

Managing health care under resource constraints : proceedings of the 21st meeting of the Operation Research Applied to Health Services, 23-28 July 1995, Maastricht, the Netherlands

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Managing Health Care Under Resource Constraints

Proceedings of

the 21st meeting of

Operational Research Applied to Health Services

23 - 28 July 1995

Maastricht, The Netherlands



Editors:

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Introduction

Managing Health Care Under Resource Constraints

From 23rd till 28th of July 1995 the 21st meeting of the European Working Group on Operational Research Applied to Health Services (ORAHS) was held in Maastricht, the Netherlands. ORAHS represents a network of health care researchers and professionals with an interest in the application of OR to health care management problems. The aims of the group are:

- 1. To improve co-operation and communication, and to encourage and stimulate group members.
- 2. To enable and support inter-disciplinary work on European health care issues.
- 3. To examine European health care systems using rational and systematic methods.
- 4. To encourage bilateral contacts between members throughout each year.

The Working Group is one of the first working groups on applications of OR established in 1975 by EURO, the association of European OR societies. Since then yearly meetings have been held in different European countries.

The theme chosen for this 20th anniversary meeting was concerned with the general trend of scarce resources for health and health care, because national expenditures are limited while demand is still growing. The conference has focused on the decision support offered to health care managers and health professionals to meet this challenge and:

- · balance efficiency in the use of resources with good quality of care;
- improve the coherence in the system between different subsystems rendering services to a single patient;
- · improve the effectiveness of health care provision;
- shift care, wherever appropriate, to ambulatory care and home care instead of inpatient care;
- bridge the gap between managers and health care professionals in developing effective and efficient health care.

Contributions on each of these topics may take the form of a review paper, a methodological paper or a case-study type paper. This distinction in types of papers is also used to organise the post-conference proceedings. The first part contains review studies offering an overview of the research area or aiming at raising a debate between practitioners and users of health OR. The second part contains papers that focus on methodological or modelling contributions to a specific decision problem. The third part contains case-studies that apply a specific technique or methodology to a problem encountered in the reality of health care. In part four a discussion report is presented, which reflects some of the dialogues and discussions that took place after the papers where presented. We would like to thank the students Monique Cox and Harriet van der Winden for writing this report. We hope that the diversity of the papers in these proceedings show that health care is a vast area for potential OR contributions, and that

the emphasis in our work is more and more on making an impact on the delivery of health care services.

We would like to thank Barry van Heerwaarden for the preparation of this publication and the sponsoring organisations for the support of the conferenceⁱ.

The Editorial Committee for the 1995 proceedings:

A. Kastelein, Eindhoven University of Technology J. Vissers, Eindhoven University of Technology and Dutch Hospital Institute G.G. van Merode, University of Limburg, Maastricht L. Delesie, Catholic University of Leuven

ⁱ The conference was financially supported by Eindhoven University of Technology/Graduate School of Industrial Engineering and Management Science, NZi Research, Information & Training in Health Care, and ZRP/interdepartmental working group on health care related research within the Graduate School.

Part One - Reviews

Some Reflections On Operational Research Applied To Health Services - What Have We Learnt?

D. Boldy, Curtin University of Technology, Western Australia.

1. Introduction and definitions

This paper draws on the author's experience of "OR Applied to Health Services" (ORAHS), from before his time as the first chairman (1975-1982) of the European Working Group of that name up to the present day.

Over the years, a variety of alternative definitions of Operational Research have been proposed. A good early example is that provided by Matson (1979)ⁱ :

"A scientific approach to problem solving for the control of systems of men, machines, materials and money. It may be characterised as follows:

- a. A systems approach to problem solving, implying efforts to avoid too narrow a definition of problems and too local or partial (sub-optimal)solutions;
- b. Specification and structuring of goals, implying efforts to make goals operational, clarify priorities and determine 'trade-offs' between conflicting objectives;
- c. model building, implying abstraction and simplification in an effort to have a manageable, but still reliable representation of the real system;
- d. quantification, implying the introduction of scales of measurement and procedures for data collection;
- e. techniques for making operations on models in order to derive their implications for decision making and planning".

Whilst characteristics c-e are probably more appropriate to <u>tactical</u> rather than <u>strategic</u> problems, the reverse is probably true as regards characteristics a-b. Boldy and Clayden ⁱⁱ found that in the UK and Ireland during the 1970s, there had been an increased attention to health and welfare OR of a more strategic nature (implying an increased importance of characteristics a-b). Whatever the relative importance today, as OR Scientists we need to be competent in all the characteristics listed in the above definition, i.e. possess the necessary skills to be able to tackle both tactical and strategic problems.

I believe we are now (or should be) less inclined to identify with a narrow definition of OR (as e.g. consisting solely of the application of certain techniques). Back in 1978, I gave a case study paper (with Neil Howell) to the Fourth Meeting of the EURO ORAHS Working Group, held in Baden, Switzerland, on 'The Geographical Allocation of Community Care Resources'. I remember clearly being told by one of the participants that this was not OR, by which he meant that we had not used a 'recognised' OR technique. I think there is less chance of that type of reaction today. We had in fact used a heuristic approach which was readily understandable to the decision makers and was adopted and implemented. The paper was published in the UK Journal of Operational Research ⁱⁱⁱ.

This does not mean, of course, that we should exclude the use of particular techniques, when appropriate. Surely it is a question of balance and what approach has the best chance of "securing improvement". This brings me to what I believe is the simplest, and in many ways best, definition of OR, namely:-

"The securing of improvement in social systems by means of scientific method" (Churchman ", see ").

"Securing improvement" emphasises <u>implementation</u>, which clearly relates to the deliberate choice of the working group's title (ORAHS) with its applied emphasis. In my introductory chapter to the edited book with the same title as that of the working group ^{vi,} ^{vii} I indicated that the "major challenge for OR Scientists working in the health field lies not in developing new and/or more sophisticated techniques, but in using what expertise they currently posses to make much more of an <u>impact</u> on the delivery of health care". I still believe this.

This edited book ⁵ (time for an updated version?) has as its <u>first</u> main chapter "Implementation of OR Projects in Health Care", written by the working group's second chairman Mårten Lagergren. This represents an analogy with an OR study in that implementation should be born in mind from the <u>beginning</u> and not only thought about at the end. How many papers presented at working group meetings (or any other OR meeting for that matter) over the years have started by addressing issues of implementation (or have addressed them at all)? In his chapter, Mårten emphasises that implementation is a <u>process</u> which takes place throughout a project and gives examples of success and failure, mainly from his experience of Health OR in Sweden. I can recommend reading, or re-reading, this chapter.

2. Decision support systems and operational research

At the previous working group meeting held in Holland (Enschede 1985), I gave a paper entitled "The Relationship between Decision Support Systems (DSS) and OR: Health Care Examples". In this paper, subsequently published in EJOR ^{viii}, I quoted Sprague's ^{ix} four recommended DSS characteristics and advocated their desirability related to health care decision support and 'securing improvement' (OR). I believe these are worth revisiting, namely that they:

- (i) tend to be aimed at the less well structured, unspecified problems that upper managers typically face;
- (ii) attempt to combine the use of models or analytical techniques with traditional data access and retrieval functions;
- (iii) focus on features which make them easy to use by non-computer people in an interactive mode; and
- (iv) emphasise flexibility and adaptability to accommodate changes in the environment and decision making approach of the user.

In my EJOR paper I discussed the relevance of the above characteristics via selected examples.

3. Balance of care: a case study

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In this paper I want to revisit and update my earlier comments in relation to "Balance of Care" (BOC), the early version of which I discussed in a review paper presented at EURO 1 in Brussels ^x. Papers about BOC have been a regular feature at working group meetings over the years, the basic aim being to provide a means by which the resource consequences of alternative assumptions of appropriate care alternatives for given types of patients/clients can be assessed. Recently the principal focus of this work has been on alternatives for elderly people.

More specifically, the BOC concept, originally developed and operationalised by the Operational Research Service of the UK Department of Health and Social Security, is based on the idea of a balance between different forms of health and social services care (institutional, day, community) and between different types of patients/clients (types of elderly, mentally ill, physically disabled,...). It also assumes as a premise that there exists a number of 'acceptable' alternative modes of care for many types of patients/clients, this being particularly true for areas of 'care' rather than 'cure'.

This concept led to the derivation of patient/client categorisation schemes and the specification of alternative modes of care by advisory groups, resulting in an initial 'minimum cost' LP model ^{xi}. However, it was found that with 'ideal'(or 'desirable') levels of care being specified, minimum cost solutions were typically much greater than existing (or likely) health and social services budgets, even with 'realistic' constraints being placed on the number of patients/clients to be treated in the model.

What were the options? Goal/multi-objective programming was considered, but in the end an MP 'Inferred Worth' model was developed i.e. patients/clients were allowed to receive less than' ideal' levels of care, but with penalties being imposed ('inferred' from demonstrated field workers' priorities). The reader is referred to Boldy et al (1982)¹¹ for specific details of model development, calibration, etc. This refined model gave feasible solutions and allowed 'what-if' questions, related to the relationships between types of patient/client and alternative types of care, to be explored at a local level. However, even with only one client group being considered at a time (e.g. elderly people), the complexity and size of the model meant that it was <u>not</u> 'easy to use by non-computer people in an interactive mode', Sprague's recommended DSS characteristic (iii) - see above. The model was also dependent on extensive survey data, rather than 'traditional data access', Sprague's recommendation (ii).

Subsequent developments, aimed at simplifying the BOC approach, led to a separation of the different functions of the model, achieved by replacing the complex utility functions and MP algorithm by heuristics.

The resulting modules, intended to be used in a step-by-step manner, permitted the following aspects to be explored:

- summary of current levels of provision;
- future resources needed to maintain current levels of care to the projected opulation;
- likely future patterns of care, assuming the continuance of field workers' current priorities;
- implications of alternative assumptions concerning field workers' use of resources;
- more cost effective mixes of resources; and
- more cost effective ways of distributing clients between alternative forms of care.

This development is in line with Young's ^{xii} concept of the DSS approach i.e. that it 'breaks the decision process into a menu of selectable modules, each of which is understood by the user, adjusted and controlled by the user, and interwoven into the decision-makers' own step-by-step human processing sequence'. These developments moved the BOC planning approach further in the directions recommended by Sprague in his characteristics (iii) and (iv) i.e. ease of use and flexibility. However, they fall short of characteristic (ii), being still dependent on extensive survey data.

The most recent developments in the BOC approach, still being refined, have taken advantage of personal computer (PC) spreadsheet software, leading to a system which is concerned with resolving <u>both</u> information and technology problems:

- the <u>information</u> problem, by providing a means of estimating the numbers of elderly people in each category (dependency group) who might be considered for care (based on the demographic profile of the locality); and
- the <u>technology</u> problem, by providing a user-friendly PC system that managers can jointly use to explore interactively various planning options. ^{xiii}

Tracing the developments in BOC over the years, provides a good illustration that Sprague's concept of DSS still provides useful guidelines for Operational Research Scientists to bear in mind if they wish to be more effective, i.e. to help secure improvement.

4. Current health care problems and health OR implications

In this final section, I wish to briefly mention some of the key problem areas for health care managers in today's environment, which we as OR Scientists need to be aware of and consider, in terms of the particular skill attributes they imply, if we are to assist in 'securing improvement'.

Unplanned and unpredictable <u>change</u>, linked to <u>cost containment</u> would appear to be endemic in many health systems, caused by political decisions, rapid growth in new technology, rising expectations and diminishing funds in real terms. Working with managers in such situations requires flexible planning skills with an emphasis on "robust" rather than "optimal" courses of action, together with negotiation and networking skills. In the important field of <u>corporate planning</u> related to health care, there is an increasing need for skills and advice in setting realistic, relevant and measurable objectives, leading to the definition of relevant <u>information</u> (rather than data) and strategies for its collection and analysis.

<u>Evaluation</u>, linked particularly to accountability, is also becoming increasingly important in relation to health services. The role (and place) of performance indicators, within the wider context of process and design (and not only impact/outcome) evaluation, needs particular attention, if health services are to avoid the trap of concentrating on performing well against what can and is being measured, at the possible expense of less quantifiable aspects.

Finally, in terms of <u>human resource management</u>, changing emphases in the status and power balances between different health professionals, whilst creating an increased potential for conflict, also implies an even greater need for an appreciation of the wider "systems" view of health care - an important educational role for Systems/ OR Scientists?

As OR Scientists we still have a long way to go in offering viable "solutions" to the health . care problem areas discussed briefly above. So, we need to journey on, working with our health management colleagues in developing <u>lifebelts</u> to help towards <u>survival</u> in these difficult resource constraining times.

References

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- 1. Matson, E., 'The Contribution of the Operational Researcher', <u>World Hospitals</u>, Vol. XIV, No. 10, 1979, pp. 226-228.
- 2. Boldy, D.P., Clayden, A.D., 'Operational Research Projects in Health and Welfare Services in the United Kingdom and Ireland', <u>Journal of the Operational Research</u> <u>Society</u>, Vol.10, No.6, June 1979, pp. 505-511.
- 3. Boldy, D.P., Howell, N., 'The Geographical Allocation of Community Care Resources - A Case Study', <u>Journal of the Operational Research Society</u>, Vol.31, No.2, February 1980, pp. 123-129.
- 4. Churchman, C. West., 'Operations Research as a Profession', <u>Management Science</u>, Vol. 17, No. 2, 1970.
- 5. Boldy, D.P., 'Reflections and Observations on Various Approaches to Strategic Planning, <u>European Journal of Operational Research</u>, 1, 1977, pp. 347-351.
- 6. Boldy, D.P. (Ed.), <u>Operational Research Applied to Health Services</u>, Croom Helm, 1981.
- 7. Boldy, D.P., O'Kane, P.C., 'Health Operational Research A Selective Overview', <u>European Journal of Operational Research</u>, No.10, 1982, pp. 1-9.
- 8. Boldy, D.P., 'The Relationship between Decision Support Systems and Operational Research: Health Care Examples', <u>European Journal of Operational Research</u>, 29, 1987, pp. 128-134.
- 9. Sprague, R.H.Jr., 'A Framework for the Development of Decision Support Systems' <u>MIS Quarterly</u>, Vol. 6, No. 4, 1980, pp. 1-26.

- Boldy, D.P., 'A Review of the Application of Mathematical Programming to Tactical and Strategic Health and Social Services Problems', <u>Operational Research Quarterly</u>, Vol.27, 2:11, 1976, pp. 439-448.
- 11. Boldy, D.P., Russell, J., Royston, G., 'Planning the Balance of Health and Social Services in the United Kingdom', <u>Management Science</u>, Vol. 28, No.11, November 1982, pp. 1258-1269.
- 12. Young, L.F., 'Right-Brained Decision Support Systems', <u>Data Base</u>, Summer 1983, pp. 28-36.
- Bowen, T., Forte, P., 'The Balance of Care Microcomputer System' *in:* Boldy, D.P., Rhys Hearn, C., (Eds.), <u>SYSTED 87</u> - <u>Systems Science in Health - Social Services for</u> <u>the Elderly and the Disabled</u>, International Institute for Systems Science in Health Care, Montreal, Canada, 1987, pp. 305-310.

Bridging The Gap Between Professionals And Managers

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1. Introduction

The health care sector is entering troubled waters as it is reaching full adulthood. Gone are the days when care providers in most Western Countries could grow unlimitedly in tune with every medical development that became available. Gone are the days when the public could expect total health protection under the aegis of its governmental authorities. Four main external driving forces now confront these authorities. First, the health care sector has grown into about the most important sector of economic life: 7 to 14 % of GNP, 10% of all jobs, Secondly, the medico-industrial complex has developed and is still developing into a rich and big industry with powerful political allies. Thirdly, the media are spreading within everybody's reach. Finally, medical developments are touching on issues which are dividing our societies: abortion, biogenetics, organ transplantation, euthanasia, privacy, individual contra societal rights.

All the while, the health care sector itself is still holding on to its old ways-of-life. Only individual professional prerogatives and the ultimate decision-making power of the professional societies prevail. The cleavage between the world of the administrators/ managers and the world of professional competence/ clinicians immobilises. Small business mode of operation isolated within one local community or local hospital shields from outside influences such as economic evolutions and democratisation trends among staff and patients. To the watchful observer, the driving forces external to the health care sector seem on a collision course with the internal way of life.

Can operational research bridge the gap between the professionals and the managers? Can operational research contribute in this way to prevent this collision course?

2. Challenges ahead

Several challenges await the government authorities -- representing the external driving forces - and the health care sector with its four constituting bodies. These four bodies are: the community and its representatives (board members in profit and non-profit organisations, elected or designated officials), the medical professionals or physicians, the army of supporting professionals such as nurses and therapists, the administrators and resource managers (financial directors, EDP managers,...)¹. The first challenge is the organisation of health care delivery: the function of the four main actors, their interaction and their decision making power with respect to policy, regulations and operations. The second challenge concerns the financing of health care: safeguarding the balance between limitless demand for health care and affordable supply of care and dividing the ultimate bill among all parties. The third challenge deals with the quality of care or the "value for money" issue.

This ORAHS meeting on "Managing health care under resource constraints" addresses two of the four challenges mentioned:

- improving health system's coherence;
- · balancing resource utilisation with quality of care;
- improving the effectiveness of health care provision;
- bridging the gap between professionals and managers.

These issues touch on the organisation of care and on the quality of care. Important as they may be, it is nevertheless my personal experience that the financing issue will be the most important and certainly the most publicised challenge for government authorities as well as the health sector people. This omission is undoubtedly due to the scientific character of this meeting. But if one wants to bridge the gap between professionals and managers, one cannot can not leave out this challenge with respect to the financing of health.

Governmental authorities

We first look at the governmental authorities. Their first task in the organisation of care is to make care available in the first place: acute hospital care, mental health, nursing care, prescription drugs, ... When it is available then they should guarantee the accessibility to care: to whom? on the basis of what criteria? financial criteria or social criteria? who supervises? federal supervision, national health or very much decentralised or privatised? The continuity of care (emergency services,...) and the diffusion of medical developments also require attention of the governmental agencies: the accreditation of emerging medical disciplines such as allergy medicine and transplant surgery, the registration of fourth generation drugs and space-age technology implants.

The financing of care has become a nightmare from the mighty United States to tiny Luxembourg: tax based or insurance based money? national insurance or local taxes? private, local community or employer-mandated insurance? private money or co-payments? How to determine "fair" rates, "reasonable" fees, "justifiable" charges or "equitable" budgets? What units of measurements? what decision rules? who can sit at the negotiating table? Recent reforms are numerous, the OECD publishes many surveys and comparative analyses related to the money issue ^{2,3}. Nevertheless, nobody seems to have discovered the magic formula so far. On the contrary, a proliferation of divergent and different approaches in many countries and different settings seems to characterise our evolution towards the global village.

Quality of care is the catch word to cover all remaining problems: total quality, continuous quality management, et cetera... planning, accreditation and financing of health care all fall back on the quality issue or the "value for money" issue: professional norms and guidelines, preferably of an international nature and under the auspices of international organisations compete with each other for attention. Unfortunately, the attention in recent years to quality does not result in the publication of the final "good practice manual" but on the contrary in an ever richer, more proliferate medical culture and into subcultures.

The Care Sector

The hospital and care sector is confronted with the same issues. First, the organisation of care: What types of care to offer? How to keep up with the ever expanding range of specialised services. How to attract those top physicians who unfortunately only fancy the most expensive equipment? Should the hospital hold on to its original mission? Should it keep its independence? Or should it merge with, buy or sell out to the competition? The administrators and executive directors have become all fully occupied with finances, buildings and equipment, maintenance, billing, staff conflicts. In this process, the administrators and executive directors have lost their contact with patient care. Care providers and patients on the other hand have become accustomed to the fact that all these facilities and amenities are available at their fingertips. Recently though, the hospital bed, the room services and linen supplies are now becoming secondary issues in comparison to the organisation, the medical and nursing care. The old hierarchical departmental structures such as the medical department, the nursing department or the administrative department are becoming empty administrative concepts and are making room for a conglomerate of specialised patient centred functional entities such as the emergency room, the pneumology programme, the oncology ward or the one-day surgery clinic. Each entity develops its own mode of operation, the entities operate one alongside the other but with numerous interactions.

This new organisation stresses the hospital finances to the limit. Over the years the hospital directors have become accustomed to the fact that "public money" would always be available to pay for expanded services. However many countries have introduced linear reductions and fee ceilings. The old inpatient per diem rates no longer reflect the cost of hospital stay, the medical and other fees become more important than the old hospital budgets. But on their turn, these fees are losing contact with the actual or estimated cost of care. Moreover, continuously revolving new government or insurance regulations are creating nightmares with all concerned: the patients, the care providers, the billing department. Public money does no longer pay for everything and a fixed budget is becoming the name of the game. As a result, board members, physicians, nurses or administrators are getting lost. Costs do no longer relate to revenues since several years. They hardly know how activities, which are done with the purpose to improve care, are still able to generate revenues beyond costs in order to survive.

This brings us to the issue of the quality of care. Gone are the days when more care meant automatically better care and hence resulted in higher revenues to pay for staff expansion and new investments. While the hospital administrators, physicians and staff are working harder and harder to keep up with medical progress and improve services, at the same time the patients, the patient representatives and the government authorities are questioning uninterruptedly what is being done, why it is being done and why the bill is not going down.

3. Ways out: management strategies

In order to avoid the collision course mentioned, some steps have to be taken now. Health care policy issues are at stake as well as some rather basic managerial issues. The policy issues are manifold and most interesting: access to care, basic care, public and private mix, the rights

of fund holders (governments or insurance agencies), care providers and patients, the diffusion of technology, et cetera... These policy issues are however not the topic of this contribution. The topic is the management of health care: the management strategies and the tools of the trade to implement them. But in the same way that we can no longer expect to find clear-cut answers to our health care policy problems, we should no longer look for clear cut answers to our management problems. If some would exist, they would have been found by now and we would have found consensus on them. The fact that the health care sector is now reaching adulthood essentially implies for the future that we have enough resources available. Plain growth lies behind us. There are enough hospital beds, enough physicians, enough medical technology, enough mental health facilities, enough nurses, enough nursing homes, ... We do not have to invent those anymore or start a crash programme or "Marshall plan" to produce them in sufficient quantities. On the contrary, we are in for a continuous fine-tuning, and a never ending debate on small shifts of priorities, limited course corrections and marginal resource reallocations. We are in for a step by step evolution and small improvements in many different areas after lengthy consultations with many parties. The "one-dimensional approach" of the past is evolving into a "multi-dimensional, multi-criteria, continuous process of decision making" for the future of our health care.

A second development runs parallel to the previous one: a shift from plain politics to **a more rational** approach in health care. The past period of expansion primarily concerned the creation of resources: beds, medical specialities, the diffusion of technologies... Power games dominated the acquisition of building permits and subsidies and the introduction of the new fancy technologies. The age of fine-tuning implies a period of rationalisation. Arguments have to be documented, hypotheses have to be checked, decision rules have to be made explicit and criteria have to be developed. We see this intrusion of a more rational approach with respect to any area of application: the development of one-day surgery: what type of patients? under what conditions? The development of criteria for heart operations: what patients should get what therapies at what time in their stage of illness. Blood transfusion: rather than relying on an abundant supply of blood by voluntary effort, a close look at the actual utilisation of this blood reveals the urgent need of a much more careful use of blood. New drugs do not find anymore a wide open market: they are being checked against existing drugs. Their specific contribution is highlighted through the introduction of strict criteria for their utilisation.

The third road ahead is the shift from "hospital" management towards "patient care" and even "patient" management. The old hospital management or institutional or organisational management implied that the managers' (boards and executive directors) main occupation was the acquisition of resources for their hospital, institution or organisation: beds, equipment, personnel, funds, subsidies, "public money", ... The managers' job was oriented to the higher up hierarchical levels in the outside world: the many agencies and authorities that had to be contacted, talked to and convinced in order to get a fair share of the increasing health care pie. Internal management was limited to the solution of conflicts between competing care providers and the delineation of fair share arrangements among all the providers. These usually amounted to the elaboration of time tables that could be accepted by all care providers only. Not everybody could grow by 10% per year. The planning and management of growth was the prerequisite task. Hence, one year all attention went to the radiology department, while the next year would be reserved for the cardiologists. Service unit by service unit would grow in a nicely scheduled but mostly frantic way.

The coming of age of hospital care runs against these well-established management practices. Hospital growth is no longer the name of the game. Productivity and rationalisation are becoming the buzz words. Attention is being drawn to the essential business of the hospital: the delivery of hospital care, the treatment of patients. Hospital management is becoming care management and patient management. Indeed, all parties are being oriented towards these patient indicators rather than the old resource indicators, or in plain terminology: "patient information" rather than "hospital information". As little patient information is available yet, the road ahead is still long. Patient classifications though are becoming widely available on the scientific and professional level: the ICD-10, the DRGs, the Management Resource Groups, the Uniform Discharge Records, the Minimum Basic Data Sets are there to stay. Several publications or anthologies, international ones as well as local ones -- in English, French, Danish, Flemish, -- do exist. Commercial companies are coming into the "patient information" market. The offer of patient classifications on the market is still very much of a dubious quality but the product is there to stay.

Nation-wide or international examples though are very limited. The Working party on Community Health data and indicators published its recommendations on "Health Data in the EC" to the high level committee on health - Council of Ministers of the European community in October 1994 ⁴. With respect to health care, they propose on the one hand some core indicators on manpower and equipment: hospitals, beds, physicians, qualified nurses, ... or resources available. With respect to the consumption of health care, the core indicators proposed deal with inpatient care and acute care admissions, total and public expenditure on health - or primarily price tag indicators. On everything which lies in between on the one hand these resources available and on the other hand, the final bill, very little is known. Hence, we still have a long way to go to fill up this "gap" between the structural indicators of our health care system and the basic outcome measures such as "total cost". Core indicators have to be developed on the diversity of patients and the variability of care between medical specialists, departments, hospitals, regions and even countries.

As a result of this shift from hospital management to patient management, a fourth strategy can be identified: the shift **from production management to product management**. Production management means the smoother, more efficient organisation of resources or "capacities" or "queues" or "work stations" towards the delivery of care. Product management implies that the attention goes towards the product rather than the production. Does the patient need hospital admission in the first place? Do the professional efforts of all those therapists contribute in the end to the patient's well-being? And if they do contribute to what extent? Is the balance between "activities" and "outcomes" still positive? Is it really necessary to monitor vital signs five times a day? Does this type of surgery to this kind of patient really require hospitalisation? Slowly but surely beds are being closed down. Specific services with a long established tradition are making room for more well-thought, effective modes of operations. With respect to psychiatric care, the shift from institutional or bed care to community care is most visible: empty state hospitals, run down buildings,...

Operational research was traditionally strong in the area of production management or hospital management. Will operational research be able to turn its attention to the emerging domain of product management?

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Finally, all the previous strategies merge into the last strategy proposed: the strategy with respect to the organisation of management. Recall the four bodies according to Mintzberg: the community and its representatives (board members in profit and non-profit organisations, elected or designated officials in public hospitals), the medical professionals, the army of supporting professionals such as nurses, paramedics and staff, the administrators and resource managers (financial directors, EDP managers,...). The traditional role of board members and executive directors was to acquire as many resources as possible while the role of the physicians and nurses was to deliver the best -- read: most -- care possible. A cleavage existed between both worlds. Once government or regulating agencies apply fully cost or budget ceilings or other brakes on the development of more resources, the traditional role of board members and executive directors becomes obsolete. But the care providers are equally challenged by the new issues: is the care necessary in the first place? is their no better, less costly therapy around? are the new possibilities of the new technology worth their extra cost: new drugs, new imaging equipment,... It does indeed become necessary "to bridge the gap between the professionals and the managers". The professionals need the managers to produce the hard data and the plain facts which are needed to justify their new technology and their new equipment to the outside world. Health economy, technology assessment, are becoming fancy disciplines. The board members and directors on their turn are called upon to help decide the real tough choices with respect to patient care: not everybody can deliver all services anymore, a choice has to be made what services to drop or sell out for the survival of the remaining services of the mutual choice between professionals and managers. Board members, managers, physicians and nurses have to start to really meet each other rather than living separate lives in different worlds.

The confrontation is not easy-going: the question of power, of ultimate decision-making emerges. A lot of talk is being spent on the issue of integrated care, but the integration itself is still a long way off. Competition rather than integration still prevails: competition between specialists, between hospitals, between institutional care and ambulatory care, between university and non-university hospitals, between general practitioners and medical specialists, between physicians (cure) and nurses (care) is still very much the name of the game. Some people even foster this competition in the name of efficiency and cost cutting: managed competition they call this. Unfortunately, health care is a very complex issue, where money is important but where society has the last word as ethical issues (abortion, in vitro-fertilisation, euthanasia, ...) cannot be avoided and are indeed infiltrating our society network. Market forces -- co-payments, non-basic care -- do exist, but are distinctly of a secondary nature. Some social upheaval such as doctors' strikes or boards - medical council deadlocks cannot be avoided and are already showing in several countries: USA, Spain, Belgium,....

Can operational research bring some logic, some sense in this new emerging world of health care?

4. New tools of the trade

Once we discern the developments and trends ahead or in classical operational research terminology, the formulation of the problem, once we have delineated a solution or the strategies to follow, we may be able to start looking for implementation. After that, we will see if and if, how, operational research can contribute to this implementation if it chooses to do so. In a very summarised way, I propose three parallel steps to implement my strategy to "bridge the gap between the professionals and the managers".

Step one: new discussion forums. Instead of the vertical organisational structure, with its strict, hierarchical, chain-of-command oriented management, a horizontal management becomes necessary. This management structure is based on communication, discussion, consensus building and is built around clusters of co-operative activity or interest. The government authorities are giving the example everywhere. Regionalisation and privatisation are examples of organising these horizontal clusters geographically or community wise. The one single, centralised agency is making room for many smaller and competing agencies, each with its own flavour, span of control and stylistic preferences. The industry concepts of "cocooning", "micro-marketing", "market niches" also reflect this approach. Another governmental change is the development towards integration: Not so long ago, there used to be separate administrations for hospital planning, for accreditation of providers and for the accreditation of hospitals, for financing of hospitals, for determining "reasonable" physician fees and for price setting of drugs, nursing care, et cetera... . Many countries illustrate this merging of these different administrations or the setting up of mixed, consultative, consensus building committees or the establishment of councils to bridge the gaps among the old divisive administrations.

Within the hospital, as indicated, the old "departmental organisation" is breaking down and reorganisational models are tried out on the basis of functional entities or operational units, the functions, the operations being patient care programmes or patient programmes. These units get wide ranging responsibilities, eventually even becoming "budget holders". Associations of physicians emerge to organise the medical speciality and to draw up a plan for medical staff development. Financial regulations are negotiated with respect to specialised equipment and/or specialised training programmes for the supporting staff. The old hospital administrators lose ground to the new "operational unit" managers. Operating theatres, oncology programmes, one-day clinics, ophthalmology clinics, IVF (in vitro fertilisation) clinics, nursing care networks, specialist- general practitioners groupings show the road ahead, the others follow.

Patient care information systems are the second tool of the trade. The old cost accounting schemes no longer satisfy. Traditionally, hospital costs and physician fees have been based on <u>allocation</u> procedures. Cost allocation on a per diem basis was most common for the hospital budget and fees on the basis of a list of procedures was most common for physicians. This allocation procedure required the formulation of myriad norms and rules and a continuous debate and effort to keep up with developments. When the governmental authorities at the time wanted to curtail costs drastically, they were tempted by the budget approach: the yearly national budget and the yearly budgets for each hospital, for each laboratory,.... The budget-

holder would have to bear the responsibility where to make the necessary cuts. Arguments were easily found: "...to give hospitals with the same functions and the same activities and which are operating within similar circumstances, the same budget...".

Essentially, this amounts to a <u>reallocation</u> procedure. Productivity indicators such as occupancy rates and lengths of stay are the prime candidates to measure "the same functions and the same activities" but soon enough attention was drawn to the patient mix and the care profile. Indicators on the diversity of patients and the variability of care. For reallocation purposes the government authorities need some index of similarity. This measure of similarity allows to measure to what extent any two hospitals, clinical departments, medical specialities, nursing units or services, laboratories and nursing homes are similar to respect to the specific indicators selected. As with some sophistication in the indicators no two units will be completely similar, some logical decision rules are developed to define similarity in a relative way with respect to the total set of units involved. Most often, the simplicity of the decision rules contrasts with the sophistication of the data collection and the data analysis. Enormous data banks are organised but when the decision has to be taken "average lengths of stay", median values, percentiles are still relied on. When comparisons have to be made, the concept of "reference group" is introduced in again a simplistic way, on the basis of "number of beds", "national averages", "relative points" or "relative values".

Two components are crucial for such patient mix and care process information system:

- (1) a common language to describe the patient mix and the care process ;
- (2) **methods to deal** with the data in a consistent way which is relevant and acceptable to the provider of the data -- "these were my patients, these were my activities" --, and which is feasible -- data handling capability within the yearly budget cycle -- for the physicians and unit administrators to arrive at decisions.

Hence the third set of tools of the health care management trade which has to be prototyped are these communication tools. Creating forums, collecting data are necessary but hardly sufficient conditions. First one cannot submerge those forums under big stacks of paper or long listings and expect them to go through all the data. Commercial banks and companies can sum their data into balance sheets and yearly accounts, based upon a 400 year accounting tradition. But how does one add four appendectomies with seven chemotherapy treatments. Again government agencies are taking the lead in developing procedures, criteria, surveys, experience to arrive at an evaluation of hospital care and decisions with respect to financing, accreditation and planning. Peer review committees, consultative boards are being organised; health policy cells are being developed; reports, documents, studies, surveys are being circulated widely to foster this communication. In the same way as health care accountants have been educated and trained, as health care economists or health care quality managers have been trained, "health information managers" become necessary. We are already training some. The communication tools are needed on the international level as well as on the local level. Indeed the diversity of patients and the variability of care are an issue on the international scene as well as between 2 physicians within one medical speciality within one hospital. We call this a macro-micro need for communication or a "glocal" (global- local) need for communication. I have some examples ready to show how we manage this in Belgium. Though some international EU-sponsored networks (e.g. AIM, TELENET) have started, they are still primarily technology oriented and hardly tuned to the users' needs.

But again the hospital sector, exception made for individual departments or even hospitals, has still to enter this communication age. In the United States as well as in Luxembourg, boards and administrators are struggling with professionals to negotiate on rules and regulations with respect to patient care evaluation and decision making power. This is certainly a game of power and mutual spheres of influence. Hence, the rules of the game are made along the road. No cookbook is available, the efforts are very consuming and only time can tell.

5. What about operational research ?

As long as I have been a student of operational research -- since 1966 -- the issue has been discussed among operational research professionals what operational research really stands for. Is it management sciences, statistics or a new sort of mathematics. Indeed, the EC classifies "operational research" as a sub-discipline of mathematics on the same level as statistics, programming and actuarial sciences. This hardly corresponds to my definition of operational research. I myself have been a member of the US-Operations Research Society and of The Institute of Management Sciences and of the UK-Operational Research Society. Because of personal feelings about the evolution of the US group towards mathematics, I resigned membership and am now a member of the UK-Operational Research Society only since the mid-seventies. But since about two years, the issue of the role and function of operational research is on the rise again. We operational researchers are indeed a neurotic group that continuously questions its very existence and scientific discipline. Operational Research is not a recognised centre, department and certainly not a faculty in most European universities, but then these excel by their strong tradition and links to traditional scientific breakdown. For instance, I myself in Belgium meet few operational researchers and then only in the universities (some in Gent, VU-Brussels, some in Faculté Polytechnique de Mons). Nevertheless, I think that this lack of clear cut boundaries along disciplinary lines, or this ability to transcend these scientific boundaries, is an essential ingredient of operational research.

I quote the 1976 definition of the UK-Operational Research Society: "...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 compare the outcome of alternative decisions, strategies or controls. The purpose is to help management determine its policies and actions scientifically....". I still like this definition very much.

 Health care, hospital care is certainly a "large system of men, machines, materials and money in industry, business, government and defence". Moreover the distinctive emphasis of health care is "men": men in both senses: the product of the industry: the patients, the care demand as well as the producers within the industry: the professionals, the care providers. However "men" not in their individual relationships -- the patient - professional relationship -- but in a group or system sense, the epidemiological perspective in health and health care as Donabedian⁵ called it.

- The distinction with management sciences or business administration is strongly related to the scientific component, but then again: "...what is sciences?..." An answer is given by the concepts of the ancient Greeks ⁱ: they identified four human components or human driving forces:
 - 1) logic or logica;
 - 2) power or economy which they called politica-economica;
 - 3) a set and scale of values called ethica and 4) beauty in life or esthetica. One can summarise that the emphasis of operational research is logic while the emphasis of management is **power**.
- The definition does not mention techniques at all but concentrates on methods. The definition also explicitly identifies uncertainty and competing objectives and/or values. Both characteristics take care that operational research can contribute to health care.

Starting from these remarks on operational research, the purpose of this contribution is to bridge the gap between the professionals and the managers in health and health care. For this purpose, I will introduce several statements which I put up for discussion:

Statement 1

Operational research as a discipline is still primarily academia oriented rather than health care sector oriented. Academia implies the education and training of "young" professionals with respect to well known and established techniques such as statistical techniques, quality control charts, decision/risk analysis, simulation, network planning and programming. These techniques imply nicely delineated sub-systems which exist so to speak independent of the world around them. Publications, periodicals, papers, meetings and workshops also... are basically and unfortunately an inter-university affair.

The health care sector though implies and demands not so much specific techniques but the diffusion of scientific methods. Methods are the mother of the techniques. Methods look primarily at the formulation of the problem and the implementation of solutions. Methods are not meta-techniques, the scientific method ⁱⁱ concerns a basic questioning spirit and an urge to manage the systems around us. The health care system requires a questioning spirit on all levels of management: clinical, transactional, operational, strategic management. The first method of science is to get a hold of the problem. But if one looks at the health care sector, one finds that the health care sector, the health system itself is hardly defined but mutates continuously. New aspects, fuzzy concepts and shifting issues pop up continuously. Operational Research in health care should go back to its roots: the operationalisation of the health care system and its constituent elements; the introduction of some rationalisation in a world of politics and pure emotions, which the health care sector still is very much. Operational research should not attempt to confront these politics and emotions -- they make life exciting !--, it should work alongside them. Even such an emotional experience as dying or illness still harbours some elements of rationality.

See e.g. Gaarder, J., <u>Sofies verden</u> (Sofie's world), Oslo, 1991, fun for reading

See Preface and Chapter I in R.Ackoff, Scientific Method, J.Wiley, 1962

My first statement concerns the "discussion forums" identified before. Operational researchers should start infiltrating those forums of managers and clinicians in order to hear their concerns, their issues and listen to the messages which they entail. Rather than copying the examples of the industrial world to the health care sector, they should "lend their ear" to the health care sector.

(A course in operational research requires as much real-life training experience as formal, academia based, classroom teaching. As such operational research resembles specialised medical training which is based on a residency programme with a lot of hands-on training.)

Statement 2

The health care sector is shifting from hospital to patient care management and from production management to product management. Operational research should not run behind these developments trying to catch up, but it should run ahead of them and rather show the road ahead. Some examples explain this point. Much operational research work deals with capacity: the planning of capacity, the utilisation or -- in straight operational research terminology -- the optimisation of capacity. It is of little avail to plan these resources if one does not know yet what the "resources" mean. Two easily recognisable items such as a physician and an intensive care unit are taken. First the intensive care units. Those highly expensive health care production centres have been introduced since the sixties in hospital care. A patient is either in or out of the intensive care unit. However at closer look -- Belgian data are available !-- one finds that intensive care is a very fuzzy concept. Some patients in intensive care units do not receive intensive care at all, and a lot of patients on regular nursing units do receive intensive care. The intensity of care is a gradual concept. Rather than a yes/no approach to intensive care, a more even, realistic, also more colourful approach or a more *operational* definition should be *researched*.

The same holds for the physician: what is for instance a cardiologist? Usually one counts heads but then practice patterns seem to vary widely. You can be sure that even in our Europewithout- frontiers a lot of Belgians are convinced that a Spanish cardiologist is somebody quite different from a Belgian cardiologist. But even in such a small country as Belgium a closer look at the facts revealed that a sizeable group of ophthalmologists did perform much less surgery than the rest of the professional group. They could be traced to one university, where indeed surgery training was much less developed than in the other 6 medical schools.

Hence my statement: operational research should orient itself to the operationalisation of the thousands of concepts and indicators in use in health care rather than to limit itself to the formulation of nice simulation and optimisation models which take all these concepts and indicators for granted. I define my actual job as the measurement of the "diversity of patients" and "the variability of care". If operational research is not doing this job, somebody else will have to do it: the London School of Economics starts a Master of Science Programme in analysis for Health Care Decisions in September 1995. It presents its aims **as**: "approaches to measurement", "hard" and "soft" problems and "interconnected problems". In my opinion these topics are pure, 100% operational research topics. The challenge is out!

Other concepts in health care which demand operational research are:

- severity of patients: what aspects does severity imply? how to measure the degree of severity?
- complexity of caseload: what aspects does complexity imply? how to measure the degree of complexity?
- emergency: what's an emergency? how do define the degree of emergency in an operational way?
- patient workload: how to define workload for physicians? for nurses? what is meant by a heavy workload? how to measure the evolution in the workload?
- patient mix, caseload, patient profiles: how to define the patient mix? how to measure the change in patient mix? the similarity and the dissimilarity in patient mix between different hospitals, between different specialists belonging to the same specialism?
- small area or practice variations: First, I hardly ever understood what health care had to do
 with geography, hence I strongly favour the terminology "practice variations". How do
 physicians treat patients differently? how to measure these differences beyond length of stay
 or resources consumed?
- outcome measurement: how to go about good care, mediocre care? how to measure the "added value" of medical care?

To bridge the gap between professionals and managers a common language is prerequisite. Participation in the discussions forums is the only way to get used to the many fuzzy concepts and indicators which are continuously used in real-life decision-making in health care. There is certainly work ahead for operational research.

The first task is the problem formulation, the first job of systems analysis is to get hold of the elements and their relationships. All operational research starts from data and information. The study of and the participation in the development of patient - and patient care information systems is very instructional.

Statement 3

Health care is by definition a very local business. The technology, the body of knowledge may be universal, but the profession, the job is primarily done on a very local basis. A dentist develops a profound knowledge of the molars, teeth and mouths of his/her patients over a 20year career but has little experience beyond this micro world of teeth. This local scope is important with respect to the patient-physician relationship and its privacy but hampers the management of the health resources whereas stated the "epidemiological perspective" becomes important.

A famous oncologist states that if the colleagues would be willing to exchange their clinical experience and results, mortality figures with respect to cancer could go down by 10% easily. Communication is the way by which this local outlook of health care can be overcome, "glocal" communication is the way to exchange this enormous clinical experience.

Operational researchers should actively participate in the development of communication on health care. A dilemma confronts these communication tasks. Either the dialogue is taking

place in too general terms, slogans or simplifications which hardly reveal the real issues but where everybody feels called upon to intervene, or the dialogue is taking place on a too detailed, technically sophisticated level, involving rare expertise and difficult training where only a happy few, the so-called experts, are able to participate. Operational researchers are well aware of this communication dilemma.

The communication also takes place on different levels: On some levels, e.g. clinicians and nurses on the floor, the health care information will be very detailed. On other levels such as national forums, the communication will have to deal with carefully designed samples: selected aspects to a selected level of detail for selected patients at selected (variable) intervals. The surest way for health informatics to stay put is indeed to want to monitor everything. To wait till all the evidence becomes available is the surest way never to proceed. It is my experience that many health informatics applications do not succeed because they want to achieve too much in too short a time. Communication and understanding require modesty and patience.

Two areas are indicated where operational research can contribute. The first one is the transformation of data to information, the developments of sensible summaries, the synthesis rather than the analysis of systems. Most information systems concentrate on the generation and the manipulation of data. The hospital sector has certainly enough data. Individual prescriptions are collected and kept by thousands, hospital bills may easily run hundreds of lines: item by item. Medical records grow with the speed of one kilometre a year in many hospitals. Nevertheless very little information is generated out of all this data. The reasons are obvious. The range of products-types of patients and services-care activities is quite large within the hospitals and much information is of a qualitative nature. These bring about many measurement problems, difficulties of standardisation and qualitative units of measurement such as severity indexes or status indicators.

Most statistical tools are geared towards easily measurable things such as admissions, lengths of stay, occupancy rates or francs, guilders or ECU. Frequency counts, averages and standard deviations are still most common in most applications. Health economists for instance have a tendency to map all data into money: one transplantation is worth 15 appendectomies. This certainly simplifies things but at the same time hides the variability of real-life experience. Also the management of health care is more than the management of financial resources. The techniques to achieve synthesis now in use in health care also favour oversimplifications. One can indeed state that the diffusion of personal computers, spreadsheets and statistical packages has increased the proliferation of "nonsense" data, statistics and information. The common averages or linear models hide the most fascinating diversity, the variability and the dynamics which we find from day to day within the hospital.

Astute hospital management is now shifting its attention to information rather than registration. The care managers who will excel are those who can turn data into information and then analyse the information quickly and intelligently enough to generate superior knowledge which translates into better, more effective, more efficient or more productive patient care (including less costly care).

Operational research can contribute in this communication process on health care by helping to deal with the voluminous data in sensible ways in order to arrive at sensible information. No solution, let alone implementation of solution can hold without strong, real-life information. Operational research looks beyond plain money, waiting - or turnaround times, occupancy levels, ... it looks at the total system of health care in a most sensible way.

6. Conclusion

This contribution is about bridging the gap between professionals and managers in health care: clinicians on the one hand and hospital managers or organisational managers on the other hand. In order to bridge this gap, the driving forces of the health care industry were identified in the first place. We then looked at the problems ahead: problems which confront the governmental authorities and problems which confront the health care sector. With a knowledge of the problems we can move towards a solution: four strategies merge into one overall strategy: to bridge the gap between professionals and managers. Three steps are identified how to pursue this strategy. Operational research can and should contribute. However some shifts in emphasis are necessary.

Three statements conclude my contribution:

- 1. Operational Research in health care should go back to its roots and work within the health care system rather than retire into the ivory towers of fancy optimisation, simulation or other models. Operational research should infiltrate the discussion forums on health care.
- Operational research should orient itself to the operationalisation of the thousands of basic concepts and indicators in use in health care rather than to the formulation of nice simulation and optimisation models which take all these concepts and indicators for granted.
- 3. Operational research can contribute in this communication process on health care by helping to master the voluminous data in sensible ways in order to arrive at sensible information on health, health care and health care management... under any type of constraint, resource or otherwise.

References

- 1. Glouberman, Sholom and Mintzberg, Henry, Part I: 'Four worlds, draft paper ', <u>Managing the care of health and the cure of disease</u>, Mc Gill University, Montreal, October 1992.
- 2. OECD, 'The Reform of Health Care A Comparative Analysis of Seven OECD Countries (Belgium, France, Germany, Ireland, Netherlands, Spain, United Kingdom)', <u>Health Policy Studies</u>, No. 2, OECD Publications, Paris, 1992.
- OECD, 'The Reform of Health Care Systems A Review of Seventeen OECD Countries (Australia, Austria, Canada, Denmark, Finland, Greece, Iceland, Italy, Japan, Luxembourg, New Zealand, Norway, Portugal, Sweden, Switzerland, Turkey, United States)', <u>Health Poliy Studies</u>, No 5, OECD Publications, Paris, 1995.

- 4. Ministry of Health, <u>Recommendations to the High Level Committee on Health from</u> <u>the Working party on Community Health Data and Indicators</u>, , Denmark, October 1994.
- 5. Donabedian, A., 'Institutional and Professional Responsibilities in Quality Assurance', <u>Quality Assurance in Health Care</u>, Vol. 1, Number 1, 1989, Pergamon Press, Oxford, UK,1989.

What Is The Role And Contribution Of Models To Solving Health Care Management Problems?

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1. Introduction

Few would disagree with the proposition that health care management is a very complicated and demanding business! Not only are the operations extremely diverse and is sophisticated and the technology developing at a breakneck pace. The health care system is also under tremendous pressure from two sides: to meet ever-increasing needs and demands of the population and to keep cost development under strict control within ever-tightening budgets.

Since its humble beginnings after World War II Health operational research and its many related disciplines has evolved and adapted in an effort to support health care management and policy planning in a multitude of ways, ranging from the efficient administration of blood-banks and laundry services to national level strategic planning and scenario development.

Modelling in different forms might be regarded as a cornerstone of operational research and quantitative analysis in general. From the start of health operational research different kinds of computer models have constituted a key element in the toolbox of the operational research practitioners, whether they have worked with long-term strategical problems or operational clinical applications.

Due to developments in computer hardware and software we witness today a tremendous increase in the possibilities to construct and use models. Modelling is no longer the exclusive realm of operational research. More and more models are used as standard tools in management and research ⁴⁸. Still, however, operational research practitioners might claim to possess special expertise and experience in the art of constructing and working with models and drawing conclusions from results produced by them.

What are the lessons we have learned? How can health care managers benefit from modelling - with or without operational research-analysts to guide them between the pitfalls? This is the subject of discussion in this article. After an introductory overview concerning the nature and objectives of modelling, some examples will be given of modelling applications from different areas in order to illustrate the versatility of the method. Further the choice of methods and models will be discussed with special attention to the problems of interpretation and implementation of results. From this overview some conclusions will be drawn as regards the advantages and disadvantages of modelling as tools for policy planning and decision-making in the health area. The paper will conclude in some observations concerning conditions for the future development in the field.

A number of applications will be cited along the text. However, due to the enormous expansion of the field the resulting list of model applications is far from exhaustive. Rather it should be regarded as an exposition of the current development in the field. Many of the examples - but far from all - are taken from presentations made at meetings of the EURO Working Group operational research Applied to Health Services under its 20 year existence. I am grateful to the colleagues in the Working Group for guidance and suggestions.

2. Models and modelling

Interpreted in its broadest sense a model is just a simplified image of some object under study. A model can be abstract or concrete, intuitive or formal, graphic or algebraic, hand-driven or computerised ... In this context, however, we will use the term "model" to mean an *abstract, formal - usually computerised - mathematical or logical description of some system of objects and activities*.

Modelling in the same vein will mean *the art of constructing and using such models as tools for analysing policy alternatives and evaluating operations* (after ⁷¹).

Confined to this form of models we can still distinguish important categories:

- analytic or simulation;
- deterministic or stochastic;
- static or dynamic;
- flow or discrete event;
- macro or micro ...

Another distinction concerns the way the model is constructed - using a general purpose programming language like C or Pascal, some kind of high-level simulation language as GPSS, Pascal_SIM or Professional Dynamo or simply a spread-sheet calculation programme like Lotus or Excel. More and more also statistical programme systems like SAS are used for modelling purposes, especially for micro-simulation.

Decision support systems combine modelling with the compiling and presentation of relevant planning data ^{25,26,62}. The model part might consist of simple calculations of indicators or more sophisticated estimations of resource consequences of alternative actions. In an expert system even the resulting recommendations are made an integral part of the model by being based upon the calculation results through more or less complicated mathematical and/or logical rules ^{9,42,52}.

3. The objectives of modelling

All models are basically tools for learning. Modelling aims at increasing the understanding of how systems function and making it possible to predict their response to different changes. Models make it possible to study systems that do not exist, to predict

complicated consequences of actions and developments and to do experiments, that are impossible or too costly to perform in reality.

In principle, models can be used to achieve three different objectives, or levels of ambition:

- a) making prognoses regarding the future development of the system (for example developing a model for predicting the future number of AIDS-cases ³⁶);
- b) evaluating decision alternatives by calculating outcomes of different choices (for example modelling the HIV/AIDS-epidemic in order to evaluate preventive strategies ³⁸);
- c) developing a deeper insight into the properties of the system and how it reacts to different stimuli as a basis for policy development (for example modelling with the purpose of achieving a better understanding of the dynamics of the HIV/AIDS-epidemic ^{35,41}).

Clearly the first objective puts the greatest demand on the quality of the model and the input data. Most models, however, have a less ambitious goal. A non-systematic scanning of the literature on modelling in health reveals that - from ca. 80 models described - around 20% aimed at making prognoses or at least calculate trends. For an equal proportion the objective was deliberately stated as providing insight or serving as a tool for education or training. The rest of the models, around 60%, were developed with the objective of supporting the evaluation of policy or decision alternatives.

However, it should be clear that models often serve dual purposes and that one purpose does not pre-empt another. Rather it should be the mark of the ideal model, that it gives as reliable predictions as possible with regard to the quality of data, describes fully and accurately the consequences of the policy alternatives and at the same time provides sound insight into the problem area. In practise of course there is no such thing and it is therefore advisable to be clear about the primary objective of the modelling effort.

The displacement of optimisation models by what-if-models should be seen as a sign, that insight is regarded as more valuable than picking the 'best' alternative. Also the increasing use of sensitivity analysis points in the same direction, reflecting that uncertainty and differences in objectives and out-look among decision-making actors are dominant features in the health area ^{17,37,54}.

4. Applications of modelling in the health area

As mentioned above the number of applications of modelling in the health area has grown tremendously over the past decades. Here only a few examples will be given in order to illustrate the versatility of the method.

• Epidemiology, health promotion and disease prevention

Models have been used among others for predicting future incidence, prevalence and mortality for a broad pattern of chronic diseases² or for different specific diseases, such as

cardio-vascular diseases ⁷, diabetes mellitus ³⁴ or dementia ²¹. Especially the field of HIV/AIDS has attracted a great number of applications ^{27,35,36,53}. In some cases there has also been a direct link towards the evaluation of intervention strategies ^{28,30,74} or disease control programmes ⁴⁷. Another aspect of this is modelling of risk factor development as basis for the planning of intervention strategies or information campaigns ^{38,9}. The evaluation of different screening programmes has also been the subject of many modelling applications ^{3,31,61,70}.

Health and care systems design

Models concerned with health and care systems design have among others been developed for estimating future resource needs in a health area ^{19,22,65}. Others have been more specifically directed towards hospital resource needs and capacity planning ^{57,72}. The introduction of managed markets in health care has prompted the development of models to assist in business planning ^{4,8}. In this context models are also used as training instruments for health care managers ²⁹. The design of emergency services - e.g. the optimal deployment of ambulances - has also been a popular field among modellers ^{23,45}.

Applications in community care have often taken the form of decision support systems, especially designed to take into account the multi-agent character of the decision-making process in this area ^{25,26,67}, c.f. below. Growing interest can also be noted in efforts to analyse systems effects on the individual level by micro-simulation models using databases containing data from a large sample of individuals ^{13,31,32}.

• Health and care systems operation

Models in this application area have as objective to improve performance by offering techniques for analysing how existing resources could be used in a more efficient way ⁶⁶. Traditionally this kind of application was confined to administrative issues - appointment systems and waiting line management ^{5,18,46,73}, staff scheduling and short-term prediction of demand ^{33,50}, the planning of auxiliary services ^{55,56,69} et cetera. Lately more specialized applications have been developed, like e.g. modelling-supported evaluations of information technology ^{1,68} or a model for analysing the diffusion of medical technology ¹².

An innovative approach towards improving efficiency of hospital operations was the visual simulation of a surgical unit tried by Jones and Hirst³⁷. Another new type of application in the area is the expert system for performance review developed by DHSS, United Kingdom, aimed at assessing operative performance in the NHS system⁹.

Models are now also more and more developed as support for analysis and decision in medical practice - either on the clinical level or in direct relation to the treatment of the individual patient. So-called *operational models* are developed as tools to be used by the medical practitioner for evaluation of various options for treatment, monitoring the progress of disease and improving current practice through appropriate comparisons ^{58,59}. Examples of diseases covered by such models comprise asthma ⁵⁸, HIV/AIDS and other sexually transmitted diseases ^{10,59}, diabetes ⁶ and coronary heart disease ⁶⁰.

Somewhere in-between clinic and administrative are models developed as tools for estimating resource needs and planning services for a specific disease ^{14,15}. A growing area is also constituted by models developed as aids in the treatment of the individual patient. This is exemplified by computer systems for assisting the clinical interpretation of tumour marker data ⁴² or simulating blood glucose profiles for patients with diabetes ²⁰. A final example is the model developed by Taylor et al describing the natural history of HIV/AIDS as a tool for design and interpretation of clinical trials ⁶³.

5. The choice of methods and models

As witnessed by the demonstrated array of different model applications many kinds of models for widely differing purposes exist by now. The choice of model category, method or programming system is of course many times determined by the problem under study. But it is a characteristic observation, that not seldom a subjective choice is involved - the modeller will choose the method or software system she or he is comfortable with and adapt it more or less successfully to the problem. This could be advantageous but there is also a risk that the choice of modelling technique will determine the assumptions that are made ¹⁵.

Despite this subjectivity there are some guidelines. Many authors in the health area agree that simulation models permit more flexibility and enforce less unwanted simplification than analytic models ^{10,16,35}. Of special importance here is the ability to describe interactions in a complicated process ^{16,31}. A very high degree of flexibility is provided by discrete-event simulation. The draw-back is that these models have a tendency to grow in size ¹⁵. In case you have a complicated problem it might, for this reason, be advantageous to develop different - often simple - submodels for treating different parts of the problem ^{5,41}.

Analytic models, on the other hand, make it possible to derive clear general principles in a way, which is difficult to achieve with simulation models. One example of this is the analytically derived concept of Basic Reproduction Rate, which is basic to all mathematical understanding concerning the spread of infectious diseases ³⁹. A disadvantage with stochastic simulation is also, that it - in principle at least - requires statistical analysis of the outcome and thus often leads to imprecise conclusions and/or high calculation times and costs ³⁹. A way of solving this problem is to use the so-called meta-modelling approach, i.e. to predict the result of a certain combination of parameters by using a regression model based upon a limited number of simulations ⁶⁹. Another solution is to use variance reduction techniques ¹⁵. High costs for development and validation are other arguments proposed against stochastic simulation ²³.

The alternative to stochastic simulation is to construct deterministic mean-value models. However, since in case of non-linearity "the output of the mean" is not equal to "the mean of the output", deterministic models could result in significant bias ⁵⁹. The suitability of the respective approaches will depend on the problem under study. For queuing problems a stochastic model clearly is needed. The same goes for all other cases where variability as
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such is a significant problem. Isham recommends in the case of modelling HIV transmission, that conclusions drawn from the application of deterministic models should be verified by simulation studies of stochastic models³⁵.

Simulation offers the possibility to construct very complex models. Simplification on the other hand is clearly the gist of all modelling ^{20,51,74}. Thus the guiding principle should be to construct as simple models as possible without loosing relevance with regard to the problem under study. This clearly puts an emphasis on the *purpose* of the modelling task. As phrased by Kretchmar et al: 'We do not want to reproduce reality; rather our aim is to understand the mechanism that relate causes to phenomena' ³⁹. It is also often pointed out models in the health area have to be simple and transparent in order to fit into the many-actor management power structure, that is characteristic of the health services ^{16,24,37,53}.

One example of a deliberate effort to take these circumstances into account is the application of visual simulation as tool for planning of a surgical unit. The author claims, that this resulted in 'instant face credibility', which obviously is a great help in the implementation of the model results, c.f. below ³⁷.

A more simple, but very effective, example is the graphical model first proposed by the Health Services operational research Unit at Strathclyde University in order to illustrate the fundamental properties of out-patient appointment systems ⁷³. A combination of "hard" and "soft" operational research approaches have also been tried in order to enhance acceptability ^{17,51}.

Being able to use existing data is sometimes pointed out as a desirable goal in modelling ⁷⁴. However, as will be discussed further below, the lack of a ready supply of data is almost always a restraint on modelling ^{14,16}. Also, not seldom an explicit purpose of modelling is to provide a guide to the sorts of data that needs to be collected ^{35,39}.

Optimization models now seem, generally speaking, to have been discarded in the health area, except for special logistics-oriented applications such as blood banks and ambulance deployment ^{23,56}. One reason for this seems to be their lack of transparency, which makes it difficult for the decision-makers to understand and assimilate the proposed solution ³⁷. Another important reason is the "many-objectives"-structure of many health care problems ⁵⁴, even though efforts have been made to circumvent this by optimising for one objective at a time ²³. Instead more and more models are used in 'what-if-model', i.e. as tools for increasing understanding and insight by varying input parameters and observing the outcome ³⁷.

The need to involve the decision-makers has also resulted in the development of 'modelling platforms', where the actual model is developed by the person(s), who 'own(s) the problem' using a set of pre-fabricated building blocks ¹⁸. The present software development is clearly favourable to the further advancement of this approach (c.f. below). Interactive models, where the user(s) can react to the result and change parameters in the search for a better solution, is another way of making models more suitable for handling complex planning problems with many actors involved ^{17,25,50}.

Among analytical techniques used in health modelling different forms of Markov processes seem to dominate. In describing random processes like disease progression or patient flows - whether analytical or by simulation - the Markov assumption, i.e. that transition probabilities are only depending on the present state, not the previous, is almost always used. Rather seldom, however, it seems that the assumption has been validated.

Advanced analytical techniques like equilibrium models, gravitation models or set covering et cetera have sometimes been used in health modelling ^{19,23}. It seems, however, that these kinds of application have been more confined to the academic scene without much impact on actual decision-making or policy planning. Recently network theory and the theory of random graphs have been proposed as basis for modelling the spread of HIV ³⁹. In this case the theory is used as basis for a conceptual model, upon which a Monte Carlosimulation model is built.

Micro-simulation, i.e. using a database containing data from a large sample of individuals for calculation of the effects of policy changes, on the other hand is a technique, that seems to attract growing interest for health applications - from estimating utilisation of home services for elderly to epidemiological analysis of effects of screening or risk factor intervention ^{13,31,32}.

Decision support systems have in later years increasingly been developed for use in clinical practice as decision support in the treatment of individual patients ^{20,42}. The models involved range from regression models to simulation. It is emphasised, that the models only serve as support, no automatic decision-making is involved.

The choice of software seems to a great extent be determined by what you have at hand. Main-frame applications have essentially disappeared - except for micro-simulation on very large databases. Instead, personal computers are used for almost all applications, sometimes in connection to a mini-computer. For simulation purposes the most common programming system in health applications seems to be Pascal (or Turbo-Pascal) and C (including variants). A special extension of Pascal, POST (Patient Oriented Simulation Technique), has been developed for modelling health care systems ¹⁴.

Spreadsheet applications are common for non-random calculation models - Excel or Lotus 1-2-3 ^{40,48,60}. Often then a user-friendly shell is developed in order to make the model easier to use for the lay-person ^{25,26}. Sometimes - though more seldom, judging from the health operational research literature - a special simulation language like INSIGHT or SIMSCRIPT or some variant of Systems Dynamics (Professional Dynamo, DYSMAP2, Stella) is employed ^{1,41,53}.

6. Interpretation and implementation of model results

The critical issues in modelling are clearly the interpretation of the results and how conclusions are transferred to the decision-maker, i.e. implementation. How valid are the

model results in relation to the decision problem? What conclusions are we permitted to draw? Do these conclusions reach the decision-maker(s) and are they perceived as relevant? Are they taken into account in policy planning, systems design or operations?

In order to be able to rely upon modelling results, one has to validate the model as well as possible. Ideally this means controlled comparisons with actual developments of the system under study. Often, however, this method is not possible to apply - either because the system and the conditions to be studied do not actually exist in reality or because there are too many factors influencing the actual results, that can not be controlled for. In these cases validation must take a different form - basically one has to judge in a systematic way, whether the results are correct or not ⁴⁹.

Judging from the literature, formal validation of health systems models is rather rare, or at least not reported. A typical example is one study, where there is a somewhat vague reference to "face validation": results were "compared with those that occurred in practice and found to be realistic" ¹⁴. In another case it was explicitly pointed out that validation was difficult depending on lack of data ³⁴.

However, there are some examples of more systematic efforts being made.

Epidemiological forecasting models on national scale were validated against local studies ⁷⁴. Calibration by comparison with earlier periods has been attempted in order to validate models concerning prediction of the spread of HIV virus ³⁹. This author applied the method of splitting the data in two periods and using the first period data to predict development during the second in the context of a model for simulating a system of long-term care for the elderly ⁴⁰. The critical problem turned out to be the lack of stability in the parameters. Knowledge of the past was simply not enough to predict the future!

In the majority of cases, however, it seems that health modellers prefer to rely upon indirect methods to ensure that their model results are valid and trustworthy. Concerning simulation models it is sometimes recommended to run extremely simplified cases, where the outcome can be calculated by analytic methods, and to compare the outcome ³⁹. One important rule is never to accept a model result, until you have found a logical, plausible explanation for it. This has also the advantage of making it easier to explain the results to the decision-maker. Clearly no one should accept policy advice, that just refers to a mysterious computer model which nobody understands the working of!

The more complex the model is, the more difficult it will be to detect mistakes and thus the more likely that they remain unnoticed. Unfortunately, purely technical mistakes are not uncommon. These may be trivial, like printing errors in input data, or more fundamental, like logical errors in the model structure. In both cases they may go unnoticed for long time. The best way of detecting them seems to be to use the model intensively and subject it to various tests by altering input parameters and assessing if the results are reasonable. Another source of errors goes back to inadequacies in the model structure. The model may not take all relevant factors in account or not duly reflect important relations between the system parameters.

The reason for this might be insufficient knowledge, misconceptions or even inherent limitations in the model language, for example regarding assumptions of linearity or continuity. Also, of course, erroneous or incomplete data may render model results unvalid. The old principle 'garbage in - garbage out' still applies despite all technological advances.

In all interpretations of model results it is important to be able to distinguish between 'real' effects and effects introduced by the modelling assumptions ³⁹. This becomes extremely important in management games and other circumstances, where models are used as explicit tools for education and training. If flying by the simulator tells a different story from real-life flying, you are in for nasty surprises!

Clearly it is not enough that the modelling effort has made the analyst wiser. The results of modelling and the deeper insight it has provided must also be transmitted to the person or group of persons who 'own(s)' the problem - the decision makers or policy planners.

This problem is eliminated if the model is designed in such a way that it can be used independently by the non-specialist. New software is increasingly making this possible, which obviously is a great advantage. However, there might also be the risk that the user is unaware of crucial assumptions hidden in the design of the model and thus prone to misinterpret results. Thus there is no short-cut to insight. Since models are not reality, you must be sure of what you have put in and interpret all results with this knowledge in mind.

The impact, that is achieved by successfully transmitting modelling results to the nonspecialist 'problem owner', is usually called 'implementation'. However, the concept implementation can be given a more or less ambitious interpretation. In the most strict sense implementation would require, that the recommendations from the models are actually carried out and this is qualified by the extent to which modelling contributed to the process ⁶⁴. In reality this level of implementation is a very rare - not to say abnormal state of affairs. Actual policy planning and decision-making in the health area depend of a lot of different factors, many of which will never be captured by a quantitative model ^{37,51,54}. A characteristic element of this sector of society is the delicate balance of power between politicians, administrators and professional actors.

(Note: This holds as long as a dominant part of the health care is paid for by a third party - government or sickness funds - as is the case in most European countries).

It has been noted that in this 'power game' model results and data in general are used more as instruments for persuasion rather than analysis ³⁷. Model results can not shift the fundamental power balance in the health care system ³⁷. However, they can change the nature of the debate by making consequences of different options more clear to the participants. Later model developments have explicitly recognized these circumstances and adapted to their demands. Thus there are many examples of models now, whose

main objective is to provide a common area of discussion for the different participating actors, where different options can be sorted out and discussed ^{16,25,26,37,51,72}.

A more realistic concept of implementation would imply, that the model results have been introduced into a real policy planning or decision-making process and been accepted as valid at least by a part of the participants in that process ¹⁷. Lack of implementation - by any standard! - has previously been a main source of criticism of modelling in the health area ¹⁸. According to a survey by Tunnicliffe Wilson, 1981, only 16 out of 200 model projects reported recommendations which had been acted upon ⁶⁴. However, the situation now seems to have improved considerably. Judging from the (non-complete) literary survey mentioned above it seems, that a third of the model projects had been implemented in the sense defined above, a third were of a character that made the question of implementation meaningless (c.f. below). Of the rest, implementation was not achieved (or attempted) for one half and not reported for the rest.

In many cases implementation in the sense defined above may not be an issue. Some model applications refer to questions for the general health debate, as for example the future development of cancer or the likely effects of introducing a home service program ^{13,74}. In this case obviously publishing the report or research article is an implementation in itself. Applications in epidemiological research often fall into the same category ^{21,34}. The same goes for example for advice on national screening programs or evaluation of alternatives for primary prevention ^{3,39,43}.

7. Advantages and disadvantages of modelling

What contributions have health managers and other actors in the health area received from the rapidly increasing modelling activities in the field? What are the advantages and disadvantages of the modelling approach? In answering this question by going through the literature one is referred of course to the modeller's point of view, since health care managers rarely find time to write research papers. However, with this limitation in mind one can sample a host of opinions - as should be expected mostly, but not entirely, positive! - concerning the value of modelling.

In the centre lies of course the basic observation that models are there for calculation! Their main contribution thus is to provide quantitative estimates concerning the systems or processes they describe. Using a model you can arrive at quantitative predictions concerning the effect of proposed organisational changes or actions ^{17,25,61,72}. Models can also be used as tools for evaluating alternative plans, or as basis for the development of alternative scenarios describing future strategic options ^{2,11,36,68}.

Generally speaking, models make it possible to study the interaction and joint impact of several different factors of importance for the decision problem ^{31,61}. A more special advantage is the ability to describe and clarify complicated dynamic processes ⁷⁴ or the dynamic impact of behaviour response ¹³. Modelling also offers an opportunity to investigate the effect of many different alternatives in situations, where actual experiments

are *impossible* - e.g. because the problem refers to a future situation - or *too costly, time-consuming, risky or unethical* - for example because of patient considerations.

Modelling an operational system - e.g. an emergency admission system - makes it possible to do experiments with very little interference on the daily routine ¹⁸. As for clinical applications ethical or safety reasons may play an important role. For example, in the case of modelling the natural history of HIV-infection the reported advantage was the opportunity to obtain a proxy for the control group in a case, where non-treatment was ethically impossible ⁶³.

Equally important as these tangible calculation results are, according to many authors, a host of indirect effects of modelling. Improved insight into the system under study is often cited as an advantage of modelling - e.g. 'simulation offers the possibility to investigate the mechanisms by which changes in performance in a system occur ' 68 ; 'the mathematical modelling of HIV-infection contributed to better understanding the course of the AIDS/HIV epidemics' 36 ; 'all the cases report improved insight into the functioning of the hospital as a whole' 72 .

Modelling a system will highlight the interdependence of the different parts of the health organisation and by this support a system's approach to the planning or decision problem ⁷². Another phenomenon of the same kind is encountered in modelling the interplay between different chronic diseases ².

By the "what-if"-approach it is possible to learn how the system responds to different changes in assumptions and reveal decisive factors ^{45,50}. Modelling a process like admission could also serve to identify bottle-necks and congestion points ¹⁸. In this way it will be possible to estimate the potential for improvements and suggest changes in the organisation ^{5,73}.

Another important, often pointed-out, advantage of modelling, concerns the potential of models to act as a focus of discussion for the different actors involved in the decision-making process²⁵. By modelling it is possible to create a shared understanding about the problem ^{16,23,51,72}. As mentioned above models are now deliberately being designed with this purpose in mind. Rather than present <u>the</u> solution, the model will explore alternatives and submit them to the group of involved actors in an interactive way ^{25,17}. The model is then seen as a tool for communication and an element of the planning process ⁵⁰. Modelling can also contribute to the integration of results from different scientific disciplines, that are relevant with regard to the system under study - epidemiology, sociology, economics et cetera ³⁶.

A further side-effect of modelling is, that it forces the model-builder into a deeper insight into the logic of the system under study and the way it operates. Model-building thus might contribute significantly to the clarification of the decision problem, even if the model is never actually used! One effect of this kind is highlighting the need for more and better data ^{25,34,58}. Modelling will show which data are of real importance for the analysis and therefore help to focus data collection ³⁹. Models put data in a context and will show, if existing data are inconsistent, as for example epidemiological data on incidence, prevalence and mortality ^{21,34}, or delimit the area of data-compatible assumption domains of data ⁴⁴. Typically model-building will help in posing the right questions ³⁹ and even initiate a host of questions concerning the system, that never have been asked before! In this way modelling can also be of assistance in the definition of research needs ³⁶.

The advantages of modelling thus obviously are numerous. Then what about disadvantages? The most important one is of course that models are not reality! The model will reflect the modeller's view of reality and this might be biased in different ways ^{50,68}. One also has to be able to decide, which of the observed effects pertain to the modelled system and which are derived from the specific way it has been modelled ³⁹.

Another often-quoted disadvantage of modelling is that it is a time- and cost-consuming activity ⁶⁸. Especially the collection of data can involve a large effort ^{16,64,72} and models are sometimes perceived as posing unreasonable demands on data collection ⁵⁴. One the other hand it has been reported that model projects, that emphasise on prudent data collection, stand a higher chance of successful implementation ⁶⁴.

Technical problems might also create an obstacle to full implementation. A survey of the use of a model-based decision support system for health authority HIV/AIDS-services planning (AIDSPLAN) revealed that rather few holders of the system actually used it for examining resource consequences. It was felt that there was a need for additional technical support ²⁶.

A criticism of a somewhat different kind concerns the shift in problem perspective, that might accrue from the 'wholesale' quantification inherent in modelling ⁵⁴. In his general critique of the operational research contribution to health planning Rosenhead referred among others to the 'scientisation' of problems inherent in the 'high-tech' operational research approach. Combined with the alleged socio-political simplicity this approach was according to Rosenhead 'highly inconsistent with aspirations to open up decision-making to those who must experience the result of the decisions'. Instead Rosenhead recommended approaches that:

- 'make reduced demands on data;
- · reject optimisation in favour of co-ordination;
- accept uncertainty and leave options open;
- are not restricted to hierarchical deduction, but facilitate participation and do not attempt a technocratic abolition of politics¹⁵⁴.

Judging from the development, since Rosenhead published this important critique in 1978, many modellers in the health field - though perhaps not all - have taken his points to heart. This is undoubtedly an important reason, why the implementation record now seems to be in a much better shape. Whether 'high-tech' or 'low-tech' the problem must clearly be of some size and generality in order to justify a modelling approach. It is

therefore somewhat discouraging to learn, that general results of modelling 'do not transfer easily between sites' ⁷³. Thus more efforts should be made to disseminate general findings and methods in order to avoid duplication of work. The EURO Health operational research Working Group is obviously a possible vehicle for intensified activities of this kind.

8. Directions for future development of models

A rapid development in the area of modelling in health is at present. Technological progress in software and hardware has simplified the construction and use of computer models enormously. Personal computers with capacity, that supersedes the main-frames of the not-so-distant past, have made it possible to run models in the ordinary office involving calculation volumes, that previously were either impossible or confined to very special and expensive applications. Spreadsheet systems for personal computers, as Lotus and Excel, have eliminated the need for expert programming competence, when constructing simple computer models like budget simulations et cetera. Also several simulation systems - such as e.g. Professional Dynamo - are available now to simplify the construction of more complicated, dynamic models. Systems simulation as a tool for health services management can thus now be done with equipment and software found in the average office environment ⁴⁸.

Secondly, the increased capacity of computers has made possible the construction of much more complicated, detailed models, while at the same time drastically reducing the cost and time of computation. Models can in this way be made more realistic and accurate. Also new graphical techniques have been developed that simplify the interpretation of results and increase the potential impact of presentation.

The speed of development is such that entirely new possibilities open up from one year to the next. Today, models combining text, graphics, moving pictures and even sound can be developed using multi-media techniques. Models can also easily be transferred between users all over the world on the Internet. In the future lies 3-D, dynamic, 'virtual reality' displays blurring the line of division between model and reality to the extent that in the end there might be an actual risk for mistaking one for the other!

It should be sobering then to recollect the basic observations made by many authors cited or referred to in this article. The crucial element of modelling still is *simplification* - to extract from the system under study all those components and relations, that are most relevant with regard to the modelling purpose, without becoming bogged down by excessive detail. Models are essentially tools for learning and never - except for playing purposes - ends in themselves. To support the complex decision process inherent in a human-oriented activity like health care, models must be able to involve people - not excluding them. The intelligent use of models carries an enormous potential. The more models are used and the more normal this use is felt by the final users, the more obvious will these observations also seem. The operational research community has a role in promoting this development, but the days of ownership to the modelling approach are over. Health care management will still have many problems to solve - not using models would seem a waste in the face of all opportunities. After all, technology is there to benefit from, or?

References

- 1. Anderson, J.G. et al., 'Physician use of clinical information systems: a computer simulation' in: Duru, G., Engelbrecht, R., Flagle, C.D., van Eimeren. W.(eds.). Proceedings of the 4th International Conference on System Science in Health Care, Lyon 4-8 juli 1988, Masson, Paris, 1988.
- Barendregt, J.J., and Bonneux, L., 'A multi-disease model of public health', in: Chytil, M.K., Duru, G., van Eimeren, W., and Flagle, C.D.(eds.), <u>Proceedings of the</u> <u>5th International Conference on Systems Science in Health Care</u>, Omnipress, Prague, 1992.
- 3. Beech, R., <u>Population carrier screening for cystic fibrosis: analysis and ethics come face to face</u>, Paper presented at EURO XIII, Glasgow, July 19-22, 1994.
- 4. Beech, R., Larkinson, J., 'Estimating the finacial savings from maintaining the level of acute services with fewer hospital beds', <u>International Journal of Health Planning and Management</u>, 5 (1990)89-103.
- 5. Bennett, J.C., 'A flexible approach to improving outpatient clinic organisation', Paper presented at 20th meeting of the Working Group OR Applied to Health Services 31 July- 4 August 1994, Technical University of Chania, Chania, Greece.
- 6. Blayden, L.J., Jones, S.K., Shahani, A.K. <u>Operational models for the care of people</u> with diabetes. Paper presented at EURO XIII, Clasgow, July 19-22, 1994.
- 7. Bonneux, L., Barendregt, J.J., 'Estimating and forecasting morbity due to cardiovacular disease in the Netherlands', in: Chytil, M.K., Duru, G., Van Eimeren, W., and Flagle, C.D. (eds.), <u>Proceedings of the 5th International Conference on Systems Science in Health Care</u>, Omnipress, Prague, 1992.
- 8. Bowen, T., 'Implementation of a business planning mode', Paper presented at the 20th meeting of the EURO Working Group on OR Applied to Health Services, Chania, Greece, July 31 Aug 4,1994.
- 9. Bowen, T., Payling, L., 'Expert systems for performance review', <u>Journal of the</u> Operational research Society, 38 (1987) 929-934.
- 10. Brailsford, S.C., Shahani, A.K., Roy, R.B., Sivaplan, S., 'Simulation modelling for HIV infection and AIDS', Journal of BioMedical Computing, 31 (1992) 73-88.
- 11. Brommels, M., Linnako, E., 'Acute myocardial infarction prediction of future need for hospital care by use of scenario analysis', Paper presented at the 5th Nordic Health Economists Study Group Conference, Reykavik, April 26-28, 1984.
- 12. Chrzanowski, R.S., 'Diffusion of medical innovations. Microcomputer dynamic model', in: Duru, G., Engelbrecht, R., Flagle, C.D., Van Eimeren, W. (eds), <u>Proceedings of the 4th International Conference on System Science in Health Care,</u> Lyon 4-8 juli 1988, Masson, Paris, 1988.
- 13. Coughlin, T.A., McBride, T.D., Perozek, M., Liu, K., 'Home Care for the Disabled Elderly: Predictors and Expected Costs', <u>Health Services Research</u> 27:4 (1992)453-479.

- 14. Davies, R., 'Simulation for planning services for patients with coronary heart disease', European Journal of Operational research 71 (1994) 323-332.
- 15. Davies, R., 'An Assessment of Models of a Health System', Journal of the Operational Research Society 36 (1985) 679-687.
- 16. Davies, R., Davies, H.T.O., 'Modelling patient flows and resources provision in health systems', <u>Omega International Journal of Management Science</u>, 22 (1994) 123-131.
- 17. Davies, R., Goddard, A., 'Soft OR and a Markov model help plan a psychogeriatric service', <u>Omega International Journal of Management Science</u>, 22 (1994) 601-611.
- 18. De Oliveira, M.J.F., 'A patient-oriented modelling of the emergency admission system of a Brazilian hospital', Paper presented at EURO XIII, Glasgow, July 19-22,1994.
- 19. Delorme, L., and Rousseau, J-M., 'A multiregional equilibrium model for resource allocation in a health care system (MEMRA)', <u>Departément dinformatique et de recherche operationelle, Université de Montréal</u>, Publication #42, 1982.
- Deutsch, T., Lehmann, E.D., 'A clinical model for simulating blood glucose profiles', in: Chytil, M.K., Duru, G., Van Eimeren, W., Flagle, C.D. (eds.), <u>Proceedings of the 5th International Conference on Systems Science in Health Care</u>, Omnipress, Prague, 1992.
- 21. Dewey, M., 'Estimating the incidence of dementia in the community from prevalence andmortality results', <u>International Journal of Epidemiology</u> 21 (1992) 533-536.
- 22. DHSS Operational research Service, 'An introduction to the acute bed planning system', <u>Department of Health and Social Security</u>, London, 1987.
- 23. Eaton, J. et al., 'Determining emergency medical service vehicle deployment in Austin, Texas', <u>Interfaces</u> 15 (1985) 96-108.
- 24. Forte, P., 'Data rich, information poor: Data, information and decision support in the NHS', European Journal of Information Systems 3 (1994) 148-154.
- 25. Forte, P., Bowen, T., 'Improving the balance of elderly care services: recent applications', in: Rey, J-C., Tilquin, C. (eds), <u>SYSTED94: Dependency, the challenge for the year 2000</u>, Swiss Institute for Public Health, Lausanne, 1994.
- Forte, P.G., Rizakou, E.N., Rosenhead, J.V., 'A decision support system for planning the provision of HIV/AIDS-related services', in: Kaplan, E.H., Brandeau, M.L. (eds), <u>Modelling the AIDS epidemics: Planning, Policy and Prediction</u>, Raven Press Ltd, New York, 1994.
- 27. Fusaro, R.E. et al., 'An annotated bibliography of quantitative methodology relating to the AIDS epidemic', <u>Statistical Science</u> 4 (1989) 264-281.
- 28. Gove, D.J., et al., 'Modelling intervention strategies for trachoma control', <u>Paper</u> presented at EURO XIII, Glasgow, July 19-22, 1994.
- 29. Gruetz, M., 'A computer-based management game for training administrative decision-making in hospitals', in: Trappl, R. (ed.), <u>Cybernetics and Systems '88</u>, Kluwer, Amsterdam, 1988.
- 30. Gunning-Schepers, L., <u>The Health Benefits of Prevention</u>, Instituut Maatschappelijke Gezondheidszorg, Erasmus Universiteit, Rotterdam, 1989.

- 31. Habbema, J.D.F., Van Oortmarssen, G.J., Lubbe, J.T.N., Van der Maas, P.J., 'The MISCAN simulation program for the evaluation of screening for disease', <u>Computer Methods and Programs in Biomedicine</u>, 20 (1984) 79-93.
- 32. Heidenberger, K., 'Health related product innovation in life insurance: a microsimulation based decision system', <u>Paper presented at EURO XIII</u>, Glasgow, July 19-22, 1994.
- 33. Hershey, J., Pierskalla, W., Wandel, S., 'Nurse staffing management', in: Boldy, D. (ed.), <u>Operations Research applied to health services</u>, Croom Helm, London, 1981.
- Hoogenveen, R.T., Ruwaard, D., Verkleij, H., 'Modelling the prevalence of chronic diseases', in: Chytil, M.K., Duru, G., Van Eimeren, W., Flagle, C.D. (eds.), <u>Proceedings of the 5th International Conference on Systems Science in Health Care</u>, Omnipress, Prague, 1992.
- 35. Isham, V., 'Mathematical Modelling of the Transmission Dynamics of HIV Infection and AIDS: a Review', Journal of the Royal Statistical Society A 151 (1988)5-30.
- Jager, J.C., Ruitenberg, E.J., 'Mathematical modelling of HIV infection', in: Baert, A.E., Koch, M.A., Montagnier, L., Razquin, M.C., Tyrell, D. (eds.), <u>Biomedical and</u> <u>Health Research</u> Volume VI, AIDS Research at EC Level, IOS Press, (1995) 36 -48.
- 37. Jones, L.M., Hirst, A.J., 'Visual simulation in hospitals: A managerial or a political tool?', European Journal of Operational research 29 (1987) 167-177.
- 38. Kaplan, E.H., 'Needles That Kill: Modelling Human Immunodefiency Virus Transmission via Shared Drug Injection Equipment in Shooting Galleries', <u>Reviews of</u> <u>Infectious Diseases</u> 11 (March-April 1989) 289-298.
- 39. Kreitchmar, M. et al., 'Network models from paradigm to mathematical tool', in: Kaplan, E. H., Brandeau, M.L. (eds.), <u>Modelling the AIDS epidemics: Planning</u>, <u>Policy and Prediction</u>, Raven Press Ltd, New York, 1994.
- 40. Lagergren, M., 'Dependency and the structure of care some results from simulation of an area-based system of care', <u>Health Policy</u>, 29:3 (1994)229-246.
- 41. Lagergren, M., 'A family of models for analysis and evaluation of strategies for preventing AIDS', in: Jager, J.C., Ruitenberg, E.J. (eds.), <u>AIDS impact assessment,</u> <u>Modelling and Scenario Analysis</u>, Elsevier, Amsterdam, 1992.
- 42. Leaning, M.S. et al., 'Computer system for assisting with clinical interpretation of tumour marker data', <u>British Medical Journal</u> 305 (1992) 804-807.
- 43. Leermakers, H.A.F., 'A case study of the CHT-screening process', Paper presented at EURO XIII, Glasgow, July 19-22, 1994.
- Habbema, J.D.F., Van Oortmarssen, G.J., Lubbe, J.T.N., Van der Maas, P.J., 'Model building on the basis of Dutch cervical cancer screening data', <u>Maturitas 7</u> (1985) 11.
- 45. Lubicz, M., Mielczarek, B., 'Simulation modelling of emergency medical services', <u>European Journal of Operational research</u> 29 (1987) 178-185.
- 46. Mattson, L.G., Weibull,J. W., 'A dynamic queue model with time-dependent demand', Royal Institute of Technology. Research Group for Urban and Regional Planning, Stockholm, 1981.
- 47. Meima, A., 'LEPROSIM: simulation model for leprosy control programmes'. Paper presented at EURO XIII, Glasgow, July 19-22, 1994.
- 48. Milsum, J.H., Brauer, M.A., 'Health care system optimization using microcomputer spreadsheet technology: a case-study of waiting-times cost trade-offs', In: Duru, G.,

Engelbrecht, R., Flagle, C.D., Van Eimeren, W. (eds.), <u>Proceedings of the 4th</u> <u>International Conference on System Science in Health Care</u>, Lyon 4-8 juli 1988, Masson, Paris.

- 49. Naylor, T.H., <u>Computer simulation experiments with models of economic systems</u>, Wiley, New York, 1971.
- 50. O'Kane, P.C., 'A heuristic approach to designing efficient nurse duty rotas', Paper presented to the 10th Annual Meeting of EURO Working Group on Operations Reasearch Applied to Health Services, Altavilla, June 1984.
- 51. O'Keefe, R.M., 'Investigating outpatient departements. Implementable policies and qualitative approaches', Journal of the Operational research Society 36 (1985)705-712.
- 52. O'Keefe, R.M., Belton, V., Ball, T., 'Experience with using expert systems in operational research', Journal of the Operations Research Society 37 (1986) 657-668.
- 53. Roberts, C., Dangerfield, B., 'Modelling the epidemiological consequences of HIV infection and AIDS: A contribution from Operational research', Journal of the <u>Operational research Society</u> 41 (1990) 273-289.
- 54. Rosenhead, J., 'Operational research in health services planning', European Journal of Operational research 2 (1978) 75-85.
- 55. Sandblad, B., 'Modelling and simulation for planning and benefit/cost analysis of health care services systems', <u>Medical data processing symposium</u>, Taylor & Francis Tolouse, 1976.
- 56. Sapountzis, C., 'Mathematical programming models in allocating units of blood to hospital blood banks', Paper presented at EURO XIII, Glasgow, July 19-22, 1994.
- 57. Shahani, A.K., Gove, D.J., Hewett, D.J., 'Hospital capacity models', Paper presented at EURO XIII, Glasgow, July 19-22, 1994.
- Shahani, A.K., Korve, N., Jones, K.P., Paynton, D.J., 'Towards an operational model for prevention and treatment of asthma attacks', University of Southampton No. OR54 (1993).
- 59. Shahani, A.K., 'Operational models for dealing with sexually transmitted diseases', <u>Upsala Journal of Medical Sciences Supplement</u> 50 (1991) 30-32.
- 60. Sherlaw-Johnson, C., Gallivan, S., Patterson, D.L.H., Treasure, T., 'Auditing and evaluating the long-term progression of coronary artery disease', Paper presented at EURO XIII, Glasgow, July 19-22, 1994.
- 61. Sherlaw-Johnson, C., Gallivan, S., Jenkins, D., Jones, M.H., 'Cytological screening and management of abnormalities in prevention of cervical cancer: an overview of stochastical modelling', Journal of Clinical Pathology 47 (1994) 430-435.
- 62. Sprague Jr, R.H., Watson, H.J., <u>Decision Support Systems: Putting Theory into</u> <u>Practise</u>, Prentice-Hall, Englewood Cliffs, New Jersey, 1986.
- 63. Taylor, J.M.G. et al., 'Applications of a computer simulation model of the natural history of CD4 T-cell number in HIV-infected individuals', <u>AIDS</u> 5 (1991) 159-161.
- 64. Tunnicliffe Wilson, J.C., 'Implementation of computer simualation projects in health care', Journal of Operational research Society 32 (1981) 825-832.
- 65. Tunnicliffe Wilson, J.C., 'A Review of Population Health Care Problems Tackled by Computer Simulation', <u>Public health</u> 94 (1980)174-182.

- 66. Tunnicliffe Wilson, J.C., 'A Review of operational problems tackled by computer simulation in health care facilities', <u>Health and Social Service Journal</u> 90 (1980) B73-B80.
- 67. Vaissi, E., 'Conceptual framework for the levels of care in the 'Turku Model'', in: Vaarama, M., Kaakinen, J. (eds.), <u>The Need, Requirements and Contents of the</u> <u>European Database on the Elderly Policy/Services. Proceedings from the COST 5</u> <u>workshop, Helsinki, 2-4 March, 1994.</u>
- 68. Van der Loo, R.P., Van Gennip, E.M.S.J., Bakker, A.R., and Rutten, F.F.H., 'The use of modelling and simulation as tools for the economic evaluation of information technologies in health care', in: Chytil, M.K., Duru, G., Van Eimeren, W., Flagle, C.D., <u>Proceedings of the 5th International Conference on Systems Science in Health Care</u>, Omnipress, Prague, 1992.
- 69. Van Merode, G.G. et al., 'Decision support for clinical capacity planning', International Journal of Bio-Medical Computing 38(1995) 75-87.
- Van Oortmarssen, C.J., Habbema, J.D.F., Lubbe, J.T.N., Van der Maas, P.J., 'A model-based analysis of the HIP project for breast cancer screening', <u>International</u> <u>Journal of Cancer</u> 46 (1990) 207-213.
- 71. Vemuri, V., Modelling of complex system, Academic press, San Diego, 1978.
- 72. Vissers, J., <u>Patient flow based allocation of hospital resources</u>, Doctoral thesis, Eindhoven University of Technology, Eindhoven 1994.
- 73. Worthington, D., Brahimi, M., 'Improving out-patient appointment Systems', International Journal of Health Care Quality Assurance 6 (1993) 18-23.
- 74. Yamaguchi, N. et al., 'Evaluation of Cancer Prevention Strategies by Computerized Simulation Model: Methodological Issues', <u>Environmental Health Perspectives 102</u> Suppl. 8 (1994) 67-71.

Shifting The Balance Of Health Care Into The 21st Century

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1. Introduction

Many forces are driving shifts in the balance of health care in Europe and indeed the world. Demographic, epidemiological and socio-economic developments drive demand ^{1,2}. Medical, information and wider technology developments enable provision ^{3,4}. Changes in public expectations and in ways of financing and structuring health services connect these developments together. This paper sets out some of the present or likely future key shifts in the pattern and balance of health care, and indicates some ways in which ORMS can assist in their management.

2. Five Shifts

The introduction said something about **why** the shifts in patterns of care are happening. Remembering the other members of Kipling's group of servants ^{*i*}, five of the key shifts are now identified and discussed. They are:

- When care is delivered; the balance between prevention and treatment;
- Where it is delivered; the balance between institutional and community care;
- How it is delivered: the balance between patient and professional involvement in care;
- What is delivered; the balance between knowledge and habit based care;
- Who is cared for; the balance between care of one group and another.

Prevention and Treatment

From the days of the development of medicine in China it has been appreciated that treating people when they fall ill is something of a second best, far better surely to prevent them falling sick in the first place. (In dynastic China, doctors were paid only when their patients were healthy!) In more recent times the growth of public health medicine, where the potential of interventions at population level to improve health is emphasised, has been a testament to the power of the "prevention and promotion" paradigm.

We are however seeing, and likely increasingly to see, a further shift in the balance between prevention and treatment. The WHO "Health for All" strategy 5 (and in England the "Health of the Nation" White Paper) 6 give it a high profile. The shift has a number of

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" I keep six honest serving-men. They taught me all I knew. Their names are What and Why and When. And How and Where and Who." underlying causes. Firstly, more attention is being paid to the outcomes of health care; people are less likely to assume that treatment is necessarily always beneficial. Such attention includes considering quality of life; which may result in a decline of some forms of "heroic medicine". Secondly the ability of medicine to anticipate the development of illness is increasing; we are moving from a "diagnose and treat" approach to one of "predict and manage". Nowhere is this more apparent than in the area of genetic screening, it will be increasingly possible to have one's own "future health profile", showing your levels of risk for various morbidities, which you will discuss with your doctor to agree the appropriate preventative measures. Thirdly, though less certainly, a greater emphasis on prevention might be cheaper, though this will depend on being able to select the most cost-effective preventative interventions and on how any knock-on effects, e.g. on lifespan and the health of elderly people, work out ^{7,8,9,10}.

Institution and Community

There has been for twenty or thirty years now in much of Europe, a shift away from providing care in an institutional setting to looking after people in the community or even in their own homes. A key reason for this shift is simply that it is what most patients and most professionals prefer. (Hopes that it might also be cheaper have largely proved optimistic, higher quality tends to come with a higher price tag).

This shift continues and indeed accelerates¹¹. It has spread from chronic care, such as for mentally handicapped or mentally ill people, to acute care; day cases in hospitals for instance have risen enormously over the last ten years. (So much so that in the UK there is a public education job to be done to explain that the number of hospital beds is no longer a good measure of the adequacy of local health care provision!) As with chronic care, shifts in acute care are being driven partly by technological change; for instance new drugs, bedside diagnostic tests ¹² and minimal access surgery ¹³, partly by a drive for increased efficiency and partly by structural change; in England for example the devolution of powers and finance to primary care practitioners (notably the GP fundholding initiative) ¹⁴.

This shift inevitably puts new demands on care in the community, for instance shorter lengths of stay and increased day cases means more intensive nursing and GP care after people have left hospital. The shift has not been without its upsets. For instance sometimes for mentally ill people "the community" has not been too keen, or even there, to receive them - and there has been some professional pressure for retaining some institutional provision, notably by the "sanctuary" lobby.

The shift is not absolute. People will move between institutional and community care. Indeed managing that interface is where many of the problems lie. In England there is current debate about the respective roles of the NHS and local social services, a debate in which financial considerations, including the balance between public and private funding, play a significant part. The goal however must be to ensure that people are maintained in a care setting that is most appropriate to their needs and makes best use of the resources available. This requires collaboration between the parties involved, and better knowledge of the dynamics of continuing care.

Neither is the shift entirely one way; best treatment and care of, say, patients with less common cancers is increasingly recognised to require concentration of expertise and hence specialist centres ¹⁵. The same may be true of accident and emergency care, as ambulance services increasingly have paramedics who can give good first line treatment (is this "care in the community"?!) the trade-off between the proximity of smaller and the facilities in larger hospital A&E departments shifts towards the latter. One effect of these twin centrifugal and centripetal shifts is that careful consideration will need to be - is being - given to the future role of the local general hospital ^{16,17,18,19,20}.

Patient and professional

Traditionally patients had little knowledge, power or involvement in medical matters. This is changing. Rises in "consumerism" affect public expectations of health services. In England for example the National Health Service has a "Patients Charter" ²¹, as part of a more general Government initiative, setting out what people can expect in the way of service standards. Patients increasingly expect to be more involved ²² in decisions about what sort of treatment to receive, where to get it and when it will be given. Investigation has shown that, when informed fully about the possible consequences and their probabilities, patients facing say, prostatectomy, are quite likely to opt for "watchful waiting" rather than for immediate surgery - in contrast to some surgeons!

There are related shifts on the professional side too ^{23,24,25}. Traditional boundaries between professions shift, become fuzzy or even dissolve as factors of patient preference, aspirations of different professional groups, and managerial concerns to increase efficiency and improve quality combine to promote, say, midwife led maternity care, nurse practitioners ^{26,27} or clinical pharmacy ²⁸. The role of informal carers is becoming increasingly important, though in some countries will come under increasing pressure as changes in demography and in family structure increase the proportion of very elderly people needing care and simultaneously reduces the proportion of carers. Lastly, such shifts will extend to more self-care. Not, one imagines, to do-it-yourself appendectomies, but certainly to a continuing rise in expenditure of effort, and money, on personal fitness.

This rise of what is often called "patient empowerment" will have a major influence on the role of health care professionals in future. Their job will to some extent shift from looking after patients to enabling people to look after themselves. Even where direct care is concerned its nature will shift, the example of minimal access surgery is familiar but what, say, about dentistry when there is effective immunisation against tooth decay? This may be ten, twenty or thirty years ahead but that is well within the professional lifespan of today's students. Will training shift sufficiently quickly?²⁹

Knowledge and habit

It has been said that half of all medical treatment is ineffective, the problem is that we do not know which half. This may have been, or still be, true but is changing ^{30,31}. Firstly our knowledge of theoretical basis of medicine constantly improves. For instance, the advances in molecular genetics mentioned earlier are not confined to screening, this knowledge is extending to allowing a revolution in the informed design of drugs - pharmacogenetics - and in

general to the major new field of genetic therapy ³². Secondly, advances are occurring too in the assessment of the efficacy of treatment. The pioneers of "evidence based medicine", such as Codman or Cochrane, set in motion changes that are still gathering pace. In England for example the Department of Health has produced a national strategy for health R&D and established a "Cochrane Centre", an "Outcomes Clearing House" and an "Effectiveness Bulletin" to gather, collate and distribute evidence on effective treatments ^{33,34}. These initiatives give particular weight to experimental evidence from control trials, but the growth, enabled by advances in information technology, in comprehensive databases of patients, treatments and their results should also generate much valuable knowledge ³⁵.

Lack of knowledge is not the whole problem, there are many examples of often ineffective procedures, such as tonsillectomy, which continued to be carried out in bulk for long after their deficiencies were known or effective ones, such as early thrombolytic therapy for myocardial infarction, which were not implemented before years or even decades had passed. Knowledge must be translated into action. One key aspect of this is to challenge unreflective habit. One such challenge may be produced by the observed trend to increased use of litigation, although any resulting rise in "defensive medicine" would seem a dubious blessing. A happier pressure comes from the, growing, use of medical audit. Finding really effective ways to bring about desirable changes in the practices of health care professionals is area of increasing research interest ^{36,37,38,39}.

Evidence based medicine will be more effective, and, as information on costs is increasingly gathered together with that on efficacy 40 , more cost effective. Whether it is also cheaper however depends on how far more knowledge leads to more treatment. For example, the evidence that beta-interferon can help in the treatment of multiple sclerosis comes, for the UK, with a price tag of £200m a year.

One Group....and Another?

Lastly, and probably most problematically, what about shifts of care between different groups in the population? The most obvious example is in care of the elderly. Most European countries are facing increases in the proportion of the population who are over 75 years old, so just to stand still a higher proportion of health and social care resources will need to be devoted to that group. How much of the cost of care of elderly people will come from public funds? Will views about care of people with diseases of old age change with a likely continuing rise in afflictions like Alzheimer's that seem almost to create a no-man's land between life and death? Will social attitudes about old age shift with a rising number of healthy and active elderly people? Will the rising proportion of elderly people give them more political clout? Important questions for anybody planning health care, and remember; the old are just us a few decades ahead!

There are even wider, and thornier, issues. Where resources are limited priorities have to be set, and deciding what treatments, what conditions or what groups are to get priority is not an easy task. How are the various objectives of health care systems - effectiveness, efficiency, economy, equity, accessibility, responsiveness and so on - to be reconciled? Which decisions can sensibly be made centrally or managerially and which are best left for local or professional consideration?^{41,42,43,44} We already see debates about the relative rights to treatment of the

"deserving" and the "non-deserving" (e.g. heavy smokers) ill. Will these be increased by the accelerating genetic lifting of the "Rawlsian veil of ignorance" about who is susceptible to what illness? ^{45,46} What about eligibility for insurance? Will there be a shift in the balance between actuarial fairness, social equity and public health? Growth in the field of health ethics is perhaps a sign that these big issues are being given increasing thought ^{47,48}. They will be best taken, as with eating an elephant, one bite at a time.

3. The contribution of Operational Research/Management Science

It is not just health care that has been undergoing shifts of balance; ORMS practice has been having some shifts of its own. For example in the balance between:

- tactical or strategic focus;
- solitary or participatory working;
- complicated or simple models;
- reductionistic or systemic analysis;
- arcane or user-friendly techniques;
- optimising or "satisficing" solutions.

The trend has been towards the latter element of each pair ⁴⁹. So, for instance, methods increasingly being "packaged" in computer software that make them easier and quicker to use, with more attention to supporting creative ⁵⁰, "right brain", visual thinking ⁵¹ (to complement traditional critical, logical, "left brain" approaches) and with a greater focus on empowering clients and on organisational learning ^{52,53}. This shift in balance reinforces the role of the ORMS practitioner not as a narrow technician but as a problem - or, rather, solution - focused "general analyst" ⁵⁴ offering "improvement knowledge" ⁵⁵ and increases the ability of ORMS to contribute effectively to a wide range of issues.

So, how can ORMS help with managing the important shifts in the balance of health care? All of the above shifts present the broad challenges of the "general problem cycle" ^{56,57}, ⁵⁸ i.e.:

- scanning for emerging issues;
- formulating and diagnosing problems;
- · setting goals and objectives;
- designing and developing options;
- appraising options and making choices;
- persuading others and gaining acceptance for solutions;
- implementing solutions;
- monitoring and controlling implementation;
- · evaluating results.

The armoury of methods on which ORMS can draw in tackling such problems is vast ^{59,60}, including for example:

- analysis and meta-analysis of literature;
- · brainstorming, Delphi, nominal groups;
- soft systems methods, cognitive mapping;
- morphological analysis, synectics;

- forecasting, scenario analysis;
- expert systems, neural networks,
- · adaptive system modelling, cellular automata;
- statistical modelling, mathematical modelling;
- simulation, system dynamics;
- multicriteria decision analysis, data envelopment analysis;
- network analysis;
- management games;
- control trials, natural experiments.

A systematic assessment, for each shift in the balance of health care, would first identify which of the above elements of the problem cycle are the most pertinent for any given situation and second decide which analytical tool or tools should be deployed. This paper can no more than skim the surface of such an assessment, but some illustrations follow.

Firstly, it is perhaps particularly appropriate for this paper to note that ORMS can itself make a strong contribution to investigating some of the "why" questions about shifts in the balance of health care. The use of forecasting, environmental scanning and scenario analysis ^{1,62,63,64,65,66,67,68,69,70,71,72,73,74} can provide deeper insight into likely or potential shifts in patterns of care in the face of demographic, social and technical change. One such issue of interest is the diffusion of technology ^{75,76,77,78}. This is an example of an area (and the coming years seem likely to reveal others) where some of the current developments in the field of complexity, co-evolution and chaos ^{79,80,81} can add insight in the health field⁸².

Secondly, in terms of the five shifts of balance discussed in the first part of this paper, here is a smörgåsbord of some actual or potential contributions from ORMS (with some possible supporting techniques shown in parentheses):

When - prevention or treatment?

- To gain greater insight into the effects at population level of disease trends and of preventative programmes (epidemiological modelling^{83,84,85,86,87,88}.
- To <u>explore jointly treatment and prevention options</u>, particularly to show how activity, resource requirements and health outcomes develop over time: (system dynamics modelling, decision analysis)^{89,90,91,92,93}.
- (Mention should be made here of the contributions, on both the above fronts, that ORMS has made to meeting the challenges presented by the HIV/AIDS epidemic ^{94,95,96}. The ever present threat of epidemics of other new diseases ⁹⁷ may call for further such contributions).

Where - institution or community?

- To assess needs for and consider alternative modes of institutional and community care, within resource constraints: (resource deployment modelling) ^{98,99,100,101}.
- (A methodologically revealing example of such work is provided by the UK Balance of Care
 model. This evolved from a complex and somewhat arcane model using mathematical
 programming and running on a large mainframe computer¹⁰², through a more heuristic

algorithmic model approach¹⁰³, to a skeletal but user-friendly microcomputer based approach.) ¹⁰⁴ .

- To help manage the interface between health and social care: (system mapping) 105,106,107.
- To help the design, operation and funding of decentralised health care services: (locational modelling)^{108,109}.

How - patient or professional?

- To consider the nature and implications of changing patterns in supply of and demand for health care professionals: (workforce modelling)^{110,111,112}.
- To allow health care managers and professionals to <u>explore and get a better "feel" for new</u> roles and ways of working: (simulation exercises/'management games') ^{113,114,115}.
- To empower patients by helping to set, implement and monitor standards for customer service: (benchmarking and simulation) ^{116,117, 118,119}.

What - knowledge or habit?

- To make the best use of limited information by augmenting traditional approaches, such as randomised control trials, of evaluating new health service interventions (clinical modelling) 120,121,122,123,124
- (A point to note here is that the randomised control trial may have been somewhat oversold as the "gold standard" for clinical assessment: the power and economy of modelling approaches, in the right situation, need to be better appreciated.) ^{125,126}.
- To <u>make sensible decisions about information technology</u> by helping assess and enable the contribution of IT to health service performance (natural experiments, system models) 127,128,129,130
- To provide an analytical bridge across the "divide between researchers and managers" (see ref. 36) and to help translate knowledge into action by providing frameworks for integrating knowledge from different sources and tools for disseminating knowledge and expertise (decision analysis, simulation models, expert systems).

Who - one group or another?

- To help managers explore values, trade-offs and priorities: (decision analysis and support) 131,132,133,134,135.
- To help explore ethical issues: (cognitive mapping) ¹³⁶.
- (Note that for balances in this area especially there can be no one right answer, or even one right method. A key contribution from ORMS can be in helping the development and use of systematic, transparent and defensible processes for handling these issues.)

4. Conclusion

The shifts in the balance of care we are seeing are large, rapid and important. In some countries they take place against a backdrop of significant resource scarcity or social conflict. In all countries they exhibit strong features of uncertainty, complexity and, of course, change. This

is all home ground for ORMS! We have made many contributions in the health service field over the last two or three decades ^{137,138,139,140} and I am sure the profession will rise to the challenge of helping take health services through this decade, on to the turn of the century and into the next millennium.

The contents of this paper represent the author's views alone and in no way commit the Department of Health.

References

- 1. Dall, J.L.C., 'The greying of Europe', <u>BMJ</u>, 1994, vol 309: 1282-5.
- 2. Parliamentary Office for Science and Technology, 'Factors Affecting Pressure on Healthcare Resources', in <u>House of Commons Health Committee Report on Priority</u> <u>Setting in the NHS</u>, vol 1, January 1995.
- 3. Morrison, I., Smith, R., 'The Future of Medicine', BMJ, 29 October 1994.
- 4. Spiby, J., 'Advances in medical technology over the next 20 years', <u>Community</u> <u>Medicine</u>, vol 10, 1988, 273-278.
- 5. <u>Health for All Targets: The Health Policy for Europe</u>, World health organisation, Regional Office for Europe, Copenhagen, 1993.
- 6. The Health of the Nation: A Strategy for Health in England, HMSO, London, 1992.
- 7. Fries, J.F., 'Compression of morbidity:near or far?', <u>Millbank Quarterly</u>, vol 67, 1989, 208-232.
- 8. Bebbington, A.C., 'The expectation of life without disability in England and Wales', <u>Population Trends</u>, no.66,1991,26-29.
- 9. Kunkel, S.R., Applebaum, R.A., 'Estimating the Prevalence of Long-Term Disability for an Aging Society', J of Gerontology, 1992, vol 47, S253-S260.
- 10. Waidmann, T., Bound, J., Schoenbaum, M., 'The Illusion of Failure: Trends in the Self-Reported Health of the U.S. Elderly', <u>The Milbank Quarterly</u>, vol 73, No. 2, 1995, 253-287.
- 11. <u>Caring for People:Community Care in the Next Decade and Beyond</u>, HMSO, London, 1989.
- 12. Marks, V., 'Stick Testing', <u>BMJ</u>, vol 302, 1991, 482-83.
- 13. Lawrence, K., 'Minimal Access Surgery: Harnessing the Revolution', <u>The Lancet</u>, 994, 343, 308-309.
- 14. Working for Patients, HMSO, London, 1989.
- 15. Chief Medical Officer's Expert Advisory Group on Cancers, <u>A policy framework for</u> <u>commissioning cancer services</u>, Department of Health and Welsh Office, London, 1995.
- Warner, M.M., Pugh, S., Riley, C., Rhodes, J., <u>Blurring the Boundaries the Future</u> of <u>Hospital and Primary Care</u>, NHS Wales/University of Wales College of Medicine, Cardiff, July 1993.
- 17. Jolly, D., Gerbaud, I., The Hospital of Tomorrow, World Health Organisation, 1992.
- 18. Vetter, N., From Centre of Excellence to Community Support, Chapman and Hall, 1995.

- 19. Stoeckle, J.D., 'The Citadel Cannot hold: Technologies Go Outside the Hospital, Patients and Doctors Too', The Milbank Quarterly 1995, vol 73; No 1: 3-17.
- 20. Hughes, J. Gordon, P., <u>Hospitals and Primary Care: Breaking the Boundaries</u>, Kings Fund Centre, London, 1992.
- 21. Department of Health, Patients' Charter, HMSO, 1992.
- 22. Sensky, T., Catalan, J., 'Asking patients about their treatment', <u>BMJ</u>, 305, 1992,1109-1110.
- 23. Calman, K., 'The profession of medicine', BMJ, 1994, vol 309: 1140-3.
- 24. Joint Working Party of the Welsh Council of the Royal College of General Practitioners and the Welsh General Medical Services Committee, 'Patient Care and the General Practitioner', <u>BMJ</u>, 1994, 309 1144-7.
- 25. Bhopal, R., 'Public Health Medicine and Primary Health care:convergent, divergent or parallel paths', J Epid. and Commty. Health, 1995, 49,113-116.
- 26. Short, J.A., Bradshaw, A., Nolan, M., Lempp, H., 'Has nursing lost its way?', <u>BMJ</u>,1995, vol 311: 303-8.
- 27. Dowling, S., Barrett, S., West, R., 'With nurse practitioners, who needs house officers?', <u>BMJ</u>, 1995; vol 311: 309-13.
- 28. Adamcik, B.A., Ransford, H.E., Oppenheimer, P.R., Brown, J.F., Eagan, P.A., Weissman, F.G., 'New clinical roles for pharmacists: a study of role expnsion', <u>Soc.</u> <u>Sci. Med.</u>, 1986, vol 23, 1187-1200.
- 29. General Medical Council, <u>Tomorrow's Doctors:recommendations on undergraduate</u> <u>education</u>, London, GMC, 1993.
- 30. Cochrane, A., <u>Effectiveness and Efficiency: Random Reflections on Health Services</u>, HMSO, Nuffield Provincial Hospitals Trust, London, 1972.
- 31. Ellis, J., Mulligan, I., Rowe, J., Sackett, D.L., 'Inpatient General Medicine is Evidence Based', <u>The Lancet</u>, vol 346: 407-410, 1995.
- 32. The Genetics of Common Diseases. Department of Health, 1995.
- Freemantle, N., Crilli, R., Grimshaw, J., Oxman, A., 'Implementing findings of medical research: the Cochrane Collaboration on Effective Professional Practice', <u>Quality in Health Care</u>, 1995; vol 4: 45-47.
- Grimshaw, J., Freemantle, N., Wallace, S., Russell, I., Hurwitz, B., Watt, I., Long, A., Sheldon, T., 'Developing and implementing clinical practice guidelines', <u>Quality in</u> <u>Health Care</u>, 1995; vol 4: 55-68.
- 35. Kassirer, J.P., 'The next transformation in the delivery of health care', <u>The New</u> <u>England Journal of Medicine</u>, 1995, vol 332,52-54.
- 36. Roland, M., 'Cetting Research into Practice', <u>J Epidemiol and Community Health</u>, 1995,49,225-226.
- 37. <u>Methods to Promote the Implementation of Research Findings in the NHS</u>. Department of Health, October 1995.
- 38. Robinson, M.B., 'Evaluation of Medical Audit', <u>Journal of Epidemiology and</u> <u>Community Health</u>, 1994; vol 48: 435-440.
- 39. Grimshaw, J.M., Russell, I.T., 'Effect of clinical guidelines on medical practice: a systematic review of rigorous evaluations', <u>The Lancet</u>, vol 342, 1993, 1317-1322.
- 40. Drummond, M., <u>Economic Analysis Alongside Control Trials</u>, Department of Health, 1994.

- 41. NHS Management Executive, <u>Local Voices: The Views of Local People in Purchasing</u> for Health, London, HMSO, 1992.
- 42. Richardson, A., Charny, M., Hammer-Lloyd, S., 'Public Opinion and Purchasing', <u>BMJ</u>, vol304, 680-2, 1992.
- 43. Klein, R., 'On the Oregon trail:rationing health care', <u>BMJ</u>, vol 302,1-2,1991.
- 44. Klein, R., 'Warning Signals from Oregon, BMJ, vol 304,1457-6,1992.
- 45. Wyld, D.C., Cappel, S.D., Hallock, D.E., 'The New Eugenics? Employers and genetic screening in the "risk society", <u>Futures Research Quarterly</u>, Fall 1992.
- 46. 'Survey on Biotechnology and Genetics', in The Economist Feb 25 1995.
- 47. Zimmern R. L., Insufficient to simply be efficient, <u>Health Service Journal</u>, 24 May 1995, p19.
- 48. Mappers, T.A., Zembaty, J.S., <u>Biomedical Ethics</u>, 3rd ed, London: McGraw Hill, 1991.
- 49. Rosendhead, J.,(ed), <u>Rational Analysis for a Problematic World: problem structuring</u> methods for complexity, uncertainty and conflict, Wiley, 1989.
- 50. Evans, J.R., <u>Creative Thinking in the Decision and Management Sciences</u>. South-Western. 1991.
- 51. Hodgson, A.M., 'Hexagons for Systems Thinking', <u>European Journal of Operational</u> <u>Research</u>, 1992, vol 59, 220-230.
- 52. Senge, P., The Fifth Discipline: The Art and Practice of the Learning Organisation, Century, 1992.
- 53. Morecroft, J.D.W., (ed), Special Issue on "Modelling as Learning"; <u>European Journal</u> of Operational Reseach, 1992, vol 59.
- 54. Royston, G.H.D., 'A Systematic Framework With Illustrative UK Examples for Applied Health OR/MS, in, <u>Proceedings of the Fifth International Conference on System Science in Health Care</u>, eds. Chytil, M.K., Duru, G., v.Eimeren, W., Flagle, Ch.D., Omnipress Publishing, Prague, 1992. pp 1140-1143.
- 55. Batalden, P.B., Stolz, P.K., 'Framework for the continual improvement of health care', Journal on Quality Improvement, 19, 1993, 424-47.
- 56. Hogwood, B.W., Dunn, L.A., <u>Policy Analysis for the Real World</u>, 1984, Oxford University Press.
- 57. Kleindorfer, P.R., Kunreuther, H.C., Schoemaker, P.J.H., <u>Decision Sciences: An</u> <u>Integrative Perspective</u>, Cambridge University Press, 1993.
- 58. Hall, A.D, <u>Metasystems Methodology</u>, Pergamon, 1989.
- 59. Jeffrey, P., Seaton, R., 'The Use of Operational Research Tools: A Survey of Operational Research Practitioners in the UK', J. Opl. Res. Soc., 46,797-808,1995.
- 60. Clark, D.N., Scott, J.L., 'Strategic level of MS/OR tool usage in the United Kingdom: an empirical survey', <u>J Opl Res Soc</u>, 1995, vol 46, 1041-1051.
- 61. Nicholson, D., Hadridge, P., Royston, G., 'First Steps in Health Futures', <u>Futures</u>. in press.
- 62. Miller, R.H., Luft, H.S., 'Estimating Health Expenditure Growth under Managed Competition: science, simulations and scenarios', JAMA, 1995, 273(8), 656-62.
- 63. Gray, A. M., Bosanquet, N., 'Forecasting the impact of demographic change: the case of the British National Health service', <u>Health Policy</u>, vol 20, 1992, 269-275.

- 64. Hall, M., 'The Impact of Behavioural and Biomedical Advance on Health Trends over the next 25 years', <u>OHE Briefing</u>, No 31, November 1994. London: Office of Health Economics.
- 65. Ginter, P.M., Duncan, W.J., Capper, S.A., 'Keeping Strategic Thinking in Strategic Planning: Macro-environmental Analysis in a State Department of Public Health', Public Health (1992), 253-269.
- 66. Taket, A., <u>Health Futures in support of health for all</u>, Report of an international consultation convened by the World Health Organization Geneva, 10-23 July 1993; WHO.
- 67. Hadridge, P., Hodgson, T., and Thornton, S., 'Tomorrow's World', <u>Health Service</u> Journal, 5 Jan 1995, 18-20.
- 68. Office of Public Management/NHS Executive Northern and Yorkshire Region, <u>Future</u> <u>Patterns: an approach to policy and strategy development in the new NHS</u>, Office of Public Management, 1995.
- 69. Longley, M., Warner, M., 'Future Health Scenarios Strategic Issues for the British Health Service', Long Range Planning, 1995; vol 28, No. 4: 22-32.
- 70. Leufkens, H., Haaijer-Ruskamp, F., Bakker, A., Dukes, G., 'Scenario Analysis of the Future of Medicines', <u>BMJ</u>, 1994; vol 309: 1137-40.
- Schreuder, R.F., 'Scenarios for Health Planning and Management: The Dutch Experience', <u>International Journal of Health Planning and Management</u>, Vol 3, 73-87 (1988).
- 72. Anthony, S.J., (ed.), Special Futures Edition of <u>Health Care Forum Journal</u>, March/April 1994.
- 73. Bezold, C., Hancock, T., Schreiber, P., 'Health Futures for the 20th Century', in <u>Health Futures</u>, newsletter of the International Health Futures Network, no.1, 1991.
- 74. Bezond, C., Carlson, R., 'Nursing in the 21st Century', J Professional Nursing, 1986, 2-9.
- 75. Battista, R.N., 'Innovation and Diffusion of Health Related Technologies: a conceptual framework', <u>Int. J of Technology Assessment in Health Care</u>, 1989, vol 5, 227-248.
- 76. Homer, J.B., 'A diffusion model with application to evolving medical technologies', <u>Technological Forecasting and Social Change</u>, vol 31, 1987, 197-218.
- 77. Chrzanowski, R.S., Glasser, J.H., 'Diffusion of medical innovations: microcomputer dynamic model', in <u>Proceedings of the Fourth International Conference on System Science in Health Care</u>, Lyon 1988, eds. Duru, G., Engelbrecht, R., v.Eimeren, W., Flagle, Ch.D., Masson, Paris, 1988, pp351-54.
- 78. Klausen, L. M., Olsen, T. E., Risa, A. E., Technological diffusion in primary health care, <u>J of Health Economics</u>, 1992, vol 11, 439-52.
- 79. Special Issue on Modelling Complex Systems I, European J of Opl Res, 30 (2) 1987.
- 80. Waldrop, M.M., Complexity, Penguin 1992.
- 81. Kelly, K., Out of Control, London: Fourth Estate, 1994.
- 82. Bhargava, S.C., Kumar, A., Mukherjee ,A. 'A Stochastic Cellular Automata Model of Innovation Diffusion', <u>Technological Forecasting and Social change</u>, vol 44, 1993, 87-97.
- 83. Morgernstern, W., Chigan, E., Prokhorskas, R., Rusnak, M., Schettler, G., (eds), Models of Non-communicable Diseases, Springer-Verlag, 1992.

- 84. Gunning-Schepers, L., 'The Health Benefits of Prevention: a simulation approach', <u>H. Policy</u>, 1989, 12,1-256.
- 85. Barendregt, J.J., Bonneux, L.A., 'Multi-disease model of public health', in <u>Proceedings of the Fifth International Conference on System Science in Health Care</u>, eds. Chytil, M.K., Duru, G., V.Eimeren, W., Flagle, Ch.D., Omnipress Publishing, Prague, 1992.
- 86. Heidenberger, K. 'Strategic Decision Support in Preventative Health care', <u>Socio-Econ. Plann. Sci.</u>, 26, 129-146,1992.
- 87. Schaapveld, K., Van de Water, H.P.A., Bergsma, E.W., 'Setting Priorities in Prevention', <u>Health Policy</u>, 1992, vol 20, 277-87.
- 88. Stoto, M.A., Durch, J.S., 'National Health Objectives for the Year 2000: The Demographic Impact of Health Promotion and Disease Prevention', <u>American J of Public Health</u>, 1991, vol 81, 151-160.
- 89. Bensleyl D.C., Watsonl P.S., Morrisonl G.W., 'Pathways of Coronary Care A Complete Simulation Model of the Potential for Health Gain', <u>Journal of</u> <u>Mathematics Applied in Medicine and Biology, in press</u>
- 90. Glickl H., Heysel J.F., Thompsonl D., Epsteinl R.S., Smithl M.E., Osterl G., 'A Model for Evaluating the Cost-Effective of Cholesterol-Lowering Treatment', <u>International</u> Journal of Technology Assessment in Health Care, 1992; vol 8:4: 719-734.
- 91. Fendrick, A.M., Javitt, J.C., Chiang, Y.P., 'Cost-effectiveness of the Screening and Treatment of Diabetic Retinopahy', <u>International Journal of Technology Assessment in Health Care</u>, 1992; vol 8:4: 694-707.
- 92. Beech, R., Rona, R.J., Mandalia, S., 'The resource implications and service outcomes of genetic services in the context of DNA technology', <u>Health Policy</u>, 26, 171-90, 1994.
- 93. Fletcher, J., Hicks, N.R., Kay, J.D.S., Boyd, P.A., 'Using decision analysis to compare policies for antenatal screening for Down's syndrome', <u>BMJ</u>, vol 311, 1995, 351-356.
- 94. Dangerfield, B., Roberts, C., (eds), <u>OR Work in HIV/AIDS</u>, 2nd edn. OR Society 1994.
- 95. Harris, C.M., Rattner, E., Sutton, C., 'Forecasting the Extent of the HIV/AIDS Epidemic,' <u>Socio-Econ. Plann. Sci.</u>, 1992: vol 26; No 3; 149-168.
- 96. Roberts, C., Dangerfield, B., 'Modelling the epidemiological consequences of HIV infection and AIDS: a contribution from operational research', <u>J Opl Res Soc</u>, 1990, 41, 273-89.
- 97. Le Guenno, B., 'Emerging Viruses', Scientific American, October 1995, 30-37.
- 98. Beech, R. et al., Health Care Needs Assessment, Radcliffe Medical Press. 1994.
- 99. Department of Health, 'Implementing Community Care. Population Needs Assessment', <u>Good Practice Guidance</u>, 1993.
- 100. Rivett, P., Roberts, P., 'Community Health Services in Rochdale Family Health Services Authority', <u>J Opl Res Soc</u>, 1995, 46, 1079-89.
- 101. Lagergren, M., 'Dependency and the structure of care some results from simulation of an area-based system of care', <u>Health Policy</u>, 29:3, 229-246, 1994.
- 102. McDonald, A.G, Cuddeford, G.C., Beale, E.M.L., Balance of Care: Some Mathematical Models of the National Health Service, <u>British Medical Bulletin</u>, 1974, vol 30, 262-270.

- 103. Klemperer, P.D., McClenahan, J.W., 'Joint strategic planning between health and local authorities', Omega, 1981, 481-492.
- 104. Forte, P., Bowen, T., 'A microcomputer system for planning the Balance of Care for Elderly people', in <u>Proceedings of the Fourth International Conference on System</u> <u>Science in Health Care</u>, Lyon 1988, eds. Duru, G., Engelbrecht, R., v.Eimeren, W., Flagle, Ch.D., Masson, Paris, 1988. pp363-366.
- 105. Harrison, G.W., Millard, P.H., 'Balancing acute and long term care: the mathematics of throughput in departments of geriatric medicine', <u>Meth Inform Med</u>, 1991, 30, 221-8.
- 106. Greene, V.L., Lovely, M.E., Ondrich, J.I., 'Do Community Based Long Term Care Services Reduce Nursing Home Use: a transition probability analysis', <u>The J of</u> <u>Human Resources</u>, 1992, vol 28, 297-317.
- 107. Wolstenholme, E.F., 'A case study in community care using systems thinking', <u>J Opl</u> <u>Res Soc.</u>, 1993, **44**, 925-934.
- Royston, G.H.D., Hurst, J.W., Lister, E.G., Stewart, P.A., 'Modelling the Use of Health Services by Populations of Small Areas to Inform the Allocation of Central Resources to Larger Regions', <u>Socio-Economic Planning Sciences</u>, 26(3), 169-180,1992.
- 109. Taket, A.R., 'Resource Allocation Models and Health Service Systems: an Exploration. in Morgernstern', <u>Models of Non-communicable Diseases</u>, Chigan, W., Prokhorskas, E., Rusnak, R., Schettler, G. (eds), Springer-Verlag. 1992.
- 110. Department of Health and Social Security, 'Operational Research Services', <u>Nurse</u> <u>Manpower Planning: approaches and techniques</u>, London:HMSO. 1983.
- 111. Denton, F.T., Gafni, A., Spencer, B.G., 'The SHARP Way to Plan Health Care Services: A Description of the System and Some Illustrative Applications in Nursing Human Resource Planning', <u>Socio-Econ Plann Sci.</u>, vol 29, 1995, 125-137.
- 112. Doyle, P., 'Changing Patterns of work', BMJ, vol 303, 1991, 982-984.
- 113. Reed, C., Kirkup, W., Richardson, V., 'Contracts at Numberside', <u>The Health Service</u> Journal, 5 April 1990, 514-515.
- 114. S. W. Thames Regional Health Authority/Office of Public Management, <u>Care</u> <u>Kaleidoscope: Futures for Community Care</u>, June 1991.
- 115. Grutz, M., 'Training administrative decision making in hospital: a management game', in <u>Proceedings of the Fourth International Conference on System Science in</u> <u>Health Care</u>, Lyon 1988, eds. Duru, G., Engelbrecht, R., v.Eimeren, W., Flagle, Ch.D., Masson, Paris, 1988. pp364-370.
- 116. Worthington, D., 'Hospital Waiting List Management Models', <u>J Opl Res Soc</u>, 1991, vol 42, 833-43.
- 117. O'Keefe, R.M., 'Investigating Outpatient Departments: Implementable Policies and Qualitative Approaches', <u>J Opl Res Soc</u>, vol 36, 1985, 705-712.
- 118. NHS Management Executive, <u>Queue Action: A guide to tackling waiting times in</u> <u>outpatient departments</u>, Department of Health, 1992.
- 119. Moores, B., 'Quality Management and Operational Research Initiatives in a Health Service Context', <u>International Journal Of Health care Quality Assurance</u>, vol 6 1993, 6-13.

- 120. Sherlaw-Johnson, C., Gallivan, S., Jenkins, D., Jones, M.H., 'Cytological Screening and management of abnormalities in prevention of cervical cancer: an overview with stochastic modelling', J Clin Patho, 147, 430-35,1994.
- Boyd, A., Davies, L.A., Bagust, A., 'Modelling the Implications for Hospital Services of Cervical Cytology Screening', 'A Case History', <u>J Opl Res Soc.</u>, 1989, vol 40, 529-537.
- 122. Shahani, A.K., Korve, N., Jones, K.P., Paynton, D.J., 'Towards an operational model for prevention and treatment of asthma attacks', J Opl Res Soc., 1994, 45, 916-26.
- 123. Bolger, P.G., Davies, R., 'Simulation Model for Planning Renal Services in a District Health Authority', <u>BMJ</u>, 1992, 305, 605-608.
- 124. NHS Executive, <u>Assessing the Options in the Cancer Key Area: cervical screening</u>, Department of Health, May 1995.
- 125. Urbach, P., 'The value of randomisation and control in clinical trials', <u>Statistics in</u> <u>Medicine</u>, 12, 1421-1431,1993.
- 126. McPherson, K., 'The best and the enemy of the good: randomised control trials, uncertainty and the role of patient choice in medical decision making', <u>J Epid and Commty Health</u>, 1994, 48, 6-15.
- 127. Van der Loo, R.P., Van Gennip, E.M.S.J., Bakker, A.R., Rutten, F.F.H., 'The use of modelling and simulation as tools for the economic evaluation of information technologies in health care', in <u>Proceedings of the Fifth International Conference on System Science in Health Care</u>, (eds.) Chytil, M.K., Duru, G., V.Eimeren, W., Flagle, Ch.D., Omnipress Publishing, Prague, 1992.
- 128. Taket, A.R., 'Why isn't IT working?: studies of the development of computerised information systems for health services', in <u>Proceedings of the Fifth International</u> <u>Conference on System Science in Health Care</u>, (eds.) Chytil, M.K., Duru, G., v.Eimeren, W., Flagle, Ch.D., Omnipress Publishing, Prague, 1992. 1193-1196.
- 129. Symons, V.J., 'A review of information system evaluation: content, context and process', <u>Eur. J Inf Systems</u>, vol 1, 1991, 205-212.
- Proceedings of the 1st European Conference on IT Investment Evaluation, Henley on Thames, UK OR Society, September 1994.
- 131. Wagstaff, A., 'QALYs and the equity-efficiency trade off', <u>J Health Econ</u>, 10, 1991, 21-41.
- 132. Charny, M.C., Lewis, P.A., Farrow, S.C., 'Choosing who shall not be treated in the NHS', <u>Soc. Sci. Med</u>, 1989, vol 28, 1331-1338.
- 133. Mullen, M. P., 'Priority Setting in Healthcare: Techniques and Pitfalls', <u>Proceeedings</u> of annual meeting of EURO Operational Research Applied to Health Services Working Group, Maastricht July 1995, forthcoming.
- 134. Ham, C., 'Priority setting in the NHS:reports from six districts', <u>BMJ</u>, 307, 1993, 435-38.
- 135. Hudson, P., Peel, V., 'Ethical Priority Settting in the NHS: avoiding 'playing with numbers', <u>British J of Health Care Management</u>, 1995, vol 1, 451-454.
- 136. Hare, A., personal communication.
- 137. Luck, G.M., Luckman, J., Smith, B.W., Stringer, J., <u>Patients, Hospitals and</u> <u>Operational Research</u>, Tavistock, 1971.
- 138. Boldy, D.(ed.), <u>Operational Research Applied to the Health Services</u>, Croom Helm, 1981.

- 139. Schreuder, J., (ed), Special Issue: OR in Health, <u>European Journal of Operational</u> <u>Research</u>, 1987, vol 29, 127-228.
- 140. Pierskalla, W.P., D.J. Brailer, 'Applications of Operations Research in Health Care Delivery', in <u>Handbooks in OR and MS</u>, ed. Pollock, S.M., et al, vol. 6, Elsevier, 1994.

Part Two - Methods

Waiting For Nursing Homes: A Dynamic Model As A Tool For Decision Support

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1. Introduction

The dynamic model presented here provides predictions of the average waiting time and the length of the waiting list for psycho-geriatric patients, that are waiting to be admitted to a nursing home, based on yearly data that are routinely collected. The predictions can vary for the projected years. The simplest projection methods, that are commonly used by nursing homes, also provide predictions for the same variables; their predictions however are constant for the projected years.

In contrast to these simpler methods, our model takes advantage of two regularities that were observed in the high quality data from the collective nursing homes of the health care region The Hague. Because these two observed regularities are - in hindsight - easy to understand, we expect them to be more than local anomalies.

First, the time spent waiting on the waiting list (after referral by the referral committee) added to the time that is spent in the nursing home after admission is fairly constant over the years until 1992: in the region The Hague 42 ± 2 months (the figures of 1993 and 1994 show a decrease, possibly as a consequence of changing attitudes of the referral committee). Doctors, that work in the nursing homes concerned, confirmed this observation, that amounts to the assumption that the time spent on the waiting list does not seriously affect the length of survival of the patients once they are admitted. This leaves the discussion of the quality of life of the patients untouched.

Second, the number of people on the waiting list that fail to be admitted (renege) seems to increase proportionally to the time spent on the waiting list. This reneging fraction can thus be approximated with a constant fraction per year by normalising it for the waiting time (in the region The Hague 0.60 \pm 0.02 per year). The doctors mentioned agreed that it is reasonable to expect proportionally more people dying, and thus failing to be admitted, when the waiting time is longer.

With these two regularities postulated, the model can describe some aspects of the dynamics of waiting for nursing homes. It provides estimates of how much time is required for the waiting list and the average waiting time to stabilise after a sudden change in the important parameters, such as the number of available beds, of potential patients et cetera. Together with the more common prediction of the values of the aforementioned variables the model thus can provide a powerful way to discuss the consequences of different scenarios in advance, such as a planned reduction in the number of beds, a

possible increase in the number of patients that apply or the delay of admitting patients by providing extra care at home.

Some validation of the model is provided by analysing the data of the region The Hague until 1989 and projecting the waiting time and length of the waiting list to 1992 and further. The actual 1992 data from the same region are in good agreement with the predictions, provided the increased number of beds and the decreased overall survival time are taken into account (in hindsight).

Two different scenarios are modelled in order to present their consequences in terms of the magnitude and the time course of important variables. It is this type of support for decision-making that we believe to be the main possible benefit of the model.

2. Common methods

Our model can be considered as an extension of the common methods that are widely used for the prediction of the average waiting time in the year $j(T_j)$ and the length of the waiting list in the year $j(W_j)$, based on the data that have been collected the year before.

These methods have only Wj as an independent variable. There are four parameters: the capacity or the number of beds (n); the number of people newly registered on the waiting list (a); the average time spent in the nursing home (τ); the percentage of people that have waited on the waiting list but reneged (died) before being admitted (v). Two dependent variables are used: the average waiting time in year j (T_j); and the number of admissions per year (o). Under several rigid assumptions these seven parameters and variables can be grouped in three equations:

$$o = n / \tau$$

 $Tj = W_{j-1} / o$
 $Wj = W_{j-1} + a - vW_{j-1} - o$

With registered W_{j-1} and known τ , v, a, o and n, predictions for the following years of T_j and W_j can be made. In equilibrium: W = (a - o) / v and T = (a - o) / vo

3. Dynamic model

Our dynamic model was developed by making use of the two observed regularities, mentioned in the introduction: The time that is spent in the nursing home after admission added to the time spent waiting (c) is fairly constant over the years; also the number of people on the waiting list that fail to be admitted (renege) seems to increase proportionally to the time spent on the waiting list. This reneging fraction can thus be approximated with the constant fraction (β) per year by normalising it for the waiting time.

Our dynamic model has two independent variables: W_j and T_j . The four independent parameters are the capacity or number of beds (n); the number of people newly registered on the waiting list (a); the reneging fraction per year (β); the time that is spent in the nursing home after admission added to the time spent waiting (c). Three dependent variables are used: the average time spent in the nursing home in the year j, (τ_j); the number of people that have waited on the waiting list but reneged (died) before being admitted in the year j (V_j); and the number of admissions in the year j (O_j) or the number of admissions in the year j per year (o_j), where $O_j = 1 \ge o_j$ for sake of dimensions. If we assume the two observed regularities to be true and add them to the assumptions of the simpler methods above, the following three equations can then be deduced:

$$o_{j} = n / (c - T_{j-1})$$

$$T_{j} = W_{j-1}(1 - 1/2 \beta T_{j-1}) / o_{j}$$

$$W_{i} = \{W_{i-1}(1 - 1/2 \beta T_{i-1}) + (1 - \beta T_{i})a - O_{i}\} / (1 - 1/2 \beta T_{i})$$

With registered W_{j-1} , T_{j-1} and known β , a, c and n, predictions for the following years of T_j and W_j can be made. If the system is in equilibrium these equations yield the following expression for the average waiting time in equilibrium T and similar expressions can be found for W and O:

T =
$$1/2 [(1/\beta + c) - \sqrt{((1/\beta + c)^2 - 4(c/\beta - n/\beta a))}]$$

Here we do not touch upon the mathematical intricacies of the equations of the model. Obviously convergence is matter of concern as are oscillations. In the application of the model so far we have not encountered any difficulties when modelling perturbations and reaching a new equilibrium as with for instance an increase in available beds.

4. Validation

By applying high quality data from the collective nursing homes of the health care region The Hague, some validation of the model is provided. By using the data of 1989 (T 0.5 year and W 443 persons) and taking into account the increased number of beds (n 2081 to 2164) and the decreased overall survival time (c 3.61 to 3.12), the model projected the waiting time and length of the waiting list for 1992 as: T_{92} 0.29 year and W_{92} 278 persons (see table 1).

Table 1: Data from the collective nursing homes of the health care region The Hague

	1989 actual	1992 simple	1992 dynamic	1992 actual	2000 simple	2000 dynamic
Т	0.50	0.53	0.29	0.29	0.48	0.32
W	443	430	278	262	403	273

Table 1: Data from the collective nursing homes of the health care region The Hague of 1989 (T 0.5 year and W 443 persons) are used to project the waiting time and length of the waiting list for 1992. The increased number of beds (n 2081 to 2164) and the decreased overall survival time (c 3.61 to 3.12) are taken into account. In addition the equilibrium values are given under the column headings 2000. The parameters used are: 953 patients are accepted for the waiting list every year; normalised reneging fraction is 0.59 and corresponding reneging fraction is 0.30. For the common method τ 2.6 years was used.

The actual data for 1992 - T_{92} 0.29 year and W_{92} 262 persons - are in good agreement with the projections made by the dynamic model. In addition the corresponding equilibrium-values indicate that the system is close to equilibrium in 3 years time. In comparison to the application of the simpler methods the dynamic model predicts a lower waiting time, this is due to the way the reneging fraction is incorporated in the model.

5. Decision support

One of the scenarios that was studied for the same region The Hague was to calculate the number of beds required to reduce the waiting time for patients from the present 3.5 months (no equilibrium!) to an equilibrium of 3.0 months, while assuming the present values for c, β and a. This resulted in 2332 beds, an increase of 168 beds (7.8%).

An alternative scenario assumes the possibility to reduce the time that is spend in the nursing home after admission added to the time spend waiting c. This is thought to be achieved by substituting the care of the nursing homes with specialized home care. Calculation of the reduced c required to achieve the same equilibrium waiting time of 3 months results in 2.91 years. This is a reduction of 0.22 or 7% from the present value of 3.12 years. The reduction of 0.22 years (2.6 months) in c reduces the expected equilibrium waiting time from 3.8 to 3 months, i.e. 20%.

From these two calculations a third idea emerged to estimate the reduction in number of beds possible if c could be reduced by 7 %. Obviously this would be something like 150 beds.

6. Discussion

It is the type of support for decision-making illustrated above, that we believe to be the main possible benefit of the model.

With a reasonable accuracy estimates can be made of the number of beds needed to reduce the waiting time prior to admission. In nursing homes - unlike hospitals where the number of referrals is fixed - a small increase in the number of beds will reduce this waiting time only modestly, but the increase will lengthen the overall stay in the nursing home and will increase the number of patients on the waiting list. This is because fewer of

the referred people die on the waiting list and more of them die in the nursing home. A drastic increase in the number of beds would be needed in order to get a substantial reduction in waiting time. Conversely the effect of an ageing group of admitted patients in nursing homes will be less dramatic than usually presumed.

This and similar outcomes are of crucial importance to policy makers in health care, because they indicate where the outcomes of plans - to reduce waiting time and waiting lists by stressing home care or to counter the effect of an ageing population - can differ from what is to be expected by common sense or by more crude models.

Extending the use of the model to other areas in health care is only possible for congruent cases. A different model emerges if the time spent on care is short as in surgery and a third model emerges if the time spent caring is extremely long as with the care for the mentally retarded.
Planning National Resources For Renal Services Using Simulation

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1. Introduction

Patients with end-stage renal failure will die without renal replacement therapy. There are three main types of therapy:

- <u>Haemodialysis</u> The patient has to use a kidney machine for two or three times a week for four to six hours a time. This may take place in a hospital unit, in an 'out-of-town' minimal care unit or at a patient's house, adapted for this purpose.
- <u>Continuous ambulatory peritoneal dialysis (CAPD)</u>: An exchange of fluids takes place within the patient's abdomen. A bag of sterile fluid is supported under the patient's clothing which needs changing every six to eight hours.
- <u>*Kidney transplant*</u>: Kidneys are normally obtained from cadavers but are sometimes donated by live relatives. The tissues have to be cross-matched with the patient's tissue to reduce the risk of rejection.

Dialysis, haemodialysis or CAPD, must either continue for the rest of a patient's life or until the patient receives a transplant. Those receiving transplants have to take immunesuppressive drugs indefinitely.

When patients are accepted onto a renal replacement therapy programme, they are normally given haemodialysis or CAPD but a few are given immediate transplant operations. Many of the patients on dialysis are put on the transplant waiting list but continue to receive dialysis while they are waiting. Some patients are unable to continue haemodialysis for medical or social reasons and transfer to CAPD treatment. Others transfer from CAPD to haemodialysis (if, for example, chronic peritoneal infection occurs).Those receiving transplants generally experience a better quality of life but they may suffer a transplant rejection and return to dialysis. Some patients receive a second transplant. Patients may die at any stage.

The number of patients on renal replacement therapy for end stage renal failure (the 'stock') has been increasing steadily over the last decade. This has arisen from the:

- growth in the numbers of patients who have started treatment; and
- improving techniques and, hence, improving patient survival over the years.

The acceptance rate (i.e. new patients taken on per year) was only 20 per million population (pmp) in 1982: by 1991/2 it had reached 65 pmp (unpublished data from a National Renal Review). This is less than the best estimate of population need for renal replacement therapy of 80 pmp which is based on population studies in the UK ^{1,2,3}. This estimate does not take into account the effect of the higher need in ethnic minorities ^{4,5}

which could increase need to over 90 pmp. Need is not an absolute concept and there is considerable scope for variation in thresholds for referral and treatment; some European countries have acceptance rates of over 100 pmp and in the US the rate is 180 pmp. As renal services continue to expand, the number of patients being accepted for treatment will continue to rise and will include a higher proportion of older patients, those with diabetes, and those with other complicating medical factors. Twenty years ago, most patients accepted for renal replacement therapy were under the age of 50 years but now, over a third of patients accepted in England are over 65 years old and the average age is increasing.

The problem is to determine how many patients will be requiring treatment in the future and what facilities will be needed for their treatment. Renal replacement therapy is not cheap; the average annual cost per patient is between £10,000 and £20,000 (this varies from unit to unit); thus the average lifetime cost of renal replacement therapy per patient will be in the region of £200,000. Transplantation is cheaper than either type of dialysis. Between 1% and 2% of a Health Authority's acute services budget may be spent on dialysis and transplantation.

Even if the acceptance rate of new patients were to stabilise at the current levels and the treatment survival were to remain constant, the number of patients would continue to rise for many years. Studies have been done to determine how many patients would require treatment if the steady state were to be reached ^{4,6}. This paper describes a study, commissioned by the Department of Health in England, to determine the increased demand for services over the next decade and more. Projections of future demand are complicated by several factors:

- the additional categories of patients accepted onto the programme are likely to be older with poorer survival probabilities;
- there are three main treatments (modalities) and patients often transfer from one to another during their lifetime on renal replacement therapy;
- there is uncertainty about the rate of growth of acceptance rates, and of the future availability of cadaver transplants;
- the immediate future depends largely on the progress and survival on treatment of the current stock of patients but data on their previous medical and treatment histories are difficult to obtain.

Simulation modelling has proved useful in determining the need for local renal services at district level ^{7,8}. This paper describes the use of simulation to look at a national problem.

2. Modelling patient flow through treatment

The work involves using the techniques of discrete event simulation to provide forecasts of future renal patient numbers under varying assumptions about future patient demand for treatment (acceptance rates), demographic factors (such as ethnic mix), availability of resources (especially cadaver kidneys for transplantation) and treatment and patient survival. The predicted workload can then be translated into costs.

Discrete simulation modelling was chosen in preference to Markov modelling, time slicing simulations or spreadsheet modelling ⁹ because it can:

- include an independent source of transplants;
- · constrain the availability of resources, such as unit dialysis;
- · describe the attributes of patients that influence resource use;
- make realistic assumptions about the shape of the survival distributions.

The simulation model used for the national study, was similar to that described by Bolger and Davies ⁷ and by Davies and Flowers ⁸. Patients (the simulation entities) take part in the different treatments (the activities), and move from one to another. Progress through treatment in the model is dependent, not only on resource availability, but also on individual patient characteristics (e.g. age, diabetic status) and the time spent on treatment. Figure 1 shows an outline flow diagram of the simulation. Patients enter the system being modelled when they are accepted onto a programme for renal replacement.



Figure 1: The flow of patients through the simulation

In practice, there are some patients for whom dialysis can be delayed, whilst others are followed up by nephrologists with planned starting dates for treatment. Figure 1 shows that the simulated patients enter a queue before starting dialysis. No distinction is made

between urgent and non-urgent patients and if there are sufficient dialysis places, patients will not be delayed in the queue at all. Patients always have to wait for kidney transplants.

Each relevant change in a patient's treatment progression (such as a transplant operation or the start of treatment) is termed an *event*. The simulation describes the activities of all patients in the simulation model by advancing simulated time from event to event. The appropriate actions for each event (such as changing a patient's treatment or accepting a new patient for treatment) are then performed at each step.

Patient and treatment (technique) survival and treatment times are sampled from probability distributions. Treatment choices and other decisions in the simulation are also sampled from distributions which are based, either on historical data, or set to reflect proposed changes in treatment policies.

An important feature of this model is that patients are allocated ages, according to their age group at the start of the simulation or when they begin treatment, and grow older as the simulation progresses. As they are detected to have crossed age bands, their survival probabilities are re-sampled.

Conventional simulation software does not provide for individual entities in the simulation to take part in parallel activities which may interrupt each other. Davies and Davies have developed simulation software for describing patient flows in systems ⁹. The simulation software is written in Pascal, using an extension of Pascal_SIM ¹⁰. The renal simulation program, which is based on this software, is easy to use but yet may describe thousands of patients.

The model output shows the change in stock over time, given as the mean and confidence limits of the number of patients in each patient group expected to be maintained on each treatment mode in each time period. The information is fed through to a spreadsheet file for analysis and graphical output.

3. Data input and assumptions

Data Sources

The input parameters may be varied. Since some parameters are more likely to be changed between runs than others (e.g. patient demand as opposed to the initial patient stock), the data set is divided into logical sections, which can be edited as separate files. The input data set includes the following:

- · patient and technique survival (graft, dialysis);
- transplant supply by year;
- · patient acceptances by age/risk group by year;
- current patient stock by age/risk group.

Data were available from three main sources.

- <u>The European Dialysis and Transplant Association (EDTA) Registry</u> has a database of patients on renal replacement therapy in renal units in the United Kingdom (UK) and in many other European countries. Renal units submit annual returns about individual patients so that the data on existing patients are linked to their previous records. The degree of co-operation between the renal units and the Registry has declined in recent years and so the data set is less comprehensive than it was; the effect on survival parameters is not known. UK data have been used.
- <u>The United Kingdom Transplant Support Service Authority (UKTSSA)</u> has data on United Kingdom and Republic of Ireland patients waiting for transplants and being transplanted. The UKTSSA has a complete set of data concerning patients waiting for transplantation and those receiving transplants but we do not know the accuracy of the follow-up information about graft failures and deaths. As UKTSSA data are for the whole of the UK and Eire, the English figures were estimated by applying a population correction factor, derived from the 1991 WHO Annual Statistics, of 78.6%.
- <u>The National Review</u> was a survey of all renal units in England which included individual patient data (e.g. age, diabetic status, modality, ethnicity) on acceptances in 1991 and 1992 and stock data for 1993. All the Renal Units responded; the Review relied on them for the quality of the data. Of the acceptance data received, 99% had information about age and 91% about diabetic status.

We thus had a comprehensive data set on all aspects of transplantation: the use and turnover of the transplant waiting list, the numbers of transplants by patient group and survival data. Where there were differences between the EDTA registry transplant survival data and the UKTSSA data, we assumed the latter to be the more reliable source.

Modifications to Patient Flow

We had data on overall dialysis survival by patient group as well as CAPD and haemodialysis by patient group. Unfortunately, we were unable to obtain reliable data on patient transfers between CAPD and haemodialysis and so the model was run with just two treatment modes: dialysis, to include haemodialysis and CAPD, and transplantation.

Data from EDTA show that up to 5% of new patients start treatment with a transplant. There are also paediatric patients who enter the adult population each year (i.e. reach the age of 16), many with functioning grafts. The simulation was enhanced to enable these patients to be put on a priority list for transplantation and given transplants before any other treatment and in preference to other patients on the transplant waiting list.

Patient Survival

For use in the model, each survival distribution is divided in two. There is an early part where survival may be less good and a later part where survival probability remains the same from one year to the next. The simulation has been designed to use defined age bands with the diabetics being placed in the 10 year age band above their actual age to represent their poorer survival. The major difference between this model and previous models in this field (including those described by Davies ^{7,8}) is that the patients age as the simulation progresses. When a new treatment commences (within the simulation), it is their <u>current</u> age that is taken into account. Once treatment is established, survival is dependent on age, rather than the time lapse since a change in treatment.

Past data shows that survival in each age group continues to improve, year on year. The data analysed from the UKTSSA and the EDTA registry were for 1985 to 1994 and from 1985 to 1993 respectively. It may be supposed that survival has continued and will continue to improve. The simulation was tested with an 'improved' survival ' scenario in which it was assumed that patients take on the survival distributions of patients who are 10 years younger than the current figures show, except for the youngest age group (who already have very good 5 year survival) and those over 75 (as the additional patients accepted in this age group may have more complex medical problems than existing patients).

Transplant Rate

We have accurate figures on the total number of transplants performed in the UK and Eire for 1994. In the simulation we tested three scenarios:

- that the current rate of a rate of 28.6 pmp would continue;
- that there would be 10% over 5 years arising from more proactive donation policies such as the increased use of donor cards;
- that there would be a 10% decrease over 5 years.

Acceptances

We have assumed that the intake rate will increase over the next five years from 65 per million found in the 1993 Renal Review to 80 per million or 87 per million. The age specific incidence rates have been estimated by comparing the current rates found in the National Renal Review with the rates found in the UK population based incidence studies' ^{1,2,3}. An adjustment for the ethnic effect at a national level has been incorporated by applying the age specific relative risks in the ethnic minorities (Asian and Black) to the population distribution in each age group, derived from the 1991 Census. Even the 87 per million population may be a conservative estimate because it is much lower than the acceptance rate in the USA.

Stock Data

Full details were available from the National Renal Review for 40% of patients. The numbers of patients by modality and diabetic status were therefore scaled up to the total number of patients known to be on renal replacement therapy in England in 1993.

The stock patients had to be incorporated in the simulation and given survival times. Those on dialysis had survival times sampled from distributions of those on treatment for at least one year. These were based on the current age of patients. For the stock patients with functioning transplants, estimates were made as to how many had had recent transplants. The recently transplanted patients were given a higher probability of failure and death than the more established ones.

4. Results

There were 18 different combinations of runs to take account of :

- the different survival rates 'current' and 'improved';
- the three different transplant rates;
- the three different acceptance rates.

The simulations were run for one tenth of the population of England and averaged over 50 replications. The results were then scaled up by a factor of ten. No constraints were imposed on the availability of resources apart from the limitation on the availability of transplants.

Wood's study showed the numbers of patients likely to be on treatment if numbers of patients were to reach a steady state ⁶. The simulation was run with different acceptance rates but with the 'current' survival and transplant rates. Figure 2 shows results from 50 year runs. They show that the steady state agrees well with that predicted by Wood but it would be a long way off, even if there were to be no increase in the acceptance rate. So many different factors can change over a period of 10 or 15 years that the steady state concept is not very helpful.

Figures 3 shows the patient breakdown by treatment type. It can be seen that whereas, there are roughly equal number of patients on dialysis and with functioning grafts at the start, the numbers of patients with dialysis increase more rapidly than those with functioning grafts.

The effect of a change in the transplant rate on the total numbers of patients is very little. Figure 4 shows the projected effect on the numbers of patients maintained on dialysis. Again the effect is quite small.

A change in the acceptance rate and an improvement in treatment survival (Figure 5) have significant effects. The total numbers of patients may thus increase by as much as 90% in 15 years.







and survival pobabilities

5. Conclusion

If the acceptance rate increases in order to meet need, then depending on survival probabilities, the stock may increase by between 50 and 100% of current levels. This increase will fall disproportionately on dialysis, even if the transplant rate increases by up to 10%; this will have important consequences for National Health Service resources.

The numbers needing treatment will vary considerably in different areas of the country, depending on the age breakdown and ethnic mix of the population. The resource requirements of different health authorities are thus likely to become increasingly disparate as patient numbers increase.

The effects of a higher transplant rate and of improved survival probabilities in all age and risk groups were tested. The former had a small effect in reducing the demand for dialysis but the latter showed a dramatic effect in increasing the need for dialysis resources.

The study has demonstrated that simulation provides a valuable way of evaluating patient stock and flow to show how patient numbers, and hence resource use, may change over time. As the output data are aggregated from individual simulated patient activities, the costs may be allocated to these activities in whatever way is thought to be most appropriate and accurate. If patient survival does improve, then it is likely that there will be at least ten thousand more patients on dialysis over the next ten years. A rough estimate, based on a conservative estimate of dialysis costs of £20,000 per patient per year, is that the increased costs to the nation in ten years time will be at least two hundred million pounds a year and will still be rising.

6. Acknowledgements

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References

- Feest, T.G., Mistry C.D., Grimes D.S., Mallick N.P., 'Incidence of advanced chronic renal failure and the need for end stage renal replacement therapy', <u>Br Med J</u>, 1990; 301:897-900.
- 2. McGeown, M.G., 'The prevalence of advanced chronic renal failure in Northern Ireland', <u>Br Med J</u>, 1990;301:900-3.

- 3. Khan, I., Catto, G.D., Edward, N., Macleod, A.M., 'Chronic renal failure: factors influencing referral', Q J Med , 1994;87:559-64.
- 4. <u>Report of an Independent Review of Specialist Services in London</u>, Renal Services, London, HMSO 1993.
- Roderick, P., Jones, I., Raleigh, V.S., McGeown, M., Mallick, N., 'Population need for renal replacement therapy in the Thames regions: ethnic dimension', <u>Br Med J</u>, 1994; 309: 1111-1114.
- Wood, I.T., Mallick, N.P., Wing, A.J., 'Prediction of resources needed to achieve the national target for patients with endstage renal failure', <u>Br Med J</u>, 1987; 294:1467-1470.
- 7. Bolger, P.G., Davies, R., Simulation modelling for planning renal services in a health district', <u>Br Med J</u>, 1992; 305:605-608.
- Davies, R., Flowers, J., 'The growing need for renal services. The use of simulation modelling to aid purchasing for renal replacement therapy', <u>OR Insight</u>, 1994; 8:6-11.
- 9. Davies, R., Davies, H.T.O., 'Modelling patient flows and resource provision in health systems', <u>Omega Int J Mgmt Sci</u> 1994; 22(2):123-131.
- 10. Davies, R., O'Keefe, R.M., Davies, H.T.O., 'Simplifying the modeling of multiple queuing, multiple activities and interruptions, a low level approach', <u>ACM Trans</u> <u>Model Comp Sim</u>, 1993; 3(4): 332-346.

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Resource Utilisation And Quality Of Care; A Logistic Approach

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1. Introduction

In manufacturing industry last decade much attention has been paid to develop logistic planning and control systems and to the introduction of quality systems, to improve performance. Important goals are realising client's orders on time, according to the agreed quality, quantity and costs. In health care we have to meet the challenge of scarce resources; national expenditures are limited while demand is still growing. One of the goals is to balance efficiency in the use of resources with good quality of care. A logistic approach which has proved its worth in manufacturing industry might be helpful in health care, but there are essential differences. One of them is that in health care, not good flows but patient flows are primary processes.

As characteristics of a hospital can be mentioned:

- they have to serve ten thousands of patients in a year;
- every patient has his own route;
- there are many independent professional care suppliers;
- output specifications are not known;
- capacities are scarce;
- high utilisation rate is required;
- demand is partly urgent;
- stocks of care cannot be build up.

What makes it complicated to handle this:

- there are many co-ordination problems;
- there are partly conflicting targets:
 - high quality;
 - high throughput;
 - high output;
 - high capacity utilisation.

This article points out that an integral (logistic) approach to control processes, focused on care processes, can be helpful in this complex situation.

2. Logistic planning and control

The individual patient has a perspective look from outside to inside. He is subject of a sequence of activities such as doctor's consultation, diagnosis, treatment, surgical

operation. The patient meets several stations on his way through the hospital and expects low waiting times. A system for flow planning and control is required.

The perspective look from a hospital's unit is from inside to outside. A unit has to deal with a sequence of patients with individual work orders. Often demand can only partly be influenced; idle time should be avoided. A system for unit planning and control is required.

There are two main rules for planning and control:

- balance between supply and demand;
- balance between uncertainty and flexibility.

Flexibility is not a goal in itself, but is needed because the demand of care is not deterministic nor static. Like in production processes, buffers are important in logistic control. In care processes buffers do not appear as stock of raw materials, spare parts, finished products et cetera. Buffers appear as waiting times, delivery dates, appointments, waiting lists and waiting rooms. Actually, patients are parked in buffers; this may appear as a stock of patients, but in logistic terms it is a queue. Conflicting targets appear here as a conflict between waiting time for patients and idle time for capacities (including staff): who is waiting for who?

For several reasons it is getting more and more important to control processes and flows:

- reduction of length of stay;
- more short-stay and day-care treatments;
- · shift from inpatient to outpatient care;
- growing co-ordination and communication with family, doctor/GP and home care institutions;
- quality requirements from clients.

As said before, a difference can be made in patient flow planning and control and unit planning and control. Both will be elaborated.

Patient flow planning and control

Patients run through a chain of activities with different stations. At each station the patient makes an appointment (agreement on delivery time) or he takes place in a buffer (joining other patients in the queue). There are two options for flow planning and control, dependent on predictability of patient-related individual work orders. If individual work orders for the same patient for several units are known in advance, a coherent planning for the individual patient can be made. This approach can be used for operational planning on the short term: a program is set up for each patient, such as:

- a coherent planning for x-ray, ECG, lab test;
- a coherent planning for pre-operative screening, admission and surgical operation.

If individual work orders are not known in advance or for some units or activities appointments are not made (joining the queue), a logistic analysis can be made to get

insight in the logistic relationships of patient flows between units. The co-ordination between units is based upon expected flows with average patterns, and not upon known orders. To get this insight sample patients registration or statistical analysis (diagnosis groups, patterns of order demands) is required. This approach is useful for tactical planning (resource allocation upon a year's base) and operational planning (week schedules). As an example: a logistic analysis indicates that A% of patients visiting the medical outpatient clinic on Thursday morning is sent to the x-ray department; B% of them for an instant x-ray photo which takes less than five minutes production time. It is important to recognise that what cannot be planned is not by definition unpredictable.

Unit planning and control

What we see as a unit here is a nursing unit, an operating theatre, x-ray department, laboratory, outpatient department, an individual doctor et cetera. Sometimes a unit is a single resource capacity (a doctor), sometimes a multiple resource capacity: a nursing unit consist of beds, nursing staff and medical staff. Buffers are appearing here as queues (waiting lists, waiting lines, waiting rooms) and as agreed delivery dates for the services to be rendered. Urgency and postpone-ability are important factors here: emergencies cannot be parked in a buffer, so resources should be 'in stock'. For these reasons we have our second main rule: balance between uncertainty and flexibility. We have two types of flexibility, internal and external flexibility.

Internal flexibility means the need of a slack of resources according to the expected demand. We need more resources 'in stock' if predictability is lower. External flexibility has to do with coping uncertainties coming from outside. Ways to create external flexibility and to reduce external uncertainties are:

- predicting the demand;
- making deals about orders and patient flows;
- electing patients, in order to balance supply and demand (the first main rule);
- creating buffers between units, such as an emergency unit to concentrate all the emergent admissions.

Levels of planning and control

The systems for planning and control have to be designed for several levels, such as strategic, tactical, operational level and the actual situation (see also the production control framework in the article from Jan Vissers). The characteristics for these levels will be briefly mentioned.

Strategic level:

- determination of functions (quality and quantity) based upon patient's demands (trend analysis);
- · development of new activities and/or reinforce activities to influence patient's demand;
- determination of yearly budget and total amount of resources.

Tactical level:

- allocation of budgets and resources to units, based upon an expected volume of production;
- determination of coherent schedules for all units, based upon expected flows (week patterns) and upon logistic interrelationships between units.

Operational level:

- scheduling of patients and scheduling of activities;
- allocating the resources to patients;
- reserving a part of the resources (slack), dependent on the unpredictability.

Actual situation:

- adjusting the operational planning, if necessary;
- using measures for flexibility, to meet unpredicted urgencies and to keep actual workload in balance.

3. Logistic information

It will be quite clear that we need logistic information to support our logistic planning and control systems. Logistic information should be directed upon patient flows and product lines. Timeliness is an explicit factor in logistic systems and also in hospital's performance. Parameters referring to timeliness are delivery time, reliability of delivery time, access time and waiting time. We can also say that these current parameters define our logistic quality rendered to the clients. Unfortunately present hospital information systems in general do not give information on timeliness and logistic quality.

Related to logistic planning and control, there are two types of logistic information: logistic process information and logistic management information.

Logistic process information

Logistic process information is related to operations and to the process of the individual patient. In practice we use a small set of indicators for urgency: it is urgent or not. The label 'urgency' guarantees immediate action; this can be an invitation to manipulate with that label. If the label is used, it is not known if any delay is allowed. Another problem is the overview of patient-related activities. Generally a unit only knows its own order (such as a request for a lab test, or an x-ray), and not if there are any more orders for the same patient for other units.

Better co-ordination, coherent information and more detailed urgency indicators are required. From a quality point of view, more knowledge about client needs and expectations and about logistic performance is required.

As an illustration the required logistic process information for the operational admission planning and control is listed:

- patients' load on beds (included length of stay), nursing manpower and operating time; these loads can be derived from patient's data on admission diagnosis, surgical operation code, age and sex;
- indication of urgency for each patient on the waiting list;
- percentage of urgent (non-elective) admissions for different specialists (surgical and medical), in order to make bed reservations;
- prediction of date of dismissal and resulting nursing workload; predictions can be made explicitly (derived from patient's data, based upon statistical research) or implicitly (using the expert knowledge of doctors and nurses).

Logistic management information

For several reasons there is a need for logistic management information, to support the management in its responsibilities and managerial decisions:

- to get insight in patient flows and resource utilisation, to tune the planning and control systems and to improve logistic quality;
- to assess the hospital's performance to the client on timeliness parameters;
- to get insight in patient flow patterns, logistic relationships between units, bottlenecks in throughput, degree of unpredictability, distribution of urgencies in arrivals et cetera.

Patient level information can be aggregated to higher level information on patient flows and product lines. A problem is that we have not the right 'language' to describe patients and patient groups based upon criteria of classification in such a way that it makes sense for both doctors and managers. Sometimes for a dedicated problem sample registration is more useful and efficient than storing large numbers of data in our information systems ('if we put in all possible data, we can get out whatever we want').

4. Organisational impact

In general we see a growing attention in health care to the market and a shift:

- from a care supplier orientation to a client orientation;
- from a production/unit orientation to a process/flow orientation.

This development ties logistic and quality approaches together. A feature of a logistic approach is to orientate dominantly upon flows and processes, and not upon unit and production. Many hospitals have a structure based upon production units with highly specialised functions. Over and between these units product-line management is required as a co-operation between the professionals and the managers, with common goals. An information system to support product line management should be developed. A feature of a quality approach is a look from outside to the process performance and output. A patient-centred co-operation between professionals is required, such as case management

and common goals on service and treatment. Information and evaluation systems to monitor quality should be developed.

As a conclusion, both logistic and quality management are based upon:

- orientation on patients and processes;
- process performance control;
- measurement systems, such as performance indicators on resource utilisation and on quality.

Five steps can be mentioned to transform an organisation into a quality organisation.

1. Best foot forward

Everyone puts his best foot forward means that quality exists by accident, depending of the ambitions of individuals. This does not mean that quality is by definition bad, but there are no common standards and no systems for quality assurance.

2. To measure is to know

Formulating specific goals and measuring the goal performance is essential in basis process control, both from a logistic and a quality point of view.

3. Our client seems to be our king

There is a growing consciousness that we are working for our clients and not for ourselves. The orientation on the outside world is starting. As professional experts we know what is good for our clients.

4. Our client is our king

In this stage of development we take steps to get insight in our clients' needs and expectations and in their experiences. Instruments such as surveys, panels and evaluation systems are used.

5. United we stand, divided we fall

There is a firm belief that the highest quality can only be performed by combining all strengths. That means multi-disciplinary co-operating professionals and client participation. This requires an attitude that we are never too old to learn and that we are always looking for improvements.

5. Concluding remarks

Last years a growing number of Dutch hospitals is working with concepts of logistic management and quality management. A recent survey proves that the transformation from policy into specific and measurable goals, and systematic measurement and feed back on aimed performance are still underdeveloped. Yet some proved results can be reported here.

As an example some results will be mentioned on the theme of admission planning, with improvements of both logistic both service quality parameters:

- in stead of one day ahead, a tentative admission and operation planning is made one week ahead;
- patients are called three days before (was one day) and confirmed the day before admission;
- reliable prediction of nursing workload and dismissal date 2-4 days ahead;
- · less fluctuations in nursing workload;
- reduction of the number of urgent admissions (the reason was that in a number of cases there was no medical urgency and postponement with a day proved to be possible, if there is a bed for sure tomorrow);
- · clear planning and priority rules;
- more time spent to regular planning, less to ad hoc deliberations;
- up-to-date information about the patient-mix and bed occupation;
- more predictability;
- more peace and quiet.

Proved results can also be presented by some facts and figures:

- reduction of emergency admissions: -25%;
- reduction of temporary additional staff: -14%;
- bed occupancy: +4%;
- level of acceptable (objectively measured) nursing workload: +8%;
- implementing a dedicated patient classification and workload control system on a 18beds Intensive Care Unit:
 - number of admissions per bed per year: +14%;
 - number of admissions per fte nursing staff: +25%.

A conclusion is that improving quality is not by definition expensive. A shift to an orientation on clients and processes, supported by logistic planning and control and by dedicated information systems, can lead to process and performance control with positive effects on both efficiency and quality.

Strategic Entry Deterrence In The UK Pathology Services Market

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1. Introduction

This paper draws on a case study involving analysis of data and information collected and collated, over an 18 month period to date, from competing providers in the UK National Health Service (NHS) market, together with interviews with senior managers and consultants of the collaborating pathology laboratories. The aim of the project described in this paper is to provide a conceptual and computable model to assist senior managers in making decisions regarding strategic investments aimed at entry deterrence in the NHS market for pathology services. Ultimately, we aim to establish method and guidelines to estimate the life of the deterrent value of strategic investments.

The study makes use of the dynamic model of entry deterrence formulated by Waagstein ¹¹, with the additional feature that market share will be determined by the post-entry equilibrium in the particular circumstances of the case study (see Section 3 below). Waagstein's original model was formulated in terms of a single product, with a single price and for which a single parameter provided an adequate representation of market share. This current work extends Waagstein's model to a more realistic framework whereby each provider has a range of products (diagnostic investigations) which are taken up in different degrees by different kinds of purchaser. The model has been reformulated to allow for a vector of products, costs, prices and market shares. As well as modifying the algebraic details, it has been necessary to consider carefully the assumptions underlying the likely behaviour of a potential provider. For example, is it more realistic to assume that a potential provider will limit the range of services where competition will be attempted? Alternatively, will there be a willingness to provide any of the entire range of services if the market for them is sufficiently attractive? On the other hand, in some cases the algebraic details of the reformulated model naturally suggest answers to some modelling decisions.

In keeping with Waagstein, the dynamic feature of the model is maintained by accepting the assumption that the stock of knowledge and goodwill, created by strategic investments, erocles over time. Investment inputs to the current model are determined in accordance with both accounting philosophy ^{2,6,8} and consultations with senior managers of pathology services. The strategic investments which appear to have potential deterrent effects are physical buildings, equipment, personnel, information systems, marketing networks and clinical pathology accreditation. The balance sheet valuation of an investment at successive year ends is not important to this study; what is important is the nature and initial cost of investments both by the established organisation to build

competitive advantage and by the potential competitor to erode it. At this stage of our analysis we argue that the periods of leasing and rental agreements, which are the norm in this field, provide good indicators of the life-times of the deterrent values of strategic investments in buildings, equipment and information systems. Case study analysis suggests that a cash flow interpretation of investments in personnel, marketing networks and accreditation is also appropriate.

2. Overview of the UK NHS market

Following the 1989 NHS White Paper and the NHS and Community Care Act 1990, an internal market was created by separating purchasers from providers of secondary healthcare. Through stimulus of competition, the market is intended to provide more efficient allocation of limited resources, by targeting resourcing to local, as opposed to national, needs. The economic agents in the emerging market are the purchasers and providers whilst patients remain the ultimate consumers of healthcare. In an emerging market system considerable difficulties arise in building analytical causal models which embrace the system in its entirety. However, a microcosm of the NHS market system is more amenable to model. The market for clinical pathology services is a microcosm of the NHS market. It is structually representative, that is, it has all the essential properties of the generalised NHS market.

Market for Pathology Services

Pathology is a clinical service which investigates and advises on the diagnosis, management and treatment of disease. NHS Clinical Pathology Laboratories offer a range of diagnostic investigations within the four main disciplines: chemical pathology, haematology, microbiology and histopathology. The repertoire of products offered to the market may vary from 300 to 600 types of investigations, depending upon the degree of specialisation and size of the laboratories.

NHS providers mainly consist of the remaining health authorities directly managed hospitals (DMUs) and self-governing Trust Hospitals. Their role is to deliver pathology services, within quality and quantity specifications in the contracts, to purchasers in return for agreed charges. NHS purchasers are the Trust Hospitals, General Practitioner Fund Holders (GPFHs), Health Authorities and other NHS Units. They have a primary responsibility to ensure that, within available resources, pathology services are secured to meet the patients needs.

In March each year the purchasers are required to negotiate contracts with the providers. Three types of contract are available in the market. Firstly, block contract for defined services, case numbers and waiting times. Secondly, cost and volume contract in which the provider receives payment for a basic level of activity but supplementary work is charged for at a higher rate. Thirdly, cost per case contract where items not covered by ordinary contracts attract additional charges. A proportion of patient referrals will not be predictable and hence not covered by contracts. This proportion, known as extra

contractural referrals (ECRs), is normally small. Each type of contract is constructed according to the requirements of pricing which in turn is influenced by market costs and demands for services. All costs are based on full costs including depreciation at current replacement cost plus 6% return and no planned service cross-subsidisation.

Competition

The factors influencing competition in the NHS market for pathology services were analysed using theories of firm, consumer and market ^{3,5,7} and analytical marketing methods ⁹. It was found that one primary factor influencing competition is the market structure. This refers to the number of providers in the market and the product itself. The market is characterised by few providers, each providing a similar range of products. Competition is thus among the few providers and when they make decisions they are aware that their actions affect each other and each provider takes this into account.

Porter's pioneering work established five forces affecting competition in an industry. Using his framework this study identifies and investigates two of these forces which are more predominant within the NHS pathology services market; namely competition among the rivals and the threat of potential entrants. There seems to have been comparatively little consideration of the potential significance of this latter ⁴.

The following case analysis indicates that providers are exposed to increased competition when (a) the proportion of contract negotiated with GPFHs is large (b) there is market testing following devolution of budgets to clinical specialties within a hospital. In addition, the threat of potential entrants is more prominent where there is competition from the independent sector rather than the NHS providers.

3. Case study analysis of pathology services

The market within the geographical region studied contains five NHS providers. These do not compete in an antagonistic manner i.e. each does not try to oust the others from the market. However, they neither co-operate, negotiate nor enter into binding profit sharing arrangements. Each provider tries to minimise cost and maximise contribution to fixed costs without planning for profit, taking the actions of the others as given. These actions correspond to the quantities of pathology services that the providers offer to the market. Competition is based on volume rather than the price of services.

Each of the five providers offers a similar range of pathology services within the four main disciplines listed above. These services are requested in different quantities by the different kinds of purchaser. Services are ranked in order of volume to ensure only high volume income generating services are selected. The study covers up to 85% in volume of the total requests per financial year. This approach produces a limited range of services thus simplifying the analysis.

During the period of the case study the providers contemplate the possibility of the arrival of a new independent provider, P. The potential entry is a threat to all established providers but provider E's market is most at risk. Were Provider P to enter the established market then it would be for the same services, on the same basis and with the same customer base. Provider E is enhancing this market by investments generating goodwill and increasing its own knowledge of the customers' needs. Therefore the reactions of the other established providers to this threat of entry is ignored.

The analysis reflects provider Es view of what might happen if provider P tries to enter its existing market. In addition, provider Es senior managers expect provider P would enter its market via a neighbouring provider, Fs market utilising an established marketing network as a base for further expansion. Currently, provider F is not as competitive as provider E and hence its market is relatively small.

In order to enter profitably, the provider P will have to make strategic investments. These investments are assumed to depend upon the efforts already made in this respect by the provider E. Therefore, the latter may make it unattractive for the provider P to enter the market by fixing strategic investments appropriately.

The optimisation problem for provider E is to decide how to deter entry. The control variable is the current level of investments over time.

4. Outline of the mathematical model

In this section we give an outline of the mathematical model which will be used during the remainder of the research project to quantify the interactions between the issues discussed above. It has the same basic structure as the dynamic model of entry deterrence of Waagstein, though generalised to a market for a range of products. We have also introduced some formal simplifications by 'hiding' the dynamics of the market before and after entry in some general transition and other matrices. This embodies a realistic requirement, in that the demands for products should be allowed to interact with each other. On the other hand it also highlights the increased range of functional dependencies and parameters which we will need to identify in the future, from data analysis, managerial experience or plausible assumption.

Provider *E*, the incumbent, offers n different products and provider *P*, the potential entrant from the private sector, is contemplating entering the market with competitive offerings for some or all of these products. Provider *E* has made a strategic decision to try to prevent entry until at least time T_1 by means of suitable strategic investments; the purpose of the model is the provision of quantitative support for managerial decisions about the level and effectiveness of such deterrent investments.

Assumption 1

The incumbent provider maximises expected discounted cash flow, while the potential entrant will enter the market if and when the expected discounted cash flow is positive. Capital is available in whatever quantity desired at a fixed rate of interest, *r*, which remains unchanged over time.

Assumption 2

The price per unit for the products is a vector $\rho \in \mathfrak{R}_{+}^{n}$ which is constant over time. The vector $q_{o} \in \mathfrak{R}_{+}^{n}$ represents the initial demands for the products and the n x n matrix $\Phi(t)$ is the market transition matrix; that is, the demand for the products at time t>0 is $\Phi(t)q_{0}$. To describe the division of the market post-entry, assume there is a (possibly time-dependent) partition

$$\alpha(t) + \beta(t) = I_{\alpha}$$

of the n x n identity matrix such that after entry at time \mathcal{T} the total market is shared as follows

$$\underbrace{\Phi(t)q_0 = \alpha(t-T)\Phi(t)q_0}_{Incumbent} + \underbrace{\beta(t-T)\Phi(t)q_0}_{Entrant}$$

Assumption 3

The marginal production cost vector $c \in \mathcal{R}_{+}^{n}$ measured as cost per unit produced, is constant over time, the same for both providers and includes 'market-preserving' investments in the products. In the period up to entry at time T, the incumbent provider may make strategic investments $I_{s}(t)$ to develop a stock of knowledge and goodwill by investment in infrastructure and intangibles, rather than directly in the products themselves. To enter the market at time T, the entrant has to make a once-and-for-all investment I_{T} .

These assumptions do not contradict the NHS requirement that there should not be planning for profit. Although strategic investment is likely to result in reduced costs, and hence correspondingly reduced prices, this would make the market less attractive to a potential entrant. It is, therefore, reasonable for a manager within the incumbent provider to make these strategic investment decisions on the basis of unchanging costs and prices. In a larger model this feedback could be examined in detail, but we believe that significant insight can be obtained by accepting that prices and costs are determined exogenously. Moreover, making the assumption at this stage that prices cannot increase over time is consistent with the UK Government's ethos of seeking reduced costs within the NHS.

ⁱ In general *I_s* may be a generalised function to allow for large capital investments made at a point in time.

With these assumptions it is easy to see that the expected cash flows for the potential entrant (discounted to the time of entry) and the incumbent (discounted to time zero) are, respectively

$$e^{rT(\rho-c)^{T}}\left\{\int_{T}^{T} e^{-rt}\beta(t-T)\Phi(t)dt\right\}q_{0}-I_{T}$$
(1)

$$\left(\rho-c\right)^{T}\left\{\int_{T}^{T}e^{-rt}\Phi(t)dt\right\}q_{o}-\int_{0}^{T}f_{o}(t)dt+\left(\rho-c\right)^{T}\left\{\int_{T}^{T}e^{-rt}\alpha(t-T)\Phi(t)dt\right\}q_{o}$$
(2)

It will be convenient to denote the first term in (1) by h(T).

The strategic objective of the incumbent provider is to ensure that $h(T) \leq I_T$ for all $T \in [0, T_T]$ whilst maximising the expression in (2) with $T = T_T$, namely

$$\left(\rho-c\right)^{T}\left\{\int_{0}^{T_{1}}e^{-rt}\Phi(t)dt\right\}q_{0}-\int_{0}^{T_{1}}I_{s}(t)dt$$
(3)

The first term in the expression (3) is a constant so the incumbent provider's objective is to minimise

$$\int_{0}^{r_{1}} I_{s}(t) dt$$

Following Waagstein, we assume that the investment I_T required to enter the market is a function of A(T), the established provider's stock of knowledge and goodwill at time T generated by the strategic investment profile $I_s(t)$ for $0 \le t \le T$. We have already noted that consultation with senior managers in the incumbent pathology service provider has identified several different categories where strategic investment might be made effectively, so we assume that $A(t) \in \mathcal{R}_{+}^{m}$; in algebraic terms, A is a function $\mathcal{R} \to \mathcal{R}_{+}^{m}$

Assumption 4

 $I_T = f(A(T))$ where $f : \mathcal{R} \to \mathcal{R}_+^m$; Waagstein's regularity assumptions correspond to requiring that f have positive gradient and negative semi-definite Hessian matrix. We also assume that A(t) satisfies a linear ordinary differential equation

$$\frac{dA}{dt} = i_s(t) - b(t)A(t) \tag{4}$$

where $i_s(t) \in \mathcal{R}_+^m$ represents the investment profile in the individual infrastructure elements or intangibles, so that $I_s(t)$ is equal to $||i_s(t)||_1$, the sum of the components of $I_s(t)$. The vector function $i_s(t)$ also embodies the significant practical requirement that strategic investment decisions might best be made, not merely in terms of the total investment, but rather in relation to the categories already identified as having deterrent potential. Furthermore, (4) models the growth in A(t) depending on the investments $i_s(t)$

and the m x m interaction matrix b(t). The diagonal elements of b(t), which will lie (strictly) between 0 and 1, represent the rate of erosion of the accumulated goodwill et cetera in the m strategic categories. Any enhancement (or undermining) of the deterrent value of accumulated goodwill in one category by investment in another will be represented by negative (or positive) off-diagonal elements in b(t).

Summarising the above discussion we arrive at the basic optimisation problem facing the incumbent provider.

Amongst (say) C^2 functions from $[0, T_1]$ to the positive cone in find \Re^m find i_s to

$$Minimise \int_{0}^{t_{1}} ||i_{s}(t)||_{1} dt$$
(5)

subject to

$$(A(t)) \ge h(t) \text{ for all } t \in [0, T_1]$$
(6)

$$\frac{dA}{dt} = i_s(t) - b(t)A(t) \tag{7}$$

Modelling the market share function

The above formulation of the model has hidden an important element, namely the market share which the incumbent provider might expect a new entrant to gain. Waagstein mentions that this "should be determined endogenously ... in the post entry game". This is an important aspect of the overall project, although, at the present time, there is little actual experience on which to base a model of this game. At the time of writing there has been only one case where the provision of NHS pathology services being taken over by an independent provider ¹⁰. We are examining this case intensively in order to identify and model the interests of both the independent provider and the other parties to the contract. There are, however, some features of the present case which may assist in extending our model to encompass the determination of market share. In particular, it can be assumed that a new entrant must take over the market for pathology services in a neighbouring provider's area entirely and then make incursions into the existing incumbent provider's marketⁱ. Product-by-product cost comparisons between this neighbouring provider and that of the incumbent, together with professional and managerial analysis of the two providers, are showing that this would only be profitable if the entrant gains more than some minimum additional market share for each product. On the other hand, the geographical distribution of service purchasers - fund-holding general practitioners and one key hospital - suggest that only a certain proportion of the markets are seriously at

ⁱ An alternative strategy for the incumbent provider is to seek to win the contract for the neighbouring provider's market for pathology services in competition with the potential entrant, thereby removing the threat of incursion. However, it is reasonable to assume that the investment required to achieve this is similar to that required to resist market penetration in the incumbent's market.

risk. Combining these two analyses will provide a small number of possible values of the market-sharing parameters. %

5. Solution procedure

Details of an explicit solution of the above optimisation problem will depend on the nature of the functions involved, particularly b(t), which has still to be established by experimental work. However, the general outline can be discerned. The ordinary differential equation (7) determines A as a linear functional of i_s and A(0), the value of the incumbent provider's stock of knowledge and goodwill at the outset ⁱ

$$A = A_s(i_s) + A_0(A_0)$$

Here cal A_s is a linear mapping $I \rightarrow A$ and A_0 is a linear mapping $\mathcal{R} \rightarrow A$ where I and A are function spaces with properties appropriate to the functions i_s and A respectively. These functionals can be computed explicitly if the function b(t) is, for example, constant or diagonal or, more generally, if the matrices b(t) and $\int b(t)dt$ commute. Now condition (6) can be written

$$f(\mathbf{A}_{s}(i_{s}) + \mathbf{A}_{0}(A_{0})(t)) \geq h(t) \text{ for all } t \in [0, T_{1}]$$

giving a single class of (non-linear) constraints on the linear objective function (5).

6. Concluding Comments

Proceeding further with analytical or numerical work requires more detailed knowledge of various functions within the model and the extent to which simplifications are judged appropriate. This will be the focus of much of our future work. Of particular importance seem to be:

- erosion of deterrent value over time;
- interaction between deterrent investment and cash flows;
- market growth estimates;
- market share parameters.

References

- 1. Arrow, K. J., (ed. J.N. Wolfe), <u>Optimal Capital Policy with Irreversible Investment, In</u> Value, Capital and Growth, Edinburgh, (1968)
- 2. Baxter, W.T., 'Asset Values Goodwill and Brand Names', ACCA Research, Ocassional Research Paper, Number 14, (1993)

¹ Waagstein can assume that this is zero because his model examines the life-cycle of a new product rather than competition in a market for existing products.

- 3. Cohen, K.J., Cyert, R.M., <u>Theory of the Firm: Resource Allocation in a Market</u> <u>Economy</u>, Prentice-Hall Inc., New Jersey, (1975)
- 4. Galloway, M., Bloxham, C., Wansborough, R., 'An Evaluation of 6 Marketing Methods Applied to an NHS Pathology Laboratory', <u>Clinician in Management</u>, Volume 4, Number 3, Pearson Professional Ltd, (1995)
- 5. Kamien, M.I., Schwartz, N.L., <u>Market Structure and Innovation</u>, Cambridge University Press, Cambridge, (1982)
- 6. Laughlin, R., Gray, R., <u>Financial Accounting: Method and Meaning</u>, Van Nostrand Reinhold, (1989), pp. 155-156
- 7. Lowes, B., Sparks, J.R., Modern Managerial Economics, Heinemann, London, (1974)
- 8. Marketing Accounting Research Centre, 'Strategic Brand Accounting', Working Paper, School of Management Cranfield, (1989)
- 9. Porter, M.E., <u>Competitive Strategy Techniques for Analyzing Industries and</u> <u>Competitors</u>, Macmillan Publishing Co., (1989), pp. 3--33
- 10. Spooner, R., 'Market Testing Some Possible Players', <u>ACB News Sheet</u>, Issue 372, April, (1994), pp.12
- Waagstein, T., 'A Dynamic Model of Entry Deterrence', <u>Scand. J. of Economics</u>, 85 (3), (1983), pp. 325-337

Some Problems In Modelling Intensive Therapy Units

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1. Introduction

"Intensive Therapy Unit" is often used generically to describe any Unit providing care for patients suffering from potentially recoverable conditions who can benefit from more intensive treatment, observation and support than is usually available in standard wards and departments. Though the problems presented in this paper could occur in relation to any such Unit, here the discussion is based on I.T.U.'s caring for patients who, while satisfying the above general specification, have as a common factor the need for respiratory support. Such Units are under the clinical direction of anaesthetists.

In 1994 a patient died while a bed was being sought for him in one of a Scottish City's five I.T.U.s. Between the time of this death and the mandatory Fatal Accident Enquiry, the Health Board commissioned a study of the adequacy of I.T.U. capacity in the city. This paper introduces some of the difficulties encountered.

2. The proposed model

In the protocol prepared for the Health Board the opening paragraphs were: -

"A simplistic view of Intensive Therapy Units is that:

- 1. A fixed number of staffed beds is available.
- 2. Patients arrive in an unpredictable way effectively randomly at any hour of the day or night.
- 3. If no free bed is available the patient does not wait but is sent elsewhere and is "lost" to the Unit.
- 4. Patients admitted are discharged according to medical judgement and independently of the level of occupancy of the I.T.U..

If these conditions are satisfied and the appropriate data is available the analysis is straightforward and is based on well established results in queuing theory."

The well established result in queuing theory referred to is, of course, the M/G/C/C model. The substance of this paper is a discussion of the extent to which the above simplistic expectations were not realised and the implications thereof.

3. Data problems

This discussion focuses on one of the five I.T.U.s studied. It was picked because of the excellence of the data available there and it was not the Unit which had been primarily involved in the Fatal Accident Enquiry.

The data available about the Unit is shown in summary on Table 1. Examination of this table shows some of the difficulties encountered.

- 1. There is no data available about <u>demand</u> for admission only for <u>actual</u> admissions. The mean and (squared) standard deviation of daily admissions are similar enough to make a Poisson distribution of admissions plausible. This was supported by a Chisquared test of this hypothesis on the observed distribution of admissions.
- 2. Distribution of occupied beds indicates that up to 8 beds can be called on although the staffed bed complement is only 5. This difficulty was exacerbated by the later discovery that the availability of extra beds depends upon the availability of suitably trained nursing staff. This can neither be predicted nor established retrospectively. The very high bed occupancy (96.9%) calculated on the 5 staffed bed complement figure suggests that extra beds are the rule rather than the exception.
- 3. The length of stay distribution has a standard deviation greater than the mean. This is no handicap so far as the M/G/C/C model is concerned but it does bar the way to some mathematical explorations using Erlang distributions. The distribution as represented in Table 1 is not satisfactory for analysis but the original data give admission and discharge times to the nearest 5 minutes allowing 'proper' distributions to be estimated.

4. Summary of difficulties and questions arising therefrom:

- 1. That at least 5 and no more than 8 beds are staffed each day is all we can be certain of. From the high mean bed occupancy and the rare occurrence of 8 occupied beds it seems that 6 or 7 beds is the likely norm.
- 2. Demand for admission is unknown but actual daily admissions appear to be Poisson distributed with a mean of approximately 1/day. How strongly does this support the belief that demand also is Poisson distributed? If the rejection rate is insignificant this evidence would be strong support. Unfortunately, calculation of the rejection rate requires knowledge of the number of staffed beds available.
- 3. The bold assumption that the M/G/C/C model applies falters when bed occupancy calculations are attempted. The fit is not good. Again difficulties are encountered arising from uncertainties about mean demand rate and staffed bed numbers. Suspicions are also entertained about the independence of discharge decisions from bed occupancy levels.

4. The behaviour of the system can be represented by a Markov chain if transition probabilities obtained from observed values are employed. This is encouraging but not useful unless these observed transitions can be derived from admission and length of stay distributions. Again the spectre of non-independence rises to frustrate us!

This statement of difficulties in attempting an analysis of a superficially straight forward problem is depressing. The steps taken to resolve some of these difficulties will be described next.

Table 1: I.T.U. DATA (1993	3)
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	MEAN	S. DEVIATION
Daily Admissions	0.99	1.01
Length of Stay (days)	4.85	7.05

Distribution of daily admissions

Admissions	0	1	2	3	4	
Number	139	125	72	20	9	Σ=365
%	38.1	34.2	19.7	5.5	2.5	$\Sigma = 100$

	MEAN	S. DEVIATION
Bed Occupancy - (of 5 beds)	96.9%	30.9%

Distribution of occupied beds

No of Beds	0	1	2	3	4	5	6	7	8
No of Days	3	8	13	38	85	88	76	48	6
(% Days)	(0.8)	(2.2)	(3.6)	(10.4)	(23.3)	(24.1)	(20.8)	(13.2)	(1.6)

Distribution of length of stay

No of Days	0	1	2	3/4	5/7	8/14	≥15
No of Patients	39	128	39	48	38	39	34

5. Dealing with the difficulties

The central problem is whether or not the system can be legitimately viewed as a M/G/C/C system. This in turn focuses on the nature of the demand distribution. Is it Poisson?

The arguments in favour are as follows:

- 1. Almost all demand is unpredictable, most of it emergency demand and arising from a number of independent sources. A very small and variable proportion of the work load is scheduled.
- 2. The observed admission pattern is Poisson. This would result from a Poisson demand pattern if the rejection rate were very small and this one would hope to be the case in an I.T.U..
- 3. A rejection process which "selects" Poisson distributed admissions from a general demand distribution is unlikely but possible.
- 4. If rejection were by an independent external random process Poisson demand would give rise to Poisson admissions but independence cannot be assumed.

This last point can be illustrated by the following argument. Consider an M/M/C/C system at the moment when a client has just been admitted.

Let	q		rejection probability
	En	=	n-phase Erlang distribution
	а	=	mean inter-arrival time for clients seeking admission.

Suppose that the next client to be admitted is the j^{th} client demanding admission. This client's inter-arrival time will be "drawn" from an E_i distribution with probability:

$$(q)^{j-1}(1-q).$$

The distribution of inter arrival times for accepted patients will therefore be:

$$\sum_{i=1}^{\infty} (q)^{i-1} (1-q) E_i.$$

The terms in 'q' are valid for both M/M/C/C and M/G/C/C systems by Sevastyanov's results and the E_i terms arise entirely from the arrival distribution hence this expression is valid for M/G/C/C.

The series sums to: $a(1-q)e^{-at(1-q)}$.

So far so good except that because we cannot stipulate independence of successive admissions we cannot claim that Poisson admissions will be generated by Poisson demand.

In this specific case no significant auto correlations have been found in the admission pattern hence the M/G/C/C model has been accepted as at least a good approximation to the I.T.U. system.

To go further it is necessary to estimate the demand rate. Were the number of available beds fixed this would be trivial. The range is from 5-8 beds and the associated admission rates for different demand rates are shown in Table 2.

Demand Rate	5	6	7	8 Beds
1.10	0.76	0.86	0.94	1.01
1.20	0.78	0.90	0.99	1.07
1.30	0.80	0.93	1.03	1.12
1.40	0.82	0.95	1.07	1.17
1.50	0.84	0.98	1.10	1.21

Table 2: Admission I	rates fo	r demand
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As the admission is 1.0/day demand rates of 1.10 - 1.50 are apparently possible.

To reduce this range of possibilities the following approach was adopted.

It was assumed that if x_i (i = 5... 8) is the number of beds available on any day then the average over the year would be given by:

 $\overline{x} = a x_5 + b x_6 + c x_7 + d x_8$, where a+b+c+d=1.0

Using this model the demand rate which minimised the squared differences between the observed bed occupancy distribution and that given by the model was calculated. Table 3 shows results:

Demand	a	b	С	d	$\sum \Delta^2$	Reject	Admission
Rate	(5)	(6)	(7)	(8)		Rate	Rate
1.20	.042	.212	.604	.141	501	19.2	0.97
1.30	.123	.232	.529	.116	327	23.8	0.99
1.35*	.154	.239	.501	.106	307	26.0	1.00
1.40	.180	.246	.475	.099	322	28.1	1.01
1.50	.223	.256	.435	.087	447	32.0	1.02

Table 3: Estimation results for different demand rates

Thus a demand rate of 1.35/day gives a best fit to observed bed occupancy and implies that 5 beds were available on 15.4% of days 6 beds on 23.9% of days etc. The rejection rate is 26% and gives an admission rate of 1.00/day. See Table 4.

Table 4: Comparison between observed and estimated bed occupancy

No of occupied Beds	0	1	2	3	4	5	6	7	8
Observed Midnight									
Bed State	3	8	13	38	85	88	78	48	6
Estimated From Least									
Squares Calculation	0.9	6.1	19.9	43.4	71.0	93.0	77.2	47.5	5.9

These findings are plausible enough except for the 26% rejection rate which is inconsistent with both anecdotal evidence and a small sample survey undertaken. One possible
explanation is that though bed occupancy figures are based on the midnight bed state count, a number of admissions, in this case approximately 12%, have lengths of stay of less than 24 hours. Such patients would not be caught in a true midnight bed count and their removal would increase the mean length of stay of the patients so counted. Further work is being carried out on this aspect of the model. Preliminary calculations suggest that rejection rate will be reduced to less than 20%. This, together with the question of the midnight bed state figures will be the subject of a future paper.

6. Conclusion

The I.T.U. is, by its professed rules of operation, designed to function as an M/G/C/C System. The modeller is, however, faced with the twin difficulties of having neither the demand rate nor having a fixed number of beds (servers) available. Either piece of information would have been sufficient to advance the modelling process. Reliance on the bed occupancy figures seemed the only way round this difficulty but the results imply a rather high rejection rate.

Possible difficulties involve:

- a) Patients staying less than 24 hours may not be included in the midnight bed count.
- b) Admissions and/or discharge rates may well be conditioned by the prevailing occupancy of the available beds.

It is hoped to carry out a parallel analysis to the above on "genuine" M/G/C/C systems to test the midnight bed state effect.

It should be point out that the difficulties described in this paper also prevent simulation of this I.T.U.

Priority Setting In Health Care: Techniques And Pitfalls

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1. Introduction

Over the past few years, in common with many other countries, there has been an upsurge of interest in explicit priority setting (rationing) and in the involvement of the public in health care purchasing within the British National Health Service. The major precipitating factors in the UK were the introduction of the NHS changes in 1991, outlined in the government White Paper *Working for Patients* ¹⁰, and the publication of *Local Voices* ¹¹.

As a result of the NHS changes, District Health Authorities (DHAs), which receive funds based on their weighted population (minus any funds allocated to local General Practitioner Fundholders), are charged with purchasing health care services from providers (semi-autonomous NHS trusts) to meet the needs of their local population. Previously, providers (hospitals and community services) were directly funded and managed by their local DHA. The changes have opened up the opportunity for DHAs to determine explicitly what services/treatments they will purchase, and thus what services/treatments will be available to their local population. Apart from setting out some overall generalised priorities (for instance, NHSE 1995) ⁴⁰ the government has devolved responsibility for priority setting to DHAs. *Local Voices - The views of local people in purchasing for health* heralded a series of publications and circulars urging DHAs to consult the public to ensure that "their decisions reflect, as far as practical, what people want, their preferences, concerns and values" ¹¹.

As a result there has been considerable debate on issues of priority setting and explicit rationing within the NHS. A number of exercises in public consultation were observed, several involving value elicitation, but few demonstrated awareness of the existence of a literature on this subject - there is considerable evidence of 'reinventing of the wheel'. Realising that there is a vast literature on the elicitation and aggregation of values and preferences, located within a range of disciplines including OR, economics, psychology and political science, and also having interests in the health care rationing debate and in consumer involvement, my colleague Professor Peter Spurgeon and I obtained funding for a research project on *Involving the Public in Priority Setting*.

ⁱ This paper draws on the findings of a research project Involving the Public in Priority Setting which is supported by a grant from the Nuffield Provincial Hospitals Trust. The views expressed, however, are the author's own.

2. Methodology

Briefly the methodology of this study involves:

- (a) literature searches on: methods/techniques of eliciting values and aggregation; examples of consumer involvement in health care and other public services; and the rationing and priority-setting debate in health care;
- (b) a survey of projects and exercises in involving the public in priority setting within the NHS, with the aim of obtaining examples, especially of techniques used, and the impact on purchasing/priority setting, i.e. it is not the aim to determine extent of consumer involvement;
- (c) the establishment of a database of projects;
- (d) a review of some priority-setting software;
- (e) detailed follow-up of techniques from the literature and the survey, which appear to have potential for use within the NHS.

It is hoped to follow up this project with empirical testing of selected techniques.

3. Priority setting and rationing

This paper focuses on priority setting and, in particular, on some of the theoretical and practical issues relating to techniques and approaches for eliciting values. However, the project as a whole must take account of the rationing debate and address issues raised in connection with public involvement in health care. These points are touched on below. More detailed discussions can be found in Mullen ^{36,37} and useful general discussions of rationing within the NHS can be found in ACHCEW ², Hunter ²⁷ and Hunter & Harrison ²⁸.

Is health care rationing really necessary?

Although many commentators appear to accept, without question, the need for health care rationing - with the only question being how that rationing should be carried out others challenge the whole notion of rationing health care at all. They claim that rationing is unnecessary and is a diversion from the real problems of the funding and delivery of health care. (Some of the points from this argument are given in Appendix 1(a & b).) This argument is anathema to those who see rationing as axiomatic; those who claim resources will always be scarce and rationing is inevitable. They accuse those who challenge the necessity for rationing of not living in the real world. Another area of debate concerns the use of the Health Cain or QALY (Quality Adjusted Life Years) in priority setting, with health authorities aiming to use their resources to maximise 'Health Gain' or to maximise the number of QALYs purchased. On the face of it this approach appears both attractive and obvious. However, it has come under criticism from a number of directions, some of which are listed in Appendix 1(c). Possibly one of the most controversial arguments is that maximising health gain can discriminate against an individual who requires expensive treatment, especially where the outcome is not certain. Other objections to rationing arise specifically in respect of rationing by exclusion, i.e. identifying services and treatments

which will not be supplied at all (at least to certain groups). Some of the problems raised by rationing by exclusion are related to the arguments above, but additional points are shown in Appendix 1(d). Appendix 1(e) and 1(f), respectively, raise issues of Rationing by Age and Rationing by Prior Consent. A question worth pursuing is whether the prior consent arguments are, at least in part, driving quest for public consultation and participation in priority setting.

The Oregon Plan, which excludes a range of lower-rated condition-treatment pairs in order to free resources to extend the coverage of Medicaid to all those below the US Federal Poverty Level, has invoked considerable interest in the UK, not only because of its approach to rationing, but also because of its attempts to elicit the views of the public. Accounts of the Oregon Plan and surrounding debates can be found in, *inter alia*, Brannigan ⁵, Fox & Leichter ¹⁵, Hall & Haas ²⁰, Honigsbaum ²⁴, Kitzhaber ³⁰, Strosberg, Wiener, Baker & Fein (eds.) ⁴⁷.

Levels of Priority Setting

Priority setting decisions relating to health care are taken a several different levels, very broadly:

- At the national level, there is the decision as to what priority to give to health services as compared to all other competing claims for national resources.
- At the level of the purchaser, there is the decision as to what priority to give to different specialties and treatments what and how much to purchase.
- At the point of delivery there are decisions about priorities between different patients. Traditionally priority decisions at this level have been taken by doctors, but especially through the control of ECRs (extra-contractual referrals) purchasers are able to choose between individual patients.

Attention here is focused largely on the level of the purchaser, in deciding what and how much to purchase. This itself involves making decisions on competing claims between:

- different specialties;
- different diseases;
- different treatments;
- different patient groups;
- different localities;
- different methods of delivery.

4. Consumer involvement in priority setting

Although in many quarters it may seem heretical even to raise the issue, the legitimacy (or possibly advisability) of public participation in health care priority setting or rationing decisions has been challenged. Some of the arguments are listed in Appendix 2. Another related issue is who - which members of the public - should be involved: those needing the service? those using the service? all citizens/residents/taxpayers? the informed public? (and who informs them?) This leads on to the question of the legitimacy of majority

decision-making and the issue of individual rights versus the collective, i.e. 'collective' decision-making does "not take seriously the individual right to access to health care based on need" ¹³. It is not solely a question of the representativeness of those participating since the right of the majority to exclude some individuals, or whole groups, from receiving some service could be challenged even if there were 100% participation in decision-making. This position can be characterised as anti-democratic, but its proponents would counter with the risk of the dictatorship of the majority or "an apparent tyranny of communal preferences over individual interest" ⁵. As noted above, the question of prior consent is being invoked, even if only implicitly, requires deeper examination.

Nevertheless, spurred largely by *Local Voices* and related documents, there is considerable interest in, and much effort expended on, attempting to involve (or at least obtain the views of) the public, whether as citizens or consumers, in health-care priority setting and purchasing decisions. At the national level the public should be able to influence decisions on total health-care (or at least NHS) expenditure and the overall philosophy of the health service through the democratic political process. In the absence of elected local health authorities, it is at the purchaser level that there is most interest in involving, or at least consulting, the public about priorities and purchasing patterns. In addition there is considerable interest in consulting consumers at the level of service delivery, not normally on decisions between individual patients, but on the pattern of health care delivery and the on quality of health care services. Thus, the list above could be extended giving the following aspects on which the public (as citizens and or consumers) might be consulted or involved:

- decisions between different specialties;
- · decisions between different diseases;
- decisions between different treatments;
- decisions between different patient groups;
- decisions between different localities;
- decisions between different methods of delivery;
- · decisions about the location of delivery;
- decisions on non-medical aspects (appointment systems, waiting, food, decor).

5. Local v national values and priorities

Involving, or consulting, the public on decisions about priorities at the level of the purchaser, however, leads us into the debate about whether, within a national health service, health-care priorities should be determined at the local level or at the national level. In recent years emphasis within the UK NHS has been put on deciding priorities at the local level. Under the slogan of 'meeting local needs', health authorities are encouraged individually to determine local priorities and to select locally what to purchase.

Such emphasis on local priorities has been criticised as it may permit the centre (the government) to shift the blame for the lack of provision of a specific service or even for a general shortage of resources.

The major concern, however, arises because of the threat to inter-district equity. Unless priorities are based solely on some nationally agreed definition of need applied to local population needs, determining priorities locally will lead to differences between health authorities in what services they choose to purchase and, more importantly, choose not to purchase. This results in unequal access to services dependent only on place of residence. It can be questioned whether the concept of locally determined priorities is compatible with a national health service. A corollary of locally determined differential purchasing priorities is that doctors find their 'duty' to treat according to clinical priority compromised. A further fear arises from the observation that, even if there were no problems with the legitimacy of participation, small local communities sometimes produce more extreme views than would be found in a larger community.

Clearly, even within a National Health Service, equity would not be achieved by having identical services in every area. There are many legitimate reasons why different services are needed to meet the different needs of local populations - and thus ensure geographical equity. Appendix 3 presents an initial attempt to identify legitimate and non-legitimate reasons for variations in services between Health Districts. Within the suggested list of legitimate reasons for variations, apart from the more technical aspects relating to demography and epidemiology, most relate to the way that services are delivered, rather than which services are delivered. Further, it is suggested that it is open to question whether, within a national health service, it is legitimate for local values (prejudices?) to result in inter-district variations in what services are provided. Thus, if the analysis in Appendix 3 is itself legitimate, it could have an important bearing on which aspects of purchasing are appropriate for public involvement.

6. Values in health care priority setting

There are a number of different ways that values can be used to inform the process of priority setting in health care. They include:

- Valuing different health states, often in order to construct some form of health status index or QALYs. The resulting scales can then be used to value to health improvement gains from different treatments. When combined with cost information, such information can produce QALY league tables;
- Directly valuing or choosing between different health services/treatments;
- Valuing attributes of health, health services and or treatments usually to use them as evaluation or weighting criteria in a two-stage process;
- Valuing or choosing between methods or aspects of health care delivery (e.g. treatment at home v treatment in hospital, travelling time etc.);
- Valuing or choosing between different patient groups (e.g. old v young, men v women) 34 .

Many of the techniques and methodologies for eliciting values and preferences are appropriate for use with more than one of these approaches. In addition, although the study reported here is focusing on public participation, many of the techniques and methodologies are equally relevant for eliciting values and preferences from professionals and authority members.

7. Techniques and methodologies for eliciting values/preferences Some general considerations

Techniques for eliciting values and preference have a long history in several disciplines (including economics, operational research, psychology, political science and philosophy). It would be impossible to synthesise the arguments, theories and techniques of such disparate disciplines - all that can be hoped it to draw on them. However, since it is not possible to master the contemporary debates in all the different disciplines and sub-areas, almost every part of the discussion here will inevitably appear naïve to one or other expert. Thus this discussion will try to touch on some of the considerations, remembering that the aim is to extract and propose practical and acceptable methodologies for use in the health service, which do not raise too many theoretical objections. The methods selected for use should be doing what the 'researchers' (and participants) think they are doing; thus transparency is an important criterion.

There is clear evidence from the study so far that there is considerable re-invention of the wheel. Many projects within the NHS demonstrate little or no evidence of awareness of the literature. This is not a new problem: Huber ^{25,26} observes that "on many occasions management scientists conscientiously expend considerable time and thought in developing MAU (Multi-Attribute Utility) models, i.e. re-inventing the wheel rather than just making minor modifications to fit a particular situation".

Different disciplines seek models and methods of value elicitation which are grounded within their own disciplinary theory. Whilst acknowledging that fact, it is worth noting that theoretical validity and purity does not always coincide with acceptability, people's comprehension and even people's value systems. It is important to get the correct balance between theoretical validity and user acceptability. In particular, how far we should move in favour of the latter and away from the former requires careful consideration. At the very least, however, users of the various techniques should understand the values implicit in the techniques, the form of choice being imposed on respondents, the implications of aggregation of values, and the relevance/appropriateness of the chosen techniques to the purposes of the exercise.

Single-stage v multi-stage

Nearly all (perhaps all) decisions within health care policy are multi-criteria or multiattribute. Thus many approaches and models are two- or multi-stage, valuing first the attributes/criteria and then the options against those criteria. Final valuations for options are usually determined by an additive model of the basic form:

$$V_j = \Sigma c_i a_{ij}$$

Where: V_j is the value (or utility) of the jth option; c_i is the value of the ith criterion; a_{ij} is the value, performance or measure of the jth option against the ith criterion.

But sometimes it is presented in the form of a multiplicative model:

 $V_i = \Pi a_{ii}^{Pi}$

Where:

V_i and a_{ii} are defined as above;

 $\vec{p_i}$ is a parameter estimated using multiple regression and the transformation:

 $\log V_i = \Sigma p_i \log a_{ii}$

In many instances the criteria or attributes are valued explicitly as a separate stage of the process. However, some methods value the criteria/attributes implicitly, determining them from observations of choices between alternatives possessing different 'degrees' of the different attributes. The former approach is far more transparent to the user, the latter approach is essential when using the multiplicative model. Examples of both explicit and implicit methods of obtaining values in multi-stage models will be examined.

Many exercises use a single-stage process, even when valuing options that clearly possess multiple attributes. Thus, respondents are asked to choose between treatments, or between packages of care. In other cases, respondents are asked to value attributes such as access, waiting times, friendliness of staff etc., without the resulting values being explicitly incorporated into a two-stage model - although it is assumed that the values elicited will be taken into account within the decision-making process.

Many, if not most, of the methods of eliciting values explicitly are applicable both to single-stage models and to the individual stages of multi-stage models. Implicit methods are usually associated with multi-stage models - although it could be argued that with single-stage models implicit and explicit methods converge.

Constrained (forced choice) v unconstrained valuations

Most explicit methods of eliciting values can be divided between those methods which require respondents to make constrained (or forced) choices which "incorporate some notion of sacrifice" ⁴⁶, and those which allow unconstrained choices or valuations. The latter are characterised by scaling methods, where each criterion/attribute/option is valued independently of the others (although the effect of constrained choice can be obtained by subsequent normalisation). Constrained choices involve some form of trade-off between different attributes or alternatives and include a wide range of voting, ranking, comparison and trade-off techniques.

However, technically, the difference is sometimes more apparent than real, with some techniques acting as hybrids and, in any case, there is the potential to normalise, as noted

above. The relevance of the distinction between offering respondents unconstrained and constrained choices lies more in psychology. Generally, if the attributes or options to be valued are independent and not in competition, unconstrained methods are preferable. However, where they are in competition, and especially where that fact is important to the purposes of the exercise, constrained methods are preferable. Of course, mutually exclusive attributes or alternatives can place severe limitations on many methodologies offering constrained choices. Unconstrained (non-normalised) valuations can cause problems (especially inter-person equity) in aggregation over and above the general problems posed by aggregation, discussed below.

Aggregation

The issue of the aggregation of individual values poses possibly insoluble theoretical problems. It takes us into the field of social welfare and social choice and has generated countless articles of varying rigour and quality. Crudely, the arguments range from the stance that it is not possible at all to make inter-personal comparisons of utility and thus aggregating values across individuals is impermissible, to those who argue that societal choices have to be made (using voting in elections as an example) - so we should stop arguing and just add up the individual values. Whilst the latter argument has force, the vast theoretical literature does offer some useful insights, for instance Arrow's *Conditions* and his *Possibility Theorem*¹ and Condorcet's voting paradox. At the very least, users of techniques should be aware of the dangers of aggregation and the implications of different methods. Also, in view of the many problems associated with aggregation, there is often a case for avoiding single aggregated measures and presenting the full range of results - as is often done with Delphi methods.

A second problem of aggregation relates to equity between respondents. There may well be justification for allowing different respondents unequal weights in the aggregated values, but it would seem preferable that such unequal weights are incorporated explicitly rather than inequality being an accidental outcome of the methodology.

Aggregation is also affected by individuals not revealing their true preferences by 'voting' strategically, by co-operating as in Logrolling and game playing (prisoners' dilemma?), and by 'reverse engineering' the decision methodology ¹⁶.

Although we are seeking methodologies which can be used to inform priority setting within health services, and thus need techniques, which are sufficiently simple and robust for widespread use and are able to incorporate the values of large numbers of individuals, it is important not to ignore the theoretical problems associated with aggregation. Further, it should be noted that much of social choice theory is concerned with aggregation of (weaker) ordinal preferences, often with the (relatively limited) objective of determining an overall winner or, and especially in the case of Arrow's Possibility Theorem, with the objective of achieving societal ordinal preferences. However, many applications associated with valuing health states and priority setting within health care require, or at least use, (stronger) cardinal valuations from individuals and seek to aggregate these into collective or society cardinal valuations. Despite the objections to cardinality, rehearsed by McLean

(1987, p.24)³², methods which permit expression of intensity of preference and which result in cardinal measures are indicated in much of health care priority setting.

8. Some Techniques for eliciting preferences/values

As mentioned above, there are a large number of methods, derived from a variety of disciplines, for eliciting, either explicitly or implicitly, values and preferences from individuals and for aggregating such values.

Overview of techniques

Appendix 4 lists a number of such techniques which are found in the literature, with greater or lesser degrees of theoretical justification. They include:

- Single Vote
 - Scaling:
- Multiple Vote
 Likert-type scale Budget Pie
 - Visual Analogue Scale
- Ranking
- Delphi-type methods
- Scoring/Rating
 Simple Paired Comparison
 - Weighted Paired Comparison
 - Constant Sum Paired Comparison
- Scaled Paired Comparison
- Analytical Hierarchy Process
- Conjoint Analysis
- Measure of Value
- Time Trade Off
- Standard Gamble
- Willingness to Pay (WTP)

Also listed are some techniques/approaches which have been found in practice but not, as yet, in the theoretical literature. They include:

- Simple Trade-off
- Priority Search
- Combined Ranking/Budget Pie/Scale
- Aggregated Scores

Appendix 4 also gives brief details of each technique/approach, including:

- Does it determine values explicitly or implicitly?
- · Are respondents presented with constrained (forced) choice or an unconstrained choice?
- Are respondents permitted to indicate intensity of preference?
- Some details of the (usual) methods of aggregation, including whether there is interrespondent equity or inequity and problems with aggregation;
- Transparency of technique;
- · Ease of use, especially for respondents;
- Where relevant, indication of limits on applicability.

Choice of Method

In selecting or recommending methods for eliciting values, there is a major question of how far it is necessary to be concerned with their theoretical bases. Some claim that it is essential that the technique is grounded in the theory of their own discipline, others take a far more pragmatic approach. In some cases, insistence on theoretical 'purity' is criticised, for instance insisting that measures of health states must have psychometric validity 6 .

At this stage, whilst acknowledging the theoretical debates, we shall adopt a pragmatic stance. It is thus suggested that the following questions be asked of any proposed technique or approach:

- Is it relevant to the problem or issues to which it is to be applied?
- Does it seek constrained or unconstrained choices?ⁱ
- Does it take account of how people perceive problems?
- Are the ways in which respondents are permitted to answer meaningful both to them and to the problem?
- Does it permit respondents to indicate intensity of preference?
- How easy is it for respondents to use?
- How transparent is it to the respondents and to users?
- Are its implications generally understood by users?
- Does it require (skilled) interviewers or can self-completion methods be used?
- How exactly are responses to be interpreted?
- Is the aggregation method appropriate?
- Is any inter-respondent inequity intentional?

This pragmatic approach has some long-standing support. For instance, Huber ^{25,26}, demonstrating that, under many circumstances, different methods of eliciting values, and indeed different formulations of the MAU model, are equally good predictors of clients' preferences, concludes that transparency is important and that acceptability of the model and method to the client should be the major choice criterion. Clark ⁹ suggests that "one good principle is to utilise instruments only as precise and complex as necessary for the decision at hand", adding that "the instruments can be no more sensitive than their users". However, it should not be concluded that it is unimportant which method is chosen. In a small-scale study, comparing a method which permitted expression of intensity of preference (budget pie) with one which did not (multiple vote), Mullen ³⁵ demonstrated that very different individual and aggregated group values resulted.

¹ The determination of whether constrained or unconstrained choices are the more appropriate in specific circumstances may be helped by posing the following questions:

Are options in competition?

Are options mutually exclusive?

- Are others disadvantaged by the adoption of particular options? e g abortion on demand
 - walk-in rather than appointment system at GP surgery

Are options complementary?

Are options interrelated?

Are options independent?

9. Consumer Involvement in Priority Setting in Practice in the UK: some findings

Despite the sometimes rather 'macho' debate, there is evidence that few health authorities have completely excluded purchasing particular forms of treatment. Klein & Redmayne ³¹, in their survey, found only 12 purchasers out of 114 had decided to discontinue purchasing specific services. Where services/treatment are excluded they are usually fairly peripheral and relatively easy targets, e.g. in-vitro fertilisation (IVF), stripping of varicose veins, tattoo removal, cosmetic surgery and gender reassignment ^{42,43}. Less 'macho' forms of rationing take the form of limiting the number of treatments purchased and agreeing treatment protocols with providers.

These findings are reflected in our survey of projects *Involving the Public in Priority Setting* (some examples of the projects are described in Appendix 5). This survey has yielded only a few projects which sought priorities between whole services and treatments - and those that did largely responded to the question asking what influence the project had had on purchasing decisions or priorities by replying simply that the values elicited from the public 'were taken into account'. This follows the pattern of a major study carried out in a London health authority ^{3,4}, which used the combined Ranking/Budget Pie/Scaling method (see Appendix 4) to elicit, from the public, their relative values of different treatments, such as hip replacements, neo-natal intensive care etc. No evidence was presented that the resultant values influenced the authority's purchasing or priority decisions - rather the aim of the exercise appeared to be to test the methodology.

Although that exercise, and those found in our survey, did succeed in eliciting responses from the public, most reported public resistance to participation in the more 'macho' priority-setting exercises. Respondents either felt that such decisions should be left to professionals, usually doctors, or felt that rationing and priority setting are a cover for cuts resulting from government underfunding of the health service and they wanted no part of it. Indeed, a survey by Richardson et al ⁴⁴ found ambivalent responses from the public about who should make priority-setting decisions, and Heginbotham ²³ reported a survey which showed that only 22% of 'general public' respondents answered that the general public should "make decisions on which treatment takes a higher priority".

A large number of the projects reported in our survey sought views on attributes of service delivery, such as geographical location (and resultant access issues), other access issues such as facility opening times and special transport, location of treatment and facilities (e.g. hospital v community), type of treatment and a range of quality issues. Generally, there appears to be far less public resistance to responding in these areas and there was often a far more direct link with purchasing plans and policy-making.

Several authorities used some form of explicit valuation technique, usually via a questionnaire survey. By far the most frequently used method was ranking, which was used both for services/treatments and for attributes of health service. Indeed, so ubiquitous is ranking that the term was used even where some form of rating scale was employed. A large number of studies using ranking aggregated responses by calculating the mean of

rank positions. Over one third of projects used focus groups, either alone or in combination with other methods. A small number of focus groups were reported to be using structured value elicitation or priority-setting methodologies but, as is more usual with the focus group approach, the aim was frequently simply to identify issues of concern to users and the public and to set agendas. Seven authorities reported using Priority Search (see Appendix 4) and several others also used external research or consultancy firms, who employed techniques of varying degrees of sophistication.

Several respondents commented on the value gained from the process of carrying out the exercise, which was independent of any results actually obtained.

Several respondents discussed the public's lack of knowledge of the structure and organisation of the NHS - in particular the 1991 NHS changes - suggesting that the public cannot usefully contribute to health care priority setting until they are educated about NHS structure and financing and understand the roles, responsibilities and relationships of the various bodies within it.

10. Conclusions

The primary aim of this paper was to examine some of the issues surrounding the choice of techniques for eliciting and aggregating values to inform priority-setting processes within health care. To this end, a range of methodologies for eliciting values has been evaluated and a series of actual projects examined. There is a clear need for the dissemination of information as there is considerable evidence of "re-invention of the wheel". A major question here is: How necessary is it to be concerned about the technical validity of methodologies used in local studies? On the one hand it could be argued that the prime objective is to find approaches which are sufficiently simple to administer and easy for respondents to use and not to worry about problems of their validity. Support for this view comes from repeated reports of the benefit gained from the process of carrying out consultation exercises with users and the wider general public. If the process is the main objective, the lack of validity of the outcome of any value elicitation exercise is of secondary importance. On the other hand, if the outcomes of such exercises are actually used to determine priorities and redeploy resources, it would appear essential to have regard to the validity of the methods used for eliciting and aggregating values, and to ensure that those who use such methods have some understanding of their implications.

References

- 1. Arrow, K. J., Social Choice and Individual Values, 2nd ed. Wiley, (1963)
- 2. ACHCEW, <u>Rationing Health Care: Should Community Health Councils Help?</u> Association of Community Health Councils for England and Wales, London, (1993)
- 3. Bowling, A., <u>What people say about prioritising health services</u>, Kings Fund Centre, London, (1993).

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- Bowling, A., Jacobson, B., Southgate, L., <u>Explorations in consultation of the public</u> and health professionals on priority setting in an Inner London Health District, Social Science and Medicine, vol, 37, no.7, pp 851-857, (1993)
- 5. Brannigan, M., <u>Oregon's Experiment', Health Care Analysis</u>, vol.1, no.1, pp 15-32, (1993)
- 6. Brazier, J., 'Review of "Health Status Measurement"' by R. C. Brooks, _, vol.4, no.2, pp 149-150, (1995)
- 7. Bull, A. R., 'Problems of Prioritisation and our Duty to Care', Journal of Management in Medicine, vol.5, no.4, pp 35-39, (1991)
- 8. Churchman, C. W., Ackoff, R. L., 'An approximate measure of value', <u>Operations</u> <u>Research</u>, vol.2, no.2, pp 172-181, (1954)
- 9. Clark, T. M., 'Can you cut a Budget Pie?', <u>Policy and Politics</u>, vol.3, no.2, pp 3-31, (1974)
- 10. DoH, 'Working for Patients', White Paper on the NHS, HMSO, London, (1989)
- 11. DoH, 'Local Voices', NHS ME Department of Health, (1992)
- 12. Donaldson, C., 'Distributional aspects of willingness to pay', Paper presented to the Health Economists Study Group, Aberdeen, July 1995
- 13. Doyal, L., 'The role of the public in health care rationing', <u>Critical Public Health</u>, vol.4, no.1, pp 49-54, (1993)
- 14. Etzioni, A., 'Health Care Rationing: a Critical Evaluation', <u>Health Affairs</u>, vol.10, no.2, pp 88-95, (1991)
- 15. Fox, D.M., Leichter, H.M., 'Rationing care in Oregon the new accountability', <u>Health Affairs</u> 1991 vol.10 no.2 pp.7-27, (1991)
- 16. French, S., Stewart, T., 'Manipulation of Analyses', Journal of Multi-criteria Decision Analysis, vol.2, no.2, p.63, (1993)
- 17. Grimley Evans, J., 'Aging and rationing: Physiology not age should determine care' <u>British Medical Journal</u>, vol.303, pp 869-870, (1991)
- 18. Hadorn, D.C., The Problem of Discrimination In Health-Care Priority Setting, (1992)
- 19. JAMA-Journal of the American Medical Association, vol.268, no.11, pp.1454-1459
- 20. Hall, J., Haas, M., 'The Rationing of Health-care Should Oregon be Transported to Australia', <u>Australian Journal of Public Health 1992</u>, Vol.16 No.4 pp.435-440(1992)
- 21. Ham, C., 'Priority setting in the NHS: reports from six districts' <u>BMJ</u>, vol.307, no.6901, pp 435-8, (1993)
- 22. Hauser, J., R., Shugan, S. M., 'Intensity Measures of Consumer Preference', Operations Research, vol.28, pp 278-320, (1980)
- 23. Heginbotham, C., 'Healthcare priority setting: a survey of doctors, managers, and the general public', pp141-156, in <u>Rationing in Action</u>, BMJ Publishing Group, (1993)
- 24. Honigsbaum, F., 'Who shall live? Who shall die? Oregon's health financing proposals', <u>King's Fund College Papers</u>, King's Fund College, (1991)
- 25. Huber, G. P., 'Multi-attribute utility models: a review of field and field-like studies', <u>Management Science</u>, vol.20, no.10, pp 1393-1402, (1974)
- 26. Huber, G. P., 'Multi-attribute utility models: a review of field and fieldlike studies', pp 193-206 in: Churchman, C. W., (ed) <u>Systems and Management Annual 1975</u>, (1975)
- 27. Hunter, D. J., <u>Rationing Dilemmas in Health Care</u>, National Association of Health Authorities and Trusts (NAHAT), Research Paper No.8, (1993)

- 28. Hunter, D.J., Harrison, S., <u>Rationing Health Care</u>, Institute for Public Policy Research, London, (1994)
- Jennett, B, 'Medical ethics and economics in clinical decision making', pp 90-102 in Mooney, G., McGuire, A., (eds), <u>Medical Ethics and Economics in Health Care</u>, OUP, (1998)
- Kitzhaber, J. A., 'Prioritising health services in an era of limits: the Oregon experience', <u>BMJ</u>, vol.307, no.6900, pp 373-7, (1993)
- 31. Klein, R., Redmayne, S., 'Patterns of Priorities a study of the purchasing and rationing policies of health authorities', NAHAT Research Paper 7, National Association of Health Authorities and Trusts, Birmingham, (1992)
- 32. McLean, I., Public Choice, Blackwell, (1987)
- 33. Menzel, P. T., 'Oregon's Denial: disabilities and quality of life', <u>Hastings Center</u> <u>Report</u>, vol.22, no.6, pp 21-25, (1992)
- 34. Mooney, G., Jan, S., Wiseman, V., 'Examining preferences for allocating health care gains', <u>Health Care Analysis</u>, vol.3, no.3, pp 261-265, (1995)
- Mullen, P. M., 'Delphi-type studies in the Health Services: the Impact of the Scoring System', <u>Health Services Management Centre, Research Report</u>, 17, University of Birmingham, (1983)
- 36. Mullen, P. M., 'Should OR help ration health care?', Paper presented to the Conference of the Operational Research Society, 14-16 September, York, (1993)
- Mullen, P. M., 'Is health care rationing really necessary?', <u>HSMC Discussion Paper</u>, 36, University of Birmingham, (1995)
- 38. Mullen, P. M., 'Cash question in health care', Letter to the Editor, <u>Daily Telegraph</u> 14 March, (1995)
- 39. Mullen, P. M., 'Girl B is victim of the internal market's climate of mistrust', Letter to the Editor, <u>The Independent</u>, 14 March, (1995)
- 40. NHSE, 'Priorities and Planning Guidance for the NHS: 1996/97, NHS Executive, (1995)
- Nelson, R. M., Drought, T., 'Justice and the moral acceptability of rationing medical-care - the Oregon Experiment', <u>Journal of Medicine and Philosophy</u>, vol.17, no.1, pp 97-117, (1992)
- 42. Redmayne, S., 'Skin Deep', <u>Health Service Journal</u>, vol.102, no.5325, pp 28-29, (1992)
- 43. Redmayne, S., Klein, R., 'Rationing in practice: the case of in vitro fertilisation', British Medical Journal, vol.306, no.6891, pp 1521-1524, (1993)
- 44. Richardson, A., Charny, M., Hammer-Lloyd, S., 'Public opinion and purchasing', British Medical Journal, vol.304, no.6828, pp 680-682, (1992)
- Saaty, T. L., 'A Scaling Method for Priorities in Hierarchical Structures', <u>Journal of</u> <u>Mathematical Psychology</u>, vol.15, no.3, pp 234-281, (1977)
- 46. Shackley, P., Ryan, M., 'Involving Consumers in Health Care Decision Making', <u>Health Care Analysis</u>, vol3, no.3, pp 196-204, (1995)
- Strosberg, M. A., Wiener, J. M., Baker, R., Fein, I. A., (eds), <u>Rationing America's</u> <u>Medical Care: The Oregon Plan and Beyond</u>, The Brookings Institution, Washington, DC, (1992)

Appendix 1: Issues in Health Care Rationing

(a) Is Health Care Rationing Necessary?

• Finite Need-Infinite Resources

The oft quoted 'finite resources, infinite demand' is challenged and indeed turned round. It is claimed that health care need (and even demand) is not infinite and that resources are not finite.

• Underfunding of the NHS

It is argued that there would be no need to ration health care within the NHS if it were funded at a level nearer to that of other developed countries. The decision as to how much should be devoted to health care is not a given and it is suggested that is obscene that a society that can afford 'fripperies' denies care to some of its members.

• Elimination of non-effective treatments

It is argued that there would be no, or less, need to ration beneficial treatments if all ineffective or non-beneficial treatments, all unnecessary treatments, and all those treatments which actually do harm, were eliminated. However, in practice it is not so simple. Few treatments are never harmful and there are few treatments which never give any benefit at all to any patient (Jennett, 1988, p.98)²⁹.

(b) Should Health Care be Rationed?

• Detraction from Underfunding and Efficiency

It is argued that the rationing debate serves to detract from questions such as underfunding of the NHS and from possible ways of increasing the efficiency of the delivery of care and reducing the cost of provision.

• Social Justice

To extend to health care the analogy of rationing during wartime, with its ideas of fair shares for all, it is argued that it would be necessary to forbid the purchase of care which is excluded from those rationed. Otherwise, rationing health care 'merely extends the prevailing class structure to health care' ¹⁴, or 'if...we allow some individuals to purchase the otherwise excluded medically necessary procedure, it would appear that we are restricting access based on ability of pay rather than on the category of illness' ⁴¹.

• Limits to Rationing

The fact that rationing can be applied only to some aspects of health care and not to others, it is argued, introduces a distortion into the debate.

(c) Rationing by Health Gain and QALYs

• Equity

The utilitarian approach of maximising total gain, without consideration of distributive justice, it is claimed, violates the principle of equal access for equal need, since people with equal need for treatment will be accorded differential access where the cost of treating them is different.

• Double jeopardy

It is argued that people with a pre-existing disability may face a 'double jeopardy' in that their potential QALY gain from, say, a particular life-saving treatment is inherently lower than the potential gain from the same treatment received by a person who can be restored to full health.

• Individual v the Collective - 'Rule of Rescue'

Bull ⁷ argues that prioritisation or selection for treatment on the basis of health gain conflicts with our 'duty to care for all who suffer from ill health'. Put another way, it conflicts with the 'Rule of Rescue', which Hadorn ¹⁸ describes as 'the strong human proclivity to provide aid to identified victims of illness or accident'. The controversy over the Child B case, where a health authority refused to pay for chemotherapy and a second bone-marrow transplant (estimated to cost £75,000) for a 10-year-old girl, powerfully illustrated the conflict here ^{37,38,40}.

• Outcomes not process

The health gain/QALY approach has been criticised as being concerned solely with the outcomes of treatment and taking no account of benefits obtained from the process.

• Innovation

It is suggested that concentration on health gain/QALY might jeopardise the introduction of new, potentially efficacious, treatments.

• Insurance Principle

It is argued that potential patients have paid contributions to the health care system (under whatever contribution system prevails) on the assumption that they are purchasing 'assurance' that the health care will be provided when they need it. It can be argued that people want, and consider they have paid for, a service which will 'pick them up and put them together' in case of catastrophe. Having paid their 'insurance' for such events, they may not be impressed by arguments that the process of 'picking them up and putting them together' scores too low on the QALY scale. Rationing which leads to the denial of treatment breaks the implicit contract.

(d) Rationing by Exclusion

• average v marginal benefit

Exclusion of treatments, especially on the justification of health gain, makes no allowance for the variability of cases. Excluded treatment could be denied to a patient who could gain a great deal of benefit, whilst non-excluded treatment could be provided to a patient who gains very little benefit.

• accuracy of diagnosis

Any justification for the total exclusion of some treatment-condition pairs must be predicated on accurate diagnosis. However, if the exclusion encompasses the initial referral to a specialist, it is possible that serious conditions might be missed where the original diagnosis is faulty. It is interesting to note that Oregon will provide 'initial evaluation and diagnosis for all conditions' ³⁰.

• co-morbidities

Rationing by exclusion, taken to its logical conclusion, could lead to absurdities where there are co-morbidities.

• diagnostic 'creep'

Diagnostic 'creep' could sabotage 'rationing by exclusion' by ensuring that the diagnosis and treatment fell within the 'included' list.

• *ability to pay*

It is argued that rationing by exclusion effectively means rationing by ability to pay. Using the much maligned waiting lists as a rationing mechanism does at least mean that patients

with low priority conditions have a choice between waiting or paying. If low priority conditions are excluded the only choice is between no treatment or paying.

(e) Rationing by Age

Some commentators argue that aggressive health care should be denied to those over a certain age, on the grounds of lower ability to benefit or a 'fair innings' argument. Against this it is argued that ago alone is not a good predictor of ability to benefit ¹⁷ and also that the 'just rewards' principle means that they should be entitled to treatment.

(f) Rationing by Prior Consent

The argument is forwarded that rationing, or denial of care, is fair if the patient had freely given their prior consent to the denial of that treatment. This is usually posed in the form of taking out cheaper health insurance, knowing that the coverage of benefits is limited.

Appendix 2: Issues relating to public participation in health care priority setting

• Legitimation of decisions

It is argued that involving the public in determining priorities for the rationing of services serves to legitimise those decisions. Some would argue that this is an advantage, for instance Ham²¹ states that the 'process of setting priorities involves making judgements on the basis of incomplete information and evidence. These judgements are likely to be more soundly based and defensible if they have been exposed to public discussion.' Others consider this a misuse of public participation since incorporating the public in the decision-making process undermines their ability to challenge the whole notion of rationing as well as deflecting criticism of the actual priority decisions. Can the public (or individual patients) be deemed to have given their 'prior consent' to the denial of treatment, if that is the outcome of a public consultation exercise?

• lack of knowledge ('dictatorship of the uninformed')

Some argue that the public simply do not have the knowledge to make the type of decisions involved in priority setting. Of course, the strength of this point will be very much influenced by the whole purpose of the exercise and the type of question being asked. Further, however, it is well known that responses can be influenced the way that questions are asked, which actually leads more to the risk of manipulation by those posing the questions than the risk arising from the respondents lack of knowledge.

• experience of condition & probability of getting condition

Responses may be influenced by whether or not the respondent has experience of the condition or health state under consideration and by the probability of the respondent ever getting that condition ³³, i.e. there is an absence of the Rawlsian 'Veil of Ignorance'. This effect might be particularly evident for congenital and early onset-conditions, which respondents know they will never experience personally.

• professional v public/lay views and values

Meaningful public involvement involves professionals giving up or at least sharing their power with lay people, but some challenge the legitimacy of public involvement in what they consider professional decisions. There is also the problem of what to do when public/lay and professional views differ, especially when the public give the 'wrong' answers, e.g. rate neonatal intensive care for ELBW babies above hip joint replacements

• victim blaming and unpopular 'diseases'

There is a fear that the public, but not of course professionals, will indulge in 'victim blaming' and will downgrade unpopular diseases.

• knowledge of structure of health service

Some health service personnel argue that the public need to understand the structure of the NHS before they can contribute to priority setting.

public resistance to certain questions

There is evidence of public resistance to answering questions directed specifically at setting priorities for treatments and services and also to answering 'willingness to pay' type questions.

Appendix 3: Reasons for variations in services between districts within a national health service

Initial Analysis

Legitimate Reasons

- Size and demographic characteristics of population
- Epidemiology/Disease patterns
- Ethnic/Religious differences
- Level of Car ownership
- · Population density and natural barriers
- Public Transport
- · Level of economic activity, especially of women
- Climate
- Socio-economic factors/situation (avoid double counting with disease patterns)
- Quality of housing
- · Provision and quality of other services

Non-legitimate Reasons

- · Historical patterns of provision and/or usage
- · Values/Choices/Prejudices of local health authority/commission

Questionably Legitimate Reasons

- Values/prejudices of local population
- Level of Private Health Insurance?

Appendix 4: Some methodes of eliciting preferences

Technique	Explicit? Constrained?	Description	Constraints on Respondents	nstraints on Implications of spondents Aggregation	
Single Vote	Explicit Constrained	Each respondent is given one vote to allocate to preferred option	Forced to give 100% of 'vote' to preferred option	If votes are summed, inter-respondent equity. Scope for strategic voting	Transparent, easy to use. Single winner, first-past-the-post can appear perverse
Multiple Vote	Explicit Constrained	Each respondent given k votes to allocate to each of k preferred options	Forced to give equal 100/k% of vote to each of k options	If votes summed, Inter-respondent equity. Potential for strategic voting	Transparent, easy to use. If respondents forced to use all votes, block voting by a group can dominate.
Budget Pie (Constant sum measurement) (Point voting system) (Clark, 1974)	Explicit Constrained	Each respondent given fixed 'budget' of points/tokens/money to allocate between options in any amounts they choose	Allows respondents to indicate relative intensity of preference	If 'points' summed, inter-respondent equity. Aggregation relatively unproblematic. Little scope for strategic voting	Transparent. Easy to use (although that is disputed). Problems of scale when using money. Useful when options in competition but not mutually exclusive. (Multiple vote is special case of budget pie)
Ranking	Explicit Constrained	Each respondent asked to rank all or top k options in order of preference	Respondents unable to express intensity of preference. If rank positions are treated as cardinal equal intervals and fixed intensity of preference are implied.	Inter-respondent equity If rank positions are added (eg Borda count) can violate Arrow's Condition 1 Independence of Irrelevant Alternatives	Transparent. Easy to use but aggregation can be misleading. (If only first choices are used in aggregation becomes single vote)
Scoring/Rating	Explicit Unconstrained	Each respondent asked to give score/mark/rating to each option (usually within a defined range)	Allows respondents to indicate intensity of preference/value	Inter-respondent inequity, if scores given to each option summed (unless each individual's scores first normalised)	Transparent, Respondents can find difficult. Useful when options not in competition.
Scaling: Likert-type scale	Explicit Unconstrained	Respondent asked to select position on 4-9 point 'scale'. Points usually categories (eg strongly agree to strongly disagree)	Within restrictions of 'scale' allows respondents to indicate intensity of preference. Subsequent scoring imposes fixed intensity of preference values	Inter-respondent inequity if 'scores' for each option summed. Summing respondents' choices for each category relatively unproblematic.	Relatively easy to use, but requires careful design. Imposing numerical 'scores' on categories can prove misleading.

Technique	Explicit? Constrained?	Description	Constraints on Respondents	onstraints on Implications of spondents Aggregation	
Visual Analogue Scale (VAS)	Explicit Unconstrained	Respondents mark value of each option on visual scale (usually marked 0-10 or 0-100)	Allows respondents to indicate intensity of preference	Inter-respondent inequity if scores summed for each item (unless each individual's scores first normalised)	Transparent. Easy to use. Useful where options not in competition.
Delphi-type methods	Explicit Unconstrained	Respondents individually value each option or estimate date by which an event will occur or estimate probability of event occurring	Where relevant, permits respondents to indicate intensity of preference	here relevant, permits Results usually presented spondents to indicate in histogram showing responses presented of every individual to each item.	
Simple Paired Comparison (dominance preference)	Explicit Constrained	Respondents state preference between each pair of options	Respondents unable to intensity of preference	If options ranked for each individual - same as ranking above. If aggregated for each pair of options - risk of voting paradox. Inter-respondent equity	Relatively transparent. Easy to use but very large number of comparisons required if more than a few options
Weighted Paired Comparison (ratio-scaled preference)	Implicit Unconstrained	Respondents state degree of preference between each pair of options. Needs complex transformation (cg. AHP) to obtain values	Allows respondents to indicate intensity of preference.	Inter-respondent inequity if resulting values for each option summed, unless first normalised	Not very transparent. Very large number of comparisons required if more than a few options
Constant Sum Paired Comparison	Explicit Constrained	Respondents given budget of money or points to allocate between two options	Allows respondents to indicate intensity of preference	Inter-respondent equity Aggregation by summing allocation for each option relatively unproblematic	Two-option variant of budget pie. Claimed easier to use (Hauser & Shugan, 1980). Large number of comparisons if more than a few options. Variants limit set of permitted responses.
Scaled Paired Comparison	Implicit Usually Constrained	Respondents indicate on a scale between two options their relative preference Option values then computed by complex method (eg Priority Search or Conjoint Analysis)	Allows respondents to indicate intensity of preference	Depends on method of anatysis, but probably equity between respondents	Not transparent but easy to use for respondents. With some methods of conversion to option values, is special case of constant-sum paired comparison

Technique	Explicit? Constrained?	Description	Constraints on Respondents	Constraints on Implications of Respondents Aggregation	
Analytical Hierarchy Process (AHP) (Saaty, 1977)	Implicit Unconstrained	Multi-stage method using Weighted Paired Comparison with limited range of weights Preferences entered into matrix and converted mathematically into values using eigenvectors	Allows respondents to indicate intensity of preference.	Aggregation issues not fully addressed. Values are usually normalised.	Not very transparent. Can involve large number of comparisons. Very widely used and there is a large OR & Management Science literature.
Conjoint Analysis	Implicit Constrained?	Pairs of options, each with different mix of values of the relevant attributes, presented to respondents. Multiple regression analysis of choices to determine coefficient or weights for each attribute.	Respondents unable to indicate intensity of preference with simple paired comparison - however weighted or scaled paired comparison sometimes used.	Equity between respondents Aggregation implicit in multiple regression to obtain coefficients for attributes	Not transparent Claimed to be grounded in expected utility theory. The very large number of options possible for every combination of attribute values, usually reduced to make number of comparisons viable
Measure of Value (based on Churchman & Ackoff, 1954)	Implicit? Unconstrained	Respondents first rank options or attributes, then offered series of simple paired comparisons betw- een single higher valued option and combination of lower valued options. Option values assigned in accordance with choices	Combinations effectively permit respondents to indicate intensity of preference	If individuals' values summed inter-respondent inequity unless values normalised. Group 'voting' at each choice can lead to problems of voting paradox.	Not very transparent. Easy to use but needs respondent/ researcher (or computer) interaction. Little evidence of recent use.
Time Trade Off	Explicit? Constrained	Respondents select between higher state of health for shorter time or lower state for longer time; or asked how much time prepared to loose from life to move from lower health state to perfect health. Responses converted into values for each health state	Allow respondents to indicate intensity of preference	Usually aggregation by computing means. Inter- respondent equity	Fairly transparent. Evidence of respondent reluctance to trade even small amounts of life for perfect health. Only applied to valuing health states?
Standard Gamble	Implicit Constrained?	Respondents determine p (probability at which they are indifferent) in gamble between state of health S and (1-p) probab- ility of perfect health and p prob- ability of death. Value of health state S relative to perfect health & death determined from responses.	Allows respondents to indicate intensity of preference	Usually aggregation by computing means. Inter- respondent equity.	Not very transparent. Evidence that respondents have difficulty dealing with probabilities. Reluctance to accept even small risk of death. Widely used by economists in many contexts.

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Technique	Explicit? Constrained?	Description	Constraints on Implications of Respondents Aggregation		Notes	
Willingness to Pay WTP	Explicit? Unconstrained?	Respondents asked how much they would be willing to pay for product/service, or how much more would pay for some change in service.	Allows respondents to indicate relative intensity of preference - but affected by disposable income	Aggregation usually by addition or means. Inter-respondent equity compromised by differential 'purchasing power' and fact that decision effectively unconstrained. Some attempts to weight responses according to income (Donaldson, 1995)	Fairly transparent. Cannot deal with joint products. When applied to public health services, problem of differential purchasing power would appear insuperable. Evidence of resistance from respondents when asked WTP for 'free' health services.	
Some Methods foun	d in Practice b	out not in the theoretical/tech	nical literature			
Simple Trade-off	Explicit Constrained	Respondents presented with status quo and asked to indicate services for increased expenditure with equivalent number for reduced expenditure	Respondents cannot fully indicate intensity of preference.	Inter-respondent equity Aggregation usually by summing numbers indicating reduced and increased expenditure for each item.	Transparent and easy to use. Does not easily produce cardinal valuations of options or service changes.	
Priority Search	Implicit Constrained	List of 14 - 42 services and attributes (mixed) drawn up. Respondents indicate scaled preference between limited number of pairs. Rankings for each individual service or attribute produced via commercial computer program.	Allows respondents to indicate intensity of preference.	Apparently inter-respondent equity. Aggregation by means of rank positions or by 'scores' derived from %age of bottom 3rd rank positions subtracted from %age of top 3rd rank positions	Not transparent. Fairly easy for respond- ents but large number of comparisons, although each option appears only 3 times in comparisons. Claimed to be based on Personal Construct Theory (Kelly 1960s) but actual algorithm commercial secret. Some uses in NHS	
Combined Ranking/ Budget Pie/Scale (Bowling, 1993)	Explicit? Constrained	Respondents asked to allocate 'budget' of,say, 4 'very import- ants' VI, 4 'quite importants' QI & 4 'not importants' NI between 12 options. Scores allocated 3 points to VI, 2 for QI and 1 for NI	Allows respondents limited scope to indicate intensity of preference (Scoring system forces fixed intensity allocations) Presenta- tion can appear similar to Likert scale or to Budget Pie	Inter-respondent equity. 'Scores' summed for each option and often mean 'scores' computed. Results often presented as overall ranking of options.	Not very transparent. Fairly easy for respondents. May mislead respondents because of presentation and because conversion 'scale' not usually presented. Users may not understand implications of technique.	
Aggregated Scores	Explicit Unconstrained	Respondents score 'performance' of option against each attribute on a unique scale for that attribute (eg 0-3 or 1-5). Option values computed by summing scores over all attributes.	Allows respondents to indicate 'intensity' of 'perform ance'. Respondents not normally able to influence attribute weights (ie maximum permitted scores).	Inequity between respondents. Values usually summed over all respondents.	Not very transparent. Fairly easy to use, although may be mislead over pre-assigned attribute values/weights. Essentially two-stage model but implications of additive model not always understood by users.	

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Appendix 5: Some selected examples of priority setting techniques in practice

Healthy Locality Project (43)

Aim: to ascertain the health needs in a defined locality in the Health authority and to develop an action plan to address those needs with an emphasis on Health of the Nation areas.

Method: Rapid Appraisal using 30 interviews. First asked participants to raise issues relating to the main health and social needs. Issues were placed in groups. From lists of the issues thus raised respondents were asked to rank top 5 from each group list and rank top 10 from all lists. The final list was based on the number of times an item appeared in the top 10. A weighting score was also calculated by using reverse rank positions and summing, in order to indicate strength of feeling.

Involving Local People in purchasing Health (139)

Aim: Consultation on Health Plans 1995/96.

Method: Interviews with key voluntary organisations to discuss priority areas for change. Series of 9 public meeting to discuss proposals in Health Plans, promoted through media and wide distribution (190,000) copies of HA newsletter. Public invited to influence health Plan proposals through attendance at meetings/completion of questionnaire. The questionnaire asks respondents to choose 3 ideas that they particularly support from the 24 described in the leaflet. Also asked to write in additional ideas. 1090 forms received with 3270 ideas selected.

Title: Consulting with people in different localities (160)

Aim: to understand how local people & local health professionals think health & health services can be improved.

Method: Focus groups - issues raised in focus groups determine the contents of a later questionnaire which includes prioritisation questions. Questionnaire to the public first asks respondents whether they agree or disagree with each of a list of statements. For each of the statements they agree with, respondents are asked to indicate whether they think action should have a high, medium or low priority.

GP Survey 1992 (114)

Aim: to seek CPs' opinions to assist Health Service Planning.

Method: Postal Survey asked respondents to rate (score) 26 hospital & 29 community services on 5 point scale on two dimensions: Quantity (1=Over provided 5=Grossly inadequate); Quality (1=Excellent 5=very poor) (6=insufficient experience). Results were presented giving the mean score of each service on each dimension, and also the percentage of respondents scoring in 4 or 5. Respondents also asked to rank 5 top hospital & 5 top community priorities (adding any missing from the lists given) then to give the 5 ranked top priorities overall. Results were presented giving: a) the total number of entries in priority lists; b) the number placing that service as top priority.

GP Survey 1994 (113)

Aim: to identify GP opinions/preferences for service development and to assist with Board purchasing process.

Method: Postal survey _ Main question. Given list of 45 services. Asked priority for service development. Two ticks to single top priority, one tick each to next four priorities. Also asked to add comments, including saying if any services currently over-provided and could be reduced; Write-in question asking what new services the respondent would like to see, also asked for discussion topics; Results presented in two appendices: Appendix 1-Top Priorities only (i.e. those services given two ticks; Appendix 2: Overall Priorities (i.e. all the services given either one or two ticks).

Involving the public in priority setting (50)

Aim: to produce and evaluate an easy to use model which considered the views of all those concerned in prioritising health care which will assist the decision making process.

Method: Participants included: CHC members, HA members, Corporate Purchasing Group, HA Staff Members, Consultants/Medical/Nursing staff (Psychiatric dept.) working in groups] A set of criteria was drawn up and each person individually ranked the list 10 to 1. The weight for each criterion was calculated from the mean of rank scores. Each service was rated 0-100 against each criterion by each participant. The mean of the group ratings was multiplied by criterion weights to produce a score for each service.

Public consultation by the local Community Health Councils in response to the Strategy for Health (41)

Aim: to introduce the concept of participation in planning and the role of participants in developing the local health strategy. Use the information gathered to influence the commissioning of health services.

Method: Interviews, involving completion of a questionnaire. First there are detailed questions on 11 possible (expensive) service developments. Then the prioritisation questionnaire. Respondents are asked to score each of 11 options on 5 point scale (5=Absolutely Urgent & Essential within 1 year; 4=Essential within 2 years; 3=Desirable within 3 years; 2=Des. within 4 years; 1=Not required).

Panel of Enquiry - Disturbed Behaviour Unit (27)

Aim: Project set up to hear evidence of need for locally-based medium stay low secure unit for those with mental illness & challenging behaviour. Evidence taken from national and local experts and local voluntary.

Method: Public panel _ experts invited to give views and examples of good practice; public invited to comment and express views (ask questions, express views & preferences); all views taken down to be used when decisions were taken to either continue with [distant] service or to switch funds to providing a local service.

Lessons (reported by respondent): the panel proved to be a very good mechanism for enabling community to make informed decisions; the public who attended appreciated being involved in the decision-making process and opportunity to influence service provision; the purchaser & provider representatives found the process challenging - the need to justify intentions. It was very time consuming.

Neighbourhood planning involving public consultation (93)

Aim: to consult the public on health issues for [location] and in particular their area, as a prelude to the Purchaser Plan 1995/96.

Method: Following discussions with public, GPs and analysis of data, lists of health issues and service developments have been drawn up for each Neighbourhood and are now open to consultation via meetings and leaflets. All the information from this is to be used in prioritisation exercise. Prioritisation exercise will take place based on following criteria: Robustness/implementability of proposal; promotion of equity; prevention v treatment; evidence of effectiveness /cost effectiveness; prioritised by primary care profession; in accordance with national priorities; collaboration with/integration with primary care.

Developing Consensus on the Management of Women with Breast Cancer using the Delphi Technique (146) [see also 159]

Aim of whole project to involve all stakeholders in the development of guidelines for management of women with breast cancer for whole county. Part of process views of users attending four DGHs were obtained & also sample from the general population.

Method: Users: postal survey covering satisfaction with services and problems encountered - also asked to rank (score/rate) for importance list of 15 issues raised by service providers on a 1-7 VA-type scale. General Public: (a) technique of policy capture used to obtain ranking and priority given to four issues (speed of access, level of specialisation, journey time, patient support) [using 16 questions giving all possible combinations of the 4 issues, rating on scale 1-10]; (b) ranking of same 15 issues as for users on a 1-7 VA-type scale.

Developing Consensus on the Management of Women with Breast Cancer using the Delphi Technique [with professionals] (159) [see also 146]

Aim of whole project to involve all stakeholders in the development of guidelines for management of women with breast cancer for whole county. [Delphi exercise involving 48 Clinicians and Nurses involved in Cancer Treatment from 7 hospitals serving local residents. Also - separately - GPs.].

Method: Three-round Delphi Exercise. Round 1: Questionnaire asking satisfaction with current arrangements for management of women with Breast Cancer & importance of guidelines. Respondents asked to list advantages & disadvantages of one specialist centre for: (1) assessment and planning of treatment; (2) treatment. Round 2: Results from Round 1 fed back to participants. Questionnaire listing points raised, respondents asked their agreement/disagreement with each point and asked to rank the top 10 most important for: (1) assessment and planning of treatment; (2) treatment. Round 3: The results of round 2 were reported back. Respondents were presented with ranked lists under (1) assessment and planning of treatment; They were then asked to rank the items again and also to select their preferred organisational arrangements. Finally, there was a Consensus Conference, to which was reported the relative importance given to the issues raised by service providers in the Delphi process.

Help us to help you (55)

Aim: to get views of resident population of [health district] on three most important issues, problems or developments in relation to health services in [District] which they would like to see considered.

Method: 36,000 questionnaires distributed via Authority's newspaper 'Health Report', i.e. one in six of distribution. Respondents asked: 'Please indicate below issues, problems or developments in relation to the health services in [health district] which you would most like to see considered'. 3 large spaces given for response, plus freepost address. Very low response, only 216 replies.

Consulting members of the public about priorities for health care (36)

Aim: to rank 60 items of Health Care and Health Authority activity in order of importance. Also to test different methodologies for doing this (recognising the virtual impossibility of an individual giving an opinion about the rank of 60 items in one go).

Method: Postal Survey: Two different versions of questionnaire used (each included 10 of the 60 items under examination, selected randomly). Preamble states 'Please imagine that we have to move money from low need services into high need services': i) asked respondents to place the 10 items in rank order (1 - 10); ii) asked respondents to indicate for each of the 10 services to indicate whether 'very high need' 'high need' 'low need' 'very low need'.

Health Authority Survey on Health Issues (68)

Aim: Locality based postal survey aimed at obtaining feedback on health issues.

Method: Postal Survey. Contains question asking respondents to: i) rank 1-6 six health promotion items; ii) rank 1-9 best places to provide information on Health Service provision; iii) rank: 1-8 importance of areas of health education in schools. Asks respondents to indicate what factors would make you travel for treatment: Asks respondents to reply Yes/No to money being transferred to 6 complementary therapies.

Market research project (32)

Aim: HA commissioned Gallop Poll to conduct survey amongst residents to assess their views on some proposed improvements in local health services over the 2 years from April 1994 to March 1995 and to rank them.

Method: Phase 1: 3 discussion groups. Phase 2: 801 interviews using a part-coded structured questionnaire. In one 2-part question, respondents: i) Asked to give importance of 14 items on 4-point scale (Very Important; Fairly Important; Not Very Important; Not at all Important); ii) 'If money was limited, which 2 do you think would be most important to you and your family?' from the list of 14.

County '50' (17)

Aim: to assess the public's opinions of the proposals in HA's 5 year plan - strategy for Health Care in the [district] area.

Method: Public Consultation Day involving (hoped for) 50 representative local people. Focus groups - some of which used prioritisation exercise. Facilitators summarised points/issues & asked groups to allocate £100 between issues. This proved too complicated for some so they ranked the issues. At end of day, short questionnaire containing statements, asking respondents to indicate their agreement on a 5-point scale.

Determining Community Priorities in Health Care (165)

Aim: to determine public perceptions of health care priorities.

Method: Meeting of members of CHC (Community Health Councils) and three localitybased meetings of representatives of local organisations. Presented with 3 case studies to discuss & determine bases for decisions. Asked to select 3 most important & 3 least important services in terms NHS priorities. Asked for values which influence thinking. Followed by postal survey of 2500 members of the public,1781 responses. Questionnaire asked relative importance of each of a list of treatments (on scale Essential/Important/Less Important/Unimportant); then to select 3 most important 3 least important services (from list of 11); and give 3 most important & 3 least important reasons for selecting them (from list of 13).

Conclusion from researcher: '...public was asked to make difficult choices in the absence of sufficient information.....People tended to choose as important those treatments and services which are for fairly common conditions. People also tended to make choice on the basis of the health experience of their age group....It would not be correct, therefore, the use the results of their survey merely to confirm or validate Health Authority decisions....(HA) .has an obligation to take public opinion into account'.

Acute Services Community Survey (166)

Aim: As part of the community consultation process in connection with Health Authority's Acute Services strategy, a population based postal survey was carried out. A questionnaire schedule was designed to answer questions of interest to the health authority.

Method: Postal questionnaire to 2500 residents selected at random from electoral register. 1512 responses. Includes questions on whether willing to travel for treatment to save money for the HA; what travel time respondents consider reasonable for different treatments; and what travel willing to undertake to get better facilities. Question gives nine (including status quo) possible service developments _ respondents asked to select 4 most important for reinvestment. Also asked to tick 4 from 10 aspects of services. Answers presented as % ticking that service/aspect.

Perceived need for health an community services in inner city area (167)

Aim: to explore the use of rapid appraisal in defining the health and social needs of a community and to formulate joint action plans between the residents and service providers.

Method: Rapid participatory appraisal. Semi-structured interviews of various key informants. Also interviewed 17 residents to represent age/social/health. Also 4 group interviews plus information from written documents. All information allotted to appropriate blocks of planning pyramid. [Questions about what improvements/changes in services] The two focus groups used to discuss and allot priority to problems identified and explore potential interventions, how to improve take up of existing services.

Long list of service improvements resulting from project given.

Marginal Analysis (162)

Description: : Marginal analysis is an economics method for considering and evaluating priorities for change when scarce resources. Examines effect altering existing balance expenditure between health care programmes. Resources for investment released by disinvestments _ therefore it is resource neutral.

Method: 1. Group discussions, 2. Ranking exercises, 3. Consensus. Respondents identified 10 items for expansion and 10 items for contraction (if more than 10 for

expansion were identified they were voted on). Group asked to estimate effect of $\pm 100,000$ invested on each of items in expansion list. The asked to assume that $\pm 100,000$ had already been deducted from each item on contraction list, and asked what they would do if ± 100000 now came available. Exercise repeated 10 times. Then evaluation team identified and (tried to) weight criteria for benefit of items and scored items against these. They thus identified five clear winners and 5 clear losers. Recommended reallocations were limited to these items.

Acute services strategy consultation (193)

Description: To seek public understanding and support for an Acute Service Strategy in the light of proposals for a new DGH to be constructed with 700 beds, compared to an existing 1100 bed figure.

Method: 700 Copies of the main strategy document were circulated, supported by 10,000 copies of a short-form leaflet addressed to a more general audience - the latter included a tear-off slip of which 120 were returned. Tear-off slip included open-ended questions: What sort of services would like to see developed at your surgery? What are your views on day surgery? Would you welcome shorter stays in hospital? How would you like to see district general hospitals develop in the next five years? From your own experience, what things could be better organised to benefit patients? Other comments?

Note from Respondent: The exercise did feed back useful information on people's concerns/expectations in relation to the proposed service re- orientation. However, it was very difficult to engender much public discussion on the very broad principles, and the response from the debate centre around those areas where existing services were perceived as threatened.

Priority Search Methodology (see Appendix 4) was used in following projects

- To determine the relative importance of issues to patients, GPs and practice staff within one GP practice (10).
- To understand how local people & local health professionals think health & health services can be improved. (The agenda is set by general public & usually revolves around social, environmental, lifestyle, general practice, hospital, NHS issues) (3).
- Setting priorities for public health issues. Public Survey of issues perceived as affecting local people's health (18).
- What kind of maternity care do you want? To consult women in [locality] about kind of maternity care they would like and the underlying values which determine this (142).
- Listening to [Locality] Voices To ask a representative sample of local people 'What do you think is important when deciding how to spend the money on health and welfare of the people of [locality].' (86)
- Locality Health Needs Assessment Research Project To explore feasibility & appropriateness of undertaking our model of Health Needs Assessment at locality level. To explore types of decision at local level re distribution of health resources; identify factors necessary to support effectiveness. (84)

Note: throughout Appendix 5 the numbers refer to entries in the research database. Further details of particular projects can be supplied on request.

Visual Interactive Simulation Of Accident And Emergency Departments

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1. Introduction

The use of simulation modelling in Accident and Emergency Departments is not as common as it is in other hospital departments ^{1,2,3}. The reason for this may be the complexity of the system and the variety of demands made upon it but a additional factor must be the lack of pressure, until recently, to assess the capacity and throughput times of the system.

The aim of this paper is to justify why visual interactive simulation is appropriate, quantify the problem in terms of patient flows viewed as a network and to consider two particular problems currently under review: the reduction of arrival time data and the feasibility of a generic model.

2. Definitions

Some definitions are required at this stage to outline exactly what is being modelled.

Within Scotland, Accident and Emergency departments are designed to provide emergency care to patients presenting with sudden onset of illness or with injuries resulting from accidents. Patients entering the department can have ailments ranging from cardiac arrests, multiple trauma injuries to broken toes.

The department functions 24 hours a day for 365 days of the year and is continuously staffed by both medical and nursing staff, with other specialists only a phone call away.

The process referred to as Triage involves the following: once the patient has gone through Reception, the patient is seen by a Triage nurse. These nurses have been given advanced training to assess the patient's condition and prioritise the patient with respect to the others in the department. In some departments the Triage nurses duties also include the ordering of certain X-rays. There are usually three or four categories into which the patient is Triaged, these are:

- must be seen immediately;
- must be seen within 10 minutes;
- to be seen but can wait;
- inappropriate attendee.

3. Why is visual interactive simulation the most appropriate tool to use?

The decision to use visual interactive simulation was taken with end point usage in mind. For the model to be understood and accepted by all staff in the department from consultants to porters, it was preferable for queues and blockages to be seen on the screen in surroundings to which everyone could relate, rather than being "disguised" in lists of numbers.

To increase the acceptance of the model and the results it is important that from the start of the project, all staff including non-medical staff such as porters, are included in all decisions being made. These can range from what the layout of the screen should be, to what experiments are to be carried out. Taking care to involve everyone can lead to a greater acceptance of the final model and of the results of the model.

The experiments to be carried out via the model are determined mainly by the staff in the department. By indicating the changes in the current working practices that they would like to see implemented and by including experiments which the modeller would deem to be appropriate, the set of experiments is compiled. The aim of these experiments is to alter the current working practices to make better use of the available resources, if possible and to make the patients visit to the department as stress free as possible by reducing the total time they are in the department.

4. The accident and emergency network

The number of different activities that it is possible for patients to go through in an A&E department are many and lead to a complex network of patient flows. The network can be split in to two halves representing the two main areas that are present in most departments. These are the Walking wounded area where patients with less serious injuries are treated i.e. broken leg, cut finger et cetera and the Trolley area, encompassing the Resuscitation area, where patients with abdominal, chest, head or multiple injuries are treated. The complexity of the network in the Trolley area, can be appreciated from the matrix in Table 1.

It can be seen that if a patient enters the resuscitation room there is a maximum of nine different processes which the patient could then require. However, to highlight the stochastic nature of the system, note that not all patients enter resuscitation, and even if they do, they may not require all nine processes, and the length of time for each process can vary for each patient.

											r
Trolley	triage	resus	refer	obs	exam	xray	blood	diag	treat	admit	disch
rec	1	1	-	-	-	-	-	-	-	-	-
triage	-	1	-	1	~	-	-	-	-	-	-
resus	-	-	1	1	1	T	1	1	1	1	1
referral	-	1	-	1	1	1	1	1	1	1	1
obs	-	1	1	-	1	-	-	-	-	-	- ,
exam	-	1	1	1	ł	1	1	-	1	1	1
xray	1	1	1	-	-	1	1	1	-	-	-
blood	-	1	1	-	-		-	1	-	-	-
diag	-	1	1	_	-	-	-	1	1	1	1
treat	-	1	1	-	-	-	-	-	-	1	1
admit	-	-	-	-	-	4	-	-	•	-	1

Table 1: Network of patient flows

5. Developing a Simulation Model

The data for the Glasgow Royal Infirmary model was collected single-handedly by observation. The exact method had to vary in accordance to the amount of assistance the patient could give, e.g. could the patient carry a card through the system on which times could be recorded as they pass through each stage of their treatment process. The times associated with the more seriously injured patients were recorded on a form, from direct observation. The data was analysed using Excel and Minitab to estimate the necessary parameters, and ECSL for curve fitting.

While vast quantities of data were gathered, it is ideal to simplify the modelling process without loosing valuable information. The following section outlines the method used to reduce the number of hourly arrival rates used in the model from 168 to 48.

6. Reduction Of Arrival Rates Problem

Arrival rates are non-homogeneous Poisson processes. For each hour of each day of the week arrival rates may be different i.e. there can be 168 different arrival rates for the week, ignoring seasonal variation effects.

Rather than use 168 mean arrival rates, consideration has been given to the question -Can the days of the week be grouped in any way, to reduce the number of means required?

Figure 1 shows the mean daily arrival rates for Glasgow Royal Infirmary, A&E Department from a 6 week period of data.





Figure 1: Mean daily arrivals at GRI

Thursday, Saturday and Sunday are apparently different from Monday and Tuesday, but where do Wednesday and Friday fit?

By listing the mean arrival rates in ascending order as in columns 1 and 2 of Table 3 below, a set of t-tests can be performed to identify significant differences between the consecutive means.

Example: Saturday / Thursday

 $H_0: \mu_{SAT} = \mu_{THUR}$

 $H_1: \mu_{SAT} < \mu_{THUR}$

Table 2: Example data: Number of patients per day of the week

Calculation 1	week 1	week2	week3	week4	week5	week6	mean	st. dev.
SAT	192	188	174	243	183	208	198	22.6
THUR	189	217	213	217	195	173	200.7	16.4

Test Statistic t = 0.236 and is less than the critical value at the 5% level therefore there is not a significant difference between the mean arrival rate for a Saturday and a Thursday.

These arrival rates are now combined and compared to Sundays rate. This process continues until a significant difference is found, which indicates that a new grouping should be started. This arises when the accumulated group is compared to Tuesdays mean, hence a new group is formed and only contains Tuesday and Monday.

		COMBINATIONS TESTED AND p VALUES $\alpha = 0.05$									
SAT	198										
		0.42									
THUR	200		0.38	0.15							
		J									
SUN	202				0.13						
FRI	207					0.034					
						*					
WED	213										
TUES	223						0.19				
MON	234				-	-					

Table 3: Test results

Note: p values are given in the above table for ease of comparison with $\alpha = 0.05$

When a significant difference is detected (* 0.034 < 0.05), a new grouping is started. This method highlights the groups as Wednesday, Thursday, Friday, Saturday, Sunday and in group two Monday and Tuesday.

These groups were confirmed by the results from 2-way ANOVAs with replication showing that there was no significant differences between the grouped days of the week with respect to the arrivals in each individual hour of the day.

7. The feasibility of a generic model

It is envisaged that a generic model of an A&E Department could be built upon the basis of A&E Departments being viewed as networks. The main differences between large and medium sized A&E Departments will be that medium sized networks will have fewer nodes and less capacity in some or all of the nodes. The first feature can be accommodated by a routing matrix which will deny certain pathways through the master matrix and the second by making node capacities parameters of the model. The process of creating such a model has been started by modelling a second large A&E Department in Edinburgh Royal Infirmary.

It has always been expected that most inner city hospitals will have similar features, in particular the arrival distribution. A comparable analysis to that shown above for Glasgow, is being carried out for Edinburgh Royal Infirmary. However the expectation is not true and it can be seen from figure 2 (created using the same 6 weeks of data as used for the Glasgow model) that some other combination of days exists for Edinburgh. These results
are currently being analysed, and initially indicate two groups being Saturday, Sunday, Monday, Tuesday in the first group and the other days in the second.



MEAN DAILY ARRIVALS AT ERI

Figure 2: Mean arrivals at ERI

It is hoped that by exploiting the concept of an A&E department as a network, it will be possible to create a generic model for A&E departments. Although from the results above, this will not be as straight forward as initially thought. Together with differences in the departmental data, relationships with the rest of the hospital also have to be considered. The amount of interaction with the rest of the hospital and the A&E department varies depending on the hospital. Most A&E departments interact with the Biochemistry and Haematology labs, the Bed Bureau and the Registrars from other departments.

The above presents some difficulties when defining the bounds of an A&E department and may cause problems when creating the generic model.

8. Uses of the model

It is expected that the main use of the model would primarily be as a management tool. The efficient running of departments is becoming an ever increasing concern as hospitals take control of their own budgets. Having the ability to test out theories, with controlled replicated experiments, without disruption to the current system, and to have a visual aid to demonstrate the effects of changes to staff, is desirable to all managers, and this would be provided by the model.

In addition to a management tool the model could aid in the teaching of new staff about the physical layout of the department and the current working practices (patient flows et cetera).

Finally the model can be used as a planning tool for new departments. Currently many of the departments are very old and have been modernised within the confines of the original building. New departments could be visualised and tested on the model.

9. Conclusion

While a generic model of A&E Departments is considered feasible and worth while, this paper has laid out just some of the problems to be overcome, together with the benefits that could be reaped if a generic model was available.

References

- 1. Dumas ,M.B., 'Simulation modelling for hospital bed planning', <u>Simulation</u>, 1984, pg. 69-78.
- 2. Jones, M.L., and Hirst, A.J., 'Visual simulation in hospitals: A managerial or a political tool?', <u>European Journal of Operational Research</u>, No. 29, 1986, pg. 167-177.
- 3. Vassalacopoulas, G., 'Allocating doctors to shifts in an accident and emergency department', <u>Journal of Operational Research Society</u>, Vol. 36, No. 5, 1984, pg. 517-523.

Some Reflections On Modelling Decision Support Systems Like Simulation For Wrong-Bed Problems

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1. Introduction

This article addresses the Wrong-Bed (also called blocked-bed) problem at Twenteborg Ziekenhuis Almelo (General Hospital) which is at present affecting 5% of their patients, well above the national average of less than 1%. The problem concerns elderly patients who are admitted to hospital but are unable to return home after a period of treatment because they cannot look after themselves and require nurse care. The specialists treating those patients face an ethical dilemma; they do not want to send them home where there is no-one to look after them, but neither can they afford to waste valuable hospital resources which should be used to treat patients with a genuine medical problem. The problem is exacerbated by the admittance policy of Nursing Homes in the area; patients in hospital are seen to be in 'good hands' and get less priority than elderly people living at home. Most doctors, however, agree that the hospital is not a good environment for these patients. The average length of stay in hospitals in The Netherlands as a whole is now 9.25 days. Elderly wrong-bed patients can often spend months in a hospital.

This article encompasses the development of a simulation model to address the issues involved. The purpose of building the simulation model is to support the managers at Twenteborg Ziekenhuis in formulating policies for reducing the wrong-bed patient problem. It will serve as a Decision Support System, providing further useful information which can be drawn upon in addition to the personal knowledge of hospital managers. When used in this manner, the simulation model can prove to be an indispensable aid in decision-making.

The model was built in a computer software package called PROSIM. PROSIM is a modelling language on PC developed in The Netherlands ⁶ which enables the programmer to build an animated version of the real world. Their fully integrated simulation environment provides the tools to perform all activities in a user-friendly way, with all facilities uniformly and directly available without the need for data conversion. The model progressed through three stages of development, building up from a basic core to the final system. This approach was intended to introduce the concept of simulation gradually to those who will use the model for experimentation, and to build up some understanding of how the software works. A <u>model</u> is defined as an acceptable representation of reality with mathematical functions on such an aggregated level that on one hand it is still possible to calculate results while on the other hand the model represents enough features of the real world. <u>Simulation</u> is an imitation of a process or system supported by a model with queues 'the art of mimicry'. It is important for developing a simulation program to make a strict separation between input data and

model definition in order to avoid misunderstandings about the real behaviour of the system.

Before any useful analysis (based on statistics) of the simulation output can be produced, it is important that the model is both verified and validated ². Verification is the process of checking the program 'logic' to ensure it models the hospital system and all important patient flows through the hospital - see Figure 1 - correctly. Verification ideally requires input from the decision-makers/users of the model to check its logic. Also an animation of the model can be very useful in this respect. Once this stage is successfully completed, the model will require validation such that results obtained from a simulation run are a true reflection of the real world situation. This will include checking whether the statistical distributions used to mimic patient attributes and flows are a true representation of the real world. If this stage is not completed correctly there will be serious doubts on the validity of any results produced by the model.



- Route A: After duration of treatment, the patient is discharged
- Route B: Once no medical diagnosis is found, the patient is placed on a nursing home waiting list, and remains in the original ward until discharged.
- Route C: After nursing home place is requested, the patients are transferred to a general bed in Ward 6N until discharged.
- Route D: Same as above, except patient is transferred to a psycho-geriatric bed in Ward 6N.
- Route E: A patient is transferred to a general Ward 6N bed some time after admission and remains there until discharge no nursing home is requested.
- Route F: Same as E, except that patient is transferred to a psycho-geriatric bed in Ward 6N.
- Route C: A patient in a general bed is placed on a nursing home waiting list and discharged after some time.
- Route H: Same as G, except that patient occupies a psycho-geriatric bed.
- Route I: After a duration of treatment, a general bed patient is discharged.
- Route J: Same as I, except that patient occupies a psycho-geriatric bed.

Figure 1: Possible flows of Wrong-Bed patients through the hospital system

There are three main sources of input related uncertainty; the time between arrivals of objects which flow through the system (i.e. patients), the length of each activity (i.e. treatment in the various wards) and branching to different activities (i.e. patients taking one of several possible paths through the system).

Over a three month period of the simulation study several of the goals set at the beginning were achieved. The final simulation network is a full working system which reflects the major patient flow of wrong-bed patients at Twenteborg Ziekenhuis - see Figure 1 -, but more importantly it has been structured in a user-friendly format. When used in conjunction with the accompanying guide, any user will be able to experiment with considerable ease. An animated version of the final model is also included so that the system can be 'watched' in progress rather than just used for collecting statistical data.

Rather than providing mountains of results, a few examples and guidelines of how to use the model for investigation are provided so that the users and decision-makers (who naturally have more understanding of what policies should be tested) can come to their own conclusions. This ensures them having 'ownership' of eventual solutions, and will therefore be more comfortable to them.

Being both multi-organisational and multi-objective, however, the problem of wrong-bed patients is very complex and, as such, many other forms of problem investigation and solving methods lend themselves to tackle it. Two main further approaches are presented, namely Influence Diagramming and Multiple Criteria Decision Making.

The aim of **Influence Diagramming** is to graphically show the major relationships at work between the variables in the system. Variables are those quantities like waiting lists which variations should be studied, see Figure 2. It is hoped that by identifying the dynamics of the system, decision-makers will have a better understanding of how to control undesirable situations. Due to ever increasing standards of living and health care, the proportion of elderly people in the population is rising steadily. Through the relations between the variables and hospital's policy of keeping patients while they are waiting, more and more pressure is being put on their resources. Obviously there are many more variables at work here, but these are the main ones from the hospital point of view. Following this view the patients should be send home to wait for nursing home places, simultaneously increasing pressure on nursing homes to take them and decreasing pressure on hospital resources, but it is not that simple. The nursing home would probably follow that by changing one of their own policies, causing a new set of problems for the hospital administrators. To avoid this, co-operation between all parties is required.

It may also be useful to think about applying a <u>Multiple Criteria Decision Making</u> (MCDM) approach to the Wrong-Bed problem. This is especially advantageous when there are several conflicting interests/objectives. One MCDM software package called V.I.S.A.¹ has been developed to help decision-makers choose one alternative from a predefined set. V.I.S.A. is a visually interactive program for Windows on PC written in the computer language Visual Basic. Animation and graphically supported output are the most important features.



N.B.: An arrow indicates that a change in the variable at the tail will cause a change in the variable at the head. A possitive sign shows that the change is in the same direction (i.e. both variables either increase or decrease), while a negative suggests a change in opposite directions.

Figure 2: Influence diagram Wrong-Bed flows

The following three steps sum up briefly how this approach works:

- Step 1. A list of possible alternatives is listed; this is usually no more than ten.
- Step 2. The criteria upon which to base the decision are defined and developed into a hierarchy. Each criterion within each family of criteria is then weighed proportionate to its importance.
- Step 3. Each alternative is scored or rated on the bottom level criteria of each branch in the hierarchy.

The V.I.S.A. software will then produce an overall score for each alternative from a simple weighed value function. It also allows, as its name implies, visual interactive sensitivity analysis to be performed, whereby moving graphs of the overall scores can be watched as the criteria weights are changed.

These are but two of the methods which may be helpful in coming to an agreement on the Wrong-Bed problem. Other non-quantified methods for dealing with complex unstructured problems can be studied in the book 'Rational Analysis for a problematic world' ⁵.

2. Conclusion

In this article three approaches for tackling the wrong-bed problem in hospitals are presented. The most known and used in Decision Support Systems simulation is more elaborately tested starting from a basic core to the final system in order to ease and structure the development of the system. Verification and validation of such a system is necessary. Simulation is used for answering 'what-if' questions and testing decision rules. Of other possible approaches for such complex seemingly unstructured problems Influence Diagramming and Multiple Criteria Decision Making are shortly described.

The main issue with this article is to present approaches to problem structuring - the identification of those factors and issues which should constitute the agenda for further discussion and analysis.

References

- 1. Belton, V., Vickers, S., <u>The use of a simple Multi-Attribute Value Function</u> incorporating Visual Interactive Sensitivity Analysis for Multiple Criteria Decision <u>Making</u>, University of Strathclyde, Glasgow 1995
- 2. Kleijnen, J.P.C., 'Statistical validation of simulation models', <u>European Journal of</u> <u>Operational Research</u>, 87, 1995, pp. 21-34.
- 3. Kooi, E., <u>Prediction of the flow of Geriatric patients through the hospital system in</u> <u>the Glasgow area</u>, Practical Training Period at Greater Glasgow Health Board University of Twente, Enschede, 1994.
- 4. Perry, J., I Khan, S., <u>A simulation model of the Wrong-Bed Problem</u>, (Final Project Msc Operational Research at Strathclyde University, Glasgow, September 1994.
- 5. Rosenhead, J., (ed.), <u>Rational Analysis for a Problematic World</u>, John Wiley & Sons, Chichester, 1989.
- 6. Sierenberg, R.W., De Gans, O.B., 'Personal prosim: A Fully Integrated Simulation Environment', (1992).

Optimisation Of The Structure Of The Clinical Laboratory

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1. Introduction

Hospital laboratories are always facing uncertainty. Production orders (requests to perform tests and to communicate the results) are received both at predictable and unpredictable time intervals. The volume, types and process-times of tests as well as the required throughput times are also often uncertain, indicating that at the beginning of a certain planning period, e.g. a day (for staff assignment) or a year (the budgeting period) the demand parameters are up to a certain level unknown. Laboratories need a flexible production system to cope with these uncertainties. When necessary, the production system (instruments, logistics as well as personnel) should be quickly adjusted to the actual demand.

Laboratory management faces various types of planning problems. A Decision Support System (DSS) has been developed ¹ to help laboratory management in handling planning problems. The aspects of the object system we are interested in are: planning and control of samples (tests), staff and equipment.

When clinical laboratories have a certain size they have to be decomposed in job shops. The exact size in terms of number of technicians is difficult to give. The span of control is dependent on the skill level of technicians, the quality of management and the planning complexity. But in clinical laboratories with more than 10 - 15 technicians decomposition in job shops is an often used tactic to deal with span of control problems in managing the assignment of staff . Within the job shop tests are performed on samples. These tests are ordered by physicians and medical departments of one or more hospitals.

Typical characteristics of clinical laboratory job shops are:

- due-times are strictly given; no violation is permitted;
- there are several service classes (required throughput times). These required throughput times depend both on the type of process that is required and on the test requester;
- At any moment rush orders can arrive, which are production orders requiring maximum throughput times between 10 and 90 minutes;
- staff is cross-trained and can depending on the specific training level and the involved processes attend more than one process at a time. For example a technician can start up a process at workstation A, than start up a process at workstation B and then return to workstation A to finish the process.

In section 2 we discuss criteria for clustering workstations in a certain way. In section 3 a deterministic mathematical programming model of the optimal clustering of workstations into departments will be discussed. (In this model everything is assumed to be known). In the next section (4) stochastic elements are introduced. The elements concern the demand characteristics. In general the mathematical programming model is too extended to solve with a computer package. However by relaxing the integer constraints and solving the relaxed model meaningful information can be obtained. This is discussed in section 5. We also present here an example from real life. After a general discussion in section 7, the conclusions are presented in section 8.

2. Clustering workstations

Uncertainty in demand is due to variations in demand. Variations in the aggregate demand of a certain department are dependent on the variations in the demand of the various department's processes. If the variations in the demand for individual processes are negatively correlated, the aggregate demand for a certain department can be more accurately estimated than in a situation where they are positively correlated. In other words, the accuracy of the forecast of the aggregated workload of departments is dependent upon the covariation between the demands for processes within each department. Successful aggregate control presupposes an assignment of production processes to departments in such way that the variations in aggregate demand are smaller than the sum of variations of the demand for each individual process. The assignment of processes to departments is therefore of a strategic importance. How such an assignment can be accomplished is discussed here.

The clinical laboratories to which our approach can be applied should be of medium or large size. Meaning that in a daily shift at least 15 technicians should be employed. For laboratories of a smaller size it would be inefficient to divide the laboratory in job shops. Our approach can be applied to large scale laboratories employing a large number of technicians (more than 75) and operating at several sites. In these kind of laboratories decisions also have to be made on which sites certain process types have to be performed.

3. A mathematical programming formulation for the deterministic problem

We first describe a mathematical programming problem in which the demand for tests is deterministic. This means that the future demand for test requests is assumed to be fully predictable. The volume and service levels for the various process types are also exactly known. The demand pattern is given for the whole planning-period (referred to as a *shift*).

Problem description

We interpret a *laboratory* as a set of workstations. A *workstation* is a combination of equipment and technicians that are able to perform certain process types. The laboratory

is partitioned into disjoint subsets of workstations, called job shops. Such a job shop should be regarded as an organisational unit. Technicians are assigned to job shops and directed to workstations. This means that with regard to staff assignment, we have a twophase scheduling approach. As the span of control of those technicians who fulfil supervising tasks is limited there has to be an upper limit on the number of technicians in a job shop. A shift is divided into a number of consecutive periods. At the beginning of each period technicians are assigned to job shops and they remain there for the whole period. During that period within a job shop technicians may be redirected several times to different workstations. The number of technicians assigned to a certain job shop may vary from period to period. However, during one shift the total available staff for the laboratory remains constant. It is also possible that in one or more periods not all available technicians are assigned to a job shop. In reality technicians are scheduled to job shops by the senior technician who is in charge of the routine management. This senior technician is responsible for assigning technicians in such way that in each period in each job shop there are sufficient technicians available to perform the required tests. A process type consists of a group of tests that can be performed on a certain machine and that require the same processing times of a technician. It is assumed here that equipment constraints play no role. Further we assume that these process times are the same for each of the technicians because of cross-training. A process type is assigned to one job shop and cannot be re-assigned from period to period. In practice a test request comes in at the registration desk at a certain moment. There it is determined which process type is required for this test. The processing time of each process type is known and constant, so the only decision to be made is when to start the processing of each test. The scheduling has to be carried out in such a way that the processing of the test can be finished before its due date. The main problem is that there should be a technician available to perform the test. Except for preparing and starting tests, the activities of the technicians have an administrative nature and are considered to be pre-emptive. The precise scheduling of these activities is not of interest on this level of the problem.

In our deterministic approach the demand for tests is assumed to be known in advance for the whole shift. The human resources needed for the workstations are implied by this demand. We are interested in optimising the efficiency of the utilisation of human resources. This goal was operationalised as minimising the idle time of technicians, which is equivalent to minimising the total number of technician time units assigned to the laboratory. This implies that the importance of information about the precise starting time of the processing of a test is very limited. Instead the number of tests within a period suffices Therefore, we assume that we can round the release- and due-times of each test in such a way that they coincide with a begin-time, respectively an end-time, of a period.

Mathematical programming formulation

Before presenting a formal description of the optimisation model we introduce the appropriate parameters and variables.

list of indices:

i,j	:	indicate job shops
e,f,g,h	:	indicate periods
p,q,r	:	indicate process types

list of parameters:

1	Jaranne		
•	N	:	set of job shops
	Р	:	set of all process type
	E	:	number of periods
	F	:	set of pairs (p,q) of process types p, $q \in P$ which cannot occur in
			the same job shop ("forbidden compinations")
	J(p)	:	set of job shop-indices of those job shops equipped to handle
	-		process type p
	U _{tot}	:	the total number of available technicians in the laboratory in each
			period
	U	:	the number of available technicians in a job shop in each
			period
	(q)	:	time required by a technician to handle any order of process type p
			bogintime respectively and time of pariod a
	e_{b}, e_{e}	•	beginame, respectively endame of period e
	δ _{pef}	:	the number of orders of process type p with release-time
			e _b and deadline f _e

list of variables:

B _{pj}	:	has value 1 if and only if process type p has been assigned to job
		shop j
N _{pje}	:	the number of orders of process type p in job shop j during period e
Uje	:	the number of technicians required in job shop j during period e

$$Minimize \sum_{e=1}^{\ell} \sum_{j \in N} U_{je} (e_e - e_b) \quad such \ that:$$
(1.)

$$\sum_{j \in N} B_{\rho j} = 1 \quad \forall \rho \in P$$
(2.)

$$B_{pj} = 0 \forall j \in N_j(p), \quad \forall p \in P$$
(3.)

$$B_{pj} + B_{qj} \leq I \quad \forall j \in N, \ \forall p,q: (p,q) \in F$$

$$(4.)$$

$$\sum_{e=g}^{f} N_{pje} \leq B_{pj} \bullet \left[\sum_{e=l}^{f} \sum_{h=g}^{E} \delta_{peh} \right] \forall p \in P, \forall j \in J, \forall f,g: l \leq g \leq f \leq E$$
(5.)

$$\sum_{e=g}^{f} N_{pje} \geq B_{pj} \bullet \left[\sum_{e=g}^{f} \sum_{h=e}^{f} \delta_{peh} \right] \forall p \in P, \forall j \in J, \forall g, \forall f,g: I \leq g \leq f \leq E$$
(6.)

$$\sum_{p \in P} \omega(p) N_{pje} \leq U_{je} (e_e - e_b) \forall e: I \leq e \leq E, \forall j \in N$$
(7.)

$$\sum_{i \in N} U_{je} \leq U_{tot} \forall e: I \leq e \leq E$$
(8.)

$$\leq U \forall e: 1 \leq e \leq E, \forall j \in N$$
 (9.)

$$B_{\rho j} \in \{0,1\} \qquad C_{\rho q j} \in \{0,1\} \\ N_{p j e} \in \left\{0,1,\dots,\sum_{\ell=1}^{e} \sum_{g=e}^{\ell} \delta_{\rho f g}\right\}, \qquad U_{j e} \{0,1,\dots,U\}, \quad \forall e:1 \le e \le E \\ \forall p,q \in P, \qquad \forall j \in N, e:1 \le e \le E$$
(10.)

je

Constraint (2) expresses that all types of processes have to be assigned to a job shop and that a certain type of process can be assigned only once. Constraint (3) and (4) apply to process types which for technical reasons cannot be assigned to certain job shops respectively the same job shop. The next two constraints express (rounded) release- and due-times of the tests. Constraint (5) assures that the number of tests scheduled in the periods g up to f does not exceed the number of tests that are released in the first f periods and not bound to be finished before period g. Constraint (6) assures that the scheduled number of orders in every subset of consecutive periods is at least as large as the number of orders that has to be processed in these periods due to their release times and due times. Constraints (7) matches the number of tests of the process types assigned to that job shop. The total number of technicians required may not exceed the number of available technicians (8), and there is a maximum number of technicians that can be assigned to each job shop (9) for organisational reasons.

Comments on this formulation

In this model some choices are built-in. The first choice is that the only resource to be optimised is labour (number of technicians). This choice is in most cases realistic. A second choice is that all production processes that have been started in a certain period e will be completed within period e. For orders with small processing times this assumption does not have much influence upon the optimality of the solution. However for orders with a large processing time (e.g. 2 hours), the optimality of the solution may be negatively influenced. To cope with this we can relax the integer constraints concerning the variables N_{prie} to:

$$0 \leq N_{pje} \leq \sum_{f=1}^{e} \sum_{g=e}^{E} \delta_{pfg}$$

The third choice is that there is no direct assignment of orders to technicians. The practical consequence of this choice depends on the level of cross-training of the technicians.

To get an idea of the number of variables involved in the model, we mention some realistic values for some constants. The number of job shops N varies between 4 and 10, the number of periods per shift between 2 and 4 and the number of processes between 15 and 30. The number of tests may be approximately 1000 per day.

Finally some remarks on the goal of the optimisation model: a more straightforward objective function would be the minimisation of the number of technicians needed per shift in the laboratory. The practical value of this goal is often limited since the number of technicians may be given or there may exist a scarceness of technicians. Therefore it was decided that the optimisation model should minimise another measure for the efficiency of the laboratory: the maximum idle time of technicians at a job shop in a period. This is expressed by adding an extra variable Z and the constraints (11) to the formulation, as well as changing the objective function to: minimise Z.

$$Z_{je} = U_{je}(e_e - e_b) - \sum_{p \in P} \omega(p) N_{pje} \quad (\forall j, \forall e), Z \ge Z_{je}$$

$$(11.)$$

A consequence of this last model is that sometimes not all technicians are assigned to job shops in certain periods. These technicians can be assigned to other jobs (e.g. research or administrative activities).

4. The stochastic problem

In this section we discuss some possibilities to express uncertainty of the data into the model presented in the former section. Formulating this model we assumed that it is known beforehand for each of the process types how many orders with a certain priority will arrive and at what time. It is obvious that predictability about the arrival of orders is away from reality. Therefore, it is desirable to adapt the model in such way that unpredictability on the arrival of orders is taken into account.

The impact of unpredictability on the arrival of samples is especially important for rush orders. These orders often have a due-time in the same period as they arrive. In a deterministic situation these orders do not cause any problem, because one can simply reserve as much capacity as the process time of expected rush orders requires. In a situation of unpredictability more capacity (slack capacity) should be reserved for being able to realise the required service levels. On average, slack capacity means idle time for technicians which is something one wants to avoid as much as possible.

For the rest of this section, let us assume that we are informed about the mean number of test requests and the variances in these numbers, for each period, for each of the priority levels (and thus each of the possible due times), and for each process type. Then there is always a chance that in a certain period in a certain job shop the number of technicians is not sufficient to process all test requests before their due time. We are looking for solutions such that the chance on such an undesirable event is α for each of the job shops for each period, where α is a prespecified number.

Formally, we have a stochastic term (the sum of the number of test requests to be performed in a certain period times their respective processing times) which can be seen as one stochastic variable, say X, which may be assumed to be normally distributed with mean μ and standard deviation σ . We want to choose μ and σ in such a way that $X \leq q$

with a probability of at least $(1-\alpha)$. q is the maximum number of test requests that can be processed. In other words, we have the following *probability constraint*:

$$P[X \leq q] \geq 1 - \alpha$$

The assumption that X is normally distributed follows from the assumption that the test request arrivals $(x_i, x_j \in X, i \neq j)$ are independent. This is however not unconditionally true, because what is in stock of samples at the beginning of each period e is also dependent on the arrival of orders of preceding periods and the scheduling decisions taken there. It seems logically that these scheduling decisions are in accordance with the goal function. Thus that the maximum idle time is minimised in each period. Since X is normally distributed the next inequality, the so-called *deterministic equivalent* of the chance constraint above, exists:

$$\mu + \Phi^{-1}(1 - \alpha)\sigma \leq q$$

In our case the deterministic equivalents of the chance constraints which we should add to the model are:

$$\begin{split} \sum_{p \in P} B_{pj} \omega(p) \left[\sum_{g=e}^{f} \sum_{h=g}^{f} \delta_{pgh} \right] &+ \Phi^{i}(I - \alpha) \sqrt{\sum_{p \in P} B_{pj}} \omega^{2}(p) \left[\sum_{g=e}^{f} \sum_{h=g}^{f} \sigma^{2}_{pgh} \right] \\ &\leq \sum_{g=e}^{f} U_{gj}(e_{e} - e_{b}) \quad \forall e, f: \ I \leq e \leq f \leq E \end{split}$$

Up to now we did not take into account the fact that the workload of the various processes can be correlated. Assume that the correlation coefficients of the demands of processes are given and that they happen to be identical in all periods. In this case the deterministic equivalents of the chance constraints which we should add to the model are:

$$\sum_{p \in P} B_{pj} \omega(p) \left[\sum_{g=e}^{f} \sum_{h=g}^{f} \delta_{pgh} \right] + \Phi^{-l} (1 - \alpha) \sqrt{\sum_{p \in P} \sum_{q \in P} B_{pj} B_{qj} \omega(p) \omega(q)} \left[\sum_{g=e}^{f} \sum_{h=g}^{f} \rho_{pq} \sigma_{pgh} \sigma_{qgh} \right] \\ \leq \sum_{g=e}^{f} U_{gj} (e_e - e_b) \forall' e, f: 1 \le e \le f \le E$$

Where product $\rho_{pq}\sigma_{pef}\sigma_{qef}$ denotes the covariance between the numbers of test requests of process types ρ and q arriving in period e which have to be completed before the end of period f. We like to remark that our approach resembles the portfolio approach from Markowitz². In essence the portfolio-approach tries to allocate processes to shops that are negatively co-variated, in order to reduce risk without extra costs, or to reduce costs without extra risk.

The optimisation model deals with tactical planning problems and requires information of an aggregate kind. Often detailed information on the future numbers of test requests is not available. The intuition of the planner is very important here. We will briefly discuss some possibilities to express the intuition of the planner about the uncertainty of the number of test requests into the model.

The most simple approach is to reduce the time-units each technician is available during a period by a fixed percentage. In other words, the inequalities (7) would be replaced by:

$$\sum_{\rho \in P} \omega(\rho) \cdot N_{\rho j e} \leq \gamma (e_e - e_b) U_{ej} \quad \forall e: 1 \leq e \leq E, \quad \forall j \in N$$
(7)

for some coefficient $\gamma \in <0,1$. This can be interpreted as overestimating the variance. An important drawback of this approach is that we deal with all process-types in exactly the same way. This drawback could be avoided by adapting the process-times of each of the process-types, instead of adapting the time of the technicians.

In order to be able to take into account ideas about covariances between the processtypes, we propose to extend the optimisation model with a so-called set of *bonifications* (bon). These bonifications are organised in a (pxp) matrix. In this matrix the planner can indicate to what extent he wants to combine processes and allocate them to the same job shop. He can express preferences by assigning penalty time-units to combinations of two processes he does not want to combine, or by assigning bonus time-units to combinations of two processes he would like to combine.

In order to formulate this, the next constraints are added to the optimisation model :

$$\sum_{p \in P} \omega(p) \bullet N_{pje} + \sum_{p \in S_j} \sum_{q \in S_j} bon(p,q) C_{pqj} \leq U_{ej}(e_e - e_b)$$
(7".)

$$C_{pqj} + B_{qj} - B_{pj} \le I \qquad (\forall p, q \in P, \forall j \in J)$$
(11.)

$$B_{qj} + B_{pj} - C_{pqj} \le I \qquad (\forall p, q \in P, \forall j \in J)$$

$$(12.)$$

$$\sum_{j \in \mathbb{N}} C_{pqj} \le 1, C_{pqj} \in \{0,1\} \qquad (\forall p,q \in P, \forall j \in J)$$
(13.)

5. Example

On the basis of these data job shops have been defined by the optimisation model for several scenarios (here: combinations of the total number of job shops and the maximum number of technicians within each job shop). For each scenario we calculated a solution on the basis the mean times and an alternative solution on the basis of minimum times. The mean times are calculated by dividing the total workload in terms of orders for a certain process type by the available capacity. The minimum time is an estimation of the required mean capacity for processing an order if the conditions are optimal (complete batches for processing). For the minimum times 17 technicians were available, for the mean time 24 technicians are available. In table 2 the results are presented. On the basis of the calculations of our program we can conclude that the best solution should be to assign 8 technicians to job shops. A maximum of 5 technicians appears to reduce the efficiency in terms of maximum times. For the mean times structure the laboratory in 3 job shops when using minimum times. For the mean times structuring the laboratory in 4 job shops is optimal. It appeared also that for both minimal and mean times more solutions were allowed. The actual organisation of the particular laboratory is a mix of

both solutions. Here three large work areas are distinguished (each work area is a set of job shops) and one small work area (one job shop). The last work area provides staff to other area's if they temporarily need them. This solution is as efficient as our solution as the small work area can also assign staff to other job shops (in other work areas) within assignment periods e.

No	workstation	minimum	mean
1	Bulk chemical analyser	0.5 min	1 min
2	Specific test analyser	1.5 min	2.5 min
3	Specific test analyser	1.5 min	2.5 min
4	Glucose and chloride analyser	0.5 min	2 min
5	Bulk haematological analyser	0.5 min	1.5 min
6	Small size haematological analyser	1 min	2 min
7	Eye blood cell differential	2 min	2.5 min
8	ESR Erythrocytes Sedimentation Rate	1 min	2 min
9	Coagulation analyser	2 min	4 min
10	Urine stick analyser	2 min	5 min
11	Eye urine differential	1.5 min	2 min
12	Metabolic diseases screening tests	10 min	20 min
13	Metabolic diseases specific tests	10 min	20 min
14	Chromatography	4 min	8 min
15	Blood Gas analyser	3 min	5 min
16	Manual techniques	60 min	60 min
17	Manual screening	2 min	3 min
18	Radio-immuno assays	5 min	10 min
19	Immuno assays	5 min	10 min
20	Reception area out-patient samples	1 min	1.5 min
21	Reception area in-patient samples	1 min	1.5 min

Table 1: Data of processes for optimisation model.

Table 2: Solution for scenarios for the optimisation model.

scenario		minimum p	ne	maximum process time				
# job Max #		#techni-	max idle	total idle	#techni-	max.	total idle	
shops	techni-	cians total	time	time (min-	cians	idle	time (minutes	
	cians	per		utes	total per	time		
		period			period			
3	5	57	16.27	90.40	-	-	-	
3 8		57	10.11	90.49	92	56.50	220.00	
4 5		57	13.00	90.49	0.49 -		-	
4	8	57	27.00	90.49	92	16.00	220.00	
5	5	58	46.00	225.49	-	29.00	298.50	
5	8	58	46.00	225.49	92	18.00	220.00	

6. Discussion

It is possible that some laboratories do opt for another goal function than used here. An alternative goal function might be to simply minimise the number of staff employed. In fact in that case only a small change is needed. It is always possible to let the module search for feasible solutions for different maximum number of technicians needed. The cost of such an approach would be an increase of runtime. But the total runtime needed to compare alternative solutions would still only be a few hours. This is not much given that decisions on the structure of a clinical laboratory are (hopefully) not taken more than once a year.

If technicians have the same skills level and are all fully employed then it is not necessary to take into account the characteristics of each individual technician. This makes planning relatively easy and the runtime of our optimisation model short. However clinical laboratories do employ part-timers and technicians with different skills levels.

Part-time work may be annoying for the management of the laboratory as it constraints planning freedom, but it does not pose any problems for our clustering model. The solution space is restricted by the fact that a certain *number* is not available in certain periods.

However, differences in skills level can, depending in the manner on which these occur, pose problems. In practice differences in skill level appear in the time technicians need to process samples. For example technician A needs 5 minutes to process sample of type X, whereas technician B needs 2 minutes to process the same process type. It is evident that our optimisation module will get into trouble if the skills level is defined in this manner. The runtime will be enormous and this way of proceeding is therefore unfeasible. In fact this is not a real problem because we cannot imagine that tactical management will be able (and prepared) to cluster workstations on such detailed information related to individual technicians. An alternative approach (and this is also applied in some clinical laboratories) would be to define skill levels in such way that technicians having a certain skill level are assumed to be able to perform test belong to a certain set of process types (thus workstations). Planning freedom is then of course restricted, but the optimisation model will be able to find a solution within a reasonable amount of time.

References

- 1. Merode, G.G. van, <u>Decision support for clinical laboratory capacity planning</u>, Maastricht, 1993. (Ph.D Thesis).
- 2. Harrington, D.R., <u>Modern Portfolio Theory, The Capital Asset Pricing Model &</u> <u>Arbitrage Pricing Theory: A User's Guide</u>, second edition, Englewood Cliffs, 1987, 1983.

Part Three - Case Studies



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.

The Federal Nursing Minimum Basic Data Set And Hospital Management In Belgium

- A Case Study Of A Nursing Department

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1. Introduction

As hospital management is moving towards the management of patients and patient care, the introduction of patient information systems becomes mandatory. Hospital applications are well established by now. Some countries such as the USA (Medicare), Sweden and Portugal have implemented some national patient information system. The best known system is the DRG (Diagnostic Related Groups) system. In Belgium, the registration of data on hospital patients and hospital patient care was started by law nation-wide on 1/1/1988. The Minimum Data team of the Centre for Health Services and Nursing Research of the Catholic University of Leuven has been involved in a co-operative effort with the Administration of the Ministry of Public Health and the Environment and the 7 Faculties of Medicine in Belgium in the development of the registration and more importantly in the development of feedback information for all Belgian hospitals.

The first "Medical Activities in the General Hospitals - National Statistics 1988" were published in October 1991¹. They were distributed to all hospitals. The booklet gives a national figure or a picture. The 'Medical Activities in the General Hospitals - National Statistics 1988-1992' became available in 1995. They cover the dynamics, the trends of patient information. A computer software programme is being distributed which allows every nursing unit or group of nursing units to interpret its own situation and to allow each unit or department to situate itself with respect to all nursing units and medical departments in Belgium. This allows the unit to compare its length of stay, age, staffing ratio and qualification level. This case study introduces the Nursing Minimum Data Set (NMDS). It shows some results and illustrates how the information inferred from the data allows to improve decision making in the Nursing Department of a major university hospital.

2. Methodology

Guiding principles

The Belgian approach starts where most applications such as DRCs stop. Many patient information systems try to get a hold on the patient mix. The diversity of the patient mix or the case mix is measured by way of the main and secondary diagnoses or by way of diagnosis related groups (DRCs). Recent improvements try to fine-tune the diagnosis or diagnosis related groups by adding measures or scores with respect to the "degree of

severity", "disease staging" or "acuity". Belgium looks at the diversity of patients as well as at the variability of practice patterns. Belgium assumes that the primary role of management is to direct the practice patterns of the physicians and nurses rather than the selection of patients. The approach implies to look at the different professions involved in patient care, e.g. the nursing profession alongside the medical profession. So far, Belgium is the sole country to have implemented a NMDS on a nation-wide basis.

Each aspect of care is investigated rather than trying to map everything into a single number such as "dollars" or "admissible length of stay" or "workload". Insight and communication is deemed more important than data or magic formulas. Several characteristics are of interest:

- medical indicators: diversity of patient (type and severity) and variability of care (type and intensity);
- nursing indicators: diversity of patient (type and severity) and variability of care (type and intensity);
- drug prescription and utilisation;
- cost indicators: itemised charges, ABC costing, ...;
- social indicators: minorities, inner-city, ...;
- ethical indicators: informed consent, privacy protection, clinical tests, ...;
- · comfort indicators: waiting times, amenities such as room / meals ...;
- outcome measures: length of stay, continuity of care in chronic conditions ...

In Belgium, the monitoring of the diversity of the patient mix and the variability of the practice patterns is deemed of interest to many parties on many levels:

- individual practice;
- ward / unit / function;
- department;
- hospital / medical council;
- regions: regional or cultural differences, e.g. inner city hospital care;
- regulating agencies;
- international comparisons.

First, the clinicians and the nurses: the micro level. Their patient records help them to plan and evaluate their progress in the management of care. If clinicians could agree on what care is "necessary", a lot of the variability of care could be reduced. The monitoring of practice patterns and their variability could help to track which procedures or activities work best and which don't. Though patient records are infinitely more detailed than any national minimum data set can envision, some links by way of some standardised items are highly recommendable in order to start an evaluation over longer periods of time -maybe years -- or involving a wider group of clinicians -- maybe regional groups or a particular medical speciality --.

Second, the hospital managers, including financial and patient care managers such as head nurses or department chiefs. The resources involved demand to get to the core business of the hospital: the patients and their care. Also, this is the only level where all partners, physicians, nurses, pharmacists, hospital hygienists, material managers, account

managers, ... interact. Decisions taken by one party determine activities by other parties. This is also the only level where the quality of hospital care is actually being determined. Quality does not involve just one profession with the exclusion of the others, e.g. quality of the medical care versus quality of the nursing care. Quality does not involve just some type of patients with the exclusion of the others -- qualitative perinatal care or diabetic care. All patients are involved. Emergency wards and intensive care units are continuously confronted with the impact of decisions for some patients, on the resources available to the rest of the patients on the unit. No bible, book of regulations, government agency or national commission will ever be able to specify how care should be delivered optimally under all circumstances. On the contrary, as care decisions are more and more scrutinised, the distance between those central agencies and the care providers in the field increases even within a single hospital. The team rather than the individual becomes responsible for the patients under its supervision.

For this reason also the diversity of the patient mix as measured by the DRGs is a necessary yet not sufficient instrument. The opportunities for management are more in the direction of the variability of practice patterns: why does the older cardiologist on the team prefer one therapeutic approach while the younger cardiologist tends to a different therapeutic plan? Why is one nursing unit caring for its patients in one way while an adjacent nursing unit takes up another approach?

Third, government, authorities, financing agencies, insurers: the macro level. Hospital care demands many resources and highly trained professionals in our Western countries. Though all parties will stay alert to see if the books balance or if the length of stay is within limits, those questions are still the easy ones. Developments in health care will push us towards much more difficult questions. To what type of patients is the hospital money going and what do the different practice patterns cost? Given so many priorities -- emergency care, intensive care, cardiac care, perinatal care -- some type of "democratic communication" seems prerequisite to stay afloat.

A dialogue among and between the parties mentioned becomes mandatory. This dialogue will involve necessarily objective facts on the patient mix and the practice patterns. For some participants, e.g. clinicians and nurses on the floor, these data will be very detailed. Other participants on the contrary will have to deal with carefully designed samples: selected aspects to a selected level of detail for selected patients at selected (variable) intervals. Each level in the hospital care sector will have to elaborate its own equilibrium. Either the dialogue is taking place in too general terms or slogans which hardly reveal the real issues but where everybody feels called upon to intervene, or the dialogue is taking place on a too detailed, technically sophisticated level, involving rare expertise and difficult training where only a happy few, the so-called experts, are able to participate.

Communication demands feed-back: feedback on different levels within a common frame of reference. Most information systems so far are "number chrunchers". Care providers are not! Hence rather than adapting the care providers to the information systems -- in a sense automating and freezing the old ways -- the information systems should adapt to the users. Belgium, where three official languages are spoken: Dutch, French and German, illustrates this. The Minimum Data team of the Catholic University of Leuven moved as fast as possible towards graphics. This experience may also be of interest for the exchange of information between different European countries. By stressing the accessibility of the information through the utilisation of graphics, the professionals are put in a position to shorten the feedback-loop between the decisions and the results, hence enhancing the learning process of patient-care delivery.

The case study illustrates the micro-macro approach to the NMDS and the short feedback cycle necessary for the management of personnel resources (staffing). Figure 1 summarises the NMDS in Belgium and Figure 2 identifies the 23 selected nursing activities: the national common frame of reference.

- Since 1988: sampling 4 periods per year, each covers a 15 day period
- Hospital data
- · Activity data: list of 23 nursing interventions
- · Patient data: age, gender, admission & discharge date, medical diagnosis, complications
- · Ward data: number, hours of personnel, beds
- · ADL not mandatory

Figure	1:	Nursing	Minimum	Data	Sets in	Belgium
--------	----	---------	---------	------	---------	---------

	1	hygiene $(1 2 3 4)$
	2	mobility $(1, 2, 3, 4)$
	2	alimination $(1, 2, 3, 4)$
	3	$\frac{1}{2} \frac{1}{2} \frac{1}$
	4	$\frac{1}{2} = \frac{1}{2} = \frac{1}$
	5	gavage reeding (U, T)
	6	care on mouth (number of times)
	7	decubitus prevention (#)
1	8	dressing (0, 1)
[9	tracheotomy (0, 1, 2)
	10	interviewing (0, 1)
	11	teaching(0, 1, 2)
	12	emotional support (0, 1)
	13	mentally disturbance (0, 1, 2)
	14	isolation (0, 1)
	15	vital signs (#)
	16	clinical signs (#)
	17	traction/cast (0, 1)
	18	blood specimen (# punctions)
	19	medication IM/SC/ID (#)
	20	medication IV (#)
	21	IV infusions (#)
	22	surgical wound care (#)
	23	traumatic wound care (#)
•	Summa	arised in Eingerprints and Maps on any level of aggregation
		and maps on any lover of abbreadont

Figure 2: 23 Selected Nursing Activities

Feedback instruments

Basically, the Minimum Data team developed and implemented two families of graphic feedback or "communication" instruments so far. The first type is called "the fingerprint". The fingerprint of the unit displays all the information available by way of the minimum data in its entirety as if the unit stands alone. Figure 3 gives an example of two fingerprints which compare a maternity and an intensive care ward.

The second type is called "the national map". Here the emphasis is on the unit under investigation and the mutual relationships between the unit and all the other units in Belgium to the detriment of the completeness of the information. Figure 4 gives the original national map for the year 1988. Both illustrate the monitoring of the "variability of nursing care activities" on the level of the "nursing unit".



Figure 4: National NMDS map for the year 1988

The Belgian NMDS monitors by way of a specific experimental design, 23 selected nursing activities in all nursing units of all Belgian general hospitals. The data is collected during four registration periods yearly ² on nationally selected inpatient days. The fingerprint compares each activity of every nursing unit with the same activity of any reference nursing unit selected: e.g. the theoretical nursing unit which we obtain by lumping together all data for all nursing units in Belgium for all inpatient days over all registration periods. For this purpose, all nursing activity experimental data are transformed to ordinal scales. A fixed number of ordered categories is determined nation-wide. Subsequently, ridit-scores (Fleiss ³, Agresti ⁴) are calculated and put forward as national bench marks for each category for each nursing activity. Finally ridits are calculated for each activity and for every selection of inpatient days: every nursing unit, group of nursing units, diagnostic group, age group selected. Ridits are probability measures and as such defined between 0.0 and 1.0. E.g. a ridit of 0.60 for *Hygiene care* on nursing unit A implies that the



Figure 3: Fingerprint example: comparison of maternity and intensive care ward

probability that nursing unit A scores higher with respect to the activity under investigation than the bench mark nursing unit is 0.60 or 60 %. By definition, the probability of a lower score is 0.40. The ridit of the bench mark nursing unit when compared with itself is always 0.50. Hence and in order to enhance the visual character of the information, the value of 0.50 is subtracted from all ridit values. As a result, a deflection to the left in the fingerprint means that the activity, measured by patient and by day, grades lower in the nursing unit than in the bench mark nursing unit; a deflection to the right means that this activity grades higher than in the bench mark nursing unit.

Moreover, as these deflections are standardised for the whole country, the most extreme deflections which are observed in Belgium are found utmost to the left and to the right. Also, if a particular nursing unit would not differentiate itself whatsoever from the bench mark nursing unit, no deflections would be visible: the fingerprint would coincide with the line in the middle which indeed represents the fingerprint of the bench mark nursing unit. The fingerprint technique puts equal emphasis on nursing activities that are present as on nursing activities that are absent in each group of inpatient days selected. Although most people accentuate the positive, one often learns as much from the things one does observe as from the things that do not occur ⁵.

To give the fingerprint e.g. by type of medical department, a box-plot technique is used to visualise the distribution of the fingerprints of all the units involved. The box-plot shows what range of every nursing activity we find on every type of nursing unit and thus highlights the variability of nursing practice in the group of nursing units selected. However, a small range, which corresponds to a low degree of variability, can be as typical for a particular selection of inpatient days as those activities that show a large range or large variability.

Figure 3 shows that the intensive care ward scores much higher than the maternity ward with respect to the activity "monitoring of vital signs" while the maternity ward scores higher with respect to the activity "teaching fixed program".

The second type of graphical instrument is the so-called "national map". The national map of the minimum nursing data uses a specific graphic projection technique to show the position of each of the 2,757 nursing units in Belgium with respect to all other nursing units on the basis of its fingerprint of nursing activities. Statistical algorithms are used to "project" the hyperspace of the matrix of the ridit variables for all nursing activities for all nursing units into a two-, three-, ...dimensional subspace. This "projection" uses an alternating approach: in the first step of each iteration the ridit variables are transformed in an optimal way while safeguarding the right measurement level of each variable. In the second step of each iteration the two-, three-, ...dimensional solution is optimised by the same criterion as in the first step. Several statistical algorithms are already commercially available. Each statistical package has its own strengths and weaknesses. The Minimum Data team has investigated, used and, when necessary, adapted several algorithms using the insights and comments developed by the work of Kruskall ⁶, De Leeuw ⁷ and Young ⁸. In view of the volume of data and the purposes of the endeavour, monotonous transformations of the variables, a factor analytic approach and a Euclidean least square

criterion were decided upon for the analysis of the Belgian NMDS. For the computing work, the team decided to use the prinqual procedure of the SAS Statistical system ⁹.

The visual display shows which nursing units are comparable to each other and which units differ with respect to the two dimensional subspace. Indeed one cannot pass over the fact that each "projection" into a subspace does summarise one way or the other the information available in the totality of original data. A graphic projection on a single sheet of A4 paper is always a synthesis of each of the original distributions for each original variable for all original observations. In this respect, the "projection" technique into a subspace does not differ from the familiar use of averages and standard deviations when one-dimensional common metric variables are dealt with. As such a warning should be given: "Blunt use of statistics may be hazardous to your understanding of the real facts". Each nursing unit has its location on the map. If two unit have the same location, they are most similar; if they have far different locations they are most different. The 'null' point of the map is the 'point of gravity' of all Belgian nursing units with respect to their fingerprint of 23 selected nursing activities. In other words, the visual display indicates to what extent every nursing unit is typical in comparison to the modal Belgian nursing unit. The map allows us to delineate blocks -- this does not necessarily imply clear-cut boundaries !-wherein which similar nursing units are located.

The graphic projection technique of the NMDS is dual: we project both the nursing units and the 23 nursing activities in the same space. Units which are located near a particular activity are characterised in their fingerprint by a large deflection to the right with respect to this activity. Units which are located near the point in space that is opposite to the null point with respect to the point of any given activity, are characterised in their fingerprint by a large deflection to the left with respect to this activity. As a result of further analysis ¹⁰ we can state that nursing units to the top of the map demonstrate an emphasis on "basic nursing care", to the right "somatic care" prevails. The bottom of the map is characterised by an emphasis on "technical nursing care" and to the left, we find a preponderance of "self-care activities": see Figure 5.



Figure 5: National NMDS Map

The national map also indicates to what extent the NMDS allows to group nursing units with similar nursing practice. Not all intensive care units (labelled by the letter I in Figure 4) are recognised as such on the basis of their Minimum Nursing Data. At the same time, we do find surgical nursing units (letter C) and internal medicine units (letter D) in the vicinity where most intensive care units are situated. Also with respect to the intensive care units, units with more or less intensive care do situate themselves further away or more close to the null point where the modal Belgian nursing unit is situated. Figure 4 shows that the intensive care nursing units in Belgium vary considerably among themselves. These experimental results allow to measure the gradation of intensity of nursing care on each care unit. The management applications are straightforward: staffing, financing.

We can also use the national map of the nursing units to give some indications on nursing staff and patients: e.g. number of full-time equivalent nursing staff by day and by patient, degree of qualification of the nursing staff, average age of the patients, average length of stay. The national map is subdivided in blocks and these indicators are given by block. A fingerprint of the nursing practice of the sum-nursing unit of every block is also possible.

Finally, because of the ordinal character of NMDS variables and the particular "projection" technique used, one can project additional inpatient days or groups of inpatient days on the national reference map of the 2,757 nursing units in Belgium. Examples are: nursing units on a later time, diagnostic groups, groups of patients with the same degree of dependency. This characteristic of the techniques used offers many opportunities. By lumping together units, we may indeed obtain the fingerprint and the location on the "national map" of departments, hospitals or of particular regions. One should however keep in mind that the more one aggregates units, the less the information will stay meaningful. Though it is technically no problem to aggregate a geriatric care unit with a maternity ward, one wonders what the meaning of their 'sum' may be. Just as an average length of stay of 7 days does not imply that any one single patient stayed 7 days, so does the fingerprint nor the location give an answer to the variability among the constituting elements. Even if two nursing units have the same location -- called the point of gravity -- in the national map, the variations of the nursing care by patient or patient day may be smaller on the one unit than on the other unit.

Fortunately however, the same methodology can also be applied the other way around. Rather than lumping together, we can enter the unit and focus in on the patients within the unit or, one step further, on the patients on their particular days of hospitalisation. This focus into everyday life within the unit envisions the variability of the nursing practice patterns to its fullest detail.

It should be stressed that the methods used allow to safeguard a national frame of reference on each level of decision making: the nation, the hospitals and the units. "This micro/macro design enforces both local and global comparison and at the same time, avoids the disruption of context switching. All told, exactly what is needed for reasoning about information" ¹¹.

Concluding this methodological part, fingerprints and national maps have so far also been developed for:

- the medical diagnostic information as measured by the 3-digit code of the International Classification of Diseases 9th Version Clinically Modified;
- the degree of dependency with respect to the Activities of Daily Living;
- the degree of behaviour control, societal functioning and relational functioning (psychiatric care patients only);
- the medical procedures profile by way of an existing national list of medical procedures and activities;
- typical psychiatric care activities (psychiatric care patients only).

3. Case study: management applications in a nursing department

The tools developed are on the one hand, very macro. These are called "the national statistics". On the other hand they are also and within the same frame of reference, very micro. So far we call these "the service unit tool". Intermediate tools, such as department, hospital or regional tools are equally available. Indeed the instruments, the fingerprints and the national maps, allow to aggregate as well as to zoom in. The fingerprint of the unit and the national map of all units show which units are comparable to each other and which units differ. Each unit has indeed its fingerprint from which we determine its location on the map. The variability of practice patterns can be investigated from many different angles ¹². Some examples with respect to nursing care practice patterns follow.

Financing hospitals on the basis of nursing care practice patterns

Hospital budgets in Belgium were traditionally based on historic hospital costs. In 1986, the new hospital law was voted which introduced patient and patient care data for the financing of hospitals. However, it took until 1991 before the political intentions were translated into practical applications. As of 1991, a small part of each hospital's budget was determined on the basis of the variability of medical activities in hospitals. A national classification of medical activities which existed since the mid-fifties was used. The decision rule was rather simplistic. All medical activities of each hospital were linearly lumped together using national weights into one single overall monetary measure. Each hospital received additional "budget points" in function of the decile of the national distribution to which it belonged.

In 1994, this same basic approach was expanded to include the variability of nursing care. All surgical, internal medicine and paediatric inpatient days monitored during the national nursing care registration days were projected in the first two dimensions of the national map of nursing units: see Figure 4. The national map itself was subdivided into national zones to which budget points were allocated on the basis of national staffing patterns by zone: the number of nursing staff and the qualification of nursing staff by zone. All projected inpatient days were weighted with the corresponding zone points. An overall number of additional budget points was calculated for each hospital for the year 1994.

Though the technique of the national map allows to give more points or less points to particular zones on the map with a view to some political priorities, no such effort was

deemed politically feasible for the first year of introduction. The same approach was extended into 1995. As of now, work has been started to evaluate the particular nursing practice pattern corresponding with each zone on the map in view of further action. This work necessarily involves the co-operation of and lengthy discussions with the nursing professional groups.

Staffing on the level of one hospital

The lack of national consensus with respect to the exploitation of the variability of national nursing practice patterns does not preclude any single hospital from adapting the national approach to its own advantage. Figure 6 shows the basket of parameters which one major university hospital used to allocate the nursing staff for its different nursing units.

•	-> define basic part of the	budget (= ± 66	5%)							
	based upon - number of	beds								
	- previous b	udget								
•	-> define the <u>activity part</u>	of the budget (=	$= \pm 34\%$							
	based upon - occupation	n of beds								
	- nursing profile (i.e. UZ-points per nursing day)									
	- turn-over o	of patients								
	- chance of	an emergency a	Idmission							
	[occupancy + NM]	DS T	75%]							
	[turn-over	accounts for	15%]							
	[emergency cases		10%]							
	_ ,									

Figure 6: Basket of parameters

One of these parameters is the "nursing profile", which is to a large extent based on the federal NMDS. The hospital closely follows the national nursing activities sampling procedure but rather than using the obligatory 20 national days only, it uses all 60 days sampled. Figure 7 shows the projection of the fingerprints of all those inpatient days on the national map of nursing units. Though the hospital sticks to the technique of zones on the map and "staffing points" by zone, some local modifications were implemented.

The 28 national zones on the map are replaced by 31 local zones in order to refine the zones in the area of the map were the intensive care inpatient days are located (figure 8 right below). The national "budget points" by zone were re-calibrated taking into account local circumstances.

This resulted in "staffing points" by zone. These points are in fact the average number of nursing hours per in-patient day measured over the 60 calendar days. Figure 8 gives a survey of the hospitals approach.



Figure 7: Projection of the fingerprints of all days on the national map of nursing units



- National NMDS map is frame of reference
- Splitting up the map into 31 zones (federal zone 28 is subdivided into zone 28, 29, 30, 31)
- Gauging of zones relevant for U.Z. Leuven with nursing hours per patient day
- Use of 60 NMDS-days (i.e. 60 fingerprints) per nursing unit
- · Exclusive psychiatry, recovery, emergency unit

Figure 8: Survey of hospitals approach

								75%									
				i			Points	Estimated				10%		15%			
					66%	NMDS	for	FTE based	AD	MISSIC	ONS 1994	FTE		FTE			FTE
Г			<u> </u>		Basic Part	1994	occupied	on NMDS	Non		Chance for	Emerg.	per 7	Turn	FTE	Difference	occupied
r	IJ	Bed	occ	FTE	FTE	Point/day	beds	& BED OCC		Emerge	Emergency	admiss.	days	over	total		beds
	A	27	94%	18,59	12,27	4,37	111	5,21	50	231	0,47	0,48	5	0,23	18,19	-0,40	0,72
	В	28	80%	16,00	10,56	3,65	82	3,84	654	174	0,38	0,39	16	0,67	15,46	-0,54	0,69
	С	28	82%	16,45	10,86	3,94	90	4,24	715	408	0,67	0,69	22	0,90	16,69	0,24	0,73
	D	28	78%	14,86	9,81	3,34	73	3,42	1381	280	0.54	0.55	32	1,34	15,12	0,26	0,69
	E	27	83%	15,00	9,90	3,71	83	3,91	879	350	0,62	0,63	24	0,99	15,43	0,43	0,69
		138	83%	80,90	<u>53,</u> 39		439	20,63			2,67	2,75	98	4,13	80,90	0,00	0.70
					66%			75%				10%		15%			

<u>Rest:</u> 27.51

Figure 9: Defining the nursing personnel budget for five nursing units

Figure 9 exemplifies how this approach was implemented to determine the staff on the nursing units. For presentation purposes, the example uses a sample of 5 units rather than all actual 85 nursing units. The occupancy level, the turn-over of patients and the probability of an emergency admission by nursing unit complete the "hospital staffing points" to fix the staffing level of every nursing unit.

The second last column in Figure 9 exemplifies that this procedure to allocate nursing staff is actually a zero-sum approach or a re-allocation procedure. The procedure involves 33% of the nursing staff or 27.51 FTE staff.

Staffing on the level of some nursing units

As mentioned, the same methodology allows to aggregate as well as to zoom in without any switching of context: a micro/macro design. The focus into everyday life within one or some nursing units will however touch on the variability of the nursing practice patterns to its fullest detail: individual patients on individual days during their period of hospitalisation. Hence, all necessary precautions should be taken to safeguard the privacy of the patients as well as the nursing units.

Figure 10 gives the fingerprints on the first and the last day of the national registration period of March of one random nursing unit. The same figure also shows the location of the 15 individual calendar days for the same unit. The path on the national map exemplifies the range of the variability of nursing care of the particular nursing unit within the selected time span. This exact type of feedback is discussed with the headnurse with a view to day to day staffing, weekend staffing and on call duty. It should be stressed that these figures are only instrumental to the discussion on staffing as the professional judgement of headnurses and nursing directors is still important. However some fast, immediate information seems most helpful to direct these discussions.

For instance, the hospital uses a quick patient classification scheme to adjust its day to day staffing levels: the San Joaquin ¹³ scoring instrument. Basically 9 items are scored for every patient every day. The instrument provides for 4 ordinal classes for the intensity of nursing care. These scores lead to a classification of the nursing work load on the particular day into four categories of patients: class 1: low intensive nursing care patients to class 4: high intensity nursing care patients. Figure 11 shows the computer screens which are daily available to the head nurses and the nursing director, immediately after the scores have been taken. The bottom screen shows the query screen and the top screen shows the results.


Figure 10: Comparison of 2 registration days for 1 nursing unit

Result: four nursing units compared for 1 day - 04/01																	
U.Z.	LEUVEN			I	PATI	ENTC	LASS	IFIC	ATIO	N		PC1	0M02		4/01/	95 0	8:44
NURSI	ING Dep		70D. 0	10101		0401	0.5	~		_							
		PER	100: 0	40195	> -	0401	95	5	HIFT	:	Ļ	AY					
NU	DD/MM	RIDIT	NMD	0	1	2	3	4	TOT	occ	*	HN	RN	NA	FTE	DIF	STU
433	04/01	0,46	3,1	0	12	10	7	0	29	104	I	1	6	2	7,76		0
442	04/01	0,45	3,0	0	15	9	3	0	27	96	t	1	7	2	7,79		0
444	04/01	0,58	3,5	0	10	9	5	2	26	93	ļ	1	6	2	8,00		0
445	04/01	0,55	5,6	0	8	9	8	3	28	100	ļ	1	8	2	9,01		0
PF3:	: Menu							 PF	 5: Pi	rint			PF7-	 8: F	Pagina	 tion	
PAI:	End																
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	CLIN	VIC :		(=COI	DE 1	DIREG	CTOR)									
	UI	NIT :	444						<u> </u>								
	PERIC	DD :	DAYS (ddmm)	5 i †)	W	EEK	M (m	ONTH mjj)	Ŧ								
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ENTE	R: Star	t Que	ry											 PA1 :	End		

Figure 11: Computer screens

Most columns give actual data: the number of patients in nursing category 1, 2, 3 and 4; total number of patients (TOT); occupancy levels (OCC); number of staff: head nurse (HN), registered nurses (RN), nursing aids (NA), nursing students (STU). The column RIDIT shows how the distribution over the different patient categories is summarised into one overall measure based upon the total hospital distribution. The column NMD gives the number of "staffing points" based upon the actual number of patients in each category and a hospital-wide bench mark. Again the technique of the fingerprint and the national map allows to gauge the simplified readings from time to time.



Figure 12: Projection of class 1-4 patients for 1 nursing unit on NMDS-map

Figure 12 indeed shows the projection on the national map of the inpatient days by class of patients of one single nursing unit. Overall, the four San Joaquin classes associate highly with the intensity of somatic care as measured by the Minimum Nursing Data but show little association with basic care, technical care or self care. In any case the Minimum Nursing Data items selected give a more detailed and balanced view of the nursing care than this "intensity of nursing care" instrument.

Management of nursing care from a clinical perspective

Traditionally, clinicians and nurses took care of patients and their care, while the hospital managers dealt with finances, resource acquisition and the administration of the overall administration of the hospital. They hardly interacted with each other except to confront the common enemy: the financing agencies and the government authorities that were insensitive to their requests for more technology and staff to expand their services to their patients. The introduction of patient and patient care data changes these traditional roles. Managers start to discover their patients beyond their traditional measures such as the number of admissions, the inpatient days and surgical procedures. More importantly, clinicians start to discover the management of care in terms of patient groups based upon clinical relevancy. The last case illustrates how the pneumology department within the hospital started to reorganise itself along patient categories or "product lines" and how this reorganisation reflects upon the organisation of nursing care by way of the NMDS.

In 1994, the hospital decided to reorganise itself into clinically more relevant entities. The penology department took the lead and identified some 11 clinically relevant patient groups: from "asthma" patients to "pneumological emergencies": see Figure 13.

- asthma
- COPD (chronic obstructive pulmonary deficiency)
- lungcancer
- chemotherapy
- interstitial pathology of the lung
- infections
- TBC
- respiratoir revalidation
- transplantation
- general pneumology
- emergencies

Figure 13: Example of a "local" classification system

The identification of those patient groups took quite some time. Overall the major diagnostic category tells a lot about the diversity of the patient mix, for which it was developed in the first place, but little about the variability of nursing care. Even when one substitutes the ICD classification by, for instance, the DRG classification the results hardly improve: some additional percentage points of explained variance in classical analysis of variance terms, depending on the model. The DRG classification though was meant to

provide for patient groups which were homogeneous with respect to hospital resource consumption. Unfortunately, the prime indicator of resource consumption was the length of stay. For obvious reasons, the 'number of overnight stays' tells little about the type and intensity of nursing care.

Figure 14 gives the NMDS information for two of these patient groups: the "tuberculosis" patients (TBC) and the "infections patients" (INFECTIES). Distinct different nursing practice patterns emerge.

Figure 15 shows how even within one single patient group, such as "lung cancer" patients, nursing care differs according to the nursing unit.



Figure 14: Comparison of two clinical groups (within the clinic pneumology: TBC versus infections (excl. TBC) 181



Figure 15: Comparison of one clinical group, Lung cancer, over two nursing units

Conclusion

The case studies show that the variability of nursing practice patterns can be looked at from many angles that are of interest. Every angle of incidence investigated so far tells a little bit more and gives some more insight into the variability of nursing care. As our knowledge is still too limited, it is preposterous to state that we understand all that goes on in the nursing unit or will ever be able to do so. So far we have looked at the variability by age, admitting physician, department, referral pattern, social class, day of stay, diagnostic group, DRG. Several instruments similar to the ones presented have been developed to estimate the intensity of nursing care.

The case studies show how the methodology emphasises description and insight through the use of interactive and windows oriented graphical displays rather than the collection of data. Though the case studies only present "nursing care" and "nursing units", any combination of patient and patient care variables, any level of aggregation or of detail can be looked at.

The cases also indicate that by focusing in on this day-to-day life within the unit one touches on the limits of privacy: privacy from the patient's point of view as well as from the care provider's point of view. This intrusion is very likely to change behaviour, hence established practice patterns. Intervention within this process of delivery of hospital care demands for the utmost caution and may well influence nursing practice patterns within some team or unit.

Also, by focusing in on such level of detail the boundary line between clinical care -- the responsibility of every care provider -- and the management of the care --the responsibility of the organisation, be it nursing unit, nursing department or the national nursing professional groups -- may look ambiguous. Cause and effect -- the diversity of the patient mix and the variability of practice patterns -- become subject of discussion. Are therapeutic patterns due to the patients, their individual care providers or the limitations -- financial as well as organisational limitations -- imposed by the organisations on their different level? The information on itself does not provide answers or lead automatically to decisions: only the individuals, including the nursing professionals and the nursing managers, who read and interpret the information do. The instruments presented are only "navigation and communication" tools. Methodologically though, this boundary line is clear-cut: clinical care involves all relevant aspect on all patients at all times. The patient care information system for management and strategy which is presented here is based on selected variables to a selected level of detail for selected patients at selected intervals.

These micro/macro readings allow to link existing patient information systems which are primarily transactional (orders of laboratory tests, drugs, records, billing, ...) or operational (admission scheduling, use of disposables, staff management, ...) with existing management (yearly budgets, staff allocations, ...) and strategic (nurse staff hiring priorities, continuing education strategies) patient information systems.

The stability of this NMDS design over the years, proven so far for 1988 till 1993, also allows comparisons over time. Looking at trends over time, those nursing units for which the Minimum Nursing Data will hardly vary will stay in the same area in the national map. Units which are reorienting their practice will move considerably in the national map. By looking at trends over years within the same frame of reference, for instance the frame of reference of 1988-1992, one can see how and in what direction nursing care develops from year to year. First comparisons on the basis of fingerprints of nursing care activities have been published.

Though similar exercises to classify patient for nursing care purposes have taken place on the level of one hospital or some hospitals, never has such an attempt been made on the level of one country. Hence, we better move with caution. Right now, the NMDS has been used to reorient the hospital financing system in Belgium. Similar efforts are running to look at the programming and accreditation of hospitals.

First results are in on a comparison of the "variability of nursing practice patterns" between some 8 Swiss hospital departments and Belgian hospital departments. As expected there are many similarities between the delivery of nursing care in Switzerland and Belgium but also many dissimilarities. We think we are ready for a "European" discussion on the delivery of hospital nursing care.

References

- 1. Ministerie van Volksgezondheid en Leefmilieu en Centrum voor Ziekenhuiswetenschappen, <u>Medical Activities in the General Hospitals, National Statistics 1988</u>, Leuven, Centre for Health Services and Nursing Research, Leuven, 1991 (Dutch, French and English).
- Ministerie van Volksgezondheid en Leefmilieu, Bestuur der Verzorgingsinstellingen, Studiedienst Nursing, <u>Minimale Verpleegkundige Gegevens</u>, samenvatting van de informatie verstrekt door de Heer H. Splingaer, Directeur-Generaal en Mevrouw A. Simoens-De Smet, Adjunct-adviseur op de informatiedag van 24 februari 1988
- 3. Fleiss, J., Statistical Methods for Rates and Proportions, J.Wiley, New York, 1981
- 4. Agresti, A., Analysis of Ordinal Categorical Data, J.Wiley, New York, 198
- 5. Hearst, E., 'Psychology and Nothing', <u>American Scientist</u>, Volume 79, September-October 1991, p.432-443
- 6. Kruskal, J., Multidimensional Scaling, Sage Publications, London, 1978
- 7. Gifi, A., Nonlinear Multivariate Analysis, J.Wiley, New York, 1990
- 8. Young, F. and Hamer, R., editor, <u>Multidimensional Scaling</u>, <u>History</u>, <u>Theory and</u> <u>Applications</u>, Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1987
- 9. The SAS ® System, SAS Institute Inc., 1995
- 10. Sermeus, W., <u>Variabiliteit van Verpleegkundige Verzorging in Algemene</u> <u>Ziekenhuizen</u>, doctoraal proefschrift, Faculteit Geneeskunde, Katholieke Universiteit Leuven, 1992
- 11. Tufte, E.R., <u>Envisioning Information</u>, Graphics Press, Cheshire, Connecticut, 1990, p. 50.

- 12. Sermeus, W., <u>Variabiliteit van Verpleegkundige verzorging in Algemene</u> <u>Ziekenhuizen</u>, doctoraal proefschrift, Faculteit Geneeskunde, Katholieke Universiteit Leuven, Leuven, 1992
- 13. Murphy, L.N., Dunlap, M.S., Williams, M.A., Mc Athie, M., <u>Methods for studying</u> <u>nurse staffing unit. A manual to aid hospitals in making use of personnel</u>, DHEW publications HRA 78-3, Hyattsville, 1978, pp 226.

The Construction Of A Care Management Tool To Trace The Clinical Path Of Depressed Patients In A Hospital

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1. Introduction

As hospital management is moving towards the management of patients and patient care, the introduction of patient information systems becomes mandatory. Non-psychiatric patient and patient care applications are well established by now. In Belgium, the registration of data on hospital patients and hospital patient care was started by law nation-wide on January 1, 1988. The Minimum Data team of the Centre for Health Services and Nursing Research of the Catholic University of Leuven has been involved in a co-operative effort with the Administration of the Ministry of Public Health and the Environment and the 7 Faculties of Medicine in Belgium in the development of the registration and more importantly in the development of feedback information for all Belgian hospitals. The Federal Nursing Minimum Basic Data Set and its application to hospital management in Belgium in published in a separate contribution ¹.

This paper uses the same methodology towards the development of a care management tool to trace the evolution of the depressed patients on the psychiatric ward of the General Hospital St. Jan at Bruges. As such it contributed to the work of the Minimum Data team of the Catholic University of Leuven in the development of the Psychiatric Minimum Basic Data Set in Belgium. As of April 1, 1996, this Minimum Basic Psychiatric Data Set will be implemented in the whole country.

The psychiatric care sector compares favourably with the general hospitals with respect to the implementation of Minimum Basic Data Sets. The psychiatric problems favour communication among team members and a team approach in dealing with them. Hence, the care providers have a tradition of keeping medical records and the utilization of patient classification systems. Communication demands feedback: feedback on different levels within a common frame of reference. Most information systems so far are "number trenchers". Care providers are not! Hence rather than adapting the care providers to the information systems - in a sense automating and freezing the old ways - the information systems should adapt to the users. The Minimum Data team favours graphics for the development of care management tools and the exchange of information. By stressing the accessibility of the information through the utilization of graphics, the professionals are put in a position to shorten the feedback-loop between the decisions and the results, hence enhancing the learning process of patient-care delivery. This paper investigates some existing patient classification schemes, it introduces the Psychiatric Minimum Data Set and develops some graphic tools to present the information that is produced and shows how this information can be used for the management of depressed patients.

2. Methodology

Different depression rating scales are used by different care providers. In the General Hospital St. Jan, where 35% of the patient population in the psychiatric wards are depressed patients, four common patient classification systems are used. The first patient classification system is the DSM-III-R². This is certainly the most widespread patient classification system in use on an international scale. It is developed by the American Psychiatric Association and identifies the patient's psychiatric diagnosis along 5 dimensions or axes.

This DSM-III-R classification however is primarily an epidemiological classification system and is mostly used for research purposes. Psychiatric clinicians favour classifications which are more geared towards their daily work. The first such instrument is the Hamilton Depression Rating Scale ³ which is used in the short version of 17 ordinal items. This scale is used by the nursing staff. The second instrument is the Beck Depression Inventory ⁴ which is scaled by the patient himself. This scale has 13 ordinal questions. The third instrument is the Johnson Patient Classification tool ⁵ which consists of 8 items. The Hamilton Depression Rating Scale and the Beck Depression Inventory produce one overall score which rates the degree of depression. The Johnson Patient Classification classifies the patient into one of four ordered categories of intensity of nursing care.

For the purposes of this study these three existing patient classification systems were tested against a first version of the Psychiatric Minimum Basic Data Set with respect to their ability to measure the diversity of the patients. This Minimum Basic Data Set was developed by the Minimum Data Team of the Catholic University Leuven for the Ministry of Public Health. The first version of the Psychiatric Minimum Basic Data Set already incorporated the essential approach of the Minimum Data Team. It looked at the diversity of patients as well as at the variability of practice patterns. It is indeed assumed that the primary role of management is to direct the practice patterns of the physicians and nurses rather than the selection of patients. The approach implies to look at the different professions involved in patient care, e.g. the nursing profession alongside the medical profession. The first version consisted of 27 items concerning the patient functioning, covering the diversity of the patients, and 22 items that cover the variability of care by way of a sample of the care activities of the team.

This paper only looks at the diversity of patients. Hence the 27 items involved are all ordinal variables with or 4 or 5 categories. The specific techniques which are used to investigate the different results are reported elsewhere ¹. Essentially, statistical algorithms are used to "map" the hyperspace of the matrix of all the variables for all the psychiatric inpatient days into a two-, three-, ... dimensional subspace.

3. Results

The data collection ends up with a set of 97 variables for the 27 depressed patients treated on the ward during one time period of 8 contiguous weeks. The observations consist of one score per week for the 27 patients or a total of 216 observations. Since the

rating scales consist of ordinal variables, specific statistical techniques for ordinal variables were used to identify the ones that are statistically most significant. Using multidimensional scaling algorithms such as princals ⁶ and prinqual ⁷, overall consistency was analysed and the interaction of these 97 variables for the 27 depressed patients and their 8 inpatient weeks were visualised. This led to 43 most significant variables for depressed patients on this psychiatric ward. The reduced set of 43 variables for 216 observations is used for further analysis.

Hamilton scale versus Beck scale

The first problem is to investigate if the Hamilton scale and the Beck scale measure the same concept. Indeed the Hamilton scale is scored by nurses and as such measures the degree of depression as perceived by the nurses while the Beck scale is scored by the patient himself and as such measures the degree of depression as perceived by the patient. We analyse the initial consistency of the Hamilton and Beck item scores using a multidimensional scaling analysis. Figure 1 shows the results of this analysis in a two-dimensional subspace.



Figure 1: Hamilton and Beck scores

When we draw a line through the centre of each cluster of answers, the two lines have an angle of about 90°. This implies that the two sets of answers are "orthogonal" or independent. This reveals that the view of the nurse on the psychiatric ward about the depression of the patient has little in common with the view of the patient on his own depression and that their views are quite independent. These results confronted the staff on the wards for the first time very explicitly with the question of the assessment of the depressed patient.

The analysis is further pursued by investigating the Hamilton scale and the Beck scale in depth and separately. Both scales are Likert, summative or linear composite scales. Their

purpose is to scale respondents and respondents only. Indeed, all items are considered to be replications of each other and each item is monotone related to the underlying "degree of depression" continuum. The weighting scheme to combine all the individual items is simple: as all raw scores are added up, each item receives the same weight. Hence the overall Hamilton score measures between 1 and 47, while the overall Beck score measures between 1 and 39 in our set of observations. It has regularly been argued that the selection of one arbitrary weighting scheme over another does not matter very much in practice as all schemes give about the same results^{8,9}. Our experience is that this holds:

- 1) for global evaluation of scales and
- 2) extreme scale scores: the bottom and the top scores.

However, as soon as a more refined analysis zooms in on intermediate scores, many of the assumptions made become shaky and results very much depend on the thoroughness by which they are made and checked. This corresponds to real-life practice: people usually agree on extreme scores: the best student, the most complex case, the least important issue, the lousiest movie,... Problems only arise when intermediate cases have to be scored: the out-of-the-rack wine, the average student,... Is a student that scores 13 out of 20 really significant smarter than the one that scores 12 out of 20? This experience has been confirmed by other researchers ¹⁰. A multidimensional scaling analysis of the Hamilton scores which only hypothesises one single ordinal underlying variable shows how most intermediate Hamilton scores cluster in between the extreme scores observed: Figure 2.



Figure 2: Hamilton scores

A similar analysis for the Beck scores shows a nicely spread range of scores. These results confirm the results of Figure 1: the Hamilton (nurses) scores are widely dispersed in the top half of the figure, while the Beck (patients) scores in the bottom half of the same figure are nicely clustered. Both results support a higher degree of randomness in the intermediate responses of the individual items of the Hamilton scale than of the Beck scale.



These results may be due to uncareful wording of the items or... uncarefulness or unfamiliarity of the respondents with respect to the degree of depression: nurses versus patients. These intermediate results certainly warrant further investigation and caution in our analysis.

Johnson scores

The Johnson score is basically a patient classification system for psychiatric nursing purposes. All patients are assigned to one of 4 ordered categories of "intensity of nursing care" on the basis of the responses to 8 individual items. Our analysis only checked the association between the Johnson score and the San Joaquin score derived from the national Nursing Minimum Data Set that was obligatory for all acute care nursing units, including the psychiatric nursing units. Results were very satisfactory and no further effort was made to investigate the reliability of the Johnson score. The 216 results were taken at face value.

Psychiatric minimum basic data set

The Psychiatric Minimum Basic Data Set will become a national scoring instrument as of April 1, 1996. The first version of 1992 of the Psychiatric Minimum Basic Data Set already incorporated the essential approach of the Minimum Data Team. It looks at the diversity of patients as well as at the variability of practice patterns. Indeed the focus is on the interaction between patients and staff at specifically sampled days, the primary role of management. This analysis only covers the 27 items that deal with the patient's functioning. All the items belong to four groups of items. Each group follows a Guttman or hierarchical measurement process and Guttman's method of scaling. The scale allows to

order both items and respondents according to one single underlying continuum. Further results are published elsewhere 11,12 . The first version identified 6 subscales of functioning which had nation-wide (2571 Dutch and French patient scores) coefficients of reproducibility between 0.8677 and 0.9894 ⁱ. Each group measures one aspect of the patient's functioning:

- the degree of dependency with respect to the physical Activities of Daily Living Selfcare);
- the degree of dependency with respect to Orientation;
- the degree of Behaviour Control;
- the degree of Social Functioning;
- the degree of Social Feedback;
- the degree of relational support (Emotional ties).

As a result of the previous analyses, the variables kept for further analysis are the responses to 9 selected items of the 17 items of the so-called short version of the Hamilton scale (nurses), the responses to 6 selected items of the 13 items of the Beck scale (patients), the Johnson patient category (intensity of nursing care), the 27 items of the patient's functioning of the first version of the Psychiatric Minimum Basic Data Set that measure the diversity of the patients and the DSM-III-R scores which are kept separate and are used for identification purposes only.

Depression space

In a further step, the analysis maps the matrix of the 43 variables for the 216 observations in a three-, four-, five-, ... dimensional subspace using multidimensional scaling techniques. This analysis led to the identification of what we call the "depression space". After careful analysis and discussion with psychiatric professionals three dimensions are retained to characterise this depression space.

Figure 4 identifies this "depression space". The first or right/left dimension stands for the effect of the depression on the emotional functioning of the patient. This dimension represents a balance between the items Fear, Interest and Social feedback at the right side and the items Social functioning, Orientation and Selfcare at the left side.

The second or upper/lower dimension of the space represents the effect of the depression on the biological functioning of the patient. This dimension is a balance between the items Orientation, Social functioning and Emotional ties at the upper side and the items Fall asleep, Sleep on and Early awakening at the lower side. The third dimension is the front/rear dimension and visualizes the effect of the depression on the behavioural functioning of the patient. This dimension is a balance between the items Social Feedback and Behavioural control in front and the items Excitement, Social functioning and Retardation at the rear side. For simplicity we only represent the labels of the dimensions on the next slides which give a representation of all the data.

ⁱ The second version of the PMDS in 1993 was based on 17575 patient scores and reduced the 6 dimensions of functioning to 4, while further increasing the reliability.



Figure 4: The depression space

Tracing the clinical path of depressed patients

The visualisation technique makes it possible to trace the evolution of patients' depression from week to week. Figures 5 and 6 on the next page show the evolution of all the patients during eight weeks in the "depression space". Notice the labels of the dimensions on the two figures. Figure 5 shows the dimensions "emotional axis" versus "biological axis" while Figure 6 shows the dimensions "emotional axis" versus "behavioural axis". The label 'a' gives the first week, 'b' the second week, and so on.



Figure 5: All patients in a depression space (emotional and biological axis)



Figure 6: All patients in a depression space (emotional and behavioural axis)

Case study: patient No. 1

Figures 7a and 7b give the clinical path of patient No. 1 during his therapy on the psychiatric ward. Patient No. 1 was emotionally very disturbed during the first two weeks of admission. This resulted in a high score on the emotional axis, a normal score on the biological and behavioural axis. This is represented in the points 'a' and 'b' in Figure 7a.



Figure 7a: Clinical path of patient No.1 (emotional and biological axis)



Figure 7b: Clinical path of patient No.1 (emotional and behavioural axis)

Due to medication the emotional disturbance faded away but the patient developed a sleeping problem. The score on the emotional axis decreased. We notice an increase on the biological axis. This can be seen in the point 'c'. This information was brought in a staff meeting and patient medication was changed. In the first week after the change the sleeping problem slowly decreased. The score on the biological axis only changed a little bit. This is visualised in point 'd'. But when side-effects of the first medication disappeared, the sleeping problem disappeared. The score on the biological axis became normal even so for the emotional axis. This is represented in point 'e'. The patient felt better and started to participate in the therapeutic program. On the behavioural axis we can see that this patient stays in the same quadrant of the depression space, which means that the depression has not a great effect on his behavioural functioning.

Case study: patient No .2

Patient No. 2 has a sleeping problem and has a very disturbed behaviour the first week of admission. Figure 8a and 8b give the clinical path of patient No. 2 during his therapy and point 'a' indicates this first week. During this week his anti-depressivum is increased while this has a sleeping side effect. In the second week his sleeping problem disappeared but his behavioural disturbance is emphasised. This can be seen on the behavioural axis. The position 'b' is the most extreme position on that dimension. Having a good sleep the patient recovers quickly and his behavioural disturbance fade away in the two following weeks. This is represented in points 'c' and 'd'.



Figure 8a: Clinical path of patient No. 2 (emotional and biological axis)



Figure 8b: Clinical path of patient No.2 (emotional and behavioural axis)

Case study: patient No. 3

Figures 9a and 9b give the clinical path of patient No. 3. About patient No. 3 we had a discussion with the staff meeting at the fourth week of admission: weed 'd'. Some team members said the patient was exactly like four weeks ago, there was no evolution. Other team members said the patient has really changed since his admission.

The depression space shows that both team members are right. The first group is concentrating on the behavioural functioning of the patient. On this dimension the

positions 'a' and 'd' are projected at exactly the same place. This means there is no evolution in the effect of the depression on the behavioural functioning of that patient. The second group is concentrating on the biological functioning. On this dimension there is indeed a difference in projection between the first week of admission, shown in point 'a' and the fourth week of admission, shown in point 'd'.



Figure 9a: Clinical path of patient No. 3 (emotional and biological axis)



Figure 9b: Clinical path of patient No. 3 (emotional and behavioural axis)

Case study: patient No. 4

There were different opinions for patient No. 4 in the staff meeting. After five weeks the overall conclusion was the patient did not really change despite all the efforts of the team. When we look at Figure 10a and 10b, which show the clinical path for patient No. 4, we can distinguish an evolution which has not been seen by the team. There are two groups of points. The first group with the points 'a', 'b', 'e' and 'h'. The second group with the points 'c', 'd', 'f and 'g'.



Emotional axis

Figure 10a: Clinical path of patient No. 4 (emotional and biological axis)



Figure 10b: Clinical path of patient No. 4 (emotional and behavioural axis)

4. Conclusion

Using the same methodology as developed by the Minimum Data Team of the Catholic University Leuven for the national Nursing and Psychiatric Minimum Basic Data Sets, we are able to visualise the patients evolution from week to week. In this evolution we can represent a synthesis of all the information from the selected variables. This synthesis is even so accurate and sensitive that it can show an evolution where the team members can not decide over the dominant functioning pattern of the patient and over the actions to take. This was illustrated by patient No. 4. With patient No. 3 we illustrated that different opinions in a team can exist with the same right of being. It only depends on the viewpoint one takes to see whether or not an evolution took place. The depression space represents the evolution with such a great accuracy we can measure the effect of medication from week to week. This was illustrated by the patients No. 1 and No. 2.

Care providers on the floor now have an overall instrument to visualise the evolution of depressed patients. Interventions can be more accurately tuned than in the past.

This study concerns only a little group of patients. With a large national database there are endless possibilities to trace the clinical paths of the depressed and other patients. This national database will start as of April 1, 1996. This date is purely circumstantial.

References

- 1. Vanden Boer, C., Delesie, L., <u>The Federal Nursing Minimum Basic Data Set and</u> <u>Hospital Management in Belgium, A Case Study of a Nursing Department.</u>
- 2. American Psychiatric Association, <u>Diagnostic and Statistical Manual</u>, version III- R and version IV.
- 3. Hamilton, M., 'A Rating Scale for Depression', <u>Journal of Neurol. Neurosurg.</u> <u>Psychiatry</u>, 1960, nr 23, p. 56-62.
- 4. Beck, A.T., <u>Depression: Clinical, experiumental and theoretical aspects</u>, Harper and Row, New York, 1967.
- Auger, J., V. Dee, <u>Patient Classification Criteria Statements</u>, <u>Patient Behaviours</u> <u>Nursing Interventions</u>, Neuropsychiatric Institute, University of California, Los Angeles, 1984.
- 6. Gifi, A., Non-linear multivariate analysis, John Wiley & Sons, Chichester, 1990.
- 7. The Sas system, SAS Institute Inc., Cary, N.C., 1990.
- 8. Joreskog, K., 'A general method for analysis of covariance structure', <u>Biometrika</u>, vol. 57, 1970, p. 239-251.
- 9. McIver, J., Carmines, E., <u>Unidimensional Scaling</u>, Sage Publications, Beverley Hills, 1981.
- 10. Likert, R., 'A method of constructing an attitude scale', in G.Maranell, (ed), Scaling: <u>A sourcebook for Behavioral Scientists</u>, Aldine Press, Chicago, 1974, p.233-243.
- 11. Delesie, L., Nassen, E., Wuyts, Y., 'Minimale Psychiatrische Gegevens: een pilootstudie voor de ontwikkeling van een registratiesysteem voor beleidsgegevens voor psychiatrische diensten en instellingen', <u>Acta Hospitalia</u>, 1993, nr. 2, 15-48.

12. Delesie, L., Nassen, E., Wuyts, Y., 'Minimale Psychiatrische Gegevens, Een proefregistratie voor de ontwikkeling van een registratiesysteem voor beleidsgegevens voor psychiatrische diensten en instellingen', <u>Acta Hospitalia</u>, 1993, nr. 4, 5-31.

Patient Classification System: An Optimization Approach

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1. Introduction

One of the major challenges for Nursing Administrators is to accurately match available personnel resources to the demands of the patients ¹. The complexity of this problem lies in the fact that the principal determinant of the workload i.e. the number and the acuity of the patients is totally dependent upon chance and changes several times daily. This is further aggravated by the scarcity of nursing personnel, an escalating technological specialisation that restricts the ability to transfer nurses between patient types, and the regulatory agencies that legislate delegation of tasks to the various staff levels.

The solution to this daily test has been the development of Patient Classification Systems (PCS) defined as "a program that entails a systematic approach to the evaluation of patient's conditions, to determining the availability and selection of nursing personnel, and to the careful consideration of the variables influencing allocation of human resources" ². Modern classification systems are ideally made up of two parts: an acuity tool and a nurse staffing tool. The acuity tool measures the illness of the patient or demand for nursing services as an indication of workload. The nurse staffing tool allocates staff to maximize the utilization of resources while best meeting the workload needs.

Although there are estimated to be approximately 1000 different patient classification systems currently in use, they continue to be a source of conflict and dissatisfaction among both administrators and nursing staffs. The two major sources of complaint are:

- (1) the inability to accurately measure the workload of a particular institution and
- (2) the difficulty in providing real time staffing patterns that effectively optimise the use of the available staff ³.

The nursing staff allocation model was first computerised and improved upon by operational researchers such as Wolfe and Young ^{4,5} who used the multiple assignment technique to obtain a staffing solution that met both the quantitative and qualitative aspects of assignments for specific personnel. Haussman ⁶ utilized a queuing model to evaluate the effect of nursing load on waiting time in a burn unit. Warner and Prawada ⁷ utilized a mixed-integer-quadratic programming algorithm which was an improvement over Wolfe and Young's original model in that constraints on the capacity of the personnel were considered. Abernathy e.a. ⁸ used the Monte Carlo technique for exploring short term scheduling and Smallwood e.a. ⁹ used Markovian reasoning to predict the desired reserve staff capacity.

Trivedi and Warner ¹⁰ proposed the branch and bound method to solve nurse staffing problems. These operational research studies did little to solve the actual staff allocation

problems encountered by nursing administrators in that they failed to consider

- (1) the complexity and variety in patient care situations;¹¹
- (2) the discrepancy in the philosophical view of patient care between operational researchers and nursing personnel; ¹²
- (3) the psychosocial factors by standardising the behaviour of workers and patients ¹³, and
- (4) the involvement of nursing in the development of the model.

2. Problem Identification

In 1990, the Nursing Administration at Herman Hospital, Houston, Texas decided to abandon the commercial PCS in use because of a lack of validity in measuring patient acuity and the inability of the system to allocate staff on a prospective basis. An internally developed manual system (HANDS - Herman Acuity and Nursing Distribution System) was then implemented. This was a prototype system that integrated the classification of patients, distributed the nursing staff on a real time basis and projected fiscal requirements for budget in a simple format based on the actual practice of the specific hospital.

The first component of the manual system was the acuity tool. The acuity tool classified the patient into one of eight categories: category 1 corresponded to a patient who required a 1:1 staff to patient ratio or eight hours of care by a Registered Nurse (RN) in an eight hour period, category 2 would be patients who required a 1:2 staff to patient ratio or four hours of RN care in an eight hour shift, and on through to category 8 which was a 1:8 staff to patient ratio requiring one hour of RN care during the shift. Points allocated to each category were in direct proportion to the number of RN hours utilized by the category e.g. category 1 was allocated 8 points and category 8 was allocated 1 point. This considerably simplified the work of a charge nurse.

The second part of the manual system dealt with nurse staffing. This tool assigned points to a staff person based on the relative value of that particular staff member in performing the complete responsibilities of an RN for a set time period. Thus, the value assigned to a fully oriented RN who delivered 8 hours of care in an 8 hour shift was set at 8 points. A Licensed Vocational Nurse (LVN), whose education and licensure limits his/her ability to perform many nursing functions, was regarded as fulfilling approximately two-thirds of the responsibilities of an RN so their point value was set at 6 for an 8 hour shift. Finally, a Nursing Assistant was assigned 4 points for an 8 hour shift as they were only allowed to perform very basic patient care functions. At no point was it implied that a RN could be replaced by two nursing assistants. Even though some nursing skills are common to all nurses, interchangeability of nursing personnel is limited by their training and technical expertise. This was recognized during staffing.

Staffing was then accomplished for each unit by calculating the number of patient care points for each patient and then totalling to determine the number of patient care points required for the unit. This acuity total was compared to the actual number of nursing care points available in the unit. Obviously, the ideal staffing situation was when these two point values were equal, utilising only staff normally assigned to that unit. However, this

was seldom the case, so staffing for the institution was determined on a per shift basis by "floating or pulling" personnel between units or utilising the out of hospital "float pool" nurses to equalise the demand if a sufficient supply was available or to share the shortage equally among units if the supply did not meet the demand.

Although the manual system was simplistic and much preferred to the prior commercial system, it was not developed for all areas of the hospital and had not had any validity and reliability checks. For the later to be established and for the system of allocation to become permanent, development of a computer optimization algorithm linking patient requirements to available nursing resources and providing continuous monitoring and access to the data for long range planning and trend analysis was proposed.

Computerisation allowed the system to account automatically for inherent workload discrepancies between units and shifts and for differences in the value of personnel when they are "floated" between units or are obtained from the 'float pool' outside the hospital. The effectiveness of this approach relative to the manual method is demonstrated in the Results section.

3. Methods

The computer model proposed in this study is a Linear Program (LP) which is a technique that uses a mathematical model to describe the problem of allocating scarce resources among competing demands in the best possible (i.e. optimal) way. The adjective 'linear' implies that the unknowns in the mathematical relationships in the model appear in the first degree. Linear programming enables arriving at a predetermined goal best among all feasible alternatives. The objective in this study was to minimise the number of personnel used (each shift) by optimally assigning the nursing staff (supply) to meet the acuity needs of the units (demand). The constraints of the LP were formulated to meet the acuity requirements in each nursing unit and for each shift taking into consideration:

- (1) the value assigned to each staff member;
- (2) the actual availability of each category of staff by shift;
- (3) the minimum requirements for the number and type of staff in each unit in each shift and
- (4) the access to a 'float pool' of nurses from outside the hospital (the value assigned to nurses from this pool was the same as the hospital based nurses).

To ensure integer values for the number of personnel (three types) to the various nursing units, the branch and bound technique ¹⁴ in linear programming was used.

The assimilation of the parameters into the model was a major point in the study. First, the acuity tool, the instrument which assigned the patient acuity points for each individual patient to be utilized as the demand parameter, had to be confirmed as a valid and reliable estimator of the RNs time required by each of the patients in a given unit for an eight hour shift (see Problem identification, paragraph 2).

Secondly, estimation of the supply parameters was required. It was simple since the basic premise of the tool was a very straightforward assumption that one fully oriented RN could provide 8 points (8 hours) of RN care in an 8 hour shift. The relative worth of the LVN and Nurse Aide was a ratio of their ability to perform a portion of the task that an RN would be required to perform (based on state regulations and job expectations. Please see Problem Identification paragraph 2).

Lastly, penalty coefficients for the decision variables were incorporated in the objective function; with a large penalty for when hospital staff are pulled from their home unit to another unit, smaller penalty for use of the float pool staff and minimal penalty for use of staff within their home unit for e.g. the penalty coefficient of a RN (LVN, NA) pulled from their home unit to another unit was 90 (60,60). The penalty coefficient for a 'float pool' RN (LVN, NA) was only 20(40,40) and the penalty associated with nursing staff assigned to their home unit was set at 1.

After the appropriateness of using these tools to estimate the demand and supply parameters was established, the next step was to formulate the constraints which facilitated the assignment of personnel to the units. This was the most tedious step in the process as the unique characteristics of each unit demanded a certain staff mix and limited the availability of staff to be floated between units. The problem was further exacerbated by the fact that the nurses expertise was particular to the nursing unit with which they were affiliated limiting their effectiveness in other clinical areas.

The primary objective of the staffing portion of the patient classification system was:

- 1. to meet the demands of the workload, as defined by the acuity tool, using the minimum amount of resources while considering both quantity and staff mix available
- to be able to be adaptable to the situation where the actual workload number was not attainable and assignments would need to be made allocating the shortages equally (percentage wise) among units
- 3. to staff the units with RN's to the extent possible (because the institutional philosophy that RNs provided the highest consistent quality of care);
- 4. to maintain a preference for keeping staff in their home unit rather than floating them to other units;
- 5. the objective function was not driven by the cost of the staffing pattern (though the cost effectiveness of the personnel assignments produced by the computer model was addressed later in the testing phase and is the subject of a separate paper) but by the number of personnel used to meet the acuity requirements weighted by the penalty coefficients.

Thus the linear program for the patient classification system was:

 $MIN \quad \sum_{i=1}^{u} \sum_{j=1}^{3} \sum_{i=1}^{u+1} p_{iik} x_{iik}$

subject to:

(0)

$$a_i \leq 8\sum_{k=1}^{u+1} x_{i1k} + 6\sum_{k=1}^{u+1} x_{i2k} + 4\sum_{k=1}^{u+1} x_{i3k} \leq b, \quad i = 1...u$$
 (1)

$$x_{iii} \ge c_i \qquad i = 1...u \tag{2}$$

$$\sum_{i=1}^{b} x_{ijk} \leq s_{jk} \qquad j = 1, 2, 3 \text{ and } k = 1...u$$
(3)

$$\sum_{i=1}^{n} x_{iju+1} \le f_{j} \qquad j = 1, 2, 3,$$
(4)

$$x_{iik} \leq 0$$
, integer

where:

- x_{ijk} = number of nursing personnel in unit i of type j from unit k (note that nurses belonging to the 'float pool' are defined as belonging to unit u+1)
- p_{iik} = penalty associated with assigning nursing staff from unit k to unit i of type j
- $p_{iji} = 1$ (since the penalty associated with assigning personnel to their home units is assumed minimal)
- a_i, b_i= the lower and upper limits of personnel demand in the u nursing units
- $c_i = minimum$ number of RN's required to staff the ith nursing unit
- s_{ik} = personnel of type j in nursing unit k available for allocation to other nursing units
- F_i = personnel of type j from unit u+1 that could be floated out to other units

The mathematical expression in (0) represents the sum total of penalty points involved in the allocation of nursing personnel to the various nursing units. This needs to be minimised. The three summations in constraint (1), a demand constraint, represent the total number of RNs, LVNs and NAs respectively that are utilized in any particular unit and the multipliers 8, 6 and 4 are the values assigned to these personnel. Therefore, the middle mathematical expression represents the total number of nursing care points available to the unit and it must lie between the upper and lower limits of the required acuity points for the unit. Constraint (2), represents the minimum number of RN's required to safely staff each unit on a given shift. The supply constraint (3) represents the total number of nursing personnel of type j from nursing unit k allocated to all the nursing units and may not exceed the total number of type j personnel available in unit k. Constraint (4) represents the upper limit to the number of 'float nurses' from outside the system that may be used in any shift.

4. Results

Before any computer runs were made to test the superiority of the computer method over the manual method, the validity and reliability of the acuity tool was tested by standard statistical methods. The supply of staff during a particular shift and the relative value of each type of staff were the same as used in the manual staffing method. The following five (u=5) nursing units within the Maternal and Child Health staffing division were considered for comparison.

- 1. Pediatric Special Care (PSC)
- 2. Maternal-Fetal Specific Care (MFSC)
- 3. The Family Centre (FC)
- 4. Pediatric Critical Care (PCC)
- 5. General Pediatrics (GP)

The upper and lower bounds for equation (1) were assigned based on the needs of the nursing units for the particular shifts. Since these demand constraints were inequality constraints a range of $\pm 10\%$ of the required acuity total for a particular unit was selected to insure that a feasible solution was reasonable during shifts with short supply. Similarly, values for c_i , s_{jk} , and f_j were substituted into the LP depending on the day and the shift under consideration. For e.g. for the data in the appendix the optimal solution resulted in assigning the following values to the decision variables (using the STORM ¹⁵ software package).

 $X_{111}=3$, $x_{121}=1$, $x_{212}=2$, $x_{313}=4$, $x_{323}=3$, $x_{333}=4$, $x_{414}=5$, $x_{434}=1$, $x_{515}=3$, $x_{525}=1$, $x_{535}=2$, $x_{316}=2$, $x_{516}=3$, $x_{326}=1$, $x_{526}=2$.

Hence the total staff assigned to the five nursing units was 37 as opposed to 40 by the manual method.

Since the objective of the problem was to use the minimum number of staff to meet the workload requirements, a simple comparison of the total number of personnel used by each method was sufficient to establish the superiority of the computer model. Data for 30 sample shifts (from days with both an abundance as well as a shortage of staff) used for manual staffing and retrieved from the hospital archives was used to run the LP. Table 1 provides a comparison of the two techniques.

It is clear from these results that the computer model did quantitatively solve the problem better (i.e. assigned fewer staff). However, the magnitude of the difference was exaggerated by the relatively large range for the required equity total ($\pm 10\%$) that was used in the model.

Day	Total staff	Total staff	Difference in favour of		
	linear prog.	manually	computer		
1	35	40	5		
2	36	41	5		
3	30	32	2		
4	33	36	3		
5	31	34	3		
6	34	34	0		
7	31	36	5		
8	34	37	3		
9	34	39	5		
10	30	36	6		
11	32	35	3		
12	36	39	3		
13	33	38	5		
14	31	33	2		
15	36	41	5		
16	34	37	3		
17	34	36	2		
18	41	42	1		
19	38	38	0		
20	32	35	3		
21	38	39	1		
22	37	38	1		
23	35	40	5		
24	37	40	3		
25	26	30	4		
26	25	28	3		
27	31	33	2		
28	32	34	2		
29	45	49	4		
30	33	40	7		

 Table 1: Daily Comparison of LP Model to Manual Method for Staffing Personnel

In examining the staffing patterns in detail several conclusions were drawn about the computer model.

- 1. The model shared the resources among units appropriately during periods of shortage.
- 2. The model slightly understaffed the units during shifts when there was more than adequate staff because it matched the lower end of the range.
- 3. The model was much more effective in cancelling staff during times of abundance as compared to the manual method.
- 4. Because of the penalty weights, the model as a whole produced results very similar to the manual method with one exception. The computer would always try to reach the

targeted acuity points by substituting an RN from the 'float pool' (if available) into a unit and cancelling a lower valued NA (Nurse Aid), which was consistent with the stated philosophy of the model. However in the manual method, the staffing secretary tended to use all personnel from within the unit as originally scheduled which resulted in overstaffing or calling off the 'float pool' RN.

5. Sensitivity Analysis

Following the attainment of the optimal solution to the linear programming problem, the effect of discreet changes in the different parameters of the problem on the current optimal solution was studied. The following changes in the LP were considered.

- 1. Changes in the values of the penalty coefficients in the objective function.
- 2. Tightness of the demand constraints (equation(1)).
- 3. Changes in the staff values in the demand constraints (equation(2)).
- 4. With respect to the first change, it was observed that the new optimization maintained the prioritising in the order consistent with the philosophy of the hospital. That is, the preference for allocation of unit personnel or 'float pool' could be changed by changing their weights in smaller increments while the penalties for using between unit floats would need a significant change before the current optimal would be affected.

The second round of sensitivity analysis incorporated changing upper and lower bounds for the total acuity values. In this context the model was appropriately responding to changes in acuity constraints by cancelling, adding, or trading personnel between units to better approximate the desired acuity total.

The final sensitivity testing was performed by changing staff weights assigned by the expert panel of nurses into the original model. For e.g. an RN from PSC assigned to PSC, MSF, FC, PCC, or GP was now assigned values 8, 4, 5, 6, and 8 respectively. Similarly, values for other nurse type by assignment were changed while keeping the 'float pool' nurses at the original value. It was observed, that although most of the staffing pattern in the units remained the same, the total nursing points available affected the assignment of 'float pool' staff to the FC and the GP units.

6. Cost Analysis

Using the average salary cost per hour as an additional coefficient in the objective function cost effectiveness of the proposed staffing solution was considered .

The costs incorporated into the model were; \$17.50/hour for a RN, \$12.00/hour for a LVN and \$8.00/hour for a NA. The corresponding costs for nurses from the 'float pool' was assigned as: \$20.00/hour for a RN, \$14.00/hour for a LVN, and \$8.00/hour for a NA. The actual comparison showed an interesting shift in personnel to using NAs in preference to

LVNs, the addition of between unit floats, an actual increase in the total number of staff by one and an overall cost saving per hour of \$9.00 in the cost adjusted model solution.

7 Discussion

This model integrates the acuity point system developed at Herman Hospital, Houston, Texas, with the available nursing skills as a consequence of the computerised operational research approach to a problem that has been investigated for three decades by health care researchers.

Furthermore, computerisation provided the flexibility that has been lacking in most of the systems researched through the literature review. It incorporates the fact that the (1) patient requirements for nursing care constantly change and (2) skill mix necessary to meet these demands need updating on a regular basis and (3) the inability to predict staff availability. Hence a model that forecasts staffing on a weekly or monthly basis according to rigidly set protocols is antiquated.

The model is not perfect. Firstly, the issue of the penalty weights in the objective function needs to be addressed. The sensitivity of the model to these weights places the quality of the solution at risk based on the arbitrarily chosen values. These penalties need careful consideration in order to arrive at a reasonable solution and to reflect the culture and philosophy of the institution using the model (It was observed that during the course of this study that without these penalties even after 72,000 iterations an optimal solution was no where in sight).

Secondly, the range of 10% assigned to the target acuity point (right hand side of the demand constraint) was so wide that the model consistently understaffed on days when there were adequate personnel. This needs to be further investigated.

Finally if this model is to be used as projected to staff a large multi-unit hospital, three separate staffing matrices will need to be developed for each of the three shifts. Therefore, the time used by the computer to produce the optimal solution cannot realistically be more than an average of 20 minutes per iteration (i.e. the final collection of information for staffing the 7am to 3pm shift is obtained by 4:30 am and the assignments must be finished by 5:30am, as this is the deadline for calling off personnel).

As these difficulties are addressed and resolved, the future possibilities for this model are numerous. The most pressing need that this model can meet is the demand to charge patients by their requirement for nursing care rather than a flat room fee. It would be relatively simple to enter the acuity information on each patient into the computerised daily census report for billing purposes, then transfer the totals for each unit to the staffing office. Thus the nursing services that a patient is billed for is tied directly into the amount of nursing service that is provided to that patient for that day. Another desirable feature that could be incorporated into the future versions of this model would be the ability to estimate the staffing needs for a 24 hour or 48 hour period. Currently the model is

designed to address a single upcoming shift; realistically the availability of staff for upcoming shifts should affect the present shift.

In summary, it appears that an operational research formulation of the patient classification system has finally been developed that sufficiently quantifies the very subjective task of nurse staffing in a simple enough format that can be programmed on a computer while taking into consideration the complexity of the environment. The results of this study are generalisable to any health care facility that has staff providing direct patient care. The advantage of the 'nurse care point' system is that various levels of staff can be utilized in the formula because the points are a measure of the skills which are interchangeable between the personnel. Plus, given the current demand for multi-skilled cross-trained staff this ability to quantify available skills allows flexibility in developing appropriate and cost effective staffing patterns.

References

- 1. Halloran, E.J., 'Variability in Nurse Staffing Research', Journal of Nursing Administration, 17,2, 1987,26-32.
- Huckbay, L.M., 'Patient Classification: A Basis for Staffing', <u>NLN Publications</u>, 20-1984: National League for Nursing, 1984
- Hershey, J., Pierskalla, W., Wandel, S., 'Nurse Staging Management', in: D. Body, ed., <u>Operational Research Applied to Health Services</u>, St. Martin's Press, New York, 1981.
- 4. Wolfe, H., and Young, J.P., ' Staffing the Nursing Unit: Part I Control ed Variable Staffing' <u>Nursing Research</u>, 14;3, 1965, 236-243.
- 5. Wolfe, H., Young, J.P., 'Staffing the Nursing Unit: Part II. The Multiple Assignment Technique', <u>Nursing Research</u> 14, 4, 1965, 299-305.
- 6. Hausmann, R.K., 'Waiting Time as an Index of Nursing of Quality of Nursing Care', <u>Health Services Research</u>, 5, 2 1970, 92-105.
- 7. Warner, D.M., Prawada, J., ' A Mathematical Programming Model for Scheduling Nursing Personnel in a Hospital', <u>Management Science</u>, 19, 4, 1972,411-422.
- 8. Abernathy, W.J., Baloff, N., Hershey, J.C., Wandel, S., ' A three Stage Manpower Planning and Scheduling Model: A Service Sector Example', <u>Operations Research</u>, 21, 1973, 693-711.
- 9. Smallwood, R.D., Sondik, E.J., Offensend, F.L., 'The Analysis of Health Care Systems', <u>Operations Research</u>, 19, 6, 1971, 1319-1321.
- 10. Trivedi, V.M., Warner, D.M., ' A Branch and Bound Algorithm for Optimum Allocation of Float Nurses', <u>Management Science</u>, 22, 9,1976, 972-981.
- 11. Stimson, R.H., Stimson, D.H., 'Operations Research and the NurseStaffing Problem', <u>Research in Hospital Management</u>, Winter, 1972, 61-69.
- 12. King, I.M., 'Patient Aspects' in Shuman, L.J., Speas, R.D., Young, J.P., eds, <u>Operations Research in Health Care: A Critical Analysis</u>, Johns Hopkins University Press, Baltimore, 1975.

- 13. Levine, E., Kahn, H.D., in Shuman, L.J., Speas, R.D., Young, J.P., eds, <u>Operations</u> <u>Research in Health Care: A Critical Analysis</u>, Johns Hopkins University Press, Baltimore, 1975.
- 14. Hillier, F.S., Lieberman, G.J., <u>Introduction to Operations Research</u>, Holden-Day, Inc., San Francisco, 1980.
- 15. STORM: Quantitative Modeling for Decision Support, Personal Version: 1.0 STORM Software, Inc.1986.
Appendix

Sample data used to run the computer program associated with the linear program.

I	ai	bi	Çi
1	27	31	1
2	· 31	35	1
3	74	82	2
4	71	79	3
5	42	46	2

The following is a matrix of s_{ik} and f_i values used in the LP.

			Nursing	Units			
Personnel	Туре	1	2	3	4	5	6 (float
							nurses)
RN	1	3	2	4	5	3	5
LVN	2	1	0	3	0	1	3
NA	3	1	1	4	1	2	2

The following additional constraints were introduced:

 $0 \le x_{iik} \le 1$ i=1,...5, k=1,...5, $i \ne k$

 $X_{i24} = 0$ (i=1,...5. It is assumed that there are no LVNs with home unit PCC)

 $0 \le x_i \le 2$, i=1..5, k=1,2,3,5(i.e. the number of LVNs that may be sent to other units is at most 2)

Also, $0 \le x_{122}$, $x_{123} \le 1$, (i.e. the number of LVNs in PSC from MFSC and FC may not exceed 1) and $0 \le x_{132} \le 1$, (i.e. number of NAs in PSC from MFSC may not exceed 1).

Additionally, $x_{435} = 0$ implying NAs were not floated from GP into PCC. All other $x_{ijk} \le 0$.

Executive Information Support Systems And Health Care Management

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1. Introduction

Every management tool-kit contains a variety of operational research tools developed during decades in which a revolutionary change in information technology took place. Seen from the operational research point of view, also health care management support is offered for several decades. However, operational tools and applications fit for purpose in the sixties seem no longer adequate to support management in the nineties. Old tools are replaced by advanced instruments using technological innovations and a better understanding of managerial work. Also a shift in the nature of managerial work and the type of problems chief executives are facing urge new tools. To get a better understanding of the features and application of Executive Information Support systems in health care management, one should take into account developments in operational research theory and practice, as well as changes in the nature of health care management.

In this paper we will discuss some changes and experiences in the application of computer technology in relation to general needs in today's management. Information technological innovations, earlier adapted in business, have come into the scope of health care organizations. In practice, however, fashionate views on opportunities of advanced information systems, are hard to be implemented. The concept of Executive Information Support systems offers such a fashionate view. In a general hospital we recently explored the gap between the idealized design of Executive Information Support systems and the support needs of health care managers at directorate level.

After discussing briefly the role of computers and information technology in management, the main features of Executive Information Support systems and their functionality will be described. Also some constraints and their impact on implementation will be elaborated. Finally, some of the results from our case on the development of an Executive Information Support system in a hospital environment in the United Kingdom, will be presented and some conclusions will be drawn.

2. The computer and its functionality, a brief summary of history

In the early fifties, as we know, computers were introduced in business (usually large companies) for small groups of users, and mainly applied for technological calculations. The increase of memory capacity made computers fit for use in office environments for electronic data processing at the operational level. Paper administration is turned into batch oriented computerised office work. Its functionality is mainly focused on the

increase of efficiency. Since the seventies, smaller and cheaper computers are available, including a wider variety of software. For the first time the computer is recognised as a tool for management support. So, the precursors of computerized reporting appeared in the 1970s, when the term management information systems (MIS) appeared. These tools were usually used to help managers follow up and control the performance of operational systems. Characterized by image-based technology, these early programs usually offered some good calculation capability and graphics. Their main limitation lay in the fact that they were based on pre-defined images that required extensive professional programming (Rioux, 1995)¹³. The largest advantage is throughput-time reduction. The information needed is available more quickly than before. Based on traditional views on organization, the development of Management Information Systems is mostly oriented on the processing of historical data in bureaucratic and stable environments. The 'what was...' type of question could be answered, however, organizations facing dynamic environments didn't get much support of the Management Information Systems available those days. In the eighties we saw the break-through of the network linked personal computers. Business conditions changed more profoundly than they had at perhaps any time in this century and the PC became a mainstay in most offices (Rioux, 1995) 13. Operational research, management science and logistic concepts entered into the scope of computer engineers. The classic vision on organization, as bureaucratic systems in stable environments is abandoned. Strategic choice and the control of business processes turned into main issues. In the 'what...if type of question the roots are found of Decision Support Systems, in which modelling and statistics play an important role. In industry, Computer Aided Design and Computer Aided Manufacturing, as well as Computer Integrated Manufacturing, were adapted on large scale. Also in the eighties, in data-communication the linking of local to external databases becomes more and more common. E-mail, Internet, the Electronic high-way and a rapidly growing family of support systems are used within organizations. In the nineties the computer is, in spite of standardised communication features, loaded with a personal choice of software, to be seen as an individually tuned multi-functional workstation, connected to local and wide area networks.

3. Computers and management

So, in a few decades a tremendous growth of application of information technology has occurred. Also we have seen a shift in computer functionality:

- from use for calculation and storage of large quantities of data;
- for data-processing (MIS, CAD/CAM and CIM);
- as Decision Support System (DSS, model-generator, simulation);
- to the computer as means of communication (E-mail, EDI, Internet, WWW, GDSS, CSCW, Video-conferencing).

From a managerial point of view, these developments and extensions of functionalities, however, didn't result into integrated support systems fit for 'hands on' managerial support of the strategic apex. At the end of the eighties and in the early nineties the first Executive Information Support systems were introduced. Nowadays an Executive Information Support system is considered to be a valuable 'what is' tool that assumes you have the data

and want to make decisions based on what the data means. Executive management can benefit from having key performance indicators across business units, time frames, channels, geographies and trading partners (Young, 1995)¹⁸. Industry researchers say that EIS is probably the fastest-growing sector of the computer market (Burger, 1995)¹⁴.

4. Executive information support

The term EIS system, first used by Rockart and Treacy in 1982, refers to a family of support systems that is used hands on by the chief executive officer. ESS, MSS and DEISS are abbreviations for support systems for which EIS now is used as a family name. To the definition of Rockart and Treacy. EIS systems have the following main purpose: to more effectively provide the senior manager with easy access to high-level strategic information about a firm's current status via a computer on his or her desk. Recently, however, Cullen defined EIS as an information system that offers support to a large proportion of the work of a general manager (Cullen, 1995)⁶. Key question is what kind of functionality this type of system should offer. The motivations for developing EIS's tend to be internal in nature, with providing easier, faster access to information being the most important. Factors to consider in the decision of whether to buy an EIS include the company's size, the complexity of the business, how quickly its data change, and the volume of detail recorded. The chief executive officer's most important role in setting up an EIS will be determining what kind of information is critical to measuring the company's progress (de long, 1995). Part of the problem is that expectations are high to begin with as a result of hype from media and vendors, and also because of the growing sophistication of end users. Building information applications typically requires the fulfilment of the key criteria: data access, user interfaces, applications integration and hardware integration (Graham, 1994)⁸. To cope with the design of EIS (including interfaces) has to be based on the nature of modern managerial work. The diversity of fashionable views on the nature of managerial work, as well as the differences in real life management practice, are illustrative for the hard job EIS designers are facing. Nevertheless, some dominant views are to be identified:

- the notion that organizations should be considered as networks instead of hierarchies;
- interaction and communication are basic elements;
- to activate and motivate people are core activities in management;
- userfriendliness of the man-machine interface should be a key-characteristic EIS should offer integrated multi-functionality and flexibility to different managers. To the design of EIS an infrastructural approach is appropriate. Provision of data around the functions 'drill down', 'exception reporting', 'trend analysis' and 'status reports' need to be integrated with the function of electronic communication (the largest proportion of managerial work).

5. EIS in operation

Let's take a closer look to EIS systems in operation. Although the term EIS was first used in 1982, it is known that since 1969 NASA top managers work with EIS. In literature we

found descriptions of an EIS system in operation within Lockheed-Georgia in the late seventies. In both cases, chief executives got on-line information without any interference of other staff members. In the 1980s, user-friendly EIS were intended to give the top management team computer power at their fingertips. But like other computer fashions, EIS often failed to meet expectations. One problem was that EIS were often conceived by senior managers to help themselves, without a thought as to how the information might be used by people lower down the organization.

Despite their origins as a means of giving top executives ready access to current company information, EIS are being increasingly used by upper and middle managers as well (Cox, 1994) ⁵. Washington Hospital Center originally designed an EIS for use by the hospital's president and CFO. Now the system has proven so valuable that managers at lower levels of the organization also get the chance to use the equipment (Bergman, 1994) ². One way to make an EIS fail is to limit it to only executives. Providing these systems only to executives denies managers the information they need to be able to run their part of the business.

Ideally, all the information systems should be integrated and able to exchange information. Some of the executives said EIS are good for providing quick hits, while others warned against building up end-user expectations only to disappoint them later when architectural and data integrity issues can quickly make an otherwise useful EIS obsolete (Slofstra, 1995)¹⁵. EISs are expensive to develop, with an average cost of \$325,000. Because the cost depends on existing and intended architecture, hardware, software choice, development personnel, training and the number of users, expenditures vary considerably from organization to organization (Jackson, 1994)⁹. The sequencing of the phases in developing an EIS varies considerably among firms; however, the more successful development efforts include an initiation, definition of systems objectives, and feasibility analysis (Watson, 1995)¹⁷. EIS are high-risk systems as evidenced by the large percentage of companies that have reported EIS failures. To minimize this risk and exploit the potential of EISs, it is important to study the keys to successful EIS development and operation (Rainer, 1995)¹². It takes an organization-wide view of EIS information requirements by identifying and linking business objectives of the organization. Effective communication between EIS executive users and EIS developers seems to be crucial (Frolick, 1995)⁷. An EIS must be flexible enough to support diverse classes of business data (e.g., external, internal, structured, and unstructured) and distinct classes of users i.e., executive as well as non-executive users (Volonino, 1995)¹⁶. According to a survey in 240 organizations, attempts to install an EIS often fail initially. 41% said they had failed at the first attempt - the system was either not completed or was not used. The reasons given for failure included the complexity of the software involved, a lack of agreement on the reason the system was required and too much concentration on presentation rather than gathering data. Another problem is that organizations underestimate the effort that has been put into changing their approach to issues such as quality improvement and empowerment if they are to realize the advantages of an EIS. However, EIS are beginning to change.

The latest products can communicate with other information sources such as spreadsheets and databases (Bird, 1994)³. Nowadays, not only in industry, applications are widely

spread, financial institutes, banks, insurance companies, hospitals, governmental institutes and many other organizations are working with EIS systems. In 1985 about 10% of chief executives within companies on the Fortune-500 list used personal computers. In 1991 over one third of all business companies in the USA used EIS systems. In 1992 the estimated annual growth of the EIS market is over 30%.

6. National health service in the UK and the hospital case

The National Health Service, the public organization for the delivery of health care in the UK, is going through a process of change towards the implementation of an internal market. With the publication of the White Paper 'Working for patients' in 1989, a wide ranging split between purchasers and providers of health care was introduced to stimulate quality enhancing and cost containing competition between hospitals, general practitioners, community care services and so on. Local health authorities (and an increasing number of general practitioners) are now purchasers of services, contracting hospitals (public or private) as their main providers. Hospitals are stimulated to become independent, self governing trusts with a new organizational structure to involve clinicians in management. One basic element in this process of change to a new market is the strategy for extensive implementation of information technology in the National Health Service. A main target in this strategy is the development of a Hospital Information Support System (HISS) for all large acute hospitals in the year 2000. The changes towards a new market as well as the high pretensions of the National Health Service management executive in the implementation of information technology are causing considerable difficulty and instability in many hospitals and other NHS organizations.

The hospital organization in our case, the Lancaster Acute Hospitals NHS Trust ('the Trust'), is an independent provider unit in the Morecambe Bay area with c. 1800 staff members and c. 590 beds. In order to get established in the new market, ongoing reorganizations take place in the Trust. To meet the information needs of its senior managers and directors, the Trust wants to develop an Executive Information System.

managers and directors, the Trust wants to develop an Executive Information System. A research project was carried out with the initial purpose to identify the information requirements of directors and senior managers as the basis for the development of such a system. The approach to the underlying problem led to a general, exploratory way of researching. During the project, the opportunity occurred to analyse the activity information, as it is used by the Business Manager of the Medicine Directorate. Interviews with directors and managers, counselling of internal and external experts and literature search led to the following conclusions and recommendations:

- The hospital in our case is in a rather unstable situation at the moment. The organization has to adapt to the new market and many members in the organization have to learn to understand their new roles. Formal structures are often passed by through informal communication.
- Caused by this instability and by failing efforts in the past to substantially develop the use of information technology in the Trust, strains between managers and medical staff

occur. Investments in information technology must be justifiable and should be made with care.

- Many managers in the hospital function in an unstructured task environment. This causes the need for an incremental approach with an end user perspective for the development of information technology. Besides, a local, adaptive approach in the clinical directorates is needed, since considerable differences occur between these directorates. In the informal organizational structure this can be realized by linking an information expert to each clinical directorate.
- National experiments with HISS make clear that a large claim on financial and human
 resources is needed for the development of such a system, while opinions differ on the
 results. This supports the conclusion that an incremental, local approach will be more
 effective than a large, all-embracing project.
- Simple integration of systems can be achieved through electronic communication. For achieving a much more far-reaching integration of systems (e.g. to realize specified cost calculations), a multi-disciplinary team should be designated for co-ordinating this development.
- Although the hospital organization in our case does not seem to be ready for the implementation of an EIS at this moment, simple improvements in the use of management information can be the first steps towards development of an EIS-type system.

7. Some general conclusions

Overall we see an increasingly crucial role computers play in the provision of information within organizations. EIS is a tool that enable companies to make better decisions based on fact rather than interpretations, gut feel, or historical information. Improved communication at all levels of the organization, improved focus on important business goals, shortening of decision-making cycle-time, flattening of the organizational hierarchy. The potential of EIS is reflected in a growing list of success stories. In spite with the problems to develop and implement appropriate, integrated Executive Information Support systems, the technology has proven valuable. EIS use is determined by experience, work group influence, user satisfaction with information, system access and assistance, perceived consequences, systems sophistication and the presence of facilitating conditions. Without agreement about functionalities, however, it is doubtful to expect benefit in any organization and risky to build an EIS.

In most countries hospital management has to cope with resource constraints. Nowadays organizational, technological, medical and other developments put more pressure on health care budgets than before, and that doesn't make the management job to an easy one. In other words: many health care managers are struggling with the development and implementation of information systems, adequate to their specific environment and needs.

EIS is (for hospitals too) considered as a fruitful concept in which an attempt is made to integrate different functionalities. However, the generation of top managers and chief executives in many organizations (like those in our case) didn't grow up with modern information technology. To have them work hands on computers demands fundamental changes in attitudes and behaviour.

References

- 1. Bergeron, F., Raymond, L., Rivard, S., Gara, M., 'Determinants of EIS use: Testing a behavioral model', in: <u>Decision Support Systems</u>, Vol: 14. Iss: 2. June 1995, p: 131-146.
- 2. Bergman, R., 'From the top down: EIS works for everybody', in: <u>Hospitals & Health</u> <u>Networks</u>, Vol: 68. Iss: 18. Sept. 1994, p: 68.
- 3. Bird, J., 'Senior service', in: Management Today, May 1994, p: 84-88.
- 4. Burger, D., 'Sector is growing like 'wildfire'', in: <u>Computing Canada</u>, Vol: 21. Iss: 4. 1995, p: 39.
- 5. Cox, B., 'EIS not for top brass anymore', in: <u>National Underwriter</u>, Vol: 98. Iss: 32. Aug. 1994, p: 7-12.
- 6. Cullen, R., <u>EIS, meer dan gegevens</u>, Dissertation, Eindhoven University of Technology, 1995.
- 7. Frolick, M.N., Robichauld, B.P., 'EIS information requirements determination', in: Decision Support Systems, Vol: 14 Iss. 2: June 1995, p: 157-170.
- 8. Graham, S. 'Time to say no to Big Brother', in: <u>Computing Canada</u>, Vol: 20. Iss: 2. 1994. p: 31.. Vol: 20. Iss: 2. 1994. p: 36.
- 9. Jackson, B., Upton, D., 'Justifying the EIS investment' in: <u>Charted Accountants</u> Journal of New Zealand, Vol: 73. Iss: 11. Dec. 1994, p: 36-39.
- 10. De Jong, J., 'View from the top', in: Inc. (INO) ISSN, Vol: 17. Iss: 4. 1995, p: 49-52.
- 11. Oland, D., 'The impact of a powerful new process at Moosehead', in: <u>CMA</u> <u>Magazine</u>, Vol: 68. Iss: 1. Febr. 1994, p: 6.
- 12. Rainer, R.K.Jr., Watson, H.I., 'What does it take for succesful executive information system?' in: <u>Decision Support Systems</u>, Vol: 14. Iss. 2: June 1995, p: 147-156.
- 13. Rioux, S., 'How EIS have come of age', in: <u>Computing Canada</u>, Vol: 21. Iss: 4. 1995, p: 42.
- 14. Slofstra, M., 'A tale of two systems' in: <u>Computing Canada</u>, Vol: 20. Iss: 2. 1994. p: 31.. Vol: 20. Iss: 2. 1994, p: 31.
- 15. Slofstra, M., 'Chief information officers get tons of advice', in: <u>Computing Canada</u>, Vol: 21. Iss: 9. April 1995, p: 1-6.
- 16. Volonino, L., Watson, H.J., Robinson, S., 'Using EIS to respond to dynamic business conditions' in: <u>Decision Support Systems</u>, Vol: 14. Iss: 2. June 1995, p: 105-116.
- 17. Watson, H.J., Watson, R.T., Singh, S., Holmes, D., 'Development practices for EIS: findings of a field study', in: <u>Decision Support Systems</u>, Vol: 14. Iss. 2: June 1995, p: 171-184.
- 18. Young, L., 'Explore all the possibilities', in: <u>Computing Canada</u>, Vol: 21. Iss: 4, 1995, p: 41.

Determining Staffing Requirements For Scotland To Meet Changing Demands For Maternity Services

Models to aid local decision-making (The MatS Model)

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1. Introduction

The MatS model has been developed as an aid to decision making when considering issues of maternity staffing and staff costs. It is a spreadsheet-based model which has been developed using Microsoft Excel 5. The model allows users to calculate the requirement for midwifery and untrained staff in their own maternity units based on current services, or on changes in services. The model has been designed for use at a more strategic level and calculates staffing required on an annual basis.

The project originally came about because of concerns about the demand for changes within maternity services in the UK, following a number of official reports published in 1992 and 1993 ^{i,ii,iii}. The main recommendations of these reports were to move away from the high-technology, high intervention model of care that had developed and to 'demedicalise' maternity services, to increase community-based care, as opposed to centralised hospital-based care, to increase informed choice for women, to improve continuity of care and carer and to recognise the professional role of the midwife as a practitioner in her/his own right. While welcoming the recommendations, the authors were concerned about changes taking place without information on the likely effects on staffing and costs.

2. Aims and objectives

The aim of this study was to inform the process of decision-making relating to changes in local maternity services. The objective was to achieve this by developing a 'user-friendly'

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tool which could be used to model changes in service provision in a particular provider unit, to estimate whether or not these changes would be possible given the resources available and, if not possible within current resources, to estimate the additional resources required. The intention was to develop a model that could be used to address issues of concern to providers, purchasers and users, particularly in light of the recent official recommendations.

3. Methods

Establishing common definitions

In order to overcome the problem of different units using different definitions to describe aspects of care, two of the authors drew up a list of Royal College of Midwives approved standard definitions for commonly used terms iv . These definitions were used throughout this project (see Appendix).

Interviews with professionals

The next stage in the study was to obtain information on maternity services throughout Scotland, particularly the models of care being provided, the models that were felt to be feasible and those that were felt to be not feasible. The views of purchaser and provider representatives throughout mainland Scotland were obtained from semi-structured interviews and from postal questionnaires. The views of a sample of general practitioners from throughout Scotland were obtained using postal questionnaires.

Literature review

In addition to incorporating local views as described above, the model was intended to incorporate 'good practice' recommendations. These were found in published papers, evaluation reports and official working papers. They related to inputs to the model such as the recommended number and location of antenatal visits. For inputs such as the average postnatal stay following a caesarean section, where no good practice recommendations could be found, Scottish national average figures were used. These average figures came from the Information and Statistics Division of the Common Services Agency in Edinburgh, the central source of health service statistics in Scotland.

Delphi study

Much of the information used in the staffing calculations is based on professional views, obtained through a Delphi survey. This is a means of obtaining a consensus of opinion from a recruited panel of experts in a particular field. Given the nature of this study, the panel was comprised of 13 midwives from throughout the United Kingdom with a range of managerial and academic experience. Eight members of the panel were recruited as midwifery managers in Scottish consultant maternity units. This technique was felt to be appropriate since it reflects the way that staffing decisions are actually made. In interviews

Heads of Midwifery and other provider representatives were asked how staffing decisions are made currently. The vast majority of respondents said that they are made through the professional judgement of the Head of Midwifery.

The survey was carried out as a series of postal questionnaires asking the respondents how they would staff particular wards, clinics and other aspects of services for a range of activity levels. After each round of the questionnaires was returned, respondents were fed back a summary of the results from the whole panel and a copy of their own replies. They were asked to change their own answers if they felt that was appropriate. In this particular survey, a broad consensus was reached after each member of the panel had returned four rounds of the survey questionnaires. The mean responses from the fourth round of questionnaires were used in the final calculations for the model.

4. Development of the model

The model has been designed for use by people with all levels of computer competency. It contains clear on-screen instructions and users are guided through the model using a series of macros attached to 'click boxes'. These macros allow the user to print pages and to move from one part of the model to another easily. The model is accompanied by an explanatory manual which contains more information about how to use the model and explains the assumptions used in the calculations and their source. As the final stage in the development process, the model was piloted in six maternity units in Scotland. A number of changes were made at this stage to deal with problems that arose and points that were made by the users. These changes related to both the content and presentation of the model.

5. Using the Model

The model is organised in a number of stages, as detailed below:

- 1. The user inputs data on the type of unit and the hospital and community workload. The user is asked to type in a lot of information at this stage. The purpose of this is to cover all possible uses of the midwives' and untrained staffs time in the hospital and in the community. The detailed questions also mean that the model should be able to deal with all types of units providing care in all sorts of different ways. At this stage the user is asked to input information on the annual budget for midwifery and untrained staff. At a later stage this figure is compared against the costs of staffing as calculated by the model.
- 2. The user chooses whether to run the model using 'good practice' recommendations and national average figures or to replace some or all of these figures with local figures. The user is presented with quite a long table covering a number of aspects of care, including length of stay in hospital and numbers of antenatal and postnatal visits. The

user can choose to overtype any part of the data in this table by typing in their local figures. This means that the model is more adaptable to local circumstances.

3. The user defines the type of service that he/she wishes to see modelled.

At the next stage in the model the user is asked to type in a number of pieces of information about the type of service provided at that unit. This includes information on the percentage of women having different types of care for the birth. Currently the majority of women in the UK deliver in hospital and stay in for 2 to 5 days. Other options are to have a 'planned early discharge', a DOMINO or a home birth (see Appendix 1 for definitions). The user is asked about the percentage of women using each of the 'non-standard' options. At present the managers of many hospitals in Scotland feel that they are unable to advertise these options to women because they feel that the additional community staffing required would be prohibitive. Therefore most units have a low percentage of women using these options, and this is largely women who know to ask for this type of care. At this stage in the model users may choose to enter the current figures or they may choose to estimate the figures if women were offered more choice.

4. The model produces a table of results showing the number of midwifery and untrained staff required and the resulting costs, including on-call and call-in payments.

After every question has been answered, the model goes on to produce a table of results. The model works by calculating the staff hours required for the service on an annual basis and working out the full time staff required, taking account of annual leave, study leave, sickness absence etc. At present the model does not consider continuity of care. The table of results shows the numbers of midwifery and untrained staff required in the hospital and in the community. Tables 1a and 1b show the sort of information that is produced. These tables relate to hospital staff only. The model then goes on to produce similar tables for community staff. The results shown are based on hypothetical data for an urban-based, consultant maternity unit with 4,200 births in this particular year.

	Midwife	Midwife	Untrained
_	Co-ordinator		staff
Consultant clinics (hospital)	0.2	0.4	0.4
Consultant clinics (outreach)	N/A	N/A	N/A
Midwife-only clinics (hospital)	0.3	0.4	0.4
Midwife-only clinics (outreach)	N/A	N/A	N/A
Parentcraft & other 'direct care' activities	0.0	1.4	0.0
'Indirect care' activities	0.0	1.0	0.0
Time for booked DOMINO/home births	N/A	N/A	N/A
Day-care	1.0	2.6	1.0
Inpatient care	6.8	42.8	17.1
Labour/delivery suite	5.7	42.8	11.4
Theatre	0.0	4.5	1.5
Additional time for students	0.0	0.9	0.0
Total	14.0	96.8	31.8

Table 1a: Hospital-based staff required

	Minimum W.T.E.*	Cost
Midwife Co-ordinators	14.0	£332,332.00
Midwives	96.8	£1,887,600.00
Untrained staff	31.8	£370,406.40
Total	142.6	£2,590,338.40

Table 1b: Costs of hospital based staff

* W.T.E.: Whole Time Equivalent staff

i.e. the total number of staff hours required, divided by the hours worked by a whole time member of staff

The next stage is the calculation of the total staff cost and the comparison of this against the fixed budget, giving a message to say if the package of care is within or over budget. This is shown in Table 2. The total fixed budget is a figure entered by the user at an earlier stage in the model, and the total cost is the sum of the cost of hospital and community staff, as calculated by the model.

Table 2: Total costs for hospital and community-based staff

	Minimum W.T.E.	Cost
Midwife Co-ordinators	16.7	£396,424.60
Midwives	114.4	£2,230,800.00
Assistants	31.8	£370,406.40
On-call & call-out cost	-	£9,530.85
Total	162.9	£3,007,161.85
Total Fixed Budget		£3,020,500.00
Excess Income		£13,338.15

Expenditure is within your available budget

The model also calculates the additional cost (or cost saving) per DOMINO and per home birth, as shown in Table 3. This is useful in allowing users to see where the additional staffing required in the community begins to be offset by a reduction in hospital staff. The percentages of women booked for DOMINO and booked for home birth are figures that were entered by the user at an earlier stage in the model.

Percentage booked for DOMINO	2.00%	No. of women	84
Percentage booked for home birth	0.50%	No. of women	21
Costs incurred	Additional W.T.E. staff	Additional cost	Additional cost per case
DOMINO:			
Hospital-based staff	0.00	£0	
Community-based staff	0.20	£3,900	
On-call & call-in costs		£1,915	
Total	0.20	£5,815	£69
Home births:			
Hospital-based staff	0.00	£0	
Community-based staff	0.10	£1,950	
On-call & call-in costs		£705	
Total	0.10	£2,655	£126

Table 3 : Additional costs incurred by booked DOMINOs and home births

5. The user has the opportunity of changing the scenario and seeing the effect on staffing and costs.

The user has the opportunity of seeing a summary of the effects of different levels of uptake of the 'non-standard' options. This is just a rough guide since the figures are calculated by simple replacement, for example from 5% to 10% uptake of DOMINO. However it does show when savings start to be realised by moving more care into the community. This model can be used many times, changing the inputs and seeing the effects on staffing and costs.

6. *The user has the opportunity of looking at the calculations underlying the final results.* These screens do not come up routinely as the user goes through the model since they are lengthy and involve some complicated calculations.

6. Relevance of the model

This model is a user-friendly aid to decision-making for professionals involved in policy and staffing decisions within maternity services. It allows for more informed decisionmaking and for users to consider different methods of delivering care. It is also a means of allowing purchasers and providers, and different professional groups within provider organisations, to discuss the issues using a standardised instrument. The model collects enough detailed information to be adaptable to local circumstances and to be used by any type of unit. It allows comparisons to be made between different units and could highlight the reasons for differences in staffing in what appear to be similar units. For example there may be practical reasons why a particular unit cannot introduce some 'good practice' recommendations at the moment and this may explain differences in staffing when compared against other similar units. The model is also realistic in that it builds in the concept of a fixed budget and allows users to see what models of care are possible within that fixed budget. This means that users can see what kind of trade-offs they want to make between quality and cost - for example, how far they can afford to go in terms of offering women choices. It allows users to consider questions such as the level of demand for DOMINOs that the unit would be able to staff within the current budget, and the point at which additional resources would be required.

7. Conclusions

In summary, this model is a step forward in terms of planning for maternity services. It is a user-friendly tool for studying the effects of changes in service and for studying the reasons for variations in staffing between similar units. It is also a tool that can be used in a wide variety of settings to address issues of concern to purchasers, providers and users of services.

References

- 1. House of Commons Health Committee on Maternity Services, <u>Second report for the</u> session 1991-1992, HMSO, London, 1992 (HCP29)
- 2. Scottish Office Home and Health department, <u>Provision of Maternity services in</u> <u>Scotland: A Policy Review</u>, HMSO, Edinburgh, 1993.
- 3. Department of Health, <u>Changing Childbirth: Report of the Expert maternity Group</u> HMSO, London, 1993.
- 4. Meldrum, P., Purton, P., MacLennan, B.B., Twaddle ,S., 'Moving towards a common definition for maternity services: standard definitions for common terms', <u>Midwifery</u>, 1994; 10: 165-170.

Appendix : Royal College of Midwives professionally agreed definitions

Domino scheme	This term is based on the definition 'domiciliary in and out'. It is a plan of care where the community midwife assesses the woman in her own home prior to accompanying her, at the appropriate time, to the maternity unit for delivery. The mother and baby return home at 6 to 8 hours after the delivery and continue with the domiciliary midwifery care.
Early discharge	A planned transfer home, at 6 to 8 hours, from a maternity unit to the care by the domiciliary midwifery services, of a postnatal mother and her baby. This discharge is planned during the antenatal period.
Home confinement	The delivery of a baby in the woman's home, as opposed to a GP unit, or a maternity unit (consultant unit).
'Low risk' woman	A classification of pregnant women which predicts probable normal antenatal, intranatal and postnatal outcomes.

- System of integrated care A pattern of midwifery care in which the midwife provides client care within the hospital and community setting for the purpose of facilitating continuity of client care and improved job satisfaction for the midwife.
- **Team midwifery** A designated group of midwives within, or without the hospital, who practise as a team in order to provide midwifery care to a designated group of women.
- Midwife clinic Antenatal care provided by the midwife in a hospital clinic, GP centre or client's own home setting. The midwife assumes responsibility for normal women and plans, implements and evaluates the care, in partnership with the client. In the event of complications the woman is referred for medical opinion/care.
- **Midwife-led unit** A unit, e.g. Labour Ward in which the pattern of normal midwifery care is planned, implemented and evaluated by teams of midwives usually led by a midwife who may be called a midwife 'consultant'. Women will be referred to obstetric colleagues on the detection of an abnormality.

Source: Midwifery (1994) 10, 165-170.

Capacity Planning for Intensive Care Units

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1. Introduction

The provision of adequate supplies of hospital beds, and the question of waiting times and waiting lists are amongst some of the most fiercely debated issues within the health service. A recent report on Intensive Care by the Department of Health ¹ highlighted the uneven spread of Intensive Care beds between hospitals, and showed that patient 'refusal rates' were strongly linked to local bed allocation. Deciding on just how many ICU beds to provide is however not simple. Intuitively one might observe the mean monthly arrival pattern, and then calculate the required number of beds based on a confidence interval related to the mean. There are however a number of complicating factors which mean that this kind of simple calculation is completely inappropriate.

- Emergency patients arrive at random often in quick succession, and must be admitted with a minimum of delay. The build up of "emergency queues" and the need to transfer patients to other hospitals is highly undesirable.
- Planned (elective) patient admissions are subject to the constraints imposed by other hospital services, such as surgeons hours and theatre space, and the number of free beds in the ICU.
- Planned patient admission profiles are often highly correlated with the time and day of the week.
- Patient lengths of stay (LOS) are often distributed with a bias towards more short LOS than long. Sometimes however, a patient will stay a very long time, which can cause a disproportionate 'blocking' effect in the ICU with respect to subsequent referrals.
- Different patient types have different LOS distribution profiles.

These features point towards a need for sophisticated bed capacity planning models from the discipline of operational research. There are a number of different ways of approaching the problem and a considerable body of literature has already been published on the subject; the reader is referred to a very informative review article by Smith-Daniels et al ². In this paper, we present a simulation model, other examples of which can be found in Goldman et al ³, Kao and Tung ⁴, Williams ⁵, Cohen et al ⁶, Parry and Pitroda ⁷ and Dumas ^{8,9}

Given the wealth of work that has already been done in this area, it is both surprising and disappointing that it has not found greater application. We aim to remedy this by bringing together past achievements under a single, flexible and sufficiently detailed model. In this paper we describe a self-contained part of this modelling work which has helped capacity planning decisions at Southampton General Hospital.

2. Methods

The simulation model was encoded in PASCAL using a 3-phase simulation shell developed at Southampton University. The model allows 'virtual' patients to flow through a virtual ICU which has a certain number of virtual beds. Patients arrive, stay and depart at rates and for times which reflect the true historical (or any other) patterns as required, thus arriving patients are tracked through time which also allows it to be extended to take into account a range of events such as resource usage over time.

The historical pattern of arrivals and LOS of 2000 patients admitted to the ICU at the Southampton General Hospital was determined using five years of past data which had been collected by the ICU staff on a database. The data was sorted into a number of different patient types using a spreadsheet; various statistics were derived using a statistical modelling package.

The length of stay (LOS) of the emergency patients and planned patients were described using either the negative exponential curve or a Weibull curve fitting routine. Planned patients could also be admitted subject to special 'admission operating rules' which are detailed below.

- Planned patients are deferred for a certain time period, if, upon arrival at the ICU, the number of free beds has fallen below a minimum level.
- Planned patients can only be deferred for a user defined maximum number of times after which a planned patient is deemed to have emergency patient 'status'; emergency status planned patients and 'true emergency' patients are always admitted if there is a free bed.
- Planned patient are deferred for either a fixed number of weeks or a random variable up to a maximum number of weeks.
- Emergency patients were assumed to arrive at random at a rate independent of the day of the week. The planned patients were allowed a variable arrival rate dependant on the day of the week but on any one day the planned patients were then assumed to arrive on a random basis.

The logic flow diagram shown in Figure 1 illustrates the flow of patients through the ICU. This is the basis of how the simulation model works. Other stages not illustrated generate the length of stay and arrival time of each patient.

3. Summary of data received from Southampton ICU

A large data set consisting of five years worth of computerised ICU patient record forms from 2000 patients was provided by Southampton General Hospital ICU for the project. Data was supplied in both dBase IV and Lotus 1-2-3 file format.

Each patient record had up to 74 fields of information. Immediately useful data included date and time of arrival; number of days length of stay (or in hours if <24 hours) and a

coding system giving the patient type. Other data on the forms included Apache II, Injury Severity Score and details of interventions during ICU stay. The ICU paper based 'log-book' was also made available, since this gave the numbers of patients who were not able to be admitted to the ICU each year; this complemented the dBase and Lotus files which only gave information relating to those patients who actually stayed in the ICU.



Figure 1: Model flow diagram

The cumulative and averaged data for six patients types included in the model is summarised in Table 1. Data was taken from the years 1988-1993. The calculated referrals column represents an average pattern of referrals which the ICU might expect to see each year, the exact figures were not easily retrieved from the data set. In 1993 there were 598 referrals, 434 admissions and therefore 164 refusals (27%).

patient type	mean LOS / days	LOS percentage point / days	LOS percentage point / %	mean annual admissions	calculated referrals for 1993
Emergency					
type 1	4.698	15.0	91.20	20.07	29.47
Emergency					
type 2	2.639	11.0	93.78	197.0	289.3
Emergency					
type 3	4.128	13.0	92.20	103.4	151.8
Planned					
type 1	1.637	4.00	94.12	6.745	9.904
Planned					
type 2	2.802	10.0	95.20	7.000	10.27
Planned					
type 3	2.260	.00	92.30	73.11	107.3
Totals	4.171	-	-	407.3	598

Table 1: Southampton ICU data: six patient type data summary

• *Mean length of stay* (LOS) was expressed in a three parameter format to facilitate the use of a Weibull distribution fitting routine within the simulation model.

- *Mean admissions* is equal to the mean number of patients of a particular type who actually stayed in the ICU.
- Calculated referrals is calculated as follows:

mean annual admissions * 1993 total referrals total mean annual admissions

• The relative daily arrival rates of the six patient types was also determined; this showed a random arrival pattern for the emergencies and a more structured pattern for the planned patients related to the working practices of the hospital consultants.

Patient type	Mon	Tue	Wed	Thur	Fri	Sat	Sun
Emergency							
type 1	10	7	4	10	5	13	8
Emergency							
type 2	33	27	. 31	32	34	20	31
Emergency							
type 3	23	8	20	11	7	22	12
Planned							
type 1	3	2	4	5	4	0	0
Planned							
type 2	0	3	7	2	7	1	1
Planned							
type 3	25	38	81	57	49	18	5

Tabel 2: Relative daily arrivals of the six patient types

4. Model Validation

The following parameters were chosen to be as similar as possible to those observed in practice:

- planned patients were accepted if there were 2 or more free beds;
- planned patients were deferred a maximum of 2 times;
- deferral times were selected by the model as a random variable between 1 and 4 weeks;
- the ICU had six beds.

With this set up the model predicts an overall transfer rate of 23 % +/- 1 % at 95 % confidence to be compared with 27 % as seen in 1993. In general, the model would be expected to underestimate the percentage transfers because it takes no account of the hourly variation in the arrival rate of the patient types each day. In real life, we might expect there to be times of the day when the arrival rate is high, and other times low; this would make transfers more likely than that simulated within the model. Given this approximation and the fact that the referral rates were calculated, it was decided that the model showed sufficiently close a match to reality to justify looking at the effect of the different model parameters.

5. Results

(1) The effect of varying the number of ICU beds.

- deferral times were selected by the model as a random variable between 1 and 4 weeks;
- planned patients were deferred a maximum of 2 times;
- planned patients were accepted if there were 2 or more free beds.

Beds	6	7	8	9	10	11
Mean % emergency	24.2	16.4	10.8	6.9	3.6	1.8
transfers						
Overall % bed days	88.3	84.4	78.5	72.6	66.7	62.4
occupied						

Table 2: Mean % Emergency transfers - vs - number of beds Overall % bed days occupied - vs - number of beds

(2) The effect of varying the planned patients deferral period

- the number of beds was fixed at 6;
- deferral times were always of fixed length;
- planned patients could be deferred only once ;
- planned patients were accepted if there were 2 or more free beds.

Table 3: Emergency & planned patient transfers - vs - planned patient deferral time

Planned deferral	1	2	3	4	5	6	7	8	mean	standard
time weeks Emergency transfers %	23.2	24.3	24.7	25.1	26.1	24.7	24.5	24.8	24.7	deviation 0.8
Planned transfers %	17.4	14.7	15.3	17.5	17.7	16.1	16.0	16.5	16.4	1.1

(3) The effect of changing the number of beds reserved for emergency admissions

- deferral times were selected by the model as a random variable in the range 1 to 4 weeks;
- planned patients could be deferred only once;
- the number of beds was fixed at 6.

Table 4: Emergency, Planned and all patient transfers - vs - number of reserved beds

Number of beds reserved for	0	1	2	3
emergency admissions				
Emergency transfers %	25.4	24.0	23.7	23.8
Planned transfers %	8.2	14.8	19.7	22.6
All referrals transfers %	21.7	22.0	22.9	23.5

(4) typical numbers of free beds at midnight - vs - day of the week

- deferral times were selected by the model as a random variable between 1 and 4 weeks;
- planned patients were deferred a maximum of 2 times;
- planned patients were accepted if there were 2 or more free beds.

Free beds	Mon	Tue	Wed	Thur	Fri	Sat	Sun
Mean	2.0	1.8	1.5	1.4	1.5	1.6	2.2
Standard deviation	1.5	1.6	1.2	1.3	1.2	1.3	1.5

Table 5:	Number o	of free	beds	at midni	ieht -	vs - c	dav o	f the	week
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(5) typical free bed probability distributions

parameters as for (4)



Figure 1: 11 Bed ICU



Figure 2: 6 Bed ICU

6. Discussion

Results

It is clear from Table 2 that percentage emergency patient transfers are very non-linear with respect to the number of beds. With increasing numbers of beds there is an initial steep drop in the number of expected transfers, which tends asymptotically to zero with ever larger numbers of beds. The trade off for having a low transfer rate is of course a lower mean occupancy level. With 6 beds, the mean occupancy is predicted to be 88 %, with an emergency patient transfer rate of 24 %; with 11 beds the mean occupancy is reduced to 62 % with an emergency patient transfer rate of 2 %. The random arrival of the emergency patients means that it becomes ever more expensive to guarantee a free bed for all admissions at all times, since there is *always* a small probability of having a sudden rush of emergency patients for which there will never be enough beds. The model was also able to show the probability distribution of numbers of free beds at any particular time in the day. From Figure 2 and ure 1 it is apparent that with only 6 beds the current ICU most often has either none ,1 or 2 free beds, but that there is also a finite but significantly reduced probability of having 3, 4, 5 or even 6 free beds. With 11 beds, the distribution has shifted such that the ICU could expect to have 4 to 8 free beds guite a lot of the time. The expected free bed probability distribution is clearly a factor that has to be taken into account by planners when they weigh up the mean bed occupancy levels, costs and transfer rates.

Table 3 suggests that the planned patient deferral time did *not* influence the mean transfers. This is unsurprising, since the simple deferral rule that we used was not a reactive scheduling policy related to current and anticipated needs. Further, Table 5 shows that the expected variance in the numbers of free beds each day is large relative to the mean level. This result implies that the process of scheduling elective patients is likely to be difficult, hinging on a knowledge of both probabilities of free beds and future emergency patient arrivals. We draw attention to the need and scope for *effective scheduling of planned patient arrivals* since this is clearly an important factor in determining ICU occupancy levels, nursing requirements, bed numbers and overall operating efficiency.

Table 4 demonstrates that the intuitive plan of trying to keep one bed free at all times for emergency admissions raises the percentage transfer of planned patients quite considerably whilst only making a small improvement in the percentage of emergency transfers. Overall transfers are minimised when no beds are reserved at all. Planned patients on mean each experienced 0.8 deferrals even though the upper limit was set at 2; a large proportion of the planned patients were thus not deferred at all.

High Dependency Units (HDU's)

Within the NHS, there is some blurring of distinction between HDU's and ICUs, a fact that is brought out in the report produced for the Department of Health¹. This is clearly an integral part of the problem of calculating ICU bed numbers and was not considered in

our model. It is well known that not all patients are 'appropriately' referred to the best level of care; sometimes this is because of pressure on bed space, other times it is more related to local referral practices or the uncertainty of medical prognosis. The situation is often complicated still further since some larger hospitals have separate areas for ICU patients from medical specialities such as neurosurgical, neonatal and cardiothoracic surgical wards. This allows for greater specialisation of the separate services, but weighs in against some of the advantages of pooling resources. Worthy of note here are the hospital models developed by Dumas ^{8,9} which included several different levels of care and allowed exploration of alternative patient transfer policies. A number of useful results were presented which gave an indication of the scope for minimising inappropriate patient settings using simulation.

Data Analysis

A major challenge in building models of this sort lies in the initial patient data analysis. We were fortunate in having access to well developed ICU database system with data collected from the last 5 years. Even with such a large database, it became reasonably challenging to identify the different patient types, since there is no agreed consensus for categorising the various medical conditions of patients at the time of admission. Health related groups (HRG's) as used in Britain and Disease related groups (DRG's) commonly used in the USA, have been criticised for their inability to distinguish different levels of severity of illness between otherwise equivalent patients. Most ICUs have therefore found it necessary to set up there own patient classification systems which makes it hard if not impossible to compare case mix profiles, medical outcome and other data from different hospitals where reported in the literature. A standardised data system such as that described in the INFORM initiative ¹⁰ would help to resolve this issue at least at the data collection level.

Lengths of Stay

A solution commonly adopted for coping with insufficient numbers of ICU beds, is the 'early discharge' or 'bumping' of the more able patients to other hospitals or alternative wards. From a purely mathematical point of view, this results in individually truncated LOS figures being mixed up with 'ideal' LOS figures. It is apparent from the literature however that few, if any ICU databases include records of which patients were early discharged and by approximately how much. This would be a very useful addition to an ICU database if one was being set up with capacity planning in mind. No attempt was made to correct for early discharge in the model. In this sense, the LOS data was assumed to be 'ideal'.

Planned patient scheduling and Inter-arrival rates

The nature of the arrival patterns of emergency patients is clearly different from those of planned patients. The former is essentially a random process and is therefore one which cannot be controlled. The times between admission of planned patients *is* however to a large extent controlled, and so we draw attention to the need and scope for *effective scheduling of planned patient arrivals* since this is clearly an important factor in

determining ICU occupancy levels, nursing requirements, bed numbers and overall operating efficiency.

Our model suggested that the planned patient deferral time did *not* influence the mean number of emergency patient transfers. This is perhaps on reflection an unsurprising result, since the simple deferral rule that we used was not by definition a 'dynamic' and therefore reactive scheduling policy related to current and anticipated needs. The operating rules of a real ICU are of course much more like this involving both medical and operational considerations.

The problem of optimising the operating rules is very complicated. Barber ¹¹ neatly summarised the issues relating to hospital admissions scheduling. 'The problem is usually stated as follows: What is the best policy to follow for booking elective inpatients in view of the current patient census, anticipated emergencies and information on patients length of stay?'. This introduces the question of 'what is it that we wish to optimise ?'. Barber's mathematical programming model maximised the mean occupancy over a planning period given certain constraints imposed on the overflow probabilities for each day of the planning period. Offensend ¹² however challenged the wisdom of maximising occupancy level on the basis of expected nursing costs, and found, using a stochastic model of patient flow, that the cost of controlling the nurse workload to some maximum level was less than the cost of controlling the occupancy level to some maximum level. The point was made that since staff costs are generally a high percentage of overall hospital budget, it follows that hospital planning should focus on work demands as well as patient census. Neither of the models explicitly considered the effect of other factors such as operating theatre and surgeon hours, which clearly constrain the options open for scheduling using any particular optimisation criteria. These features will be relatively easily incorporated into a simulation model.

Obviously the ability to accurately *predict* LOS is a useful step towards developing ICU patient scheduling systems. There are a number of articles detailing work related to cardiac patients, notably Tu and Guerriere¹³ who developed a neural network method for predicting the risk of a cardiac patient staying longer than 2 days: patients were able to be stratified *pre*-operatively into low, intermediate and high risk groups accordingly. More recently Tu et al ¹⁴ have used discriminant analysis for *post*-operative prediction of LOS and other outcomes. Rawlings et al ¹⁵ have also describe a nomogram for predicting the LOS of neonatal patients.

7. Further Work

As a result of this work, a multi-disciplinary Intensive Care Modelling Task Group of 12 people has been set up. Work is in progress on a more comprehensive simulation model that will include the following features:

- a range of different levels of care;
- a range of different patient types;
- a more flexible system for describing patient transfers and deferral operating rules;

- a system for describing other constraints effecting ICUs including operating theatre and surgeons hours, nurse availability;
- an elective patient scheduling system with alternative optimisation criteria. This will be used both for optimising long term capacity planning and for day to day scheduling on the ward;
- a method for describing the cost of ICU care;
- a well defined data input/output format exploiting a range of commonly used data systems; suitable for use by a range of health professionals;
- semi-automated historical data analysis;
- facility to extend to multiple hospital sites.

Most importantly, the model will be effectively disseminated to all potential users through influential co-ordinating bodies representative of the interests of both the health profession and the general population.

8. Conclusion

This paper presents a simulation model that demonstrates the power of operational research methods for capacity planning at a single level of care in a single hospital. It is clear that there is a heavy trade off between numbers of transfers and mean occupancy; there is also a strong non-linear relationship between numbers of beds and numbers of transfers. Recent reports have shown that there is both an uneven distribution of ICU beds between hospitals, and an inefficient overlap between HDU and ICU facilities. There is a clear need then to address both the issue of capacity planning at each different level of care within individual hospitals and also relative levels of care across different hospitals in a region. Both represent difficult problems for the planner, but both are soluble with a simulation modelling approach.

References

- 1. Metcalfe, A., McPherson, K., 'Study of Provision of Intensive Care in England 1993', <u>Revised Report for Department of Health</u>, Jan 1994.
- 2. Smith-Daniels, V.L., Scweikhart, S. B., Smith-Daniels, D.E., 'Capacity Management in Health Care Services: Review and Future Research Directions', <u>Decision Sciences</u>, 1988, 19:889-919.
- 3. Goldman, J., Knappenberger, H. A., Eller, J.C., 'Evaluating Bed Allocation policy with computer simulation', <u>Health Services Research</u>, 1968, 3:119-129.
- 4. Kao, E.P.C., Tung, G.C., 'Bed allocation in a public health care system', <u>Management</u> <u>Science</u>, 1981, 27:5:507-520.
- 5. Williams, S.V., 'How many intensive care beds are enough?', <u>Critical Care Medicine</u>, 1983, 11:6:412-416.
- Cohen, M.A., Hershey, J.C., Weiss, E.N., 'Analysis of capacity decisions for progressive patient care hospital facilities', <u>Health Services Research</u>, 1980, 15:145-160.

- Parry, R., Petroda, H., 'Planning surgical services using computer modelling', <u>OR</u> <u>Insight</u>, Vol. 5, 1992, 3:20-22.
- 8. Dumas ,M.B., 'Simulation Modelling for hospital bed planning', <u>Simulation</u>, August 1984, 69-78.
- 9. Dumas, M.B., 'Hospital Bed Utilisation: An implemented simulation approach to adjusting and maintaining appropriate levels', <u>Health Services Research</u>, 1985, 20:1:43-61.
- Leaning, M.S., Yates, C.E., Patterson, D.L.H., Ambroso, C., Collinson, P., Kalli, S.T., 'A Data Model for Intensive Care', <u>International Journal of Clinical Monitoring and</u> <u>Computing</u>, 1991, 8:213-224.
- 11. Barber, R.W., 'A Unified Model for Scheduling Elective Admissions, <u>Health Services</u> <u>Research</u>, 1977, 12:407-415.
- 12. Offensend F L, 'A hospital admission system based on nursing work load', <u>Management Science</u>, 1972; 19:2:132-138.
- 13. Tu, J.V., Guerriere, R.J., 'Use of Neural Network as a Predictive Instrument for Length of Stay in the Intensive Care Unit following Cardiac Surgery', <u>Computers and Biomedical Research</u>, 1993, 26:3:220-229.
- 14. Tu, J.V., Canadian Medical Association journal, 1994, 151:2:177-185.
- 15. Rawlings, J.S., Smith, F.R., Garcia, J., 'Expected duration of hospital stay of low birth weight infants: Graphic depiction in relation to birth weight and gestational age', <u>The</u> <u>Journal of Paediatrics</u>, 1993, 123:2:307-309.

Aggregate Production Control Of Hospitals

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Summary

The paper considers the level of aggregate production control in hospitals and looks in particular to the allocation of hospital resources. It describes an allocation procedure that takes the patient flow as point of departure. The paper describes a production control perspective to this problem, that is based on principles used in industrial settings. The results show that hospitals may benefit from this type of business-like approaches to improve workflow and capacity management.

1. Introduction

Aggregate production control has become an important managerial issue for hospitals. It involves the contracting between insurance organizations or regional health authorities as purchasers and the hospital as provider, the translation of the volumes agreed upon into resource requirements for specialties, the allocation of resources to specialties, and the control functions to ensure that plans are realized accordingly. Aggregate, as opposed to individual patient scheduling, refers to the level of planning that is concerned with flow of patients and use of resources. We will consider in this paper a patient flow based allocation method for resources and its contribution to improved production control.

The current practice of allocating resources within a hospital may easily introduce peaks and troughs in the workloads of departments. When allocations are not patient flow based they can lead to over-capacity of one specialty and under-capacity of another specialty. This can easily result in less optimal use of resources, i.e. fewer patients treated. Another form of capacity loss may arise when the capacities of resources that are simultaneously used by specialties for production are not balanced, resulting in one resource being the bottleneck resource for the specialty and other resources being under-used. The consequence will be that some resources may be overloaded and other resources underused, which leads therefore to loss of capacity. This happens when requirements for capacity co-ordination are not well taken into account in the decision making process of allocating resources to specialties. Based on an analysis of the hospital's production system on dependencies between resources and capacity co-ordination requirements, an approach was developed to allocate resources to specialties according to demand while taking into account a balanced utilization of resources. The approach makes use of a set of computer models to support hospital managerial decision making on resource allocation issues in various parts of the hospital. The approach developed was applied in a number of case-studies, illustrating the use of the models when applied in various resource management projects, such as a reorganization of an operating theatre time-table, or the development of a master plan for activities of a group of general surgeons serving two

locations of a merged hospital system, or the development of a method for a more flexible and coherent allocation of inpatient resources for a hospital that was faced by a structural shortage of beds.

First, we will analyse the hospital's capacity structure and find out what co-ordination is required to prevent capacity loss. Then we describe an alternative approach that takes into account a balanced use of resources, using patient flow requirements as a common denominator. Next, we will summarize the main findings of the case-study applications. Lastly, we will discuss the results obtained and formulate recommendations for future research.

2. Hospital capacity structure

This first part of the study involved an analysis of the hospital production system and capacity structure. We will report here the main conclusions; further evidence may be found in the thesis 1 .

Many of the resources in the hospital concern scarce shared resources, such as beds, nursing staff, operating theatre facilities and diagnostic services. The scarcity results from the limited hospital budget or limited availability on the market for resources. Shared resources are resources used by more specialties. Both features make resource management a complicated task for hospital management.

Looking at the hospital's capacity structure, one can distinguish 'leading' resources and 'following' resources. 'Leading' resources act as triggers for production on 'following' resources. A 'leading' resource for inpatient production of a surgical specialty is the operating theatre capacity allocated to this specialty, while beds and nursing staff are 'following' resources. This distinction is important for allocation of resources.

Resource allocation - which is the focus point for this study - is a **medium term decision** with a planning horizon of a few months to one or two years. There is as yet no procedure available in hospitals to update resource allocations on a regular basis. To reallocate resources one needs support for this decision. We have introduced 'critical resource incidents' as events that cause a major shift in the hospital production system and are critical to the need/use of hospital resources. These events can further act as legitimate triggers for reallocating resources. Examples are: increase of medical staff for a specialty, a request for more operating theatre capacity for a fast growing specialty, a merger of two hospitals, the move to a new hospital. These 'critical resource incidents' can be used to improve the use of resources by a better allocation of resources.

The **utilization rate** of a resource, defined as the ratio between the utilized capacity and the usable capacity of the resource, can be used as a measure of resource need/use performance. One should, however, not only look at the average level of utilization but also at the variations in the utilization of resources over day-parts within a week, as these cause variation in resource use at other places in the hospital because of the knock-on effects between interdependent resources.

Apart from being the generator of hospital production, the specialist also is one of the most important hospital resources. Almost all hospital production involves **specialist-time as resource**, acting as a 'leading' resource for the workstations in the hospital. As specialists spend their time in more workstations, the specialist as a resource type can be labelled as a '**product line key operator**' (considered at the level of a product line) or a '**multi-functional operator**' (considered at the level of a speciality). To improve hospital resource allocation it is therefore important to include specialist-time as a resource in the allocation procedure.

To handle this complex supply structure, hospitals use for some of the most important 'leading' resources **sessions as a batch processing mechanism.** A session is a period of time allotted to a specialist in a workstation to treat a number of patients that require the same type of resources. Sessions are usually organized for a fixed period in the week. Sessions provide for the short term match between demand for resources and supply of resources.

Time-tables regulate the allotment of sessions in a workstation to specialists. The most important time-tables are the operating theatre time-table for allocating operating theatre sessions, and the outpatient department time-table for allocating clinic sessions. These time-tables perform a similar function to Master Production Schedules in an industrial setting, in that they define a production schedule per period (which in this case is a fixed schedule per week). Investigation of these time-tables, and the linking time-table of specialties, on resource impacts for other departments can identify areas for resource use improvement.

The use of the session mechanism and time-tables for scarce shared hospital resources led to the following **requirements for co-ordination of capacity allocations**:

- co-ordination of the allocations of 'leading' resources to specialties sharing the same resource (capacity load levelling per 'leading' resource department);
- co-ordination of the allocations of different resources to one specialty (capacity load levelling per specialty);
- co-ordination of the resource impacts for 'following' resource departments that are shared by specialties but often not allocated to specialties (e.g. x-ray);
- co-ordination of specialist capacity within a specialty (specialty planning restrictions).
- Ignoring these co-ordination requirements may result in avoidable capacity loss or violations of the policy for planning specialty practice.

To illustrate the occurrence of capacity losses in health care we will provide some data on the use of resources by Dutch hospitals. Figure 1 shows patterns in admissions, discharges and average bed occupancy rates averaged over all hospitals in the Netherlands (1991).



Figure 1: Distribution of patient admissions, patient discharges and average bed occupancy rates in Dutch hospitals in 1991 [source: Stichting Informatiecentrum Gezondheidszorg, Utrecht]².

From Figure 1 one can see that most admissions are concentrated in the beginning of the week and most discharges at the end of the week resulting in a pattern of average bed occupancy rates with an accumulation in the middle of the week. These activity profiles also exist on the individual hospital level and for other types of hospital resources.

Table 1 shows some resource-use related performance measures of Dutch hospitals (1992). While acknowledging the over-simplification of showing such crude ratios Table 1 nevertheless illustrates the wide range in performances hospitals show in the use of beds, operating theatres, outpatient clinic sessions and x-ray facilities.

 Table 1: Distribution of Dutch hospitals over classes of resource-use related performance measures³.

Patients Occupancy per bed rate beds (percentage)		Procedures per operating theatre		Visits per clinic hour		Procedures per x-ray room			
class	%	class	%	class	%	class	%	class	%
	hosp.		hosp.		hosp.		hosp		hosp.
<17	2.9	<40		<1000	3.8	<2.0		<3000	
18-20	19.2	40-49	2.9	1000-1500	7.7	2.0-2.9	3.3	3000-4000	5.8
21-23	26.9	50-59	6.7	1500-2000	25.0	3.0-3.9	17.8	4000-5000	25.0
24-26	30.8	60-69	23.1	2000-2500	33.7	4.0-4.9	37.8	5000-6000	29.8
27-29	15.4	70-79	58.7	2500-3000	12.5	5.0-5.9	28.9	6000-7000	17.3
30-32	2.9	80-89	7.7	3000-3500	10.6	6.0-6.9	11.1	7000-8000	9.6
>32	1.9	>90	1.0	>3500	6.7	>7.0	1.1	>8000	12.5

These national data on patterns and levels of resource use raise further research questions for this micro level study such as:

- What explanations can be given at the level of an individual hospital for the wide range in resource-use performance?
- What would be reasonable capacity load targets for scarce hospital resources?

Based on statistical analysis of data from a hospital on the relationship between the timetable for clinics in an outpatient department and the workload of a diagnostic department, we have shown that the clinics time-table can be used for levelling the x-ray department workload¹. In a later paper we have shown that the same applies for the relation between the operating theatre time-table and the bed and nursing workload by surgical specialties, i.e. that the operating theatre time-table can be used for levelling the use of beds and the workload for nursing staff ⁴.

To illustrate further the problem analysis part of the study we reported on a case-study about a reorganization of an operating theatre time-table in a hospital. This demonstrated that such a change causes many **knock-on effects** on inpatient and outpatient resources. Not taking these knock-on effects into account can easily introduce new imbalances in resource needs elsewhere in the hospital. In this case-study we calculated that the operating theatre time-table change resulted in a 14% decrease of variation in bed requirements, a 20% increase of variation in nursing workload, a 30% decrease in variation of outpatient staff requirements, and a 25% decrease of variation in workloads of diagnostic departments.

3. Development of an alternative approach

Because of these characteristics the hospital as a production system can benefit from an approach that enables capacity load levelling and development of workload target profiles for resources. The modelling part of the study involved the development of a production control framework for our research, the building of a set of computer models to support hospital managerial decision making on resource allocation, and the development of an implementation strategy for our approach to hospital resource allocation.

Apart from some minor adjustments **production control** principles developed for industrial settings can be applied to hospitals. Production control in hospitals or health service organizations can be defined as the design, planning, implementation and control of co-ordination mechanisms between patient flows and diagnostic & therapeutic services in health service organizations to maximize output/throughput with available resources, taking into account different requirements for delivery flexibility (elective/appointment, semi-urgent, urgent), acceptable standards for delivery reliability (waiting lists, waiting times) and acceptable medical outcomes ^{5, 6}.

The **production control framework** developed distinguishes five levels of planning, according to the type of decisions to be made ^{6, 7, 8}. Decisions with impacts at a further horizon are placed at a higher level in the framework and set boundaries for lower level

decision making. Strategic Planning is concerned with the future hospital profile. Main Patient Flow Planning looks at the development of hospital activities in the next year. Resource Allocation concerns the allocation of resources to specialties or departments. Capacity Scheduling considers the scheduling of allocated capacities in time-tables. Operational Planning looks at the planning of day-to-day activities. This systematic description of decisions to be made and controls to be performed, is a framework for production control decision making and allows a precision of planning contributions.

Capacity Management focuses on the higher levels of production control (as opposed to Patient Flow Management on the lower levels) and conditions these levels of planning. In our study we concentrate on Resource Allocation and Capacity Scheduling. The method we have developed for resource allocation, that takes into account capacity co-ordination requirements, is labelled '**Time-phased Resource Allocation**'. This method allows for development of capacity configuration plans that can be evaluated via detailed capacitychecks on the fluctuations of capacity requirements throughout the week and on opportunities for capacity load levelling.

In our study on hospital resource allocation we are looking at different alternatives of allocating resources and to the impact of these alternatives on resource requirements. While our study concentrates on Capacity Allocation and Capacity Scheduling in the framework, we will also need the links to Main Patient Flow Planning and to Operational Management. First of all, we will call the combination of Capacity Allocation and Capacity Scheduling Time-phased Resource Allocation. This refers to the fact that using the session-mechanism for allocation of 'leading' resources in hospitals, resource allocation and capacity scheduling are one and the same. The link to the above level, that we have labelled Resource Planning because of our capacity management perspective, is needed because the 'rough-cut capacity checks' performed at that level to determine the amount of resources required makes use of capacity load factors determined by lower level performance. The link to the lower level is needed because the capacity configuration chosen, as a result of considering alternatives for resource allocation, conditions the way capacities can be used for operational planning. This leads to the following framework for capacity management for hospitals that we have used for our study (Figure 2).

As can be seen from Figure 2 Time-phased Resource Allocation for 'leading' resources produces capacity configuration plans for the whole hospital which are evaluated on capacity requirements performance. This is done via detailed capacity checks on the fluctuations of capacity requirements throughout the week and on opportunities for capacity load levelling. The plan that is selected introduces a capacity loss due to the level of fluctuations accepted or imbalances in capacity loads of different resources.

The capacity configuration plan defines the available capacity per specialty as input to Operational Planning. Moreover, it defines target workload profiles for capacities to be filled up with scheduled patients via Operational Planning. When Operational Planning does not keep up to these profiles it introduces another capacity loss, this time due to operational performance. The losses of capacity due to the performance of the capacity configuration plan chosen and due to operational performance influences the capacity load factors used for determining the resource requirements for the whole hospital via the rough-cut capacity check.



Figure 2: Production Control Framework Hospital Capacity Management.
It was necessary to develop a set of dedicated decision support computer models to provide for the information needed for the co-ordination requirements of capacity allocations, as the current hospital information systems do not produce this information⁹. It concerns relatively simple 'what-if' models which visualize patient flows and resource requirements in different areas of hospital resource management decision making. The model 'Patient Flows and Resources' supports the long term decisions on resources required to match future demand. The models 'Inpatient Capacity Management', 'Outpatient Capacity Management' and 'X-ray Capacity Management' each support decision making at medium term level for balancing of resource requirements of services performed in the corresponding parts of the hospital. The model 'Specialist Capacity Management' supports decision making in matching the organization of specialty activities and the time-tables of resource departments such as operating theatres and outpatient clinics. Depending on the resource management problem looked at, single models or combinations of models need to be used. The wide range of the models allows following through consequences of changes throughout the hospital. We will conclude this description of the model set by going briefly into the relationships between the different models as illustrated in Figure 3.



Figure 3: Relationship model set Hospital Capacity Management.

As can be seen from Figure 3 the core of the model set is represented by the Specialist Capacity Management model. This reflects the premise that all resource allocation changes in hospitals require consultation of specialty planning organization, because this refers to the key human resource in the hospital. The three capacity management models

surrounding the specialist model allow for investigation of resource allocation changes in separate areas of capacity management decision making, trying to arrange a balanced use of resources at a medium term level of planning, i.e. one year. Using one of these models will always require the use of the specialist model at the same time, because of the interactions between specialist activity planning organization and the planning organization covering these areas. This also illustrates the integrative perspective required on the contribution of the different professional subsystems to the overall hospital objectives.

The strategic level support model Patient Flows and Resources surrounds the management control level support model set, reflecting another premise that resource allocation issues can only be discussed after having looked at the long term balance between demand and supply for the hospital considered.

Depending on the resource management issue looked at, the different questions to be answered may require the use of a combination of models shown. This will be illustrated in the third part of this study, where the models will be shown at work as part of the casestudies performed.

The **implementation strategy** for using the method in a hospital setting is characterized by the following elements:

- problem orientation: the existence of a formal and concrete problem that legitimizes reallocation of resources is considered as a condition for a project (cf. 'critical resource incidents');
- model support: one or more of the models is used to provide the information for capacity co-ordination requirements, and to offer the parties involved in the resource management problem a global hospital perspective;
- participation: the different steps in the project are taken with maximum involvement of departments or groups in the decision making process.

According to the change model used, improved understanding of the system coherence in the hospital production system (subsystems, linkages between subsystems, knock-on effects, etc.) is an important intermediate variable to explain the relationship between strategy variables and output variables (improved decisions and improved quality of the decision making process).

4. Case-study applications

The third part of the study involved a number of case-studies to illustrate the use of this approach in concrete hospital settings and to answer in an explorative way research questions of this study. Three case-studies were performed, involving different resource management issues:

• reorganizing a specialty time-table for a group of eight general surgeons as part of a concentration of the specialty on one location of a multi-location hospital;

- improving the interface between the x-ray department and the outpatient department in a hospital that had problems with fluctuations in x-ray workload and waiting times for walk-in patients from outpatient clinics;
- development of a method for a more flexible and coherent allocation of inpatient resources in a hospital that had structural shortages of beds resulting in many 'admission stops'.

The paper does only allow us to discuss the third case in more detail. The results of the three case-studies will be summarized further-on.

Case three: flexible and coherent allocation of inpatient resources

This case-study deals with the development of a method for a flexible and coherent allocation of the inpatient resources (beds, nursing staff, operating theatres, operating theatre staff) in a hospital that experienced problems in this area. Previous investigations highlighted imbalances in the use of inpatient resources. One specialty did have a shortage of operating theatre time while the use of beds was below average, another specialty showed a shortage of beds. Allocation of resources was based on historical 'rights' rather than on real data on the need for and use of resources. Up to now it had been almost impossible to discuss a reallocation of resources. However, a number of specialties asked the hospital management to reconsider the allocation of resources, as they faced increasingly problems with very long waiting lists. The bottleneck capacity was identified as beds, leading to many days when there is a stop on new admissions for specialties who do not have beds free any more. The board of directors of the hospital decided to start a project to reach for more flexibility in the allocation of resources by an annual revision of the allocation of inpatient resources. The project's objective was to develop a method for a more dynamic capacity planning and a more flexible allocation of inpatient resources, taking into account developments in the catchment area, and technology, and a balanced use of resources per specialty. This instead of the current rather rigid allocation of inpatient resources, which - when reallocation would be considered at all - would result in a piecemeal approach to the separate resources: a new operating theatre allocation in the first year, followed by a need for a new bed-allocation plan next year, to find out that the nursing staff allocation needs to be reconsidered the year after. Hospital management commissioned the project to consider these resources in a joint approach. This would involve the use of the model 'Patient Flows and Resources' to look at the longer term projection of patient flows and resource needs, and the model 'Inpatient Capacity Management' to look at a balanced use of inpatient resources. Figure 4 gives an outline of the approach and of the different variables involved.

Figure 4 shows that the inflow of patients into the hospital is determined by the demand for inpatient care from patients in the catchment area of the hospital and by the marketshare of the hospital. The demand (development) for inpatient care in the catchment area in turn is determined by the population structure (development) and the need for care (development).



Figure 4: Overview analyses patient flow development.

Both variables determine the total demand for inpatient care in the catchment area (the 'market') while the market-share (development) of the hospital determines which part of the market is covered by the hospital and which part goes to other hospitals in the area. The next variable in the diagram is medical technological developments, such as use of non-invasive surgery, which influences the throughput of patients by shortening the length of stay. The influence of each of these variables on the inflow of patients into the hospital and the throughput of patients was investigated, first by varying one variable and keeping the other variables constant and next by looking at the combined effect of variables. To perform these analyses use was made of the model 'Patient Flows and Resources' and of data on population projections and on consumption of inpatient care by the inhabitants of the catchment area. Because of reasons of limitations we will not discuss the results of this part of the analyses.

The second part of the project involved an analysis of the current use of the resources as indicated in the lower part of Figure 4.

Current utilization of resources

We will first look at the use of individual resources throughout the year. As beds are the bottleneck resource for hospital production we will concentrate on this resource. For a more detailed description of the development of bed occupancy throughout the year we will first have to look at the development in the number of admissions from week to week as is shown in Figure 5.



Figure 5: Development in weekly number of admissions (1991).

According to Figure 5 on average 270 patients are admitted per week. Day-care patients, short-stay patients and regular patients, each make up one-third of the number of admissions. Concentrating on regular admissions it appears that the admission pattern does not show large peaks and troughs in weekly admissions or seasonal trends. These are much more evident when considering short-stay patients and day-cases. The dips here are assumed to be caused by the preference of patients not to be admitted during holiday periods.

For surgical specialties the admission pattern within a week shows a definite shape. Figure 6 shows for example the admission pattern per day of the week for General Surgery. Figure 6 shows that there is clearly a pattern of admissions during the week for General Surgery. Below the graph are shown the number of operating theatre hours available per day. Patients with a length of stay of more than five days are in general admitted one day before the operation. On Sunday on average three patients are admitted to be operated on Monday. Short-stay patients are admitted on the day of operation. General Surgery will try to use fully its seven beds on the short stay ward in the beginning of the week as this offers the patients best conditions for rehabilitation, without having to be transferred to a regular ward on Friday. As the week proceeds fewer patients are admitted. Surgical specialties in particular show these patterns, which seem related to the days operating theatre facilities are available.



Source: SIG-data 1991

Figure 6: Average number of admissions (with 95% confidence limits) per day of the week for General Surgery (1991).

The hospital uses a fixed allocation of beds to specialties. This allocation has not been changed for years. The available beds can be distinguished according to the length of stay of patients:

• day-case beds:

The hospital has a centralized facility for day cases of 12 beds which are used for one day-surgery or one day observation patients. These beds are not allocated to specialties but can be used by all specialties.

short-stay beds:

There is also a centralized facility of 39 beds for short-stay patients who have a length of stay of not more than 5 days. The beds are in practice used for general purpose but in principle the beds are allocated to specialties.

regular beds:

The rest of the beds are scattered over the different wards and used primarily for patients who have a length of stay of more than 5 days. These beds are allocated to specialties, except for a group of general purpose beds.

The way these beds are used by specialties can be seen in Table 2.

In Table 2 a distinction has been made between the use of beds by a specialty in the allocated wards and the use of beds outside these wards. This is an indication of the number of beds borrowed from other specialties. General Medicine, for example, uses on average 63.8 beds of which 3.2 beds are in wards where no beds are allocated to this specialty. This results in an overall occupancy rate of 99.6%, but of 94.7% when looking at

the occupancy of the beds on the wards allocated to General Medicine. Also Neurology has a high occupancy rate of own beds combined with a large number of borrowed beds elsewhere. The average occupancy rate at hospital level of more than 85% is quite high, which indicates that beds can be considered as a bottleneck. The occupancy rates of Urology and Paediatrics are below 70%. The beds in use by 'wrong-bed' patients refer to patients who have been discharged from hospital but are waiting for a bed in a nursing home or elsewhere.

Specialty	Allocated number of beds	Average number of beds in use (n=12)	Standard deviation beds in use (n=12)	Percentage "own" beds in use	Occupanc y rate of allocated beds	Beds used from other wards	Number o day-case beds used	Number o admission stops
General	64	63.8	2.8	94.7%	99.6%	3.2	1.1	30
Medicine								
Cardiology	17.7	18.3	1.5	99.0%	103.5%	0.8	0.1	67
Pulmonology	14	11.9	1.5	80.7%	84.9%	0.6	0.1	4
Rheumatology	14	10.4	2.2	72.3%	74.5%	0.3	-	12
Anaesthesiology	-	0.1	0.0	•	-	0.1	0.9	-
General Surgery	52	44.2	4.3	79.8%	85.0%	2.7	1.3	2
Urology	14.1	9.8	[]1.8	64.4%	69.2%	0.7	1.0	1
Orthopaedics	25.2	22.1	2.6	76.2%	87.6%	2.9	2.2	6
Plastic Surgery	4.7	3.6	0.8	73.2%	75.4%	0.1	0.6	1
Gynaecology	24	18.0	2.3	73.0%	74.9%	0.5	2.0	2
Paediatrics	24	15.0	2.9	53.6%	62.4%	2.1	0.2	5
Neurology	23.4	27.1	2.3	101.2%	115.7%	3.4	0.5	42
Dermatology	3	2.5	0.7	71.7%	81.7%	0.3	-	3
ENT	7.1	5.2	0.7	42.6%	72.8%	2.2	2.5	-
Ophthalmology	3.6	4.3	1.1	111.3%	121.4%	0.4	0.2	-
Radiology	0.7	0.8	0.0	112.7%	112.7%	0.0	0.3	-
'Wrong-bed' patients	-	5.9	1.2	-	-	5.9		-
Hospital total	304.1	262.9	9.0	86.5%	86.5%	-	13.0	175

Table 2: Utilization of bed resources by specialty (based on monthly figures over 1991).

As the number of beds in use varies - as can be seen from the fluctuations at monthly level - there are occasions when no bed will be available to admit a patient. In this case the hospital is forced to use an 'admission-stop 'for one or more days. During 1991 in total 175 'admission-stops' have been occurred, most of them concentrating in General Medicine, Cardiology and Neurology. This large number of 'admission-stops' is a further indication of beds as most important bottleneck in the case-study hospital.

The simultaneous use of resources by specialties

These patterns in the number of admissions influence the utilization of the different resources that are required for admissions. In this case we are interested in the simultaneous use of resources for specialty admissions. This can be investigated by collecting four weeks of data on admissions and analyzing these with the help of the

model 'Inpatient Capacity Management. This model visualizes whether or not a specialty given its admission pattern - uses its resources in a coherent way. We will present the model's output to illustrate the simultaneous use of inpatient resources in a busy period. What in this hospital's practise is regarded as busy, average and below average, is shown below the graph in Figure 5. The first analysis was done for week 3-6 (January/February). The average number of admissions per week in this period was 290. As four weeks are a short period for analysis, a second period of analysis was chosen. An average busy period (week 35-38, August/September) was deliberately chosen, to make it possible to compare a period with many 'admission stops' with a period with few 'admission stops'. The average number of admissions per week in the second period was 270. We will only show the results of the analysis for the busy period (see Table 3).

	Number of admissions per specialty				Average occupancy rate per week			
Specialty	Day	Short	Regular	Total	Beds	Nursing	OT hours	
• •	cases	cases	admissions	admissions		staff		
General Medicine	11	5	25	41	104%	89%	-	
Cardiology	2	10	8	20	119%	95%	-	
Pulmonology	2	0	4	5	51% ^c	98%	-	
Rheumatology	0	0	4	4	101%	97%	-	
Anaesthesiology	11	1	0	11	0	0	-	
General Surgery	11	15	19	45	98%	101%	74%	
Urology	3	5	4	12	70%	96%	23%	
Orthopaedics	11	10	7	29	111%	110%	68%	
Plastic Surgery	5	3	2	10	91%	157% ^c	64%	
Gynaecology	9	11	10	31	83%	98%	75%	
Paediatrics	1	4	11	15	85%	91%	-	
Neurology	4	13	10	27	139%	101%	35%	
Dermatology	0	0	1	1	103%	97%	-	
ENT	18	12	1	31	143% ^c	75%	81%	
Ophthalmology	1	6	0	7	0%	0%	72%	
Radiology	2	2	0	4	0%	0%	-	
Hospital total	89	99	105	293	99%	95%	73%	

Table 3: Simultaneous use of inpatient resources by specialty (January 1991).

N.B.: With ^c marked figures show deviations from expected values that can be explained by the short period of data collection (Pulmonology), the inability to take into account short stay beds (ENT) and the lack of good nursing workload measurement data (Plastic Surgery).

Table 3 shows that in a busy period on average 293 patients are admitted, of whom were 89 day-cases and 99 short-stay patients, resulting in an average bed occupancy of 99%, an average nursing workload pressure of 95% and an average operating theatre occupancy of 73%. This implies that it is not only the beds which act as a bottleneck but that also

nursing staff utilization is of the same high level, while the utilization of operating theatre resources stays behind. Or expressed in another way, the high bed occupancy and nursing workload prevent a higher utilization of operating theatre resources.

The specialty bed occupancy figures only relate to the regular beds. The overall hospital bed occupancy figure takes also day-case beds and short-stay beds into account. General Surgery, Orthopaedics, Plastic Surgery and Neurology/Neurosurgery show the same picture as for the overall hospital: an imbalance between the use of bed resources and the use of operating theatre resources due to a shortage of beds or a over-capacity of operating theatre hours. Internal Medicine and Cardiology show imbalance between the use of bed resources and the use of nursing staff resources. Specialties with a well-balanced use of all inpatient resources are Rheumatology, Gynaecology, Paediatrics and Dermatology.

Important to note, but not shown here, is that the analysis for the second period produced an overall similar picture of the coherence in the use of resources, but on a lower performance level.

Method for inpatient resource allocation

The results of the analyses before have been used to develop a method for flexible and coherent allocation of inpatient resources. This approach is, in principle, also applicable in other hospital settings. As the three resource types of beds, nursing staff and operating theatres are interdependent, a step-wise approach can be chosen to allocate resources, starting with the bottleneck resource. The approach is as follows:

- 1. Defining the bottleneck resource as the resource that is most critical for hospital inpatient production. This is based on occupancy rate figures (average and standard deviation) as realized in the past.
- 2. Allocating the bottleneck resource to specialties or departments. This is based on the current use of the bottleneck resource.
- 3. Allocating the other resources to specialties or departments.

The procedure for resource allocation is illustrated in Figure 7.

The allocation of the bottleneck resource is in principle based on the current utilization of resources. Hospital management, however, can decide to increase or decrease capacity for the bottleneck resource based on strategic considerations for the future profile of the hospital. Information on current use and the analyses on population, need and market-share development are used to support decisions concerning the actual allocation of the bottleneck resource. This is the first phase of resource allocation as shown in Figure 7.



Figure 7: Procedure for allocating resources.

In the second phase, again the basis for allocation is the current utilization of the resource at hand. When the current use of the resource does not produce any difficulties (e.g. sharp peaks and troughs), the current allocation can be maintained. Otherwise, some adaptations need to be made to alleviate resource impacts. To achieve coherence in resource use, every change in allocation of one of the resources needs to be checked on resource impacts for the other resources. This is illustrated in Figure 7 by the vertical arrows. The checks on coherent resource use can be supported by the model 'Inpatient Capacity Management'.

We should also use some reference points here for what can be considered as a target capacity loads in case of a balanced use of inpatient resources. What we learned from the analyses in the very busy and average busy periods is that the three resources show different capacity load performances but that the differences between resources are, relatively considered, the same in both periods. Based on the results of this case-study we would suggest as capacity load targets for beds, operating theatres and nursing staff at overall hospital level: 85% - 80% - 100%. For specialties with more or less than average urgent admissions, this should be corrected with about 5%.

As beds are the bottleneck resource for the case-study hospital, the allocation procedure should start with this resource. From the analyses before it may be clear that the available beds will from time to time not be enough to cover all demand for specialties, resulting in 'admission stops'. This requires managerial decisions to protect specialties that are important for the hospital strategic profile from not being able to meet demand, as their beds are used by other specialties that borrow beds to be able to admit patients in these busy periods. The current use of beds by specialties differs from the historical based allocations as has been shown in Table 2. In the setting of the case-study hospital this does not result in capacity losses because the actual use of beds at operational level is very flexible. This results, however, for example in on average four beds more in use than allocated to Neurology and eight beds fewer in use than allocated to General Surgery. This illustrates that the actual use of beds by specialties has moved away from the allocated numbers, and that hospital management does not use bed allocation as a tool of management to shape the future according to hospital strategy. To make room for allocating beds to specialties that need to be stimulated, different options can be considered. This could be done either by reallocating bed resources, or by stimulating shorter length of stay or by finding solutions for 'wrong-bed' patients. We illustrate below an example of the first option, i.e. a review of the current bed allocation based on the current use of beds. The calculations are shown in Table 4. The allocation of the other resources can be calculated in a similar way.

	Allocated	Average	Standard-	New bed	Old bed	New bed
	number of	number of	deviation	allocation	occupancy	occupancy
Specialty	beds	beds in	average			
		use	number of			
			beds			
General Medicine	64	63.8	0.8	65.6	99.6%	97.4%
Cardiology	17.7	18.3	0.4	19.2	103.5%	95.3%
Pulmonology	14	11.9	0.4	12.9	84.9%	92.2%
Rheumatology	14	10.4	0.6	11.8	74.5%	88.1%
Anaesthesiology	-	0.1	-	•	-	-
General Surgery	52	44.2	1.2	46.9	85.0%	94.2%
Urology	14.1	9.8	0.5	10.9	69.2%	89.9%
Orthopaedics	25.2	22.1	0.7	23.7	87.6%	93.2%
Neurosurgery	-	-	-	-	-	-
Plastic Surgery	4.7	3.6	0.2	4.1	75.4%	87.8%
Dental Surgery	-	-	-		-	-
Gynaecology	20	16.5	0.5	17.7	74.9%	93.2%
Paediatrics	24	15.0	0.8	16.8	62.4%	89.3%
Neurology	23.4	27.1	0.7	28.6	115.7%	94.8%
Dermatology	3	2.5	0.2	2.9	81.7%	86.2%
ENT	7.1	5.2	0.2	5.6	72.8%	92.8%
Ophthalmology	3.6	4.3	0.3	5.0	121.4%	86.0%
Radiology	0.7	0.8	-	0.7	112.7%	-
Obstetric beds	4.0	1.5	-	4.0	37.5%	37.5%
Wrong-bed patients	-	5.9	-	(5.9)	-	-
Total allocated	291.5	-	-	282.3	-	
Not allocated beds	-		-	9.2	-	

Table 4: Example bed allocation scheme based on actual resource use.

The bed allocation scheme suggested results in average bed occupancies of about 90% for most specialties. Apart from the average use of beds the fluctuations in bed usage also need to be taken into account. In this example the suggested number of beds allocated is equal to the upper confidence limit (95%) for the average number of beds in use. It should be noticed that this calculation is based on monthly figures. Fluctuations from day to day can be much higher but could not be calculated as bed occupancy figures in the hospital were not collected for each day. It should also be noted that this procedure benefits those specialties with high occupancy levels. Hospital management has again the task to check that the allocations suggested do not harm specialties that need to be stimulated. The allocation scheme shown leaves allocation of about nine beds to the discretion of hospital management. The bed occupancy figures for most specialties are at about 90%, which can be considered as a high bed utilization performance.

General discussion of case-study results

Each of the elements of the implementation strategy (problem oriented, model use, participation) seems to have contributed to a successful project.

The more accepted or formal the **problem** is, the more support it can give to act as stepping-stone for our project and to achieve improvements in resource use. Improving the use of hospital resources alone without an underlying problem having already been recognized does not create enough support for a project.

The contribution of the **decision support models** was most important for a good start to the project. The models created support for the project because of their good 'organizational fit' to the problem experienced. The model gave also good support for data collection, data analysis and resource impact evaluation. Halfway through the project the role of the model was more or less taken over by participants who had internalized the planning philosophy underlying the models and performed better in the stage of developing solutions. Nevertheless, the models played an important role as catalysts to discuss problem perception and alternative solutions. The standardized method and terminology used allows for comparison of project results in different hospitals and of repeated applications.

The **participative mode** of executing the project was considered as necessary to create commitment in the multi-actor hospital setting and inherent to the type of problem investigated that makes it important to use all local expertise available. However, the hospital characteristics do not leave much room for alternative approaches. The difference with our approach is that we tried to stimulate participation in different ways.

The resource impacts for the three case-studies can be summarized as follows:

• The reorganization of the specialty time-table of the group of general surgeons (case one) led to a 33% reduction of the variation in operating theatre staff requirements, a 12% increase of the variation in outpatient staff requirements, and a 12% increase of variation in the workload of the x-ray department; using a weighing function for the reduction of variation of use of different resources with a higher weighing factor for

reduction of the expensive operating theatre resources, the overall result can be qualified as positive.

- The rearrangement of x-ray room programmes and reservations for direct referrals expected from specialty clinics (case two) resulted in a better balance between the requirements and availability of examination capacity for direct examinations; this directly affects the waiting times for walk-in patients from outpatient clinics, whose projected average waiting time during peak hours showed a reduction from more than 100 minutes to 25-30 minutes.
- The method for a more flexible and coherent allocation of inpatient resources (case three) led to a more balanced use of resources and a managerial decision space of nine beds that could be allocated to specialties that need to be stimulated because of the strategic hospital profile.

The different cases can be linked to another, in that the point where one case stops can act as starting point for another case. This is supported by the complementary role of the models. From this point of view, the sum of cases can be said to offer broad support for resource management issues faced by hospitals.

The **conditions for achieving these results** with our implementation approach in other hospital settings are:

- support from the board of directors (because of the consequences of resource allocations for hospital production and the potential conflicts between specialties);
- service department managers (as they are responsible for the efficient use of scarce shared resources and are required to adopt an overall hospital perspective on their department's contribution), and
- specialties involved (as all resource allocations affect the organization of specialty practice), and
- availability of data. The logistic analyses performed with support of the models requires much data that with some effort can be collected or extracted from routine hospital information systems.

5. Discussion

Based on the findings in this study on hospital resource allocation we now discuss some implications of this research in a wider context, and formulate recommendations for future research in this area.

The approach to hospital resource allocation issues as described in this thesis can be applied to a **wide range of problems**. The conditions for this approach (problem oriented, use of decision support models, participative mode) are not difficult to fulfil, as there are plenty of problems that can act as stepping-stones for a project, models are available that have been specially developed for this type of problems, and participation is a change strategy that is familiar to hospitals.

Potential areas of application are:

- reorganization of time-tables for specialty activities, operating theatres and outpatient clinics;
- improving workload and service levels of medical support services departments (x-ray, laboratories, organ examination departments) caused by interface-problems with other parts of the hospital;
- reallocation of inpatient resources (beds, operating theatres, nursing staff) due to shortages of for instance beds, or structural over-loading of for instance nursing staff;
- evaluating impacts of introduction of centralized facilities for day-surgery or short-stay;
- business planning for a new hospital;
- multi-location planning problems due to mergers;
- evaluating impacts of changes in outpatient programs for resource use and treatment times.

According to the experiences with the models in the case-studies and by hospitals who have used the models without further outside support, the implementation of the models requires much time and effort. The support for hospitals using these models can be improved for instance by **organizing workshops** with users and potential users and making use of the experiences in the case-study hospitals.

The wide range in performances which hospitals show in the use of beds, operating theatres, outpatient clinic sessions and x-ray facilities (reported in the introduction), may find partly explanation in the local, hospital dependent, imbalances in the allocation of hospital resources. The models developed by this research can be used to track down these imbalances in the hospital system, as they visualize resource requirements rising from the patient flows faced by the hospital. Taking the patient flow as a rationale for resource allocation may then lead to savings by closing down a ward or an operating theatre without affecting the throughput of patients, though this study has not been motivated by a philosophy of reducing hospital services as the models can equally be applied to expansion situations.

Capacity load targets are needed to determine what can be considered as reasonable resource use performance. This study shows that when resources used for the same production are allocated in a coherent way, high utilization rates can be achieved. In the example of resources for inpatient production, **capacity load targets for beds, operating theatres and nursing staff** at overall hospital level could be set for 85% - 80% - 100%. For specialties with more than average or less than average urgent admissions this should be corrected by about 5%. These are average figures for a busy season. When one would go beyond these levels there is reason to believe that the system will be over-loaded, resulting in many admission stops or by-passing the elective planning systems by specialists by misuse of the label 'urgent case'.

Though it is important that allocations of resources may be flexible to match patient flow development, it is even more important that **resources are used flexibly**, and that empty beds or under-used sessions that were allocated to one specialty can be used for patients of another specialty. This operational flexibility tends to be more customary in smaller or

medium-sized hospitals than in larger hospitals. Also, introduction of centralized facilities for day-surgery or short-stay tends to be more successful in these hospitals. One possible explanation for this phenomenon is that, in general, larger hospitals have more specialized facilities. Therefore, specialties tend to claim their own resources and do not allow other specialties to use their resources. As day-surgery and short-stay introduction require beds to be reallocated from the specialty beds to the general purpose beds of these centralized facilities, larger hospitals have more difficulty in realizing this resource-effective development than other hospitals.

The above danger of lower level resource use performance may also apply to hospitals that adopt a **divisionalized organizational structure**. These hospitals have chosen for decentralisation to reduce co-ordination efforts. Co-ordination effort requirements in organizations increase exponentially with the size of the organization_[B8]¹⁰. To enable divisions to be managed as business units they require maximum independence, also in resources required for production. In principle each division will require its own beds, nursing staff, operating theatres, outpatient facilities and diagnostic facilities. In this way the operational flexibility within the division increases. This can only be realized without much loss of resource utilization performance when the divisions are large enough, and the specialty-mix of a division is chosen in such a way that shared resources fall within the new boundaries drawn. A hospital with two divisions (one of surgical specialties and another of non-surgical specialties) will have less difficulty in maintaining high resource use performance than a hospital with as many divisions as specialties. The models can as well be used for resource interactions between divisions as for balancing within divisions.

To conclude this study on hospital resource allocation we present the following recommendations for future research in this area of hospital planning.

The models on 'Hospital Capacity Management' can be further improved, based on the experiences with the models gained in the case-studies and otherwise. One of the principles used in modelling the current set was to make the models as simple as possible, avoiding claims for optimization. This was done purposely, as this level of support was considered more in balance with the current state of resource management in hospitals and simple, transparent models enhance participation. It was judged more important to help hospitals on the way to a systematic review of resource use and resource allocation than to aim for optimal solutions. Perhaps after a few years' experience with the current tools there will be a need for more sophistication, to give longer support in the decision making process than the present models do. It would be possible to super-impose on the present models a solution generator that would help the user in finding feasible solutions. This would bring the support of the models at a higher level, though still not at the level of optimization. This level of support will probably remain out of reach as resource allocation requires many variables to be taken account of at the same time, and the sophisticated models required would do harm to participation of those whose input is required for an effective solution. Moreover, as the primary function of the models, according to the casestudies, was to act as catalysts for discussion of problem and solution perception, one might just as well be doubtful of the benefits of further developing the models.

Constraint programming may be a useful method for upgrading the level of support given to hospitals. Constraint programming is a planning method that produces feasible solutions where many variables need to be taken into account, when utilizations of resources are very high and when the objective function is difficult to define. This applies particularly to the problem of resource allocation in hospitals as the case-studies have shown.

One further improvement could be that these types of models would become available as management tools **linked to the Hospital Information System**. Though these systems have always claimed this sort of management tool as their contribution to improved management of hospitals, the actual development of the tools in this study was done independently of hospital automation. Instead of taking a data system point of view on the problem of resource allocation, we took a different point of departure by concentrating on the problem and on the management information required to look at it from a hospital-wide perspective, thereby creating a dedicated support system for those involved in the problem-solving process. We have demonstrated that this was a necessary way to proceed, because the help needed would not come from hospital information system development; that was too burdened with other preoccupations. However, perhaps now it is time to link both developments. This could result in easier data collection for the dedicated decision support tools for management purposes, and also increase the benefit from the vast amount of data within the hospital information system for improved hospital management.

References

- 1. Vissers, J.M.H., <u>Patient Flow based Allocation of Hospital Resources</u>, Thesis Eindhoven University of Technology, Eindhoven, 1994
- 2. Stichting Informatiecentrum voor de Gezondheidszorg (1993), Jaarboek ziekenhuizen 1991, SIG Utrecht
- 3. Spaan, J.M., <u>De intramurale gezondheidszorg in cijfers per 1 januari 1992</u>, Nationaal Ziekenhuisinstituut, Utrecht
- 4. Vissers, J.M.H., <u>Capacity loss due to patterns in hospital resource use</u> (underway), 1995
- 5. Bertrand, J.W.M., Wortmann, J.C. Wijngaard, J., <u>Production Control: A Structural</u> <u>and Design Oriented Approach</u>, Elsevier, Amsterdam, 1990
- 6. Groot, P.M.A., Kremer, P.G.M.T., Vissers, J.M.H., 'Raamwerk voor productiebesturing in ziekenhuizen', <u>Acta Hospitalia</u>, no. 2, 1993, pp. 29-39
- 7. Anthony, R.N., <u>Planning and Control Systems: A Framework for Analysis</u>, Harvard University, Boston, 1965
- 8. Anthony, R.N., Herzlinger, R.E., <u>Management Control in Nonprofit Organizations</u>, Revised Edition, Richard D. Irwin INC., Homewood Illinois, 1980
- 9. Vries, G. de, 'De mythe van managementinformatie' in: <u>Sturing van zorgprocessen.</u> <u>Bedrijfskundig instrumentarium voor de ziekenhuismanager</u>, Hoorn, J.W., Lettink, J., Van Tuijl, H., Vissers, J., De Vries, G., eds., De Tijdstroom, Lochem, 1991

10. Kuipers, H., 'Sociotechniek in de gezondheidszorg?' in <u>Sturing van zorgprocessen:</u> <u>ontwerpen en veranderen</u>, Hoorn, J.W., Lettink, J., Van Tuijl, H., Vissers, J., De Vries, G., eds., De Tijdstroom, Utrecht (to appear), 1992

Part Four - Discussion Report

Discussion Report

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1. Introduction

This essay/article is based on the 21st meeting of the European Working Group on Operational Research Applied to Health Services (ORAHS), held in Maastricht, The Netherlands, July 23-28 1995. It aims to give a general overview of the subjects discussed at this meeting.

The health care sector has grown into about the most important sector of the economic life. The health care system can be characterised as a complex system with complex flow processes. It has to deal with partly conflicting targets, such as high quality, high accessibility, high throughput, short waiting times and high capacity utilisation. Over the last decade there has been an increased pressure on the system to perform under coercive restraints in relation to resources.

The health care sector is at a turning point between teenage life and adult life. It's left the growing period behind and is now trying to cope with the increasing pressure on its resources. Most European governments want to get a hold of the increase of health care costs, which means that from a governmental perspective health care is all about finance. They try to achieve this by stimulating and improving efficiency and effectiveness or by changing the health care system. Simply formulated, there are three policy alternatives for managing the increased pressure put on the health care system:

- increase the amount of money available for health care;
- increasing the efficiency of the primary processes;
- advocate the shift away from public health care.

The last alternative is already taking place. In most European countries the responsibility balance is shifting from the government to the insurers (shifting from public to private health care).

As for increasing the amount of money available for health care, most governments are trying but working under great financial restraints. So the solution offered by that option is very restricted.

So that leaves us, generally spoken, one possibility namely working on the processes themselves. The health care system needs to develop an understanding of how processes are working. That also means accepting the systems view of health care.

In this situation one is struck by the ambivalence; on one hand the government wants to decrease the health care costs as a percentage of the GNP, but on the other hand they

want a positive reaction to the growing demand and scientific and technology developments.

Another specific characteristic of present-day health care is the shift in responsibilities and power. This means a governmental withdrawal, more power for the insurers and the patients becoming more emancipated. Also the pharmaceutical industry has developed and is still developing into an industry with powerful political allies.

A third issue is that demographic, social and economic developments, for instance the greying process, the increase of chronic diseases and unhealthy lifestyles, influence the demand of health care. Apart from that, public expectation is changing alongside with the financial and organisational structures of the health care system. In this process there are five shifts to be recognised.

1. The shift between treatment and prevention

More attention is being paid to the outcomes of health care including the consideration of quality of life. This shift is found in a transition from 'diagnose and treat' to 'predict and manage'.

- 2. The shift between institution and community A shift to more community care is what most patients and professionals prefer. This puts new demands on care in the community. This shift is of course not absolute and entirely one-way.
- 3. *The shift between professional approach and patient approach* Rises in 'consumerism' affect public expectations of health services.
- 4. *The shift from habit to knowledge* Our knowledge of theoretical basis of medicine constantly improves, and must be translated into action.
- 5. *The shift between one group or another* Shifts in care between different groups in the population are taking place. Where resources are limited, trade-offs and prioritising are required.

In Western Europe this renovation of the health care system has been incremental; no drastic measures, partly because of social pluralism and the great value people assign to good health and health care. The question is where does the renovation of the welfare-state end? It is a battle between capitalistic logic and social security. Social values such as the equity among citizens and the general accessibility of health care facilities should be taken into account. But even so medical developments are touching on issues that are dividing our societies, for example abortion and euthanasia.

Another very important issue in day-to-day health care is the 'greying' process. The group of people over 65 years of age is growing explosively, which puts an extra strain on geriatric facilities. The gain in life expectancy over the last decade has not been a completely healthy gain. People live longer but, that also means that they have more time/chances to be prone to diseases. The health care system should pay attention to the balance between quantity of life and quality of life.

2. Operational research

Under the circumstances mentioned above, there might be a place for operational research (hereafter OR) to help solving the problems that arise in the health care situation.

A workable definition of OR is the scientific study of the effective use of men, money and machines. Another way of looking at it is defining OR as the securing of improvement in the social systems by means of scientific method. This puts the emphasis on implementation right from the beginning. A third definition of OR is: operational research is a science to make vague professional ideas workable. The professional is dealing with individuals and has sometimes problems seeing the big picture. OR might be able to help the professional in that respect.

OR can also be defined using five characteristics:

- systems approach;
- specification and structuring goals;
- model building;
- quantification;
- techniques.

In present-day OR, there is a tendency/need to put more emphasis onto the first two characteristics. This shift will be discussed later in this essay/article.

OR has evolved and adapted in an effort to support health care management and policy planning. In OR in health, *theoreticians* (providing the body of knowledge) and *appliers* (OR people who apply that body of knowledge to real life problems in health care) meet with the *customers or clients* who own the problems and look for solutions.

The expertise and skills of OR practitioners lie in the development of the scientific principles and the application of those principles to an area of management. Particularly in health care, OR is aimed at (or at least should be aimed at) analysing policy alternatives and evaluating operations. In the changing environment of the health care system OR practitioners and professionals need certain (extra) skills to cope with present-day problems and constraints.

More specific, the skills of OR practitioners can be assigned to five different key problem areas found in health care management. To deal with the increase in financial constraints and the ongoing change in the environment, they should have flexible planning skills and negotiation and networking skills. The OR scientists should look for robust rather than optimal solutions. With the increasing importance put on performance indicators the professionals and managers should also have the disposal of evaluation skills. To be able to handle the modern demands put upon the corporate planning of the organisation they should also have objective setting skills related to defining relevant information. The information systems should be designed to acquire 'information' rather than data. And last but not least the professionals should appreciate a wider 'systems view' where it comes to human resource management.

3. Modelling

OR practitioners have special expertise and experience in the art of working with models and drawing conclusions from the results produced by these. In this context a model is an abstract, formal, mathematical or logical description of some system of objects and activities.

Modelling is a very commonly used tool for OR practitioners. All models are basic tools for learning; anybody's learning. Models make it possible to study systems that do not exist, to predict complicated consequences of actions and developments, and to conduct experiments, that are impossible or too costly to perform in reality. One very important rule in working with models is never to accept a model result, until you've found a logical, plausible explanation for that result.

The crucial element of modelling is still simplification and in that respect it has several advantages:

- it provides quantitative predictions;
- it lets us learn how the system reacts to different changes;
- it puts data into context;
- it forces the model builder into deeper understanding;
- it creates a shared understanding;
- it helps posing the right questions.

The problem of transmitting the insight provided by models from the model specialist to the user is eliminated, if the model is designed in such a way that it can be used independently by the non-specialist.

This emphasises the importance of the implementation. Hospital managers make decisions by comparison rather than rationalism. Managers don't have time to lose themselves in detailed modelling procedures, they must make decisions at a moments notice. OR provides a different look at reality. In order to be supportive to hospital managers the OR practitioners should keep their models simple, start at the bottom and go slowly and comprehensibly. For example visual interactive simulation is an application that increases the visual impact, it clarifies the relation to reality, and it is suitable for people with restricted computer knowledge. Two- and three-dimensional models for different purposes have been developed and tested and were found to be useful.

Models can be very helpful for improving efficiency and effectiveness. However model results cannot shift the fundamental power balance in the health care system, they can change the nature of the debate by making consequences of different options more clear to the participants.

4. Bridging the gap

The medical professionals need the managers to produce the hard data and the plain facts which are needed to justify their new technology and their new equipment to the outside

world. But competition rather than integration prevails. The gap between professionals and managers cannot be bridged at once. Board members, managers, physicians and nurses have to start to really meet each other rather than living separate lives in different worlds.

In this process the question of power emerges. To this power struggle there are a few tools OR can contribute. First more attention should be paid to a more horizontal discussion form that is based on communication, discussion and consensus building. Secondly there should be an adequate patient care information system. And the third set of tools of the health care management are communication tools. A common language is a prerequisite to bridge both the gap between medical professionals and managers and between OR scientists and managers. By using OR modules to improve communication among the prospective users, some of these problems can be solved. Of course this will put some restrictions on the modelling part of the solution.

There are three statements to be made about the role of OR scientists in health care:

- Statement 1: OR as a disciple is still primarily academia oriented rather than health care oriented. OR should infiltrate the discussion forums on health care.
- Statement 2: The emphasis in the health care sector is shifting from hospital to patient care management and from production to product management. OR should orient itself to the operationalisation of the thousands of concepts and indicators in use in health care, rather than to limit itself to the formulation of nice simulation and optimisation models which take all these concepts and indicators for granted.
- Statement 3: Health care is by definition a very local business. OR can contribute in the communication process to decrease this effect, by helping to master the voluminous data in sensible ways in order to arrive at sensible information on health, health care and health care management.

5. 'Hard' versus 'soft' OR

Maybe a shift towards the 'soft' side of OR will improve the communicational possibilities between professionals and managers. 90% of hospital managers does not know anything about OR (and they don't want to know either). If they need to know, they will hire an expert. In this situation it is more than crucial that OR scientists do not work in an ivory tower, but communicate regularly with the prospective users of the models they are developing. The gap between professionals and managers might also be reduced if the emphasis on the mathematical angle of OR lessens.

Lately there has already been a shift from 'hard' to 'soft' OR. More emphasis is put on the organisational science rather than on the mathematics. 'Soft' OR tends to pay more attention to the environment of a problem area with more emphasis on the definition and ownership and the politics involved in the problem and in any subsequent application of a 'solution'. One of the main differences between 'hard' and 'soft' OR concerns the way in which uncertainty is handled. A point where the management might have some doubts

about the viability of OR systems in health care, is the way it is dealing with this uncertainty. In this respect the increasing social emphasis in OR is sensible and it certainly does not make OR unfit to use in situations of uncertainty.

There seems to be a consensus from the OR profession that indicates that 'soft' OR methods may have limited uses:

- they have no predictive power;
- · they have little explanatory power;
- · only their originators can use them effectively;
- they are not 'techniques'.

Another element in the shift towards 'soft' OR is the social responsibility the OR practitioners have towards the society. OR specialists should be the ones to signalise the effects of policy decisions made be the government. There is a whole field to be discovered in that area.

One could explain the tendency towards 'soft' OR by establishing that people probably get softer when they get older, and that OR will get softer as it develops as a science.

It might be the best solution to practice 'hard' and 'soft' OR at the same time. This would involve accepting the concept of people as active rather than passive subjects, accepting uncertainty as part of the process, concentrating on simplicity and transparency when applying more 'hard' techniques and sort of wrap those 'hard' techniques in a 'softer' approach.

But one thing has to be kept in mind; OR will never be able to supply people with the complete answer, it's solutions will always be part of a bigger picture.

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