stated in the Robbins Report.[3] A major programme of expansion following the Robbins Report meant that the number of entrants to Higher Education rose from 7% of all 18 year olds in 1960 to 14% in 1970.[4]

The total number of 18 year olds—the group that provides the largest number of entrants into university courses—has been subject to wide fluctuations, which have caused concern to planners. In 1978 a government paper entitled "Higher education into the 1990's" stated in its first paragraph that the "fall in the birth rate since 1964 has already caused primary school rolls to decline sharply . . . ; and our higher education institutions will begin to feel the effects in the early 1980's". The feeling that there is a direct and simple link between demographic trends and the number of university students is widespread. Indeed, using merely demographic considerations, a report predicted a sharp decline in the demand for mathematics courses and suggested compulsory early retirement for staff in the 35–45 age group.[6]

The new financial situation created by the cuts could have produced widespread chaos if every institution had acted independently, unless advice was made available to every individual university on how to implement the cuts. The University Grants Committee (U.G.C.) was asked by the Government to produce a plan to reshape the university system for the period up to 1983/84. Universities in the United Kingdom are permitted to behave autonomously, even though they are largely financed by public money. Specific suggestions made by the U.G.C. could not easily be enforced, but if a particular university chose to ignore the advice received, the U.G.C. might retaliate in the next budgetary round by allocating to the 'rebel', a smaller budget than it would otherwise have done.

Guidance from the U.G.C. finally came in the form of two letters.[7] The first one stated the general principles on which its budgetary allocation was based. The second letter gave specific advice to each individual institution. The procedure followed to determine the grant distribution was later made public.[8] The U.G.C. claims to have taken into account a large number of statistical facts, and to show that this was the case, it attached the titles of 105 statistical tables as an Appendix to its explanatory document.[8]

U.G.C. joint advice was asymmetric with respect to both subjects and institutions. Regarding subjects, it chose to protect student numbers in such disciplines as physical sciences, technology, mathematics, computer sciences, business studies and some aspects of biology,[8] thus having to recommend a heavier than average cut in other disciplines. Institutions were also treated in an uneven way, although it is not very clear what principles were followed in the distribution of cuts to whole institutions—at one extreme the University of Salford was told to cut student numbers by 30%, and at the other, the University of York received instructions to cut student numbers by 0.3%.

THE CUTS IN SOUTHAMPTON

The advice given to the University of Southampton was vague. Target student numbers, the basis for planning, were to remain largely unchanged. It was at first thought that the University had done reasonably well since the cut in budget was smaller than average, but the real situation relative to other universities was unclear, given the problems associated with interpreting university accounts.[9] What was clear was that Southampton had no hidden reserves to support the financial blow and that the cut came on top of a planned programme of over-expenditure. Drastic measures had to be taken and they had to be taken quickly.

The University of Southampton requested from one of its committees—Budgets and Developments (B&D)—the drafting of a strategy to cope with the effects of the cuts. Although the deliberations of the committee were kept secret, the final report[10] was not. The B&D Committee realized that cuts of the scale being proposed could not be implemented without affecting the academic activities of the University, and in a clear parallel with the U.G.C., it took upon itself the task of deciding which activities should be protected and which ones should be cut.

The parallel between the national and the local situation does not end here. For financial matters, the University of Southampton is organized into 18 largely autonomous budgetary groups. Among these are the eight faculties. The Budgets and Developments Committee recommends how the budget should be distributed between the groups but has little control over the behaviour of the groups. The report of the B&D Committee contained the criteria that had been used to arrive at the budgetary allocation. Besides the claims to U.G.C. advice, the report explained that B&D had taken into account "the general impression of the relative effectiveness of Faculties and Departments which can be gained from such sources as the Annual Research Reports, level of student demand and public reputation".[10] The recommended budgetary allocation discriminated against some faculties—Social Sciences being one of them—while at the same time protecting some others. Further light was thrown on the way in which the general impression of faculties and departments had been quantified by a circular letter from the Vice-Chancellor.[11] Some of the evidence presented relied on personal judgement on what is meant by 'respectable publication' or 'academic potential'. Some other evidence relied on the interpretation of statistical data.

Universities are, on the whole, democratic institutions. A set of proposals, like those of the B&D Committee, that implied a large internal redistribution of resources could not be approved without ample discussion. Such discussion took many forms, including a completely different interpretation of published University accounts[12] and a reinterpretation of statistical data, in which it was shown that what seems to be true on a superficial analysis of the data turns out not to be when figures are differently examined. It is this last point that will now be taken up and expanded, since many interesting facts appeared as a result of the discussion. Such facts may be used to improve the management of the University, and to increase understanding between the different faculties.

The vehicle through which most of the discussion took place was the internal publication "Viewpoint: A Paper for Comment". Viewpoint is a legacy from earlier difficult times for education; it was born as a result of student unrest in 1968.

THE MYTH OF THE FALLING BIRTH RATE

The views that universities had expanded too quickly, and that the size of the university system ought to be eventually reduced, given the fall in the birth rate, had been expressed by some supporters of government policy. Cuts, they argued, had to take place sooner or later.

It is, therefore, worth examining the link between births and applications for university places. The application system in the United Kingdom is computerized and centrally organized through the Universities' Central Council for Admissions (UCCA). UCCA generates a large amount of statistics that are later published in the form of Statistical Supplements. The 1980 Statistical Supplement[13] contains a table that shows the number of applicants and entrants by social class. This table also contains a column headed "social class of family head". The interested reader is referred to a note[14] that explains its meaning:

> "The final column gives the distribution (from the 1971 census) of those aged 10–14 by social class of family head. By 1979 these would have been aged 18–22, and form therefore a proper group to compare with the university candidates to which the table refers."

The figures for 1979 are presented in Table 1. In this Table it can be seen that 20.3% of all university applicants and 21.9% of all first year entrants belong to social class I. It can also be seen that only 5.3% of all 18–22 year olds belong to social class I. At the other extreme, 1.2% of all applicants and 1.0% of all entrants belong to social class V, while 7% of the age group belongs to class V. It is interesting to notice the differences between the distribution of applications and the distribution of entrants. It indicates that applicants from social classes I and II are more likely to be accepted to follow a university course than applicants from social classes III, IV and V. UCCA explains that there is a correlation between social class and examination results, so that it would be wrong to suggest that there is "evidence of social class bias by university selectors".[14]

The percentage of all 18 year olds that actually enter university courses, known as the age participation rate (A.P.R.), is published by the Department of Education and Science.[15] It is found there that $7\frac{1}{2}$% of all 18 year olds are actually accepted as first year university

TABLE 1

Social class		Applicants	Entrants	Social class of family head	A.P.R.
I	Professional	20.3	21.9	5.3	0.31
II	Managerial	41.6	42.4	19.6	0.16
III.V	Skilled—*non-manual*	13.6	13.4	9.7	0.10
III.M	Skilled—*manual*	17.4	16.3	40.2	0.03
IV	Partly skilled	5.6	5.0	17.8	0.02
V	Unskilled	1.2	1.0	7.3	0.01
		100.0	100.0	100.0	

entrants. It is now a simple exercise in conditional probability to work out the percentage of all 18 year olds in a particular class that go to university. The results can be seen under the column A.P.R. There it can be seen that 31% of the 18 year olds that belong to class I enter university education, while only 1% of those that belong to class V do so.

The importance of the above analysis becomes apparent when seen in the light of demographic trends for the different social classes. The Office of Population and Census Surveys has been collecting such information since 1970.[16] The raw data was processed by Pearce and Britton;[17] their results are presented in Table 2.

Table 2 shows that classes I and II have not changed their family plans. The drop in natality has affected classes III, IV, V, i.e. those social classes whose children are less likely to go to university. Leaving aside the problems of dynamic response to changes in applications studied by Hill and Mar Molinero,[18] and assuming that the A.P.R. for every different class remains constant over the years, an estimate of the number of university entrants that would have entered university education can be worked out from the number of births in every different class. This would be, however, a very simplistic projection, and one should take into account the facts that not all students are aged 18 when they come to university, and that an increasing number of girls wish to go to university. Projections produced in this way were prepared by Diamond and Smith, and reported by Holt.[19] They show that, had demand characteristics and acceptance criteria (determined in part by government policy) remained the same, the number of entrants would have continued to increase year by year up to 1990.

The above analysis is not without implications for the Faculty of Social Sciences at the University of Southampton. Social class mix changes across universities. In the south there are more middle-class students, hence Southampton should be less affected by observed movements in the birth rate. Women are not equally likely to apply for all courses. They tend to apply for courses in arts or social sciences. If current trends continue, these faculties should face a higher than average increase in demand. Finally the effect of U.G.C. advice has to be taken into account. If U.G.C. advice is followed by other universities, there will be a reduction in social sciences places at 31 other universities. Were applicants to take these recommendations as judgement of quality, they would be identifying Southampton as a desirable place to go to study social sciences. A well prepared plan for the future of the University should have taken these facts into account if it wished to give due weight to probable patterns of applications.

MARKET SHARE AND MARKET POTENTIAL

An interesting way of assessing courses from the point of view of student demand was proposed by Doyle and Lynch.[20] They suggested that for every course, two figures should

TABLE 2. ESTIMATED LEGITIMATE LIVE BIRTHS BY SOCIAL CLASS OF HUSBAND. INDEX (1970 = 100)

	All	I & II	III*N*	III*M*	IV & V
1970	100	100	100	100	100
1971	100	104	99	99	95
1972	92	102	94	90	84
1973	86	100	85	82	78
1974	81	99	78	77	72
1975	76	96	75	71	67

TABLE 3

	A	B	S.S	C	D	E	F
Market potential	19.2	5.7	19.3	5.3	15.5	16.5	11.4
Market share	2.8	4.8	3.0	3.1	3.6	3.6	2.8
Availability of places	1.7	3.2	1.6	2.3	1.9	2.6	3.0
Applications per place	14.5	21.3	19.6	12.6	14.3	14.9	14.6
A-level score	11.0	11.5	11.2	13.0	11.6	12.1	12.8

be computed: market share and market potential. Market potential is defined as the percentage of all applicants nationally who apply to study a particular course at any university. Market share is defined as the percentage of all applicants for a particular course who wish to go to a particular university. It seems desirable to have a large share of a large market. Unfortunately, in applying this model to every different course, there are difficulties both of definition and of data. Take, for example, "Accounting with Statistics"; there is only one other course in the country with the same name. Obviously, competition does not take place only between these two courses. An applicant who considers following such a course may well consider as an alternative "Accounting with Finance". The problem is further complicated by UCCA. It is the main source of statistics and classifies such courses under 'combinations', thus making it impossible to know what is the national total demand for this particular course. Furthermore, for UCCA an 'applicant' is a person applying for acceptance at university, whereas for Southampton University an 'applicant' is an entry on the UCCA form. It is assumed here that the percentage of applicants that do not use all their five choices on the form is small enough to be disregarded.

In order to classify students by "preferred subject of study", UCCA takes into account only the first entry in the form. It is possible for someone whose first choice is Law to end up in Mechanical Engineering, hence appearing as an entrant in this latter subject while as an applicant in the former. A further difficulty with the UCCA system is that it does not provide details about individual universities—in line with the best statistical ethic: the sin is disclosed but not the sinner. Comparisons have to be made with respect to the national average.

Most of the above problems are overcome if one considers faculties and not courses as the basic units. Even then, some data manipulations are necessary prior to analysis. To give one example, UCCA lists Law under Social Studies, but in Southampton Law is an independent faculty, so a correction has to be made to the total Social Studies figure by removing the Law figures. Table 3 shows market share and market potential for seven faculties (the eighth does not engage in undergraduate teaching). Only the Faculty of Social Sciences is identified, by S.S.; faculties A and B can be defined as 'arts', and the rest as 'science'.

Table 3 shows that the largest market is in the social sciences; 19.3% of all applicants want to follow that type of course. Of all those students who want to do social sciences, 3% apply for admission to Southampton. Although few policy-making inferences can be drawn by simply looking at "market share" versus "market potential", it is worth noting that the fact that social sciences operates in a large market means that small swings in the market share will involve large actual numbers of applications. The attitude taken by the official representatives of the University when projecting an image of this faculty may help to increase or decrease the share of a market that is still growing.

Information only about demand is not enough for decision making. The supply side of the argument has to be examined too. A sensible way of proceeding is to look at the percentage of places for a particular discipline that are offered at Southampton and compare that with the market share. This percentage is presented under the heading "availability of places". A traditional way of doing this comparison is through the applications to places ratio, and so this ratio is also presented in Table 3. The number of applications per place looks very impressive, although it has to be remembered that the national average is 10. This is consistent with the fact that every applicant lists five universities on their UCCA form, and nearly half the applicants do not go to university.

Applications per place is, however, not a good measure of popularity since the number of available places is influenced by the willingness to provide such places. Availability of places versus market share is, in this sense, a better criterion to be used for policy analysis.

The University of Southampton as a whole makes available to the country 2% of all university places, whereas 3% of all applicants want to come here. This means that for every two students that we accept, we reject one who would have come had we provided a place. Social sciences has a market share that is about average for the University, but the provision of places is lower than might have been expected. It can be argued that, if regard is given solely to 'application potential', this faculty has already been discriminated against by not allowing it to offer the number of places one would have reasonably expected. To suggest a larger than average cut for this faculty was, therefore, unfair unless other, perhaps unrelated, arguments were thought to be persuasive.

THE QUALITY OF STUDENT INTAKE

From an interpretation of the figures related to student demand, emphasis shifts to an assessment of the quality of student intake in every faculty. Table 3 contains the average A-level score for entrants with three A-levels for every faculty. Scores have been computed here using the well established point scale A = 5, B = 4, C = 3, D = 2, E = 1, F = 0; so that a student that enters a faculty with three Bs at A-level is considered to have scored 12 points.

Examination of A-level scores seems to indicate a very different ranking of faculties than the one suggested by demand data. Take, for example, faculty "F"; it seems to be less successful that S.S. at attracting students, but the students that enrol in the first year seem to be 'better' in faculty "F" than in Social Sciences.

The discrepancies seen between A-level scores at Southampton are also found in the national data. Social science students seem to obtain a lower average A-level score than those that apply for type "F" faculties. It is difficult to believe that those students that apply for social sciences courses are in any way 'better' or 'worse' than the rest of the student population. Some other factor must account for the difference.

Students that join different faculties are different in the sense that they are interested in different subjects. The standard medicine entrant might have studied Biology, Physics and Chemistry at A-level; while the standard arts entrant might have studied French, English and History. It will be argued that the probability that a randomly chosen student has of attaining a particular A-level score depends on the subject mix and, what is more important for university purposes, that the degree to which this score can be anticipated before the examinations take place also depends on the subject mix.

It is reasonable to assume that the percentage of students who obtain a certain grade in a particular A-level examination does not depend too much on the particular subject chosen, According to UCCA,[21] one might expect that around 10% of all those students that sit a particular paper will get grade A in that paper. It is not reasonable to assume, as was pointed out by Holt,[19] that the percentage of students that obtain two A grade A-levels when sitting two different papers is independent of the papers chosen. This percentage will depend on the extent to which the result of the two examinations are correlated; if the results are perfectly correlated, every student that obtains grade A in one paper will obtain grade A in the other paper, and 10% of the students will end up with two A grades; if the results of the two papers are perfectly uncorrelated, only 1% of all examinees will obtained two A grades. It is easy to see how correlation between results may arise: a student who is good at Pure Mathematics will find Applied Mathematics easier than one who is good at French. The correlation between the marks in two particular papers will also be affected by the uncertainties introduced by the marking process;[19] it is easier to allocate a mark to a Mathematics paper than it is to allocate a mark to a French paper; this is a well known problem (error in variables) that tends to bias downwards correlations. Correlations between pairs of A-level examinations were computed by Holt and are reproduced in Table 4.

TABLE 4

		M	P	C	B	G	H	E
Mathematics	M							
Physics	P	0.77						
Chemistry	C	0.70	0.75					
Biology	B	0.60	0.71	0.74				
Geography	G	0.48	0.48	0.54	0.55			
History	H	0.45	—	—	0.48	0.56		
English	E	0.35	0.46	0.39	0.46	0.52	0.56	
French	F	0.50	0.55	0.69	0.50	0.50	0.51	0.54

Correlations between 'science' subjects turn out to be higher than correlations between 'arts' subjects. A faculty in the 'science' area is at an advantage when looking for students with high A-level grades: there are relatively more such students in the sciences than in the arts. Students that apply for entry into social sciences tend to do a mixture of arts and science A-levels, i.e. the type of combination that produces the lowest correlations. Social sciences faculties are at a definite disadvantage over other faculties when looking for highly qualified students: there are relatively less of them around.

The relative abundance of students who have attained high grades at A-level is only part of the problem. Students apply, and are selected, before the results of their examinations are known. If maximizing the A-level score of university entrants is considered to be a desirable objective, then it becomes crucial to be able to predict A-level results on the basis of UCCA information available to selectors. Possible predictors of A-level results are O-level results and headmaster predictions. A large statistical analysis carried out by Murphy[22] using a sample of 13,500 applicants to university courses discovered "moderate" correlations between O-level results, predicted A-level results and actual A-level results. He found headmaster predictions more valuable than O-level results when explaining A-level performance; but what is important here is that the results varied across subjects. Murphy's results are reproduced in Table 5.

Although the correlations shown in Table 5 are not high enough to make it possible to predict with accuracy the outcome of the examinations, a policy of making offers only to those students that are forecast to do well will meet with a varying degree of success across faculties. The Faculty of Medicine is clearly in a much better situation than the Faculty of Arts, since the results of science A-levels are much more predictable than the results of arts A-levels. Differences of A-level scores between faculties are, therefore, to be expected. The apparent paradox present in Table 3, where arts-based faculties with more applications per place than science-based faculties have 'worse' qualified students than science-based faculties is now explained through a combination of correlation between results and difficulty of identifying those students that are going to do well in the examinations. Students in different faculties, one has to conclude, are not comparable and, on the basis of A-levels, should not be compared.

MODELLING STUDENT DECISION MAKING

A social sciences selector, faced with a large number of applications, knowing that only a small number of applicants will get high grades and that these cannot be identified before

TABLE 5

	Correlations between A-levels and	
Subject	O-levels	Headmaster's predictions
Physics	0.58	0.69
Chemistry	0.57	0.67
French	0.57	0.64
Biology	0.47	0.63
Mathematics	0.47	0.61
Geography	0.40	0.54
History	0.37	0.52
English language	0.35	0.51
English literature	0.34	0.47

examinations take place, may be tempted to simply raise the qualifications required for entry. If it is considered desirable that no entrant should have less than three Bs at A-level, this qualification can be made a condition for entry and communicated to any applicant. It has to be remembered, however, that applicants have five choices; an applicant who receives a conditional offer that is considered to be 'too difficult' will simply decline it and accept a lower offer from another university. A high offer policy may have some paradoxical consequences; such offers may be accepted only by those applicants that have been already rejected by three or four courses, since their choice is simply one of going or not going to university, and declined by those students that have a real choice between universities.

Little is known about the way in which the level of the conditional offer affects the probability of the offer being accepted by the applicant. Some preliminary work on this subject by Jordan[23] produced some encouraging results and formed the basis for further research. This research took the form of an undergraduate project. Undergraduate projects are used in the Faculty of Social Sciences at Southampton University as a means by which a student applies the knowledge acquired through traditional teaching methods to a real-life problem; they often involve students with research in the process of being carried out by members of staff. This was such a case. Further details about the work reported here can be found in Chan.[24]

An applicant's decision whether to accept or to decline a conditional offer may be influenced by his/her stated preferences, the level of the offer, the course applied for, past and expected academic record, personal characteristics and year of application. Most of the data needed are easily available either from the UCCA application form or from the UCCA alpha lists available to selectors and regularly updated by UCCA.

An important point that was taken into account was the relative difficulty of the conditional offer. According to the UCCA rules, a candidate may hold two offers: one of them as firm acceptance, the other one as provisional acceptance. Firm acceptance binds the candidate to go to that university and to none other, if he/she meets the conditions of the offer. The provisional acceptance acts as insurance; if the candidate does not meet the condition of the firm offer, he/she may go to the university whose offer he/she has provisionally accepted provided this second offer is met. A sensible student would, therefore, accept a low offer as insurance.

The variable to be explained—the probability of an offer being firmly accepted—can, in theory, take any value between zero and one, but in practice what is observed is the fact that the offer has or has not been firmly accepted. An appropriate way of modelling this qualitative choice situation is by means of a logit discrimant function. Full details about the rationale and properties of logit models can be found in Pindyck and Rubinfeld[25] and McFadden.[26] After some manipulation, a logit model results in a regression equation of the form

$$\ln \frac{P_i}{1 - P_i} = \beta_0 + \sum_{j=1}^{k} \beta_j X_{ij} + \epsilon_i. \qquad (1)$$

In equation (1) P_i is the probability of the ith applicant's offer being accepted, hence the left-hand side represents the logarithm of the odds of the offer being accepted. The right-hand side is similar to the right-hand side of any regression equation, with X_{ij} being the ith observation on the jth explanatory variable.

This model was estimated using information about 194 candidates that applied for admission to three social sciences courses during the years 1979 and 1980. The three courses were considered to be sufficiently similar to justify the pooling of the data, although this was also checked as part of the analysis. No major changes took place between 1979 and 1980, but the possibility that the applicants might have behaved differently was also made part of the analysis. The package GENSTAT was used to perform the computations.

The dependent variable (Y_1) was a dichotomy that took the value 1 if the highest offer had been firmly accepted and zero otherwise. The offers made by Southampton University for these three particular courses were often the highest offers the applicant had received, but to widen the decision-making framework the model was also estimated using as dependent variable another dichotomy (Y_2) that took the value 1 if the second highest offer had been firmly accepted and zero otherwise. Notice that no more than one of these two dichotomies can take the value of unity for any one candidate. If both dichotomies take the value zero, then the candidate must have accepted one of the other three offers.

Nine possible explanatory variables were considered. The first two (X_1 and X_2) measured the level of preference for the university that had made the highest and the second highest offers, after ignoring the effect of the number of rejections. In the analysis indifference between two universities is ruled out, hence X_1 and X_2 cannot take the same value for any one candidate. The scoring system used was a very simple one and is reproduced below.

Position of the university	Points
1	5
2	4
3	3
4	2
5	1

The number of rejections that a candidate received prior to accepting or declining an offer was thought to be an important explanatory variable (X_3). No candidates that had received four rejections were included in the data set since there is no real choice for them; they are, in a sense, outliers in the model. The logit model is known to be very sensitive to the presence of outliers.[27]

Academic ability was modelled only through the head teacher's forecast of the candidate's advanced level examination score (X_4). The degree of difficulty of the highest and second highest offer (X_5, X_6) was also taken into account. Two scoring systems were considered. The first is the usual one, where A = 5, B = 4, C = 3, D = 2, E = 1, F = 0. Though this system is simple and straightforward, it may not accurately reflect the worth of the different grades. If comparatively grade A is much more difficult to obtain than grade B, then it is not fair to have just one point difference between A and B. The second scoring system that was considered had been proposed by Diamond[28] and allocated scores as follows A = 7, B = 5, C = 4, D = 2, E = 1, F = 0. The analysis was repeated with the two scoring systems, and only minor differences were found. The traditional scoring system was retained, the casting vote going for the status quo. It is interesting to note that, in general, universities give standard offers. This increases the model's usefulness as a possible basis for admissions policy.

To take into account the course the candidate had applied for, two dummy variables were used (X_7, X_8). A final dummy variable was used to distinguish between applicants for entry in 1979 and entry in 1980 (X_9).

The strategy adopted to select the 'best' model can be summarized as: "Start with the most general; move towards the most specific". A start is made with a regression equation that contains all the explanatory variables. Such an equation can be considered as a totally unrestricted model. Removing variables from the equation is equivalent to imposing constraints on the coefficients; i.e. the coefficient of the variable being removed is constrained to zero. Proceeding in this way has many desirable statistical properties. For a full discussion see Mizon[29] or Mar-Molinero and Mitsis.[30] The following equations were found

$$\ln \frac{Y_1}{1 - Y_1} = \underset{(4.47)}{0.96}\ X_1 - \underset{(-4.84)}{0.41}\ X_5 \qquad (2)$$

DF = 192 Deviance = 220.9

$$\ln \frac{Y_2}{1 - Y_2} = \underset{(4.61)}{-3.01} + \underset{(4.25)}{0.7}\ X_2 \qquad (3)$$

DF = 192 Deviance = 234.4

Figures in brackets are asymptotic t statistics.

TABLE 6

Position of preference on the UCCA form	Highest offer			Second highest offer
	ABC	BBC	BCC	
1	0.465	0.556	0.664	0.628
2	0.251	0.336	0.433	0.454
3	0.114	0.162	0.226	0.291
4	0.047	0.069	0.100	0.169
5	0.019	0.028	0.041	0.091

It was found that the coefficients of the dummy variables (X_7, X_8, X_9) did not differ significantly from zero. This shows the validity of pooling the data. Equation (2) may be interpreted to mean that when considering to accept or not to accept firmly the highest offer, what the applicant has in mind is his/her preference for that particular university, and the level of the offer. The number of rejections received does not seem to influence this choice; neither does the degree of preference nor difficulty of the second highest offer influence it. The academic ability of the student does not seem to influence the decision either. It is quite possible that the students who apply to go to university do not doubt their academic ability, and judge an offer on absolute rather than relative terms. When it comes to the second highest offer, the only variable that remains in the final model is the preference for the university that has produced such an offer. It is possible that offers of this kind do not vary sufficiently amongst individuals for the effect of the difficulty of the offer to be discernible.

In order to see the full implications for decision making, a table (Table 6) was prepared using equations (2) and (3). It can be seen from this the extent to which raising the level of the conditional offer deters students from accepting it. Since the probability of the offer being declined by a 'promising' student is the same as the probability of the offer being declined by a 'non-promising' student, there is no point in giving high offers in order to attract the 'best' students. Offers should be used only as a rationing device: to match the demand for places with the number of places available.

Does it matter? Is a student with high A-levels in any way better than one with less good A-levels? It must not be forgotten that A-level results are only the results of a particular examination. It is known that neurotic introverts examine better on average than intelligent extroverts, although there is no general agreement on how to measure neuroticism, introversion or intelligence.[28] A selection procedure that overemphasizes examination results may produce students that are good at taking examinations.

If one is interested in examination results, then one relationship to be examined is that between A-level results and final degree qualifications. This was done by UCCA in 1967.[31] UCCA considered a sample of 9000 students that entered university in 1963 and graduated in 1966. It was found that in science subjects high score A-level entrants tend to do better on average than students with low A-level scores, although the dispersion of the results is very large indeed. In the social sciences the average A-level entry qualifications do not seem to make any difference when it comes to explaining final degree results. These results have been later confirmed by a large number of studies.[28]

CONCLUSION

It has been argued that the decline in the birth rate does not necessarily mean a decline in the demand for university places, that an increase in demand for places in social sciences at Southampton should be expected, that admissions figures could be used to show that this faculty has already take a cut, that the average A-level score of entrants to social sciences has little to do with the quality of the student intake, and that an admissions policy based on high conditional offers does not necessarily reflect the quality of a department. Data does not speak for itself in a way that can be easily understood.

This analysis has concentrated on student demand for university services. If one believes that the supply of graduates should match the demand for them, then it may well be justified that entry into science-based courses should be easier than entry into arts-based courses. It is in this context that claims of the 'national interest' are often made. It is difficult to understand how the national interest can be served by offering less education instead of more, and it sounds rather contradictory that a society that otherwise believes in freedom of the individual should tell students what is good for them and for the country. These, and other related issues, are not explored here. The only objective of this paper is to contribute to the understanding of the British education system so that the implications of any decisions taken can be fully appreciated.

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CHAPTER 9

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An Econometric Model for Supply and Demand of Undergraduate University Places in the United Kingdom

C. I. HILL and C. MAR MOLINERO

Prudential Assurance Company and Department of Accounting and Management Economics, University of Southampton

This paper presents a model describing the demand for Undergraduate University places and the way in which universities satisfy this demand, and respond to changes in it.

The model comprises a number of equations examining not only the whole academic field but also the individual subjects of accountancy and economics; in addition they deal with both the total figures for all Universities and those for Southampton University only.

INTRODUCTION

THE NUMBER of students in higher education in the United Kingdom has been increasing fairly steadily since the Second World War. These numbers have included a large proportion of "home" school-leavers, or "young home entrants" (i.e. those of British Nationality who embark on a university course under the age of 21 years), the remainder being made up of "home" mature students (i.e. those over 21 years) and "overseas" students (i.e. those of other than British Nationality).

The increases in these students have been accommodated by massive increases in the scale and range of courses in universities, polytechnics, teacher training colleges and so on. All these establishments require large capital sums for their expansion and maintenance, so that it is clear that accurate predictions concerning the number of places required each year are very valuable for planning purposes.

This paper is confined to modelling the demand (represented by the number of applicants) and the supply (represented by the number of entrants) of full-time undergraduate university places in Great Britain.

The level of demand will depend upon various factors such as the relative size of the 18-year-old age group and the level of tuition fees charged, but since home applicants will be affected by different factors from those affecting overseas students, the two series have been estimated in separate equations in this model.

The supply of university places is not likely to respond immediately to changes in demand and so the actual number of entrants will be a function of lagged values of applicants and entrants and partial adjustment models have been used to describe these relationships.

The model deals with the whole university academic field but also examines the demand and supply within two sub-sets of this, i.e. the particular subjects of accountancy and economics and the way in which trends in these follow the overall pattern. In addition, equations were estimated for the numbers of students at Southampton University in particular, in order to examine in a similar way how national trends are reflected at a local level. Finally, the supply and demand for places in accountancy and economics at that university were modelled, although the amount of data that was available on the latter was severely limited, and thus the results obtained should be interpreted with care.

The Ordinary Least Squares (O.L.S.) method was employed initially to estimate all the equations, but in equations (1), (2), (7), (11) and (13) it was found that the errors generated were significantly serially correlated and so these were re-estimated using Auto-regressive Least Squares (A.L.S.) by the Cochrane–Orcutt method. All the estimations were carried out using the computer packages COSAP and NCOSAP which were run on the Southampton University PDP 11/45 mini-computer.

HISTORICAL BACKGROUND

Since the Second World War, the numbers of undergraduate students at universities in Great Britain has more than trebled, from 65,000 in 1946 to 211,000 in 1975. This generally increasing trend has displayed fluctuations through the years, and these have been followed by similar changes in the expectations and plans of the Government, as stated from time to time in the various publications of the University Grants Committee (U.G.C.).

From 1946 to 1953 there was a noticeable "bulge" in the total student population which reached a maximum of 78,000 in 1949. This temporary increase was due to the return of those whose education had been interrupted by the war and permitted by the availability of financial assistance under the further education and training scheme. Thus those who had the necessary qualifications and wanted to enter university at this time gained admission. Following this, the U.G.C.'s quinquennial report 1947–52 predicted a stable level of student numbers and stated that "any future increase in the student population of the universities must await an increase in the output of suitable pupils from secondary schools".[1]

From 1953, the 18-year-old age group represented a correspondingly increasing proportion of total student numbers and so it should be expected that changes in the total numbers would be progressively more closely tied to the size of this age group and this expectation is confirmed by the figures, since the number of students started to increase again. Moreover, the proportion of the age group which was qualified for admission to university also started to increase, and universities did not keep pace with this expansion in demand. Thus in the 1950s it was realised that "any planning based on the stability of student numbers would be unrealistic".[2]

It was only in 1961–63 that a serious attempt was made "to review the pattern of full-time higher education... and to advise Her Majesty's Government on what principle its long-term development should be based".[3] This publication, known as the "Robbins Report", dealt with the whole range of higher education and initiated a large number of surveys and statistical enquiries. It laid the foundation for a regular presentation of statistical series in Higher Education[4] and these have been important for government policy-making. The Report stated that "courses in Higher Education should be available for all those who are qualified by ability and attainment to pursue them and wished to do so",[3] this had not been the situation for the period 1954–62. The Robbins Report therefore represented a major change in policy, and was followed by a period of considerable growth in the university sector as well as in the rest of Higher Education, due partly to the considerable increase in the proportion of 18-year-olds eligible and successful in getting places in Higher Education. (This proportion is known as the "Age Participation Rate" or A.P.R.)

In 1963 also, the Universities' Central Council for Admission (U.C.C.A.) was set up to centralise the admission procedure for undergraduates and to provide data concerning applicants and entrants in the form of the Universities' Statistical Record. This was the first time that data concerning the total numbers of applicants was compiled, because previously each applicant applied separately to each university of his choice, and only the total number of applications was known. Initially, only half of the universities belonged to U.C.C.A., but as this proportion grew over the period 1963–77, the statistics give a better and better picture of the relationships between applicants and entrants to universities in Great Britain.

The Government paper published early in 1978, entitled "Higher Education in the 1990s"[5] was concerned with another "bulge" in the number of "young home entrants" which is predicted over the period 1978–1994. Since it estimates that young home entrants represent 70% of all Higher Education entrants, the substantial fluctuations in the numbers in the age group predicted for this period will have fairly significant effects upon the total student numbers and these will apply to universities as a sub-set of total Higher Education. The paper does not give details of the methods used to produce the projections of future student numbers, but it indicates the general principles upon which they were based.[5]

One can see from these series of publications that government interest in the prediction of demand for student places has grown over the years, acknowledging the importance of an adequate system of Higher Education in the economy in general. It also becomes apparent that the variables that influence student numbers are many and complex and thus any practical and usable model is necessarily a simplification of the real world, and the results it gives will depend upon the variables that are selected as being important.

METHODS OF RELATING SUPPLY TO DEMAND

A brief survey has been given of the UGC's attempts of forecasting the demand for places in Higher Education, and it is clear that they have examined long-term trends and used these to project into the future. However, this paper also examines the relationships between demand and supply in the short-term by using partial adjustment models[6] where possible to describe the way in which changes in the numbers of applicants affect the number of entrants. The parameters of these models reflect to some extent institutional decisions regarding selection of applicants; however, it is neither possible, nor perhaps desirable, for universities to adjust their supply to every short-term fluctuation in demand, but they are no doubt able to take these into account where they reflect long-term trends.

The "Cobweb Theorem" has been developed since the 1930's to explain the behaviour of supply and demand once they have deviated from an equilibrium, given certain assumptions as to the type of market.[7,8] The main assumptions are that the market exists at discrete intervals, the suppliers' plans concerning one period are made in the previous period based on prices in the latter, and that the price in each period depends upon the quantity supplied. Exactly what constitutes "price" in the market for university places, however, is not immediately obvious, but the nearest to the concept would seem to be the qualifications required for entry (i.e. the level of conditional offers) which are normally expressed in terms of A-level results. Thus if we know that there are many applicants for few places, the qualifications required (i.e. the price) will be higher compared with courses for which there is little competition. It appears that universities determine the level of conditional offers (i.e. set the price), and these decisions are made primarily on the basis of the previous years' situation, so that the market for university places fulfills the above conditions for the Cobweb Theorem to operate.

The difficulty is that sufficient data concerning the stringency of conditional offers is not available, and so in default of forming the equations for supply in terms of price, they have had to be formed in terms of demand. Nevertheless the basic idea of the Cobweb Theorem, namely, partial adjustment, has been adopted in these equations by relating supply in one year to demand in that and the previous year.

The model most frequently used in this paper is

$$E_t^* = \alpha_1 A_t + \alpha_2 (A_t - A_{t-1}),$$

$$E_t - E_{t-1} = \alpha_3 (E_t^* - E_{t-1}),$$

where

E_t is the number of entrants in year t,

A_t is the number of applicants in year t,

and

E_t^* is the desired number of entrants in year t.

The model describes a dynamic situation where supply is adapting to changes in demand on a year-to-year basis, but in general the adaptation is insufficient to gain equilibrium, i.e. $E_t \neq E_t^*$. The "desired" number of entrants is a proportion, α_1, of the number of applicants, plus a proportion, α_2, of the increase in applicants, so that this desired number already includes a form of adjustment. The actual increase $(E_t - E_{t-1})$ that finally results will be a proportion, α_3, of the difference between the new desired level of entrants and the actual level in the previous year. This system describes the way in which universities respond to the number of applicants in terms of three parameters, i.e. α_1, giving the proportion of applicants they would ideally accept assuming that the quality of applicants remains constant, α_2, showing their ideal response to changes in applications and α_3, showing the actual responsiveness to these changes.

In order to find the values of the parameters of the above models the following equation was estimated

$$E_t = \beta_1 A_t + \beta_2 A_{t-1} + \beta_3 E_{t-1}.$$

This is a symmetric supply function. However, because of the high capital element in the cost of university education, one may expect supply to adapt faster to decreases than to increases in demand and a better supply function may be an asymmetric one such as those used by Gemmill in his cobweb model of the cane sugar market[9] and this could be a subject for further research. Since the form of equation actually adopted includes a lagged value of the dependent variable as an independent variable the Durbin–Watson statistic from the O.L.S. estimation will not be appropriate. Thus where this equation was used the χ^2 statistic was calculated to test the null hypothesis that there was no auto-correlation present, against the alternative hypothesis that ρ took the value ρ_0 as estimated using A.L.S., i.e.

$$H_0: \rho = 0 \quad \text{against} \quad H_1: \rho = \rho_0.$$

The form of the test is

$$T \times \log(S1/S3) \sim \chi^2$$

where

$$T = \text{number of observations},$$
$$S_1 = \text{R.S.S. from O.L.S.},$$
$$S_3 = \text{R.S.S. from A.L.S.}$$

The actual value of the χ^2 variable at 5% significance is 3.841 and in all cases the test statistic was lower than this, so that the alternative hypothesis was rejected showing that O.L.S. is the appropriate method of estimation.

EXPLANATION OF THE MODEL

Home applicants (A.L.S.)

$$\text{AH} = \underset{(3.13487)}{-56738.6} + \underset{(4.55411)}{94.9029\,\text{N18}_t} + \underset{(6.24482)}{4273\,t} \qquad (1)$$

$$\rho = 0.816917 \quad Y = 1950\text{–}75 \quad \text{d.f.} = 22$$

This equation describes the number of home applicants in terms of two independent variables: the number of 18-year-olds and a linear time trend; the final estimation incorporates a first order autoregressive scheme. It therefore reflects the influences of demographic changes separately from the general time trend.

The numbers of home applicants to all universities are not in fact known for the period 1950–75 and were estimated from the corresponding entrants by using the consistent relationship between U.C.C.A. entrants and applicants for the period 1964–77, on the assumption that this would be adequate for the years prior to 1964.

The number of 18-year-olds is used here as an index representing the size of the 18–21 school-leaver age group, since trends in the former series closely follow trends in the latter. This age group is the most significant one of those applying for university, but the time trend is intended, partly, to take into account the increasing numbers of mature home students applying.

It would appear from government publications that their method of estimation combines changes in the size of the 18-year-old age group with a trend variable, i.e. the Age Participation Rate (A.P.R.). However, insufficient data is available on the A.P.R. to use this in this analysis, so this equation assumes that these influences are independent.

The equation was alternatively estimated using the sizes of separate age groups as independent variables, but it was found that since these separate series were very closely connected the effects of multicollinearity meant that the co-efficients produced were not sensible, so finally N18 was selected to represent the broader age group. Other independent variables that were tried included unemployment but it was found that their coefficients were insignificant, indicating that the level of unemployment, whether of the total population or among school-leavers only, does not appear to be an important influence upon individuals' application decisions. An attempt was made to see whether the rest of higher education had a significant competitive effect upon the home demand for university places. However, it was found that the number of higher education entrants was

TABLE 1. BELOW LISTS THE ABBREVIATIONS USED IN THE MODEL. THIS IS FOLLOWED BY A LIST OF SYMBOLS AND VARIABLES, GIVING THEIR DEFINITION

All universities	Southampton only	Description
AH	—	Applicants—Home (estimated for full data, actual for U.C.C.A.)
AO	—	Applicants—Overseas (estimated for full data, actual for U.C.C.A.)
AN	AN(S)	Applicants—Home plus Overseas
EH	EH(S)	Entrants—Home
EO	EO(S)	Entrants—Overseas
EN	EN(S)	Entrants—Home plus Overseas
TH	TH(S)	Total Students—Home
TO	TO(S)	Total Students—Overseas
TN	TN(S)	Total Students—Home plus Overseas
Aa	Aa(S)	Applicants for Accountancy
Ea	Ea(S)	Entrants for Accountancy
Ae	Ae(S)	Applicants for Economics
Ee	Ee(S)	Entrants for Economics

N18	Number of 18-year-olds in Great Britain in a given year
F$	Yearly tuition fees for overseas students—in equivalent U.S. Dollars
DUM	Dummy variable (=1, where t = 1, 2 or 3 and =0 where t = 4 or more)
Y	Years for which an equation was estimated
t	A time trend which takes the values 1, 2, 3, etc. for successive years commencing with the first year in Y. When used as a suffix to another variable it indicates the value of that variable in the appropriate year
$\bar{R}^2$	Adjusted R-squared ratio
F	F—ratio
DW	Durbin–Watson statistic
χ^2	Chi-squared value to test $H_0: \rho = 0$ against $H_1: \rho = \rho_0$
ρ	The parameter of a first-order autoregressive scheme
d.f.	Degrees of freedom
O.L.S.	Ordinary Least Squares method of estimation
A.L.S.	Autoregressive Least Squares method of estimation using the Cochrane–Orcutt method

Note: The bracketed figure under each coefficient of an equation represents the so-called t-ratio for that coefficient.

affected by similar influences to the dependent variable, so that it could not be used as an independent variable without changing the structure of the whole equation.

Overseas applicants (A.L.S.)

$$AO_t = \underset{(3.17227)}{-17.6136}\ F\$_t + \underset{(6.90951)}{1163.12\,t} + \underset{(0.875898)}{2566.52}\ DUM_t \qquad (2)$$

$$\rho = 0.753006 \qquad Y = 1950\text{–}75 \qquad d.f. = 22$$

The equation describes the number of applicants from overseas for the same period as for equation (1) and, as in the latter, the number of overseas applicants are not known, so they have been estimated from entrants in a corresponding way to that used in equation (1).

This group is a much smaller and more diverse one covering a wider range of ages than for applicants overall,[10] and the factors that affect it are less clear. The applicants come from many different countries with varied political and social environments, and therefore it is to be expected that their decisions will reflect these factors; an examination of the series will show that quite large fluctuations are observed from year to year.

Instead of attempting to model all these influences, two important variables have been picked out as those that affect the aggregate level of applicants most significantly, i.e. a linear time trend and the level of tuition fees; in addition a dummy variable for the first three years was included. Whilst the significance of the dummy variable was low in the A.L.S. method it was nevertheless retained since it reflected a temporary increase in overseas applicants from the Commonwealth of about 2500 per annum for three years, and without the variable it was found that the estimated results were negative in the early years.

The well-developed systems of university education in Britain and the U.S.A. have always attracted students from other countries, especially from those that do not have a fully developed system of their own; the equation shows that there is a strong upward underlying trend that is very significant.

One may expect the numbers of overseas applicants to be sensitive therefore to the level of tuition fees charged to them. The real cost of the tuition fees to the individual will depend upon the market exchange rate between sterling and the currency of the native country, so one would expect currency fluctuations to affect the overseas demand for university places, as for any other goods. These effects have been generalised in the Model by using the level of tuition fees converted to U.S. Dollars, and this has the added advantage of taking into account the effect of exchange rates upon the costs of British courses compared with courses of the main competitor, i.e. the U.S.A. It was also found that the equation was a better fit when tuition fees were given in terms of Dollars rather than in the original sterling values.

Total applicants—home plus overseas

$$AN_t \equiv AH_t + AO_t \qquad (3)$$

Home entrants (O.L.S.)

$$EH_t = \underset{(5.29678)}{0.412134}\,AH_t - \underset{(1.91176)}{0.25227}\,AH_{t-1} + \underset{(3.65505)}{0.711058}\,EH_{t-1} \qquad (4)$$

$$F = 4091.15 \quad \chi^2 = 0.6235453 \quad \bar{R}^2 = 0.99886 \quad Y = 1964\text{–}77$$

$$d.f. = 11$$

The partial adjustment model that is derived from the equation is:

$$EH_t^* = 0.5534225\,AH_t + 0.8729329\,(AH_t - AH_{t-1})$$
$$EH_t - EH_{t-1} = 0.288942\,(EH_t^* - EH_{t-1}).$$

This indicates that the "desired" number of entrants is a proportion, 0.553425, of applicants plus a proportion, 0.8729329 of the change in applicants from the previous year.

The value of α_1 is in line with the long-run proportion of entrants to applicants.

However, the value of α_2, the proportion of the change in applicants, would seem to be rather high. The adjustment value, α_3, similarly is lower than one would expect.

Overseas entrants (O.L.S.)

$$EO = \underset{(3.53131)}{0.222088}\ AO_t - \underset{(1.97919)}{0.150763}\ AO_{t-1} + \underset{(3.587559)}{0.782783}\,EO_{t-1} \qquad (5)$$

$F = 743.318 \quad \chi^2 = 0.9549032 \quad \bar{R}^2 = 0.993753 \quad Y = 1964–77 \quad d.f. = 11$

This equation was estimated using U.C.C.A. data and the partial adjustment model that is derived from it is:

$$EO_t^* = 0.3283582\,AO_t + 0.6940663\,(AO_t - AO_{t-1})$$
$$EO_t - EO_{t-1} = 0.217217\,(EO_t^* - EO_{t-1}).$$

When these coefficients are compared with those of the previous equation, it is found that the proportion of overseas applicants that universities desire to accept (α_1) is lower than the proportion for home applicants. The possible reasons why the proportion of entrants to applicants is so much lower for overseas students are many; applicants may apply to other than British Universities so that the proportion of serious applicants out of the total is smaller, or the quality of overseas applicants may be perceived to be less by selectors. The value of α_3 is also lower than for home students indicating that universities respond less to changes in the desired number of entrants where these are from overseas.

Total home students—all academic years (O.L.S.)

$$TH_t = \underset{(160.584)}{2.96192}\,EH_t \qquad (6)$$

$F = 25787.2 \quad DW = 1.64384 \quad \bar{R}^2 = 0.999264 \quad Y = 1957175 \quad d.f. = 18.$

The equation estimates the number of home students in all academic years as a proportion of first year home entrants assuming that this relationship is constant over the period of estimation. This is a very simple equation and ideally a more refined one would include lagged values of entrants as independent variables corresponding to students in their second and third years, and the extent to which the co-efficients of these variables differed from unity would indicate the "drop-out" or "wastage" rate in that particular year. However, when this method of estimation was used it was found that the coefficients produced did not make sense and this was probably due to multicollinearity between the lagged values, especially at this level of aggregation.

Thus, instead, the single coefficient is assumed to incorporate the effects of the weighted average length of courses pursued by home students, wastage rates and the effect of changes in the number of entrants. For example, where the student population concerned attends longer courses, wastage rates are lower or the number of entrants decreases from one year to the next, one would expect the coefficient to be higher. However, in this equation it is not possible to distinguish between these effects.

Total overseas students—all academic years (A.L.S.)

$$\mathrm{TO}_t = \underset{(20.574)}{2.06515\,\mathrm{EO}_t} \tag{7}$$

$$\rho = 0.73993 \quad \mathrm{Y} = 1957\text{–}75 \quad \text{d.f.} = 17.$$

This equation was originally estimated in a similar way to the previous equation but it was found that there was significant positive serial correlation as indicated by a low Durbin–Watson statistic. The coefficient of 2.06515 in the equation adopted is also lower than in the previous one and this would seem to indicate either that the weighted average length of courses pursued by overseas students was shorter, that wastage rates were higher, that the number of entrants were increasing at a higher rate than for home entrants or a mixture of these effects. Possibly higher wastage rates may be due in part to the steeper increase in fees to overseas students already on courses.

Total students—all academic years

$$\mathrm{TN}_t \equiv \mathrm{TH}_t + \mathrm{TO}_t \tag{8}$$

Accountancy applicants (O.L.S.)

$$\mathrm{Aa}_t = \underset{(9.35032)}{1.60452\,\mathrm{Aa}_{t-1}} \underset{(1.85396)}{-0.000164733\,(\mathrm{Aa}_{t-1})^2} \tag{9}$$

$$F = 313.035 \quad \chi^2 = 1.1964 \quad \bar{R}^2 = 0.981134 \quad \mathrm{Y} = 1966\text{–}77 \quad \text{d.f.} = 10.$$

An examination of the trend in demand for accountancy as a university subject indicates growth which has followed a different pattern from that studied in other parts of the paper.

The subject was first introduced as an undergraduate subject in 1965, when there were 20 applicants through U.C.C.A. with accountancy as their first choice. Since then the path of the growth of applications over time has approximated to a "logistic" curve since this is often the curve used to describe the dynamic path followed by demand where a new product is introduced to the market.[11] Until the level of demand has reached an equilibrium, it will not follow the trends of the market and so in general it will be independent of year-to-year changes in the latter. From observation of the level of accountancy applicants to date[9] it does not seem to have been affected by the fluctuation in the total number of applicants, and so a form of the equation has been used which does not take into account such fluctuations. The equation chosen was

$$d\mathrm{Aa}/dt = K_2\mathrm{Aa}(K_3 - \mathrm{Aa}).$$

Since in this case the market (i.e. matching demand and supply) only exists once a year, a discrete form of the equation is used

$$\mathrm{Aa}_t - \mathrm{Aa}_{t-1} = K_2K_3\mathrm{Aa}_{t-1} - K_2(\mathrm{Aa}_{t-1})^2 + e_t$$
$$\mathrm{Aa}_t = (1 + K_2K_3)\mathrm{Aa}_{t-1} - K_2(\mathrm{Aa}_{t-1})^2 + e_t$$

where e_t is an error term of the estimation. From the results it is found that the equilibrium level of applicants that demand is tending towards, is 3670. However, it is to be expected that once this level of realised, demand will tend to follow the general trends of the market rather than stop increasing altogether.

Accountancy entrants (O.L.S.)

$$\mathrm{Ea}_t = \underset{(9.96286)}{0.430484\,\mathrm{Aa}_t} \underset{(2.70106)}{-0.15352\,\mathrm{Aa}_{t-1}} \tag{10}$$

$$F = 1261.65 \quad \mathrm{DW} = 1.56974 \quad \bar{R}^2 = 0.995263 \quad \mathrm{Y} = 1966\text{–}77 \quad \text{d.f.} = 10.$$

This equation relating accountancy entrants to applicants uses U.C.C.A. data also and it was found that neither a lagged value of entrants nor an intercept term were significant. Thus the equation is a special case of a partial adjustment model, in the sense that desired and actual entrants are equal, i.e. $\alpha_3 = 1$; it thus resolves itself into the form

$$Ea_t = 0.276964 Aa_t + 0.15352(Aa_t - Aa_{t-1})$$

with no adjustment equation for the difference between desired and actual entrants.

The fact that the lagged value of entrants was not significant is probably due to the rapid growth in the number of applicants and that the number of entrants has been able to keep pace.

Economics applicants (A.L.S.)

$$Ae_t = -165.165\,t + 0.034828\,AN_t \qquad (11)$$

$$(2.16423) \qquad (6.83074)$$

$$\rho = 0.590025 \quad Y = 1966\text{–}77 \quad \text{d.f.} = 9.$$

In this equation the number of applicants for economics through U.C.C.A. was regressed on the total number of applicants in all subjects through U.C.C.A. and on a linear time trend; the estimation was finally carried out using the A.L.S. method. An intercept term was found not to be significant in both O.L.S. and A.L.S. estimations.

The coefficients indicate that the effects of the two variables tend to counterbalance each other, i.e. an increase in applicants for all subjects increases the number of economics applicants by 3.5%, but this is counteracted by a decrease of 165 from year to year. This reflects the fact that economics has been studied as an academic subject for a long time and the demand for it was thus fairly stable over the estimating period, unlike accountancy which, as stated above, was only introduced as an academic subject at the beginning of the period and its demand has not yet stabilised.

Economics entrants (O.L.S.)

$$Ee_t = 0.31834\,Ae_t - 0.245951\,Ae_{t-1} + 0.910829\,Ee_{t-1} \qquad (12)$$

$$(2.401) \qquad (2.0403) \qquad (10.2917)$$

$$F = 633.834 \quad \chi^2 = 1.5074937 \quad \bar{R}^2 = 0.993719 \quad Y = 1966\text{–}77 \quad \text{d.f.} = 9.$$

The equation relating entrants in economics to applicants through U.C.C.A. is interpreted in a similar way

$$Ee_t = 0.8117998\,Ae_t + 2.7581949\,(Ae_t - Ae_{t-1})$$

$$Ee_t - Ee_{t-1} = 0.089171\,(Ee_t^* - Ee_{t-1}).$$

It involves a lagged value of entrants in contrast to the equivalent equation for accountancy and the lagged value is very significant. This is again indicative of the fact that the demand for economics has not been so buoyant, and the fact that α_1 is high and α_3 is rather low emphasizes that although supply meets a large proportion of demand it is not very responsive to changes in it.

Home entrants to Southampton (A.L.S.)

$$EH(S)_t = -158.356 + 0.0240925\,EH_t \qquad (13)$$

$$(3.49305) \qquad (23.7443)$$

$$\rho = 0.454599 \quad Y = 1949\text{–}75 \quad \text{d.f.} = 24.$$

There was insufficient data to estimate the number of home applicants at Southampton and so home entrants have been estimated directly from all home entrants. An O.L.S.

method was first tried and in this approach a time trend was found to be positive and significant; in the event, however, the rather low DW statistic led to adopting an A.L.S. approach where a better fit was obtained, but without a time trend. The coefficient of the independent variable showed that an increase in total home entrants leads to an increase of 2.4% thereof at Southampton.

Overseas entrants to Southampton (O.L.S.)

$$EO(S)_t = -9.81854 + 0.00843929\, EO_t + 1.5296\, t \qquad (14)$$
$$(1.79853) \quad (2.72908) \qquad (3.1259)$$

$F = 54.3727$ DW $= 1.92023$ $\bar{R}^2 = 0.804136$ Y = 1949–75 d.f. = 24.

One would expect changes in the number changes in the number of entrants to Southampton from overseas to reflect changes in total number of entrants quite closely, because the factors that affect the latter will be common to the former. In fact the number of overseas entrants has fluctuated considerably from year to year and there must be other influences at work which have not been identified and allowed for. The high significance of the time trend which has been included, however, does appear to reflect the increasing relative popularity of Southampton with overseas students.

Total home students at Southampton (O.L.S.)

$$TH(S)_t = 2.71328\, EH(S)_t \qquad (15)$$
$$(71.8709)$$

$F = 5165.43$ DW $= 1.50589$ $\bar{R}^2 = 0.998067$ Y = 1966–75 d.f. = 9.

Whilst this equation is comparable with the one for all universities and might have been expected therefore to have approximately the same coefficient, the lower coefficient which was obtained may perhaps be accounted for by the shorter period of observations, a lower weighted average of the length of the courses and a higher wastage rate, but no conclusive evidence was found.

Total overseas students at Southampton (O.L.S.)

$$TO(S)_t = 1.83978\, EO(S)_t \qquad (16)$$
$$(23.9066)$$

$F = 571.524$ DW $= 1.53817$ $\bar{R}^2 = 0.982774$ Y = 1966–75 d.f. = 9.

As for students at all universities the coefficients is lower for overseas than for home students. Again, no cause was discovered for the coefficient being lower for Southampton than for all universities.

Total Students—All Academic Years $TN(S)_t \equiv TH(S)_t + TO(S)_t$. (17)

ECONOMICS AND ACCOUNTANCY AT SOUTHAMPTON

The complete model includes equations for Accountancy and Economics applicants and entrants at Southampton University. Data was available, however, for a very limited period, so results are dubious, especially with the nature of conclusions drawn from them, so they have not been reported here.

SIMULATION

The complete model was simulated to produce projections into the future. Given the structure of the equations the percentage of 18-year-olds that apply to go to University becomes a crucial variable. The model assumes that this percentage will continue to increase, thus compensating the eventual decline in the number of potential applicants.

Alternative assumptions about age participation rate produce different results. This is an area where much discussion has taken place and factors such as changing behaviour of different social classes, and changing attitudes towards university education have to be taken into account, this is obviously beyond the scope of this paper.

CONCLUSION

This paper has used econometric models to describe features of the demand for university education in Great Britain and the way in which changes in this demand have been met. However, it was found that limitations on the amount of comparable data meant that the equations could not all be estimated for the same period and that many of the periods were rather short. Nevertheless, the paper demonstrates the extent to which equations can be made to yield a reasonable model of many subdivisions of the field of study, without employing more than a time trend and two other exogenous variables.

There is potential for much further research since the whole field of higher education is one that is vital for the economy as a whole and the large sums invested in it emphasize the need for careful planning.

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