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&
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PREFACE

The EURO Working Group on Operational Research Applied to Health Services (ORAHS) was created in 1975 as part of a programme for developing special interest groups within EURO, the European branch of the International Federation of Operational Research Societies (IFORS). The group has members from many countries, mainly from Europe but also from overseas. Every year its members take part in a one-week meeting, each time in a different host country. The objective of the group function is to exchange ideas, information and know-how concerning the application of operational research to problems in the health services, mutual members' support, cooperation in joint projects, and mutual informing about the posture of operational research. More information about the group can be found at the group's website http://www.orahsweb.soton.ac.uk/.

The 2003 meeting took place in Prague, Czech Republic, at the Faculty of Informatics and Statistics, University of Economics, from July 27 to August 1. It was a great pleasure for me to welcome all participants of the 29th meeting. I was proud to host the meeting, which afforded the participants another opportunity to share the knowledge with young and experienced professionals from European and other countries. Health services research is a very interesting area of self-fulfilment, which offers unique opportunities for meeting of researchers with very different backgrounds: mathematicians, economists, IT professionals, sociologists, and physicians. That is the reason why health services research gives the researchers intellectual excitement.

The meeting statistics say that 48 participants enjoyed the meeting and 16 accompanying persons enjoyed the social programme. There were 35 presentations, which dealt with variant topics, and all of them were excellent and interesting. They showed us how wide the area of applied operational research in health services was. I also hope that participants enjoyed their stay in the city of Prague.

I am grateful to the members of the programme committee, to the members of the local organization committee, to the session chairpersons, and to anonymous reviewers.

Martin Dlouhý, Editor

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THEORY

LIMITS TO EFFICIENCY: REFLECTIONS ON EFFICIENCY IN HEALTH CARE

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Abstract: In the face of apparently inexorably rising costs, many governments are seeking greater efficiency or productivity in the health care sector. However, pursuit of efficiency and greater productivity, taking insufficient account of the complexity of health care and its labour intensiveness, may prove counter-productive. This paper explores conflicts between efficiency and quality, equity and health itself as well as problems arising from the requirements of services with stochastic demand and high degrees of uncertainty. The implications of the labour-intensive nature of health care on the potential for increasing efficiency and productivity, as demonstrated by 'Baumol's Cost Disease', are examined. It is concluded that the pursuit of efficiency in health care might prove to be a double-edged sword. Technological change, perhaps in the form of pharmaceuticals substituted for labour-intensive treatments and OR interventions improving efficiency without compromising quality, might prove the best hopes for greater efficiency and increased productivity. Beyond that, unthinking pursuit of efficiency in health (and social) care could destroy its very essence.

1. Introduction

Efficiency is a good thing. It is unlikely that many champions of inefficiency in health care could be found and, as Street and Jacobs (2002:1109) suggest, "Promoting public sector efficiency remains an important concern for many governments." But is the pursuit of efficiency unequivocally beneficial and are there limits to such efficiency in the complex, professionally-driven, labour-intensive 'industry' of health care? Thus, the aim of this paper is both to explore the scope for increased efficiency in health care and to ask whether the unthinking pursuit of such efficiency could destroy the very essence of health care.

After examining definitions of efficiency, this paper reviews reasons for and approaches to the pursuit of efficiency healthcare. It then explores conflicts between efficiency and quality, equity and health, leading to the question of how healthcare output should be measured. The implications of the labour-intensive nature of health care on the potential for increasing efficiency and productivity are then examined, before drawing conclusions about the scope for, and consequences of, the pursuit of efficiency in health care.

2. What is Efficiency?

Despite its being a widely-used term, Reinhardt (1997:17) suggests that "'Efficiency' is not something absolute that we can easily recognise when we see it." A dictionary definition offers "producing results with little waste of

effort" (Oxford Paperback Dictionary), whilst Checkland (2001:78) suggests that "The degree to which achieving the transformation uses up resources measures the *efficiency* of the system."

Economists distinguish between a number of types of efficiency, possibly the most common being technical (or technological) efficiency and allocative efficiency. Whilst there appears to be consensus in defining technical (or technological) efficiency as a "state in which it is not possible to increase output without increasing inputs" (Parkin and King, 1992) or "where the costs of producing a given output are minimised, or where output is maximised for a given cost" (McGuire *et al.,* 1988:76), definitions of allocative efficiency vary. Definitions such as "Allocative efficiency exists where it is not possible to make any individual better off without making some other individual worse off" (McGuire *et al.,* 1988:76) and the "situation that occurs when no resources are wasted – when no one can be made better off without making someone worse off" (Parkin and King, 1992) appear to equate allocative efficiency with a Pareto optimum. However, as Mcguire *et al.* (1988:76) warn, with this definition "each different individual endowment will produce a different state of allocative efficiency – there is no uniquely allocatively efficient state". Other definitions avoid such limitations by defining an allocatively efficient state as when "Productive activity has been allocated to those products which consumers value in excess of their costs (marginal cost has been equated to marginal value)" (McPake *et al.,* 2002:43) or "the outcomes achieved with the available resources match the priorities of society" (Kielhorn and von der Schulenburg, 2000:55).

This paper focuses on technical efficiency, defined here as producing more output with the same amount of input or the same output with less input. However, that definition does not solve the question of terminology. Terms such as efficiency, productivity, reducing waste and cost-cutting are used, sometimes apparently interchangeably, in the literature. For example, Evans *et al.* (2001:307) state that because of the "similarity between performance and efficiency, we use the terms interchangeably". Following that line, no attempt is made here to make clear distinctions between the different terms, although contradictions will be explored.

3. Pursuit of Efficiency in Health Care

The increasing share of GDP spent on health care, both over time and between countries, is one of the main factors behind governmental concern about health care efficiency. Not only does per capita health expenditure increase with per capita GDP, a phenomenon long observed by Schieber and Poullier (1991) among others, but also, as Figure 1 indicates, the percentage of GDP spent on health rises with GDP per capita. Further, as Figure 2 shows, between 1990–

2001 the growth rate of per capita health care expenditure exceeded the per capita GDP growth rate in all but three OECD countries.

Figure 1: % GDP Expenditure by GDP/capita 2000 OECD Countries (data source: OECD)

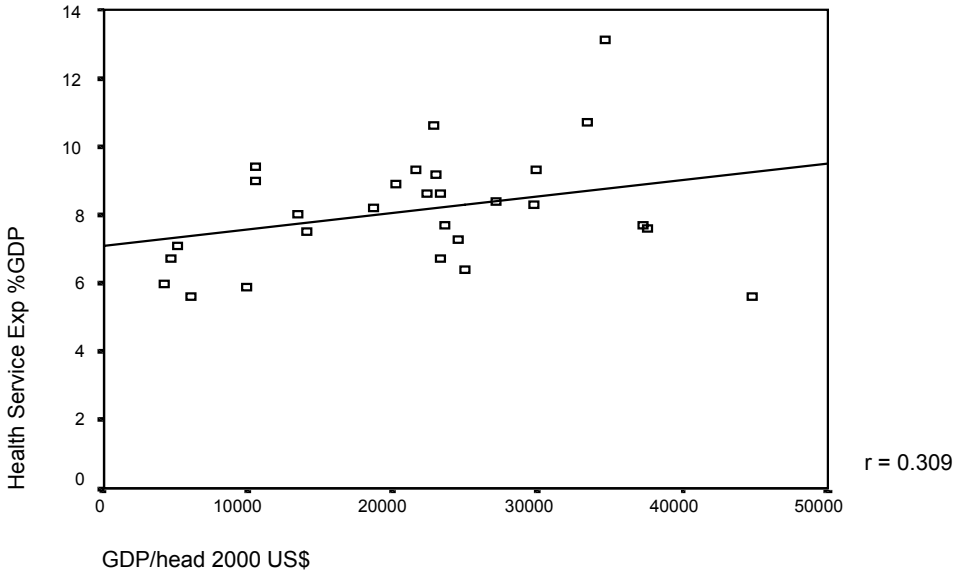
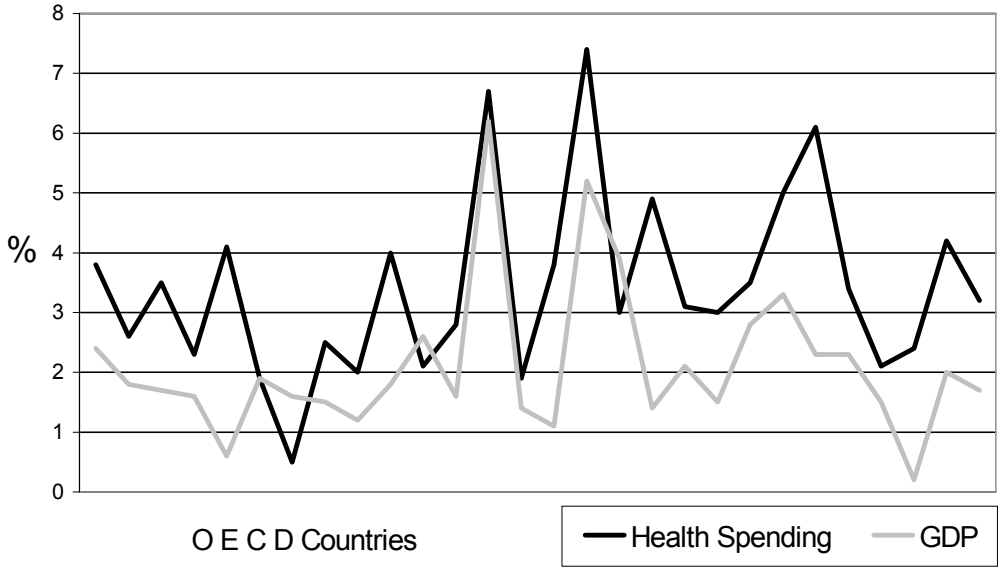


Figure 2: Annual/capital growth rate in Health care spending and GDP 1990-2001 OECD Countries (data source: OECD)



This phenomenon of health care taking an ever increasing share of GDP has prompted various governments to attempt to halt or even reverse the increase in health care costs and improve efficiency, often by introducing health care

'reforms'. Many such 'reforms' are predicated on the assumption that markets and competition lead to greater efficiency. However, despite the textbook claim that perfect markets are perfectly efficient, market failures in health services and clinical medicine are widely and well described both in theory and in practice, leading to attempts to obtain the benefits of markets without the costs.

According to Light (2001:691) Enthoven's "model of managed competition ... appears to surmount the obstacles to beneficial markets in health care, and it has been widely acclaimed as the key to making health care services more efficient and responsive". But, Light claims, "managed competition does not solve the fundamental sources of market failure – the uncertainty, contingency, and information asymmetry of medical practice ..." Further, competition itself introduces particular problems to health care. Light (1991b:779) observed, in respect of the capacity-constrained NHS, that there "must be slack and duplication for competition to exist at all ... without them there is no choice of buyers or sellers ..." Elsewhere Light (2001:692) argues that "Because it is much easier to make money by skimping on equity, quality, and service than by becoming truly more efficient, managed competition threatens societal goals." Writing about environmental health, Corkey (2002:58) further claims that a "policy of embracing a private sector approach to public sector provision is putting at risk the very *raison d'être* of public services". "Competition," he argues, "does not guarantee improvements ..." Along similar lines, Malone (1999:19) suggests that a view of human agency "reduced to rational choices made to buy or to sell ... leaves little space for the kinds of actions that embody different values – for example, generosity, mercy or solidarity".

Rather than competition promoting efficiency, Light (1991a:104) argues that "a ... theoretically disturbing source of inefficiencies is competitive behaviour itself. An ethic of service, trust, and professionalism," he claims, "is very efficient, and the introduction of competitive behaviour into health-service professions ... is likely to increase expenses and perhaps decrease quality of service ..."

3.1 Comparative productivity

The propensity for health care expenditure to take an increased proportion of GDP can lead governments to seek the same productivity in health care as in other service sectors or even non-service sectors. For example, an official government document, whilst acknowledging that "overall the [English] NHS is an efficient as well as a fair way of providing health care", goes on to claim that "it can be more efficient still which is why we expect to see improvements in NHS productivity of 2% per annum. This means we expect the NHS to match the productivity performance of the wider UK economy ..." (DoH, 2002:37). Earlier Wanless

(2002:64), in an official report to the UK Government, had made the rather more modest assumption that "the health services should at least be able to match the productivity performance of the wider service sector ..."

3.2 Cost cutting and 'efficiency gains'

For many years 'efficiency gains' have been imposed on the English Health Service requiring provision of the same amount of health care at lower cost year-on-year (i.e. cost-cutting), or greater provision for the same expenditure. As Dawson and Jacobs (2003:67) explain, "most of the required cost-efficiency gain must come from hospital trusts reducing their unit costs" and, they continue (p. 71), the "only way to achieve an 'efficiency gain' is to increase the number of patients treated per pound of budget". However, their careful study of performance over six years found no evidence of a reduction in unit costs.

Further, if cost cutting leads to underfunding, this itself can result in inefficiency. As Light (1991a:103) suggests, "underfunding is a form of embedded inefficiency". He (1990c:1472) suggests that "underfunding produces inefficiencies through underuse of capacities, lower quality staff, staff turnover, and depleted work units" and elsewhere (1990b:1604) that "waste comes from underfunding facilities and work teams so that work is not done efficiently" because of high staff turnover resulting from low pay and lack of possibilities for promotion etc.

4. Some Problems with Efficiency

The pursuit of efficiency, especially if it is accompanied by underfunding, can also lead to problems with technological innovation, equity, quality and even health itself.

4.1 Efficiency versus New Technology

Controlling the introduction of new technology can be seen as a route to greater efficiency, especially since "It is widely accepted that technological change has accounted for the bulk of medical care cost increases over time" (Cutler and McClellan, 2001:12). However, reducing spending and attempts to reduce waste could lead to less technological innovation and the result might be neither cost-effective nor efficient.

Cutler and Huckman (2003:187) note the apparent paradox that "many medical innovations ... appear to reduce *unit* costs and increase *total* costs". That increased total cost is usually attributed to treatment expansion. However, they go on to argue that although technological innovation can increase costs in the short term, it

can reduce them in the long term because of substitution for existing therapies or care.

However, the arguments relating to new technology go further. Cutler and McClellan (2001) suggest that simply looking at cost is too narrow – increased output in terms of health gain must be considered. On this basis, their study of a number of new interventions shows benefits far outweigh costs. Thus they (p. 13) argue that, although reducing waste is valuable, "waste reduction must be balanced against the potential for less rapid technical innovation" and report that their "... findings imply that the quality-adjusted price of medical care is actually falling over time".

4.2 Efficiency and Equity

It has been observed by many authors that the pursuit of efficiency can jeopardise equity and also that the pursuit of equity can jeopardise efficiency. As Vågerö (1994:1203) notes, in "moving towards market solutions equity has come to be seen as conflicting with efficiency goals". However, the question of 'equity in respect of what' complicates the debate. This is illustrated by Sassi *et al* (2001), who observe that, with screening for cervical cancer, the policy appears to be equity of access, rather than equity of take-up. They claim that more even (more equitable?) takeup would increase the number of cases of invasive cancer prevented for the same or lower cost. In another example they observe that a policy of universal screening for sickle-cell disease, in those communities where the ethnic minority population at high risk exceeds 15% of local population, is very expensive per life year saved. They argue (p. 763) that "Significant efficiency gains may be sacrificed for what seems to be an inappropriate conception of equity in this context".

4.3 Efficiency and Quality

The pursuit of efficiency (cost-cutting) can lead to reduction in quality. As Light (2001:692) stated above, "it is much easier to make money by skimping on equity, quality, and service than by becoming truly more efficient". Looking at a completely different sector, Coyle (2002:4) cites Schlosser (2001) as pointing out that "assembly-line techniques that economise on labour in fast-food restaurants ... industrialisation of food ... has led to such a great drop in quality that the apparent efficiency gains have ... made consumers worse off ..." She further notes that "critics fret about the impact of efficiency drives on the quality of services in ... airport security, teaching and transport ..." Light (1990a:1552) notes that in some cases where contracting-out is employed in the pursuit of efficiency "the same workers get laid off and rehired by the contracting company for wages even lower than those in the NHS ... quality of work done drops, so the lower price represents

lower quality and poorer service". Numerous examples can be seen, especially in the UK, where the pursuit of 'efficiency' has cut 'surplus capacity' so far that no allowance is made for the stochastic nature of demand, leading to long waits and patients being turned away from hospitals. Redundancy in the form of 'excess' capacity is seen as bad, not as necessary, and the fact that services cannot be stockpiled appears to have been overlooked.

On the other hand, rather than posing efficiency against quality, it can be argued that improved quality should be a component of the measurement of efficiency – increased productivity. Coyle (2002:4) suggests that "improved productivity in services often only manifests itself as an improvement in quality – rather than quantity – per worker" and goes on to observe that "in rich countries quality is becoming more important that quantity". This appears to be recognised within the English NHS, as can be seen by continuing the quotation given above, "This means we expect the NHS to match the productivity performance of the wider UK economy ... about half these gains will come from improvements in cost efficiency ... [the] ... **remainder from improvements in service quality**" (DoH, 2002:37) [my emphasis]. Noting that the "emphasis of the 'new' NHS is on quality" Dawson and Jacobs (2003:71) argue that "the present activity-based efficiency targets need to be dropped and substituted with targets that relate to the costs of achieving quality gains".

However, measuring efficiency by improvements in quality encounters the problem of how to measure quality, especially in health care. Further, in all sectors, it is difficult to compare a product today (whether manufactured or service) with one produced in the past.

4.4 Efficiency versus Health

It is possible that the pursuit of efficiency can have a detrimental effect on health itself. For example, a study reported by Shen (2003) found that financial pressure adversely affects short-term health outcomes.

Pursuit of efficiency can also affect the practice of health care and, possibly, health itself. For example, pursuing efficiency defined as producing more output with the same amount of input, where output is measured as the number of (weighted or unweighted) cases treated, can have perverse outcomes such as the cessation of health promotion, as it would lead to fewer cases being treated, failure to implement policies to prevent hospital admissions and lower use of less invasive or less intensive treatment if its adoption meant a reduction in the volume of weighted cases. Appleby and Little (1993) argue that the English Efficiency Index contained several such perverse incentives.

The solution thus could be to measure output as health and not as activity and it has been suggested that the UK Treasury is interested in using QALYs (quality adjusted life years) as an output measure. However, even then perverse incentives could arise, over and above any arising from the fact that health care is far from being the only determinant of health. If output is measured in QALYs/head, it could be increased by 'eliminating' (voluntary or compulsory euthanasia?) those with lower than average health status. Using aggregate QALYs as an output measure might result in a cessation of birth control programmes.

In a major comparative study, the World Health Report 2000 (WHO 2000) ranked "the health systems of the world according to their efficiency in turning expenditure into health" (McKee, 2001:295). Evans *et al* (2001:308), who were responsible for the Report, explain that their "efficiency scores compare current population health levels with the maximum possible for observed levels of health expenditure and education in a country". According to Pederson (2002:96), in addition to rankings based on composite indicators which are not being considered here, the efficiency of the ith country was measured thus:

$$E_i = \frac{Health_{it} - Health_{it(min)}}{Health_{it(max)} - Health_{it(min)}}$$

$Health_{it}$ = actual health attained (DALE Disability Adjusted Life Expectancy)
$Health_{it(max)}$ = maximum health possible given level of expenditure and education
$Health_{it(min)}$ = minimum health achievable without a health system

Whilst this report is widely acknowledged as a brave and valuable attempt to compare efficiency, it has been subject to many criticisms. One of the most common is the exclusion of income/head as a determinant of health. This is especially curious as Evans *et al* (2001:309) reported they found "that efficiency [on this index] is positively related to health expenditure per capita". They explore possible explanations including there being "a minimum level of expenditure below which the system simply cannot work well" and the possibility "that goals other than health may be deemed important", for example responsiveness and reduction of inequalities. However, they do not appear to consider the well-known relationship between wealth and health as a possible explanation for their finding.

McKee (2001:295) is concerned about the restricted definition of health system actually used. He welcomes the Report's definition of the health system as "'all the activities whose primary purpose is to promote, restore, or maintain health'" but notes that it actually uses the more narrowly defined 'health care expenditure'. Navarro (2001) goes further and criticises the scientific assumptions of the Report

and the underlying political agenda. Blendon *et al* (2001) observe critically that there appears to be little relationship between the WHO ranking of overall system performance and the view of citizens in each of the countries.

On more technical aspects, many point to problems with data quality; for example Williams (2001:98) suggests that "The underlying data base is skimpy and of dubious quality", with much of the data imputed. Hollingsworth and Wildman (2003) criticise the static nature of the model used, arguing that it says nothing about changes over time. They also demonstrate that alternative techniques yield a wealth of useful information and consider it inappropriate to analyse all countries together (e.g., OECD with non-OECD).

4.5 How should output be measured?

All this leads to the question of how output should be measured – what aspects of output should be used in calculations of efficiency and productivity. Following on from his quotation above that "'Efficiency' is not something absolute that we can easily recognise when we see it" Reinhardt (1997:17) claims that "'Efficiency' can be judged only against a crisply defined objective that is rooted in subjective norms". Thus, he argues, "The relative efficiency of alternative health systems ... simply cannot be judged in abstraction from the specific goals that society posits for its health system". But, he continues, "more and more one sees terms such as 'efficiency' and 'value' treated in the health-policy literature as some absolute ... that transcends the varying objectives nations may posit for their health systems". However, if the approach he is advocating were adopted, would it then be possible to compare the efficiency of countries' health systems? Indeed, should we even attempt to compare the efficiency of different countries' health systems?

5. Is it feasible for health care systems to match the efficiency of the rest of the economy?

Having explored some aspects of the efficiency debate, we return to the question of whether it is possible for the efficiency or productivity of health care systems to match that of the rest of the economy. As noted above, this is the stated aim of the government in respect of the English Health Service. In addition, there is the universal concern about health-care expenditure outstripping GDP. But are there limits to efficiency in health care?

5.1 A Handicraft Industry and Baumol's Cost Disease

In analysing the different productivity rates of different sectors of the economy, Baumol identified the phenomenon which has come to be known as Baumol's Cost Disease, first reported by Baumol and Bowen (1965) in an article on the

productivity of the performing arts, although the underlying analysis was not new (and possibly dates back to the Labour Theory of Value). The cost disease arises when certain services "are plagued by cumulative and persistent rises in their costs, increases that normally exceed to a significant degree the corresponding rate of increase for commodities generally, i.e. they almost always outstrip the economy's rate of inflation" (Baumol, 1995:14).

Baumol differentiates between the rising productivity sector – manufacturing and agriculture – and the stable or stagnant productivity sector, which includes the performing arts, health and education. This latter sector is characterised by services which are relatively labour intensive and where quality is related to the amount of personal attention – where "the human touch is crucial" – and are "resistant to labor productivity growth" (Baumol, 1993:19). Surowiecki (2003) summarised the argument in the *New Yorker*: "When Mozart composed his String Quintet ... in 1787, you needed five people to perform it ... Today you still need five people, and, unless they play really fast, they take about as long to perform it as musicians did two centuries ago." He went on to point out that in "A number of industries, workers produce about as much per hour as they did a decade or two ago. The average college professor can't grade papers or give lectures any faster today than he did in the early nineties. It takes a waiter just as long to serve a meal, and a car-repair guy just as long to fix a radiator hose." The rising productivity sector, in contrast, is characterised by increasing substitution of capital for labour.

Of course, it is not argued that the labour-intensive 'handicraft' services have not increased their productivity. Baumol (1993) points out that speed of travel means that itinerant performers have higher productivity than in Mozart's day. The college professor can teach larger classes or overflow classes by video-link; teaching can be outsourced "to poorly paid adjuncts" (Suroweicki, 2003), meals can be self-service, doctors can spend less time with each patient, recording and broadcasting means that music can be listened to other than directly in a live performance. But most of these mean lower quality or a change in the product. Thus, according to the 'cost disease', if the quality of 'handicraft' industries is not to fall to the extent of destroying them, if those working in the stable productivity sector are not be become impoverished relative to those working in the rising productivity sector, or if their working hours are not to become excessive, then the relative cost of the output of 'handicraft' industries must rise.

But, Baumol argues, the increasing productivity of the rest of the economy means that an increasing share of GDP consumed by services such as health and education is not a problem. "Contrary to appearances", he argues, "we can afford ever more ample medical care, ever more abundant education, ever more adequate support of the indigent, and all this along with a growing abundance of private comforts and luxuries. It is an illusion that we cannot do so, and the main step

needed to deal effectively with these fiscal problems is to overcome that illusion." (Baumol 1995:19) Indeed, he demonstrates that even if the differential rates of productivity meant that education and health care absorbed over half of GDP in the future, this would not matter. It would however mean that "society must change the *proportions* of its income that it devotes to the different products" (Baumol, 1993:23) and necessitate a change in the balance of inputs.

Thus, if Baumol is correct it means that health care (where labour input is part of the product) can never achieve the productivity of the wider economy, at least without total degradation in 'product' and impoverishment of health-care workers – that is there are limits to productivity (efficiency).

5.2 Has Baumol's Cost Disease been cured?

Triplett and Bosworth (2003) argue that "'Baumol's Disease' has been cured". They demonstrate that labour productivity in US service industries has accelerated since 1995 (Table 1).

Table 1: U.S. Labour Productivity 1977–2000

	All Services*	**Health Services**
1977–1995	0.8–1.1	-0.2
1987–1995	1.3–2.0	-0.5
1995–2000	2.0–3.0	+0.7

* Average Services Industry Labor Productivity (lowest-highest) using different weightings and number of industries included in the average
Source: adapted from Triplett and Bosworth (2003; 2002)

As Table 1 indicates, labour productivity in the US health service follows this trend having increased by 0.7% per annum between 1995 and 2000, after showing a negative annual growth rate in the earlier periods, although it is noted that the data are affected by the introduction of new medical care industry price indexes in 1992. However, in the light of discussion above, it is also interesting to note that auto repair, health care, amusement and recreation and education are all in the bottom 10 of labour productivity growth services industries 1995–2000.

Moreover, notwithstanding the effect of the change in the price index on health service productivity figures, it is interesting to look at Triplett and Bosworth's (2002) breakdown of the components of the +0.7% increase in health service productivity in the 1995–2000 period, which are (percentage points): Deepening capital input (0.3); Multifactor productivity (-0.4); Intermediate inputs (0.8). Thus,

the largest component (accounting for 110%) of the 0.7% productivity increase is 'intermediate inputs', i.e. purchased goods and services. This could include products such as pharmaceuticals but also includes contracting-out. If such contracting-out is to more efficient suppliers, there could be a true efficiency gain. However, lower prices of contracted-out services could result from lower pay and worse employment terms.

There appears to be little evidence, therefore, that Baumol's disease has been cured, especially in respect of health services. Thus, it would appear that, in order to increase productivity/efficiency in health care, there needs to be: more capital input, more intermediate inputs (purchased goods and services), and/or a reduction in labour input. The latter might be achieved by changing the skill-mix, perhaps introducing a form of Taylorism, but with what result for quality? Basically, if health care productivity is to match that of the rest of the economy it needs to move from being a labour-intensive industry to a capital-intensive industry.

6. Conclusion

Technical efficiency in health services could be improved by genuinely more efficient ways of working, which do not involve reduction in quality or in pay. It is in this area that OR interventions can help. OR can also assist in aiding the recognition that 'surplus' capacity is essential to deal with the stochastic nature of the demand for health care and to allow patient choice – a current objective of the health service in England.

But are there limits to efficiency? Taking Reinhardt's argument that efficiency can be determined only in relation to the objectives that society establishes for that health care system, it is possible that, with certain objectives, efficiency can increase indefinitely.

However, on more conventional definitions, health care cannot attain the productivity growth of the whole economic sector (or even whole service sector) unless there is major capital investment, greater use of intermediate inputs or a change in the product. Could major capital investment – substituting for labour – consist of robotic surgery, robot nurses or medical innovations that do away with the need for surgery and personal care altogether – Star Trek medicine? Paradoxically, attempts to stem the rising costs of technological advances in medical care might actually contribute to the lower productivity of health services.

Pharmaceutical breakthroughs which substitute drugs for surgery and care – leading to greater use of intermediate inputs – could result in greater efficiency provided the labour input in developing and manufacturing those drugs does not exceed the labour input of the treatments being replaced. Changing the product

could however merely mean a reduction in quality or an impoverishment of those working in health care. Mechanistic political and managerial attempts to secure productivity increases to match those of less-complex and less-labour-intensive sectors could either result in failure or could destroy much of the essence of the health-care 'industry'. Thus the pursuit of technical efficiency could prove counter-productive.

Health-care productivity will continue to lag behind the rest of the economy. Health-care expenditure will continue to increase as a share of GDP unless artificially constrained. But – if Baumol is correct – does it matter?

References

1. Appleby, J., Little, V., 1993. Health and Efficiency, *Health Service Journal,* 103(5351):21-22.
2. Baumol, W.J., 1993. Health care, education and the cost disease: A looming crisis for public choice, *Public Choice,* 77(1):17–28.
3. Baumol, W.J., 1995. *Health Care as a Handicraft Industry*, OHE, London.
4. Baumol, W.J., Bowen, W.G., 1965. On the performing arts: the anatomy of their economic problems, *American Economic Review,* 50(2):495–502. Reprinted in Towse, R. (Ed.), 1997. Baumol's Cost Disease, Edward Elgar, Cheltenham.
5. Blendon, R.J., Kim, M., and J. M. Benson, 2001. The Public Versus The World Health Organization On Health System Performance, *Health Affairs,* 20(3):10-20.
6. Checkland, P., 2001. Soft Systems Methodology. In Rosenhead, J., Mingers, J. (Ed.), *Rational Analysis for a Problematic World Revisited*, Wiley, Chichester.
7. Corkey, J., 2002. Could the Government's performance management culture be harming the environmental health service? *Environmental Health Journal,* 110(2):58-59.
8. Coyle, D., 2002. Have a very nice day. *Worldlink*, July/August 1-5.
9. Cutler, D., McClellan, M., 2001. Is technological change in medicine worth it? *Health Affairs,* 20(5):11-29.
10. Cutler, D.M., Huckman, R.S., 2003. Technological development and medical productivity: the diffusion of angioplasty in New York state, *Journal of Health Economics,* 22(2):187-217.
11. DoH, 2002. *Delivery in the NHS Plan*, Cmd 5503, Department of Health, HMSO.
12. Dawson, D., Jacobs, R., 2003. Do we have a redundant set of cost-efficiency targets in the NHS? *Public Money and Management,* 23(1):67-71.

13. Evans, D.B., Tandon, A., Murray, C.J.L., and J. A. Lauer, 2001. Comparative efficiency of national health systems: cross national econometric analysis, *British Medical Journal,* 323(7308):307-310.

14. Hollingsworth, B., Wildman, J., 2003. The efficiency of health production: reestimating the WHO panel data using parametric and non-parametric approaches to provide additional information, *Health Economics,* 12(6):493-504.

15. Kielhorn, A., Graf von der Schulenburg, J-M., 2000. *The Health Economics Handbook*, Adis International, Chester.

16. Light, D.W., 2001. Cost containment and the backdraft of competition policies, *International Journal of Health Services,* 31(4):681-708.

17. Light, D.W., 1990a. Labelling waste as inefficiency, *Health Service Journal,* 100:1552-1553.

18. Light, D.W., 1990b. Biting hard on the research bit, *Health Service Journal,* 100:1604-1605.

19. Light, D.W., 1990c. Learning from their mistakes, *Health Service Journal,* 100:1470-1472.

20. Light, D.W., 1991a. Embedded inefficiencies in health care, *Lancet,* 338:102-104.

21. Light, D.W., 1991b. Perestroika for Britain's NHS, *Lancet,* 337:778-779.

22. Malone, R.E., 1999. Policy as a product: Morality and metaphor in health policy discourse, *Hastings Center Report,* 29(3):16–22.

23. McGuire, A., Henderson, J., and G. Mooney, 1988. *The Economics of Health Care*, Routledge & Kegan Paul, London.

24. McKee, M., 2001. Measuring the efficiency of health systems, *British Medical Journal,* 323(7308):295-6.

25. McPake, B., Kumaranayake, L., and C. Normand, 2002. *Health Economics: an international perspective*, Routledge, London.

26. Navarro, V., 2001. The New Conventional Wisdom: An Evaluation of the WHO Report Health Systems: Improving Performance, *International Journal of Health Services,* 31(1):23-34.

27. Parkin, M., King, D., 1992. *Economics*, Addison Wesley.

28. Pederson, K.M., 2002. The World Health Report 2000: Dialogue of the Deaf? *Health Economics,* 11(2):93-101.

29. Reinhardt, U.E., 1997. *Accountable health care: is it compatible with social solidarity?* Office of Health Economics, London.

30. Sassi, F., Le Grand, J., and L. Archard, 2001. Equity versus efficiency: a dilemma for the NHS, *British Medical Journal,* 323(7316):762–3.

31. Schieber, G.J., Poullier, J-P., 1991. Health Care Systems in Twenty-Four Countries, *Health Affairs,* 10(3):22–38.

32. Schlosser, E., 2001. *Fast Food Nation*, Allen Lane The Penguin Press (cited by Colye, 2002).

33. Shen, Y.-C., 2003. The effect of financial pressure on the quality of care in hospitals, *Journal of Health Economics,* 22(2):243-269.

34. Street, A., Jacobs, R., 2002. Relative performance evaluation of the English acute hospital sector, *Applied Economics,* 34(9):1109-1119.

35. Surowiecki, J., 2003. What ails us, *The New Yorker,* 7/7/03 27.

36. Towse, R. (Ed.), 1997. *Baumol's Cost Disease*, Edward Elgar, Cheltenham.

37. Triplett, J.E., Bosworth, B.P., 2002. "Baumol's Disease" has been cured: IT and multifactor productivity in US Service Industries, Mimeo (to be published In Jansen, D., (Ed.) *The New Economy: how new? how resilient?* University of Chicago Press, Chicago).

38. Triplett, J.E., Bosworth, B.P., 2003. Productivity Measurement – Issues in Services Industries: "Baumol's Disease" has been cured, *FRBNY Economic Policy Review,* 9(3):23–35.

39. Vågerö, D., 1994. Equity and efficiency in health reform: A European view, *Social Science and Medicine,* 39(9):1203–1210.

40. Wanless, D., 2002. *Securing our Future Health: Taking a Long-Term View*, HM Treasury, London.

41. Williams, A., 2001. Science or Marketing at WHO? A commentary on 'World Health 2000', *Health Economics,* 10(2):93-100.

42. WHO, 2000. *World Health Report 2000. Health systems: improving performance*, World Health Organisation, Geneva.

AGEING POPULATION

WHAT HAPPENED TO THE SWEDISH AGED CARE SERVICES?

Evidence from two surveys in 8 Swedish municipalities 1994 and 2002

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Abstract: Results compared here are taken from two different surveys that were performed in 1994 and 2002, respectively in order to estimate standard costs for the Swedish tax equalization scheme. The surveys were made in the same eight municipalities and each time involved around 5 500 recipients of care. The comparison shows that the proportion of the elderly persons that receive aged care services diminished between 1994 and 2002. A higher proportion of those receiving care services are in now in institutional care, but depending on the increased number of elderly people these persons constitute a lower proportion of the total number of the elderly. As a consequence of the developments the average level of disability has increased both in home care and institutional care. Due to stricter prioritisation the hours of provided home help to the given disability have decreased. The frail elderly thus have to cope more on their own or with the help of spouse, children or other supporting persons.

1. Introduction

Up to the year 2000 Sweden used to have the oldest population in the world. The proportion of 80+ years old increased from 3% to over 5% between 1980 and 2000. The rapid increase in the number of old and very old persons and economic pressure due to a severe national economic crisis in the 1990-ies resulted in public services for the elderly not being able to keep up with the population development. The previous generous allocation of care had to be replaced by a more restrictive approach. Different studies indicate that the reductions in the provision of services mainly affected persons with lesser needs of care. However, in Sweden there exist no national data showing how services are provided in relation to some measure of need or ill health. As result of these statistical deficiencies there has been a severe lack of solid facts to guide the public debate in Sweden concerning the recent developments of the elderly care system. Instead the Swedish debate has been focused on the cuts, which are described as dismantling of the public care system, and the questions about the factual needs development have been discarded.

In 1994 a survey of all recipients of elderly care services was made in eight Swedish municipalities as part of establishing basis for a tax equalization scheme. In the survey all received services were registered together with an assessment of functional limitations making it possible to establish a relation between provided services and a measure of needs. This survey has now been repeated in the same municipalities with a methodology that allows making valid comparisons between the years and thus provides a factual basis for analyzing the actual development of Swedish elderly care system. In the following sections a short description of the Swedish scheme for equalisation

taxes between the municipalities is given; the two surveys and the results from the surveys are discussed.

2. The Swedish tax equalisation scheme for the municipalities

The care of frail elderly persons as well as many other welfare systems in Sweden is decentralized and relies upon the municipalities. The system is partly financed by the state and partly by the municipalities, who have the right to levy taxes in their population. In order to provide equal opportunities to access services across Sweden an equalisation scheme is employed. This system consists of two parts: Income-equalisation with regard to differences in tax-base, and expenditure-equalisation with regard to structural factors (population composition, sparse population etc.). The basic idea behind the second part of the system is that the municipalities should be compensated for factors that are outside their control. For the aged care services these so-called structural factors consist of the number of elderly persons per

- age-group (65+, 5-year)
- gender
- civil status(married / non-married)
- ethnic origin (Nordic /non-Nordic)
- socio-economic group

In addition there are some other factors included in the equalisation scheme such as supplement for sparse-populated areas to cover extra costs for home help and housing and compensation for extra costs connected to shrinking populations.

Each combination of the above factors constitutes a “cell”. The method to equalise for structural factors consists of establishing a per capita “norm cost” per cell and calculates the total norm costs for the municipality according to the number of persons in each cell. The municipality will then pay or receive money according to their total norm cost. Similar methods are used in other areas of municipal activity.

In order to establish the norm costs you have to estimate the distribution of ill-health and disability in the elderly population in the respective subgroups and the amount and cost of provided services given ill-health and disability. This is done using surveys in a number of municipalities in order to measure provided services in relation to ill-health per combination of age group, gender, civil status and ethnic origin and converting provided services to costs using standard costs estimations of ill-health distribution (per combination of the above factors) in each of these municipalities by multiple regression analysis based upon a

national health survey (the so-called ULF-study, [1]) using the above variables together with socio-economic group as predictors.

Using these data per capita norm costs are calculated per age, gender ...-combination and socio-economic group using the ill-health distribution per combination and socio-economic group as predicted by ULF-survey.

Finally total norm costs for each Swedish municipality are calculated using the population distribution per combination of age group, gender, marital status, ethnicity and socio-economic group.

3. The field studies in 1994 and 2002

In order to establish the provision of services in the different sub-groups in relation to needs a field survey was made in 1994 in nine Swedish municipalities judged to be a representative sample of the Swedish municipalities. In these studies provided services were expressed in terms of weekly hours of home help in ordinary housing or service housing and round-the-clock care in residential homes and nursing homes. In addition the level of disability was described in terms of functional limitations according to the Katz ADL-index [2][1].

As mentioned in the introduction, there have been large changes going on in the Swedish system of care for the frail elderly in the last decade and when the tax-equalisation scheme was overhauled in 2002 it was felt that there was a need to update the 1994 field study. In order to make results comparable the same municipalities were chosen for the study as in the 1994 survey. This gave an excellent opportunity to see what exactly had been going on since the beginning of the 1990-ies in terms of provided services to the frail elderly in relation to needs. As mentioned above, information of this kind is not available through the official statistics.

Eight of the nine municipalities agreed to take part in the survey. These municipalities represent small municipalities in the south (Oskarshamn, Surahammar) and north (Ragunda, Krokom, Nordmaling, Vilhelmina) of Sweden as well as larger municipalities (Kalmar, Lulea). What is lacking is the big cities of Sweden – Stockholm, Gothenburg, Malmo…. However there is no reason to believe that the results from these cities should be entirely different, though of course the development there could have special features.

In the survey all recipients of long-term care, 65 years and above, were registered (without identification by personal number) and data were collected

[1] In addition, the so-called ASIM-index, developed by the author [3], was used. One municipality, Lulea, only used the ASIM-index.

on age, gender, marital status (married /non-married) and ethnic origin (Nordic /non-Nordic). Disability was measured in terms of five ADL-variables (bathing, dressing, transferring, toilet and feeding), incontinence and dementia. From this the so-called SNAC PADL-index [4] was constructed and also the Katz ADL-index used by seven municipalities the 1994 survey. Finally the registration involved provided services measured in the same way as in the 1994 survey. In total around 5 500 persons were registered in the 2002 survey. In the calculation of the norm costs, data on 2 500 persons collected in the SNAC study [4] were also used. These results are reported elsewhere, since the municipalities participating in the SNAC-study did not take part in the 1994 survey.

4. Results

Comparison between the two field studies in 1994 and 2002 gives a unique possibility to analyse what happened with the Swedish system of care for the elderly in the period. Table 1A and Table 1B show the number of inhabitants and recipients of care in the surveyed municipalities in 1994 and 2002.

As seen from Table 1 the number of recipients of long-term care for the elderly has fallen in all municipalities except Surahammar, where the proportion receiving services was very low already in 1994. The share of the recipients receiving institutional care has increased and the same goes for the absolute number. The decreased share of persons receiving home help reflects drastic cuts in the provision. In fact the total number of home help receivers in the involved municipalities has fallen from over 4000 to less than 3000. It is also interesting to notice the big variations between municipalities.

Table 1: Number of inhabitants and recipients of care services in home care and institutional care in the surveyed municipalities, 1994 and 2002

1A. 1994	Number of persons over 65 years	Recipients of care services		Proportion of recipients with	
		Total	% from all 65+	home care	institutional care
Oskarshamn	5106	873	17.1%	80%	20%
Ragunda	1767	414	23.4%	67%	33%
Luleå	9131	1551	17.0%	64%	36%
Krokom	2747	562	20.5%	65%	35%
Nordmaling	1718	360	21.0%	58%	42%
Vilhelmina	1737	326	18.8%	54%	46%
Kalmar	10247	1681	16.4%	68%	32%
Surahammar	1679	225	13.4%	73%	27%
All surveyed municipalities	**34132**	**5992**	**17.6%**	**67%**	**33%**

1B. 2002	Number of persons over 65 years	Recipients of care services		Proportion of recipients with	
		Total	% from all 65+	home care	institutional care
Oskarshamn	5047	722	14.3%	60%	40%
Ragunda	1609	287	17.8%	53%	47%
Luleå	10459	1477	14.1%	44%	56%
Krokom	2560	436	17.0%	58%	42%
Nordmaling	1645	283	17.2%	46%	54%
Vilhelmina	1740	302	17.4%	50%	50%
Kalmar	10460	1517	14.5%	64%	36%
Surahammar	1733	233	13.4%	83%	17%
All surveyed municipalities	**35253**	**5257**	**14.9%**	**56%**	**44%**

Given the increase of institutional care one may ask how this has affected the prevalence of disability among the residents. Tables 2A and 2B show the distribution of the residents according to the Katz scale in 1994 and 2002 respectively for each participating municipality. Also the mean value has been calculated after transforming the Katz categories to a numeric scale (A=1, B=2,…, O (others) deleted). Lulea is missing for the year 1994 since they only applied the ASIM-scale in that survey.

Table 2: Distribution of persons in institutional care according to Katz /ADL-groups, 1994 and 2002

2A. 1994	A	B	C	D	E	F	G	Mean
Oskarshamn	3%	15%	8%	9%	19%	23%	23%	4.87
Ragunda	2%	9%	16%	17%	9%	14%	33%	4.96
Luleå	-	-	-	-	-	-	-	-
Krokom	3%	20%	5%	4%	9%	28%	31%	5.04
Nordmaling	1%	21%	8%	5%	7%	30%	28%	4.98
Vilhelmina	8%	27%	7%	5%	4%	27%	22%	4.39
Kalmar	3%	17%	7%	8%	16%	15%	34%	4.98
Surahammar	0%	7%	5%	7%	9%	49%	23%	5.57
All surveyed municipalities	**3%**	**17%**	**8%**	**8%**	**13%**	**22%**	**29%**	**4.95**

2B. 2002	A	B	C	D	E	F	G	Mean
Oskarshamn	3%	9%	9%	5%	7%	17%	50%	5.55
Ragunda	8%	11%	12%	9%	9%	20%	31%	4.85
Luleå	5%	10%	10%	8%	9%	15%	43%	5.26
Krokom	6%	17%	9%	6%	7%	25%	30%	4.86
Nordmaling	3%	10%	12%	5%	12%	9%	48%	5.30
Vilhelmina	5%	12%	17%	12%	14%	12%	29%	4.70
Kalmar	1%	5%	9%	6%	10%	10%	60%	5.90
Surahammar	0%	10%	10%	3%	13%	13%	53%	5.65
All surveyed municipalities	**4%**	**9%**	**10%**	**7%**	**9%**	**15%**	**46%**	**5.35**

It comes out clearly from table 2A and 2B that the residents in institutional care on average are more disabled in 2002 than the case was eight years earlier. The only exceptions are Ragunda and Krokom, where the development for some reason has gone in the other direction. The share of the residents that have been classified as belonging to the most disabled category – G according to the Katz scale – has increased from 29% to 46% as total in the surveyed municipalities. On the other hand, the share of the least disabled categories, A and B, has diminished from 20% to 13%. The development in Lulea as measured by the ASIM-index is similar. As a consequence of the changed composition of the residents the workload in institutional care obviously must have increased in accordance with general belief. Again, however, it is worth noting the big variation between the municipalities.

As seen from tables 3A and 3B, a corresponding comparison with regard to home help in community care (ordinary housing or service housing) reveals a similar pattern.

Table 3: Distribution of persons in home care according to Katz/ADL-groups, 1994 and 2002

3A. 1994	A	B	C	D	E	F	G	Mean
Oskarshamn	59%	13%	10%	4%	4%	7%	4%	2.21
Ragunda	38%	23%	14%	9%	5%	4%	7%	2.60
Luleå	.	.	.	.	.	.	.	.
Krokom	38%	19%	8%	4%	6%	12%	13%	3.09
Nordmaling	53%	32%	8%	3%	1%	2%	1%	1.77
Vilhelmina	57%	20%	7%	2%	4%	8%	2%	2.08
Kalmar	47%	26%	6%	7%	4%	5%	5%	2.30
Surahammar	36%	27%	9%	5%	3%	15%	5%	2.77
All surveyed municipalities	**48%**	**22%**	**8%**	**5%**	**4%**	**7%**	**5%**	**2.37**

3B. 2002	A	B	C	D	E	F	G	Mean
Oskarshamn	39%	20%	15%	7%	6%	7%	6%	2.67
Ragunda	41%	22%	9%	7%	9%	5%	5%	2.58
Luleå	25%	26%	15%	11%	3%	7%	12%	3.09
Krokom	47%	22%	10%	8%	4%	7%	1%	2.25
Nordmaling	36%	26%	18%	9%	6%	2%	3%	2.42
Vilhelmina	56%	19%	9%	6%	3%	3%	4%	2.07
Kalmar	37%	23%	14%	9%	2%	4%	12%	2.74
Surahammar	31%	16%	20%	9%	9%	9%	6%	3.01
All surveyed municipalities	**37%**	**23%**	**14%**	**9%**	**4%**	**6%**	**8%**	**2.72**

First observation to be made from table 3, as compared to table 2, is that the distribution of disability among the recipients of care is entirely different. Only a small minority of the persons receiving community care belong to the most disabled category G. The proportion has increased, however, and the average increase in (numerical) Katz-value among all recipients of home care amounts to around 15%, which is almost twice as much as the corresponding increase for institutional care. In this case, however, the difference is almost totally made up by the disappearance of persons with a lesser degree of disability. The number of the most disabled (i.e. the G-category) provided community care services has increased somewhat (+18%), whereas the number of the least disabled (A-category) has almost halved (-44%). Thus the increased workload comes more from having less "light" cases than more "heavy" ones. As seen for the case of institutional care there are big differences between the municipalities. In some of them there has been a very little change and in one—Krokom—the average level of disability among the recipients of home help has actually decreased.

Given more disabled persons in community care the question then arises whether people get more or less help to the given disability. A comparison is shown in table 4 A and B below in terms of average amount of weekly hours home help per Katz-category in 1994 respectively 2002.

Table 4: Average number of home help hours per Katz ADL-group

4A. 1994	A	B	C	D	E	F	G	Mean	Stand. Mean
Oskarshamn	5	13	17	21	28	40	50	13.1	14.4
Ragunda	3	7	9	13	16	21	25	8.6	7.9
Luleå	.	.	.	.	.	.	.	.	.
Krokom	3	9	14	17	23	23	32	13.0	9.7
Nordmaling	5	11	22	30	42	40	34	10.4	14.5
Vilhelmina	6	10	20	22	32	33	40	12.0	13.6
Kalmar	4	8	13	17	21	25	32	9.6	10.0
Surahammar	2	8	12	16	24	28	47	12.0	10.0
All surveyed municipalities	**4**	**9**	**15**	**19**	**25**	**29**	**36**	**11.2**	**11.2**

4B. 2002	A	B	C	D	E	F	G	Mean	Stand. Mean	D:o 1994
Oskarshamn	4	7	15	16	17	23	24	10.5	11.0	8.9
Ragunda	3	8	12	14	20	14	37	10.1	11.3	8.8
Luleå	4	8	11	15	16	27	28	12.1	10.7	9.3
Krokom	2	6	10	10	31	17	17	6.5	7.3	6.8
Nordmaling	2	4	9	9	20	23	33	7.2	8.8	7.3
Vilhelmina	5	12	20	19	18	28	50	12.5	16.3	13.2
Kalmar	3	6	10	13	15	22	24	9.2	8.9	7.4
Surahammar	2	4	6	8	10	13	23	6.6	6.1	5.2
All surveyed municipalities	**3**	**7**	**11**	**13**	**17**	**21**	**26**	**9.7**	**9.7**	**8.1**

Here first to be noted is that there are very big differences between the municipalities in the amount of provided home help. As an average Oskarshamn provided more than 50% more help than Ragunda in 1994 and in 2002 the differences have become even bigger. A second observation is that the average provided help increases very much with disability. This could possible explain the municipality differences given the large differences in distribution in terms of disability between the care recipients. However, as can be seen from table 4 standardising for disability does not diminish the differences in provision. After disability standardisation recipients of home help in Vilhemina are still provided with more than twice as much home help as in Surahammar in 2002.

Comparison between tables 4A and 4B also reveals that the average amount of provided home help has been reduced from 11.2 to 9.7 hours per week, i.e. around 13%. However, depending on increased average disability the decrease in the *given category of disability* has been sharper. The reduction after standardisation for disability amounts to 28%. In this case all municipalities except Ragunda show reductions—the heaviest ones in Nordmaling and Surahammar, where the disability-standardised amount of help has almost halved in the eight-year period. No regional pattern can be discerned.

Nordmaling and Vilhelmina, where reductions have been very small, lie both in the upper North of Sweden not far from each other.

5. Discussion

The surveys of 1994 and 2002 were made using the same methodology making comparisons between them valid. Missing observations were negligible (less than a few per cent). The results tally well with the general observations made in the current Swedish debate regarding the development of the system of care for the frail elderly. These observations have partly been anecdotal, partly based upon different studies regarding care services provision made by the National Board on Health and Welfare. As pointed out above there exists no national statistics in Sweden connecting the provision of services to needs such as disability.

In summary the results show that the proportion of the elderly persons receiving home care has diminished between 1994 and 2002. A higher proportion of those receiving care are now in institutional care, but depending on the increased number of elderly people these constitute a lower proportion of the total number of elderly persons. As a consequence of these developments average disability has increased both in home care and institutional care. Due to stricter prioritisation the hours of provided home help to the given disability have decreased. Thus the frail elderly have to cope more on their own or with the help of spouse, children or other supporting persons.
The development is undoubtedly forced by economic constraints arising from the growing economic difficulties Sweden has experienced in the last decades. The results shown by the surveys provide precise figures on the development for a representative sample of the Swedish municipalities and can thus serve as a basis for a more informed debater about the development.

References

1. Statistics Sweden (SCB), 1975–97. *The Swedish National Survey of Living Conditions*, Stockholm, SCB.
2. Katz et al., 1963. Studies of illness in the aged. *Journal of American Medical Association*, 185:914–919.
3. Lagergren, M., 1994. Disability transitions in an area-based system of long-term care for the elderly and disabled. *Health Policy*, 28:153–174.
4. Lagergren, M. et al., *SNAC - The Swedish National Study on Ageing and Care*. (work in progress, available at www.aldrecentrum.se).

HOW BIG IS THE PROBLEM OF AGEING?

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Abstract: The Czech Republic, same as other European countries, is facing the problem of ageing. In the paper, the demographic projection of Czech population is combined with the data on age-related health expenditures in order to predict future health expenditures. According to projections, the population ageing is a factor increasing the health expenditures, but the trend does not seem disastrous. Health expenditure burden on person in productive age may increase by 30% or even more. However, with more efficiency in health sector, some better-designed reforms in social policy, and growth of gross domestic product, the health care financing seems to be sustainable in the years coming.

1. Introduction

The Czech Republic, similar as other European countries, is facing the problem of ageing population. Ageing of population in itself is not a health-policy problem; in fact, ageing of population is an example of a very successful story if the objective of a society is longer and healthier life. There is however a relatively widespread worry among many people, especially if they are economists, whether ageing is economically sustainable in the long term. The objective of this paper therefore is to investigate two questions related to ageing of population: firstly, how much health expenditures will rise in the future, and secondly, whether these health expenditures will be economically sustainable. I consider this paper an initial view on the problem, with some calculations carried out; in any case, this is no profound analysis of population ageing. I recommend two publications as examples of comprehensive analysis, Wanless Report (2002) from the United Kingdom, and the study of Lagergren and Batljan (2000) from Sweden, which deal with the future of health and social services in the time of ageing population.

2. Data and methods

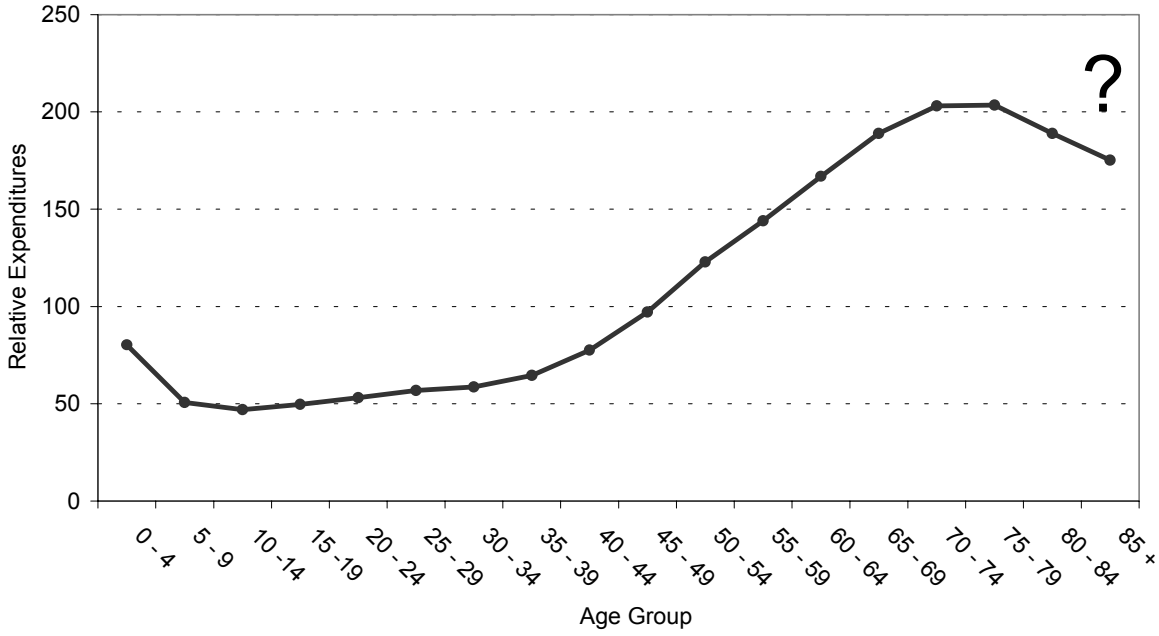
A first simplification is the idea that health expenditures, resource consumption and health needs are perfectly interrelated. If you believe that the expenditures have little in common with the real health needs of population, then you, of course, cannot regard the results of projections presented here as valid, applicable or useful. In this study, I assume that there is, albeit imperfect, a relation between health expenditures and health needs of people from the different age groups. In the base-case scenario, I further assume unchanged health expenditures per person in a given age and sex group during the projected

period. Such assumption is not realistic; several researchers for example argue that consumption of health services by old people is: (a) changing with the changes in life expectancy, and (b) is concentrated in the last years of life. However, I do not have sufficient knowledge and data to introduce more realistic alternatives, so constant health expenditures is a necessary choice for the base-case scenario.

Demographic data I use in this study were taken from the demographic projection of the Czech Statistical Office (1999), which predicted age and sex structure of Czech population till the year 2030. The year 2030 is also the horizon of my calculations. I will combine the demographic projection of the Czech Statistical Office with the data on health expenditures from public health insurance system. It should be explained here that the public health insurance in the Czech Republic is compulsory for the whole population and made up around 83% of total health expenditures in 2001. With lack of information, I assume that the remaining part of health expenditures, consisting of health expenditures from state and local budgets and private health expenditures, follows approximately the same distributional patterns among the age groups as expenditures of public health insurance. As an estimation of sex and age expenditures from public health insurance I used data from General Health Insurance Fund of the Czech Republic (Všeobecná zdravotní pojišťovna České republiky). This insurance fund is the largest health insurance fund in the Czech Republic and covers approximately 70% of population.

Figure 1 shows the relative expenditures per capita for different age groups (here, both sexes together). The number 100 denotes average expenditures per member of General Health Insurance Fund between 1995 and 2001. This relative scale enables to overcome problems (a) with inflation and (b) with the variation in expenditures from year to year. The assumption is that there was no trend in age-related health expenditures and no change in the health insurance package. I know that it was not the case because financing of long-term care institutions was transferred to the health insurance during that period. The question mark in the right top corner of Figure 1 is placed there to emphasize the uncertainty about future trends of the cost of care for the old old. This uncertainty limits the possibilities of using data for predictions. The old old (80+) were less costly for the system than the young old, but the data from last years show that the expenditures for age groups 80+ are nearly equal to expenditures in the group 75–79 years. I therefore decided to use data from the year 2000 as more appropriate (the 2001 data were preliminary in the time of analysis) than the 1995–2001 average. The impact of this choice is that projections of health expenditures based on the 2001 data are about 4% higher than those calculated with the 1995–2001 average.

Figure 1: Health Expenditures per Capita for Different Age Groups, General Health Insurance Fund of the Czech Republic, the 1995–2001 Average

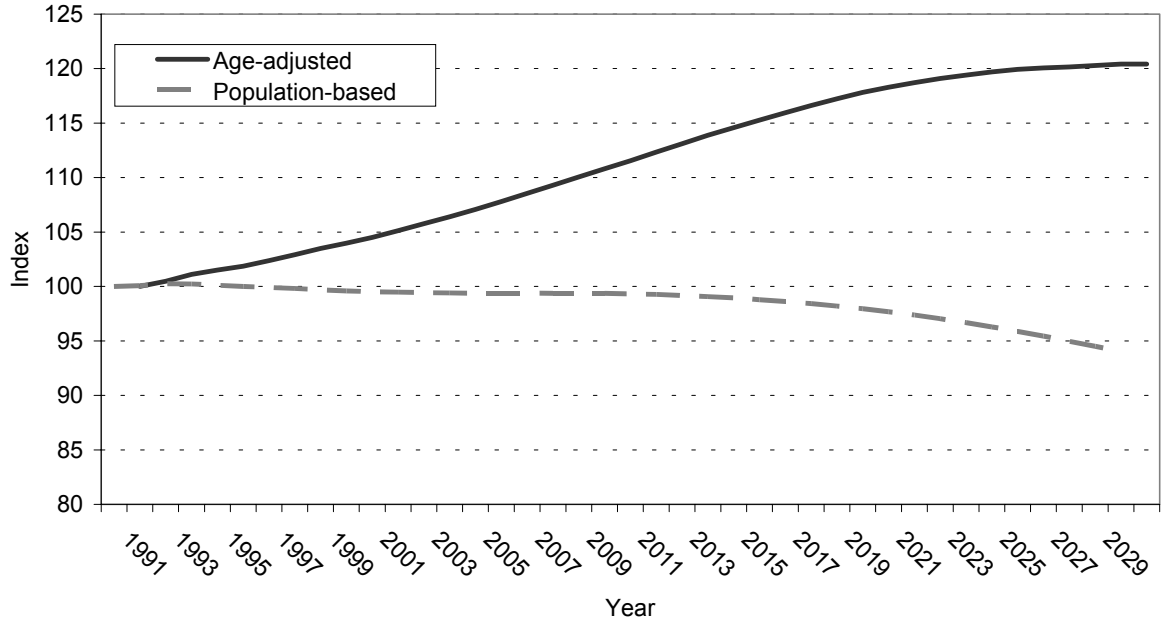


3. Projections of Health Expenditures

Figure 2 shows two predictions: firstly, the expenditures (or resource requirements) are calculated by a simple population-based indicator; secondly, ageing of population is taken into account. If one plans health resources according to simple population-based formulas as the number of beds or physicians per 1000 inhabitants, he or she will reach conclusion that the reduction is needed (dashed line). This prediction is a direct consequence of the decreasing number of inhabitants in the Czech Republic to 94% of the 1991 level, and it is, of course, a wrong health-policy conclusion. I use this prediction to show that population-based ratios are inappropriate if they are used in long-term planning. In the age-adjusted projection, I projected the future trend in health expenditures multiplying the projected number of persons of specific age and sex group by health expenditures for this group in 2001 (solid line). I used the 2001 to estimate past health expenditures (1991–2000), which will appear useful in further analysis. According to this medium variant of demographic projection, ageing of population would increase total health expenditures by 20.4% in 2030 if compared to the 1991 value. Health expenditures per capita grew by 28.1%. Total health expenditures were decreased by the 6%-population decline (it is simply 1.281 x 0.94 = 1.204). The 20% increase in total health expenditures is not good news, but this increase does not seem as catastrophic or

insurmountable development; it is a result of 39 years (1991–2030). If this growth is discounted, it is less than half-percent increase per year (0.48%).

Figure 2: Total Health Expenditures in the Czech Republic, the Population-Based and the Age-Adjusted Alternatives, 1991–2030 (1991=100)



As a sensitivity analysis I carried out simulations for different variants of demographic projection (low, medium, high), for different patterns of age-related health expenditures (the 1995–2001 average, and the years 1998, 1999, 2000, 2001), and for various combination of all these parameters. The projections stayed within the 10% interval, which is a relatively stable result for time horizon of 39 years. Now we have some answer to the first question concerning how much health expenditures will rise. It will be around 10–30%, no simulation showed that health expenditures would double or likewise. In the next section I will investigate if the projected growth in health expenditures is economically sustainable. Will there be someone to pay the bill?

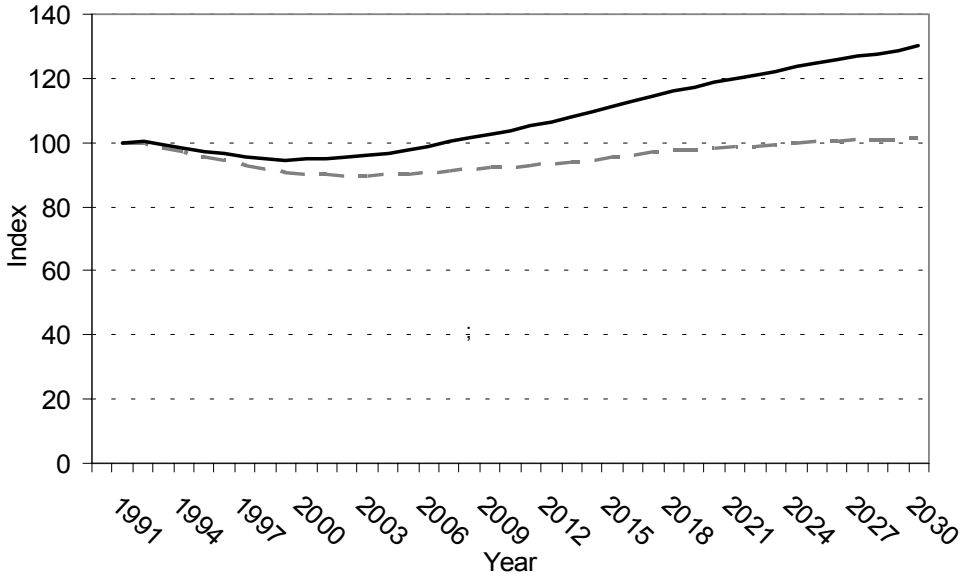
4. Economic Sustainability of Health Expenditures

The dependency ratio is used to measure the relative weight of young and old (non-working age) population in proportion to the working age population. Those in work have to hand over part of their resources to all those not in work, whether too young or too old. This ratio gives us basic information on the economic consequences of changes in the age-structure of population. First, I will define the dependency ratio as the population (working or non-working age)

divided by working age population. The idea is that working population must pay the health care bill for all those not in work as well as for themselves. Everyone in work knows that he or she depends on his or her payroll, too. Secondly, I define the *health expenditure burden* as total health expenditures divided by productive population. For the base-case scenario I define productive population as those between 20 and 59.

The results for the base-case scenario are shown in Figure 3. Both the modified dependency ratio and the health expenditure burden are set to be 100 in 1991. The dashed line represents the dependency ratio, which will reach a relative value 101.5 by year 2030. This says that there will be a modest relative increase in non-working population. The real value of dependency ratio was 1.89 in 1991, which means that one person from working population has to pay health expenditures for himself and nearly one other person (0.89). The dependency ratio reaches its minimum in 2002, with value 1.69, and will reach value 1.92 in the year 2030. The health expenditure burden or health expenditure that has to be financed by a person in productive age (solid line) will increase by 30.0% between 1991 and 2030. Interestingly, both parameters declined during the 1990s. This decade may have been used for reforms and the preparation of a cushion for the less favorable future. Decline in the 1990s is explained by the fact that population ageing incorporates two processes—extension of life expectancy (higher numbers of old people) and lower birth rates (lower numbers of young people). The fall in birth rates in the 1990s thus means that the productive population, in the short term, is saving money. This process, however, will reverse in the future. The pension system is a different case.

Figure 3: The Health Expenditure Burden and the Dependency Ratio 1991–2030 (1991=100)



I performed a sensitivity analysis by changing variants of demographic projection and variants of health expenditures. Furthermore, I made experiments with the definition of productive (working) population, for example, defining it from 20 to 64 years. Estimates of the health expenditure burden are located +/- 10% around the base-case. There is no doubt that the proportion of productive population will be lower and health and social systems will have to meet greater demands, nevertheless, we should not be too pessimistic due to ageing of society from economic point of view. If an average annual economic growth is at least 1%, it will mean 47% in 39 years. If an average economic growth reaches 2% yearly, the gross domestic product will have doubled (116.5% growth) in 39 years. One may also raise the question whether the older working population is able to produce more and better quality than the younger one. There is at least one argument for being optimistic because the countries with older populations are still the richer ones.

5. Discussion

Results show that population ageing is a problem the Czech Republic has to cope with, but it is not necessarily an economic disaster from the health perspective. There are, nonetheless, many other factors one has to take into account. These factors may have stronger, both positive and negative, effects than the process of ageing. I am giving some positive factors below:

- Increased efficiency. Developments in the health sectors of many countries show that the health resources may be used more efficiently. Thousands of hospital beds were closed or transformed to long-term care ones during the nineties. Who would predict such massive process twenty years ago? There is a chance that such unpredicted efficiency gains in the health sector may continue in the future.
- Better health. It is necessary to distinguish between the young old and the old old. Trends in mortality, morbidity, and functional disabilities are very positive, particularly among the young old (Lagergren and Batljan, 2000). This may have a long-term impact we are not able to predict today.
- Longer and healthier life will likely mean longer productive life. Changing working patterns from manual to non-manual work enable such development. The retirement age will surely increase.
- The potential of economically productive population is not fully used today. The unemployment rate is reaching 10% of workforce in many countries. The present problem is not in who will work, but what to do with those without work. However, early retirement as a cure for unemployment should be abandoned.
- Health expenditures are determined by many other factors than health needs. The development in the salaries of medical staff is one of crucial

parameters. A known relation between national health expenditures and gross domestic product provokes the question whether the population ageing is really such an important factor.

I conclude that an economic impact of the population ageing is not as bad as it is usually presented. From an economic point of view, positive economic growth rates and efficiency gains in the health sector have a potential to moderate the effects of ageing as well as other factors with negative economic impact. In the year 2030, both the population and the health care will be different from what we know today. There is a possibility of securing the comprehensive and universal health system in the Czech Republic in the future, which seems to be likely for other European countries as well (Lagergren and Batljan, 2000; Wanless, 2002).

References

1. Czech Statistical Office, 1999. *Projekce obyvatelstva České republiky do roku 2030*, Prague. (in Czech)
2. Institute of Health Information and Statistics of the Czech Republic, 1996–2002. *Czech Health Statistics Yearbook 1995–2001*, Prague.
3. Lagergren, M., Batljan, I., 2000. *Will There Be a Helping Hand? Macroeconomic scenarios of future needs and costs of health and social care for the elderly in Sweden 2000–30*, Stockholm.
4. General Health Insurance Fund of the Czech Republic, 2001. [Annual Report of General Health Insurance Fund of the Czech Republic 2000], Prague. (in Czech)
5. Wanless, D., 2002. *Securing our Future Health: Taking a Long-Term View*, Final Report.

HEALTH SERVICES

OPTIMIZING THE PLATELET SUPPLY CHAIN IN NOVA SCOTIA

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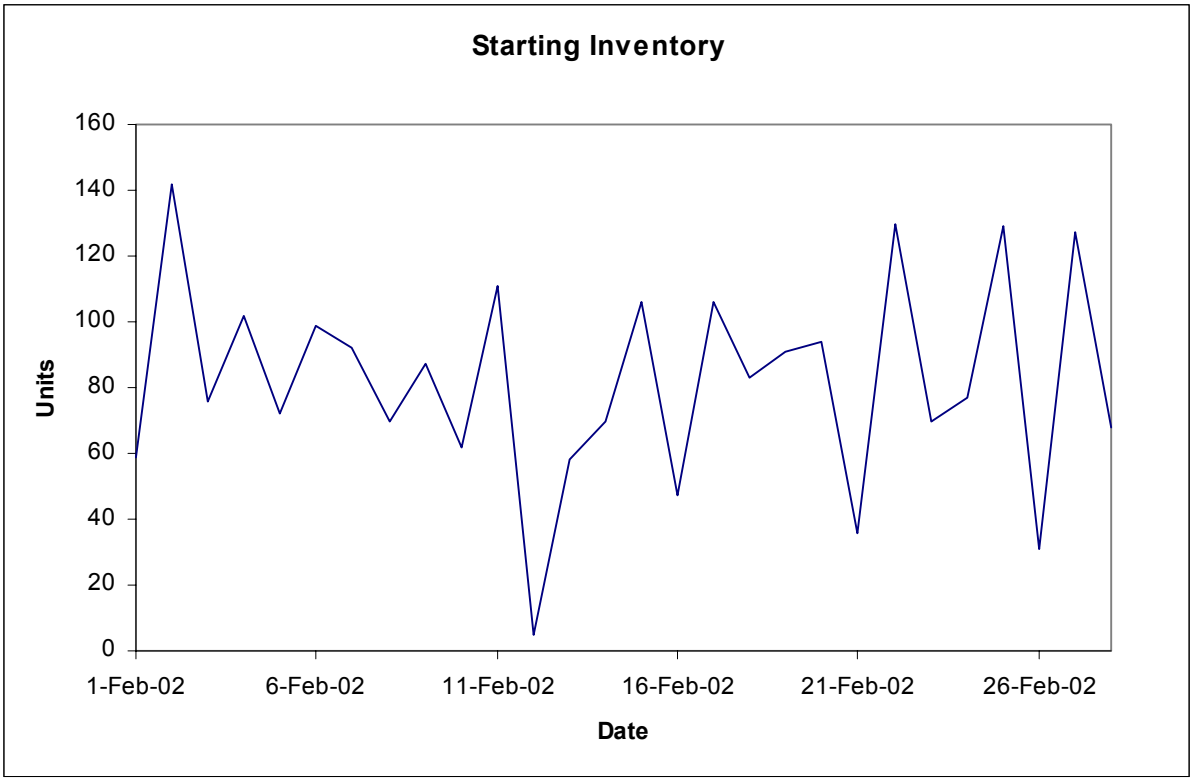
Abstract: This paper describes a methodology for determining local inventory ordering policies for platelet suppliers. The model is based on a dynamic programming approach to a perishable inventory problem and the assumption of a market-free supply chain for blood and blood products. Operational and implementation issues are discussed. Finally, results are presented that indicate a dynamic programming approach to order management is feasible and has the potential to lower costs by 18%, while decreasing wastage and shortage rates.

1. Introduction

Platelets are blood cells that initiate the haemostatic plug that causes blood clot formation. Patients receiving intense chemotherapy or suffering massive bleeding complications require platelet transfusions for the prevention of a potentially fatal haemorrhage. A stable, readily available inventory of platelets is required for the safe and effective delivery of care in all tertiary medical facilities. Platelets are typically produced from whole blood through a process that separates blood into three main products: red cells, plasma, and platelets. Platelets can also be collected through apheresis, a donation process that removes platelets and some plasma from a donor's blood, and returns the remaining red cells and plasma back to the donor's system.

Platelets, which must be kept warm to remain viable, are subject to the bacterial contamination, and thus have a shelf life of only 5 days. This short shelf life poses a number of inventory management problems, both in theory and in practice. Furthermore, since transmissible disease testing, component processing, nucleic acid testing, and blood bank testing can require up to 24 hours to complete, platelets are generally available for transfusion for 96 hours before they must be discarded. (By comparison, red blood cells have a shelf life of 42 days.) The short-shelf life and random nature of both platelet supply and demand make it difficult to establish and maintain consistent reserves to handle unforeseen contingencies. As a result, platelet inventories tend to experience both periods of over-supply and shortage. See Figure 1.

Figure 1: Sample Starting Initial Inventory Levels



In all parts of Canada, except the Province of Québec, blood products are collected by Canadian Blood Services (CBS) from unpaid volunteers and provided free-of-charge to accredited health care facilities. Blood services in the Province of Québec fall under the aegis of Hema-Québec (Canadian Blood Services, 2002). CBS is federally mandated and is regulated through Health Canada's Department of Biologics and Radiopharmaceuticals. However, within the Canadian constitutional framework (Canada, 1867), health care is a provincial responsibility and thus funding for CBS is a provincial responsibility. Provincial Ministers of Health are responsible for the overall expenditure of public funds by CBS in delivering the blood program and for selecting a Board of Directors for CBS, but do not have the power to direct operational decisions of the Board or CBS staff (Canadian Blood Services, 2002). Total expenditures for CBS in 2001/02 were $687 million ($CAN); CBS collected approximately 800,000 units of whole blood, as well as 40,000 units of plasma via plasmapheresis and 20,000 units of platelets via plateletpheresis during that period (IBM, 2002).

Within the provinces of Nova Scotia (NS) and Prince Edward Island (PEI), Canadian Blood Services maintains two permanent blood collection centres, a permanent plasma collection centre, and a fleet of mobile collection facilities that tours the province. The blood supply chain in NS/PEI is tightly coupled. In

2001/02 approximately 18,000 units of platelets were collected and shipped to 41 facilities in the province. However, 70.3% of all platelets collected in Nova Scotia and PEI were distributed through two tertiary care facilities located in Halifax.

2. Problem Statement

In the Canadian blood supply chain, traditional market mechanisms for supply chain coordination are absent. Additionally, because of regulatory controls that enforce organizational separation, no one body fully controls inventory and ordering policy throughout the entire supply chain. Nevertheless, all health care expenditures within the blood supply network are derived from the public purse. In this environment it is natural to assume that coordinated policies would provide for better system performance than would be the case if each party in the supply chain acts independently.

In 2001 the Nova Scotia government funded a project to investigate mechanisms to coordinate the platelet supply chain between CBS and local hospitals. The project consisted of three phases. The first phase of the project involved the development of a platelet repository to store information necessary for an integrated planning model; the second phase involved development of a dynamic programming model to identify locally optimal ordering policies for both the producer (CBS) and consumers (hospitals); the third phase of the project encompassed the creation of a simulation model to evaluate integrated order policies, for both the producer and the consumer, once optimal local policies have been identified. In this paper we will discuss the results of the second phase of the project: the dynamic programming model to local inventory policies. For brevity, this paper discusses only the model applicable to the platelet producer.

At first glance inventory and ordering decisions appear to be a simple matter. Each day, when managers review their system, they must answer the simple question, “Do we order platelets today, and if so, how many?” In an operational environment a good policy would satisfy three goals: it would minimize wastage, maximize service levels, and minimize the overall cost operations. Of course, these objectives are contradictory. Therefore, the identification of a good policy that balances wastage, shortage, and costs is a key concern for decision makers.

3. Literature Review

Blood bank management and inventory policies have been the focus of operational research for at least three decades. Much of the literature notes the

difficulty of developing optimal inventory policies for perishable goods because of the computational complexity involved in carrying forward a large state vector describing the age of the stock at each decision point. Thus, the use of heuristic techniques to set appropriate inventory policies under a variety of conditions is frequently discussed.

Perishable inventory models can be divided into two categories, depending on the lifespan of the item under consideration. Fixed lifetime models consider the situation where goods are considered useful for a fixed and known lifetime (m) after which their utility essentially drops to zero through natural processes, or legal statute, and the unit must be discarded. Fixed lifetime models are typically applied to problems in blood banking and inventory. Variable lifetime models deal with situations where either the remaining lifetime of the product is not known and cannot be determined or where the utility of the item declines in a random fashion as the unit ages. Variable lifetime models are typically applied to problems involving fresh produce and radioactive materials (Nahmias, 1977). This review will focus on fixed lifetime models.

Veinott (1965) describes a periodic review policy under the assumption of stationary demand. Results show that optimal ordering policies for perishable inventory correspond closely to the non-perishable case. Optimal order quantities are set as:

$$Min\,(Q^{*}, \lambda m)$$

where Q* is the economic order quantity, λ is the demand rate, and *m* is the lifetime. Under this restrictive set of assumptions, no units expire. In another early work, Pierskalla and Roach (1972) use a dynamic programming formulation to show that FIFO policies are optimal in perishable inventory problems.

Fries (1972) describes a dynamic programming approach to perishable inventory policies under the assumption of no backordering. Ordering policies in this case depend on the stock on hand, its age distribution, and the length of the planning horizon. Fries considers three specific cases. In instances where the shelf life (m) of the product is one period, the problem reduces to that of the well-known newspaper vendor problem. When the shelf life is two or more periods and the planning horizon (n) is one day, the optimal policy is an (s, S) type policy where a quantity of product is ordered to bring the inventory on hand up to a critical value x*. When the planning horizon is $1 < n < m$ the ordering policy is an (s, S) policy, where an order is placed to bring the total usable inventory on hand in the next period up to y*, where y* depends on the age of the stock on hand. When the planning horizon is greater than the lifespan of the product, the

optimal ordering policy is based on the expected number of units to be consumed in the next period and the age distribution of the remaining stock.

Nahmias (1975) adopts a similar approach to Fries, but notes the extreme difficulty of computing optimal policies when m is greater than two days. In place of exact solutions, Nahmias argues for the use of heuristic solutions (1977, 1978). Nahmias (1982) later summarizes this work, as well as other relevant perishable inventory literature.

Prastacos (1981) describes a model for managing red cells with the context of a regional blood bank. This model assumes that the regional centre produces stock continuously, but releases it to hospitals at fixed intervals. If demand at one location exceeds inventory, excess demand is either lost or supplied from outside the region at additional cost. No transhipment of product is permitted during a particular inventory period, but excess units are returned to the regional centre for redistribution at the end of every inventory cycle. Under these assumptions, Prastacos shows that any policy minimizing an average shortage also minimizes expected outdates. In a later paper Prastacos (1984) provides an overview of the issues and the relevant literature relating to all aspects of blood bank management.

Cohen and Pierskalla (1979), acknowledging the problem of a priori shortage rates, suggest a simple decision rule that obviates the need for managers to set explicit rates in the case of red blood cell supply. Using regression techniques in combination with simulation methods, they develop a target inventory level S* that depends on daily demand, average transfusion to cross match ratio and cross match release period. Brodheim et al (1976) adopt a similar approach, but suggest an equation for setting target inventory that depends on mean daily demand in conjunction with an explicit management decision regarding acceptable shortage rates. Brodheim and Prastacos (1979) in a later paper, describe a model for setting hospital inventory policies under the assumption of a fixed delivery schedule from the regional blood bank.

Freidman et al (1982) describe the use of simulation to set inventory levels for red blood cells under the assumption of an extended 35-day shelf life. Describing blood management policies from a clinician's standpoint, they argue against the setting of a priori shortage rates common in the operations research literature. Instead they suggest an empirical approach to inventory policy in which safety stocks are gradually reduced.

Hesse, Coullard, Daskin, and Hunter (1997) describe an application of inventory management techniques to platelets in a system in which a centralized blood bank supplies 35 client hospitals. Hesse et al. adopt the framework of a period

review model and develop (s, S, t) policies for each of the client institutions, using a simulation model as a test platform. Noting the complexity of a dynamic programming approach, the authors aggregate institutions into risk pools and develop, via an enumerative process, an (s, S, t) policy for each pool.

Sirelson and Brodheim (1991) use simulation to test platelet ordering policies for a blood bank, based on average demand and a fixed base stock level. They show that a base stock level based on a mean demand plus a multiple of standard deviation can be used to reduce current outdate and shortage rates. They also show that, on a regional level, low shortage and outdate rates can be readily obtained; within individual hospitals low outdate and shortage rates are more difficult to achieve. Katz et al.(1983) report similar results.

In addition to work in perishable inventory theory, a number of additional models of blood product management appear in the literature. Popp and Vollert (1984) describe a strategic planning model making use of integer programming to minimize the cost of collecting blood products subject to capacity constraints and donor availability. Pink et al. (1994) provide a retrospective analysis of outdate rates in New South Wales. Kendall and Lee (1980) describe a goal programming model to set ordering policies for hospitals within a regional network.

4. Producer's Model

Consider the platelet producer's problem. In this problem, a blood product producer collects units (either whole blood or apheresis units) from donors. The units are processed (i.e. spun to separate platelets from other blood components) if necessary, tested, labelled, and prepared for release. Production, testing, and preparation for release require a minimum of one evening to complete. Collections are available five days per week, typically Monday through Friday. Demand occurs seven days per week.

The typical ordering cycle is as follows. At the beginning of each day, the inventory state, comprised of the total number of units available and their age distribution, is observed by the decision maker. The decision maker then places an order for platelets to be collected during the day. We assume that the order for collections must be placed at the beginning of the day before demand is observed. This corresponds to the planning problem faced by most blood product producers, who must set aside platelet specific collection equipment and consumables and establish platelet collection schedules for their clinics each day, prior to the start of those clinics. Collections are assumed to be deterministic. A cost for placing an order is assumed.

Over the day demand is observed. Demand is assumed to be random and to be unknown by the producer prior to its realization. (In our model we will assume production losses and product discards for quality control purposes are included in demand.) The producer fills demand from available stock, starting with the oldest stock on hand. If orders cannot be filled from available stock, then units must be imported from other producers outside of the region. An expedite cost is associated with shipment of units from out of region producers. Expedited units are assumed to arrive instantaneously. The day then ends.

At the end of each day, all stock remaining in inventory is "aged" by one day. For example, stock that will expire in two days becomes stock that will outdate in one day. Any remaining stock with one day to outdate becomes stock with zero days to outdate and is thus "outdated" and removed from inventory. A disposal cost, corresponding to a cost to incinerate the unit, is incurred if stock is outdated. Finally, stock that was ordered today becomes available for use and enters inventory as five day to outdate stock.

The problem the decision maker faces is to select an appropriate order today that will minimize not only the cost of operations today, but also the cost of operations for some number of periods into the future.

4.1 Producers' Model

The producer's problem may be formulated as a dynamic programming problem. Accordingly, let us define the following:

Parameters

t = (0, 1, 2, …, T) represent the planning horizon (in days).

x_i represent the amount of inventory on hand that will outdate in exactly i (i = 1, 2, …, 5) periods. Thus $x = (x_1, x_2, x_3, x_4, x_5)$ is a vector describing the age of all stock on hand at the beginning of a given period. Note here that the "youngest" stock is age 5 and the "oldest" stock is age 1.

w_j be the total amount of stock on hand at the start of a given period of age j (j = 1, 2, …, 5) or less, where

$$w_j = \sum_{i=1}^{j} x_i$$

For example, if x = (10, 20, 0, 20, 0) then, w_1 = 10, w_2 = 30, …, w_5 = 50.

d_t be demand on day t, where d_t is a random variable.

$p_t(d_t)$ be the probability demand = d_t on day t.

Y be the maximum amount of product that may be ordered.

X be the maximum inventory that may be held at any time including collected, but not tested, units.

Decision Variable:

y = $\left(0, 1, 2, ..., Min\left(Y, \left(X - w5\right)^{+}\right)\right)$ be the amount of stock to order. y is constrained to fall within the range of 0 and the minimum of either the maximum order size (Y) or the remaining inventory capacity $(X - w_5)^{+}$, where remaining inventory capacity is constrained to be a non-negative number. For example, if maximum order size is 60, maximum inventory is 80 and a total of 50 units of age 5 days or less are in stock, then the maximum order size is $Min\left(60, \left(80-50\right)^{+}\right) = 30$. The notation $(80\text{-}50)^{+}$ indicates the maximum of the quantity in the brackets or 0.

Cost Functions:

Let us assume the existence of the following cost functions.

1. Order cost: The cost of placing an order, which is defined as follows:

$$O(y) = \begin{cases} 0 & \text{if } y = 0 \\ k_o + v_o y & \text{if } y > 0 \end{cases}$$

Where k_O is the fixed cost of placing an order.
v_O is the variable (per unit) cost of placing an order.
y is the order.

2. Holding cost: The cost of holding inventory, which is defined as follows.

$$H(n) = \begin{cases} 0 & \text{if } n = 0 \\ k_H + v_H n & \text{if } n > 0 \end{cases}$$

Where k_H is the fixed cost of holding any units in inventory.
v_H is the variable (per unit per period) cost of holding inventory.
n is the number of units in inventory.

3. Expediting cost: The cost of obtaining inventory from external sources, should demand exceed locally available inventory.

$$E(z) = \begin{cases} 0 & \text{if } z = 0 \\ k_E + v_E z & \text{if } z > 0 \end{cases}$$

Where k_E is the fixed cost of placing an expedite order.
v_E is the variable (per unit) cost of an expedited order.
z is the number of units to be expedited.

4. Disposal cost: The cost of disposing of an outdating unit, which is defined as follows.

$$U(g) = \begin{cases} 0 & \text{if } g = 0 \\ k_U + v_U g & \text{if } g > 0 \end{cases}$$

Where k_U is the fixed cost of disposing of a batch of outdating units.

v_U is the variable (per unit) disposal cost.
g is the number of units to be disposed.

5. Boundary cost: A penalty cost associated with variances from user specified inventory bounds.

$$B(r) = \begin{cases} v_B^{+1}\left(r - B^{+1}\right) & \text{if } r > B^{+1} \\ v_B^{0}\left|r - B^{0}\right| & \text{if } B^{+1} <= r <= B^{-1} \\ v_B^{-1}\left(B^{-1} - r\right) & \text{if } r < B^{-1} \end{cases}$$

Where
B^{+1} is a preferred upper bound on starting inventory
B^{0} is a preferred target starting inventory
B^{-1} is a preferred lower bound on starting inventory
v_B^{+1} is a per unit penalty cost for starting inventory in excess of B^{+1}
v_B^{0} is a per unit penalty cost for variations in starting inventory from the target value of B^{0}
v_B^{-1} is a per unit penalty cost for starting inventory below B^{-1}
r is the total amount of inventory on hand.

Dynamic Programming Recursion

If $t = T$:

$$f_T(\mathbf{x}) = \min_y \left\{ O(y) + \sum_{d_T=0}^{\infty} p_T\left(d_T\right) \left[\begin{array}{l} U\left(w_1 - d_T\right)^+ + \\ E\left(d_T - w_5\right)^+ + \\ H\left(\left(w_5 - d_T\right)^+ + y\right) + \\ B\left(\left(w_5 - d_T\right)^+ + y\right) \end{array} \right] \right\} \quad (0.1)$$

If $t < T$:

$$f_t(\mathbf{x}) = \min_y \left\{ O(y) + \sum_{d_t=0}^{\infty} p_t(d_t) \left[\begin{array}{l} U\left(w_1 - d_t\right)^+ + E\left(d_t - w_5\right)^+ + \\ H\left(\left(w_5 - d_t\right)^+ + y\right) + \\ B\left(\left(w_5 - d_t\right)^+ + y\right) + \\ f_{t+1}\left(\begin{array}{l} \left(x_2 - \left(d_t - w_1\right)^+\right)^+, \\ \left(x_3 - \left(d_t - w_2\right)^+\right)^+, \\ \left(x_4 - \left(d_t - w_3\right)^+\right)^+, \\ \left(x_5 - \left(d_t - w_4\right)^+\right)^+, \\ y \end{array} \right) \end{array} \right] \right\} \qquad (0.2)$$

Equation (0.1) describes the end of the planning horizon decision. The equation represents a decision in which a value of *y* must be selected to minimize a cost function consisting of five elements: order cost$\left(O(y)\right)$, disposal cost$\left(U\left(w_1 - d_T\right)^+\right)$, expedite cost$\left(E\left(d_T - w_5\right)^+\right)$, holding cost$\left(H\left(w_5 - d_T\right)^+ + y\right)$, and boundary cost$\left(B\left(w_5 - d_T\right)^+ + y\right)$. Since disposal cost, expedite cost, holding cost, and boundary cost are dependent upon the experienced demand, the expectation of these elements is taken over all possible values of d_T. Order costs, which are independent of demand, are simply *O(y)*. Disposal cost $\left(U\left(w_1 - d_T\right)^+\right)$ is charged for any unit of age 1 remaining in stock at the end of the period. Holding cost$\left(H\left(w_5 - d_T\right)^+ + y\right)$ is charged on all elements remaining in inventory at the end of the period, including any units just ordered units. (Units are assumed to be "in stock" immediately upon ordering, but are not available for use until one period after their collection. This delay simulates the delay incurred for testing and production purposes.) A bounds cost $\left(B\left(w_5 - d_T\right)^+ + y\right)$ is charged on inventory remaining in stock at the end of the period.

Equation (0.2) describes the inventory ordering decision made at periods $t < T$. Like (0.1) equation (0.2) describes a decision in which a value of *y* must be selected to minimize a cost function. The elements of this cost function are

essentially the same as (0.1): order cost, disposal cost, expedite cost, holding cost, and boundary cost, with the addition of the cost to go function, which represents the cost of arriving in period *t+1* with a particular inventory vector *x*. The cost to go function, $f_{t+1}\left(\left(x_2 - (d_t - w_1)^+\right)^+, \left(x_3 - \left(d_t - w_2\right)^+\right)^+, \left(x_4 - \left(d_t - w_3\right)^+\right)^+, \left(x_5 - \left(d_t - w_4\right)^+\right)^+, y\right)$, is dependent on the actual demand realized and thus, the expectation of this function is taken over all values of d_t. The inventory states are updated for a given value of d_t by taking the stock currently on hand for a particular age (say for example x_3) and subtracting from this value any demand which has not been satisfied by older stock $\left(w_2 - d_t\right)^+$. Because negative inventory is not possible, the greater of either this quantity or 0 becomes the starting inventory of age *i-1* in the next period.

For example, assume that on a particular day *t* a starting inventory of *x* = (10, 20, 0, 20, 0) is observed. Assume, furthermore that we are considering an order size *y*=30 and that in a particular instance of demand d_t is 15 units. In this example, we would expect the 10 units of demand to be drawn from the oldest stock (x_1) and five units to be drawn from the second oldest stock (x_2). In addition we would expect an order for *y*=30 units to be issued. At the end of day *t*, the remaining x_1 inventory will be outdated and the inventory vector for day *t+1* will be (15, 0, 20, 0, 30). Employing the Bellman optimality principal and working backwards in our planning horizon, the cost to go for a particular inventory vector $f_{t+1}(x)$ on day *t+1* is always known. Thus, to solve the inventory ordering problem, we simply solve equations (0.1) and (0.2) until we arrive at $f_0(x_0)$ where x_0 represents the starting inventory on the beginning of the planning horizon.

4.2 Implementing the Producer's Model

It has long been recognized that blood inventory and ordering problem can be formulated as a dynamic programming problem and solved optimally (see Fries (1972) or Nahmias (1975)). However, it has also been acknowledged that the curse of dimensionality, which affects all dynamic programming problems, makes an exact solution to a practical blood inventory problem difficult. As a result, many authors have formulated the platelet problem as a dynamic program and then gone on to adopt heuristics or solved approximate problems using other analytical techniques.

In this application it was decided to implement an approximate solution to the problem within the framework of dynamic programming. The application problem size, which is by Canadian standards moderate, makes dynamic programming potentially feasible. In the CBS NS/PEI example, a total inventory size of less than 400 units is common with order sizes in the range of 4-180 units

per day. The limited scope makes the problem potentially solvable, if not in real time, then with modest computational requirements. Finally, it was noted, that in practice it is uncommon for either producers or consumers to deal in single unit quantities of platelets. A typical adult dose for platelets is 1000 ml; the average volume of platelets available from a unit collected via a random donation process is approximately 200 ml. Thus, adults typically require five random units per dose. Amalgamating units in batches of five, therefore, would reduce the problem size, without any practical loss of generality. Amalgamating units into batches of 10, 15, or 20 would provide approximations to the actual problem with some loss of accuracy. Thus, it follows the dynamic programming framework can be adopted as a heuristic solution approach to the platelet ordering problem if an appropriate accuracy/time trade off can be identified and if the resulting loss in accuracy does not materially affect operations of the system.

The concept of batches or "buckets", requires only minor notation changes to (0.1) and (0.2). To implement this simplification, replace y, the order quantity with y', d_t the demand on day t with d_t', and $p_t(d_t)$, the demand on day t with $p_t'(d_t')$ where:

n is the bucket size.

y' $= \left(0n, 1n, 2n, \ldots, Min\left(\left\lfloor \frac{Y}{n} \right\rfloor, \left(\left\lfloor \frac{X}{n} \right\rfloor - w_5 \right)^+ \right) \right)$ the number of units ordered.

d_t' be demand on day t where demand is constrained to be (0, 1n, 2n, …)

$p_t'(d_t') = \sum_{d_t - n + 1}^{d_t} p_t(d_t)$ be the probability that demand = d_t' on day t.

If $t = T$:

$$f_T(\mathbf{x}) = \min_{y'} \left\{ O(y') + \sum_{d_T' = 0}^{\infty} p_T'(d_T') \left[\begin{array}{l} U\left(w_1 - d_T'\right)^+ + \\ E\left(d_T' - w_5\right)^+ + \\ H\left(\left(w_5 - d_T'\right)^+ + y'\right) + \\ B\left(\left(w_5 - d_T'\right)^+ + y'\right) \end{array} \right] \right\} \quad (0.3)$$

If $t < T$:

$$f_t(\mathbf{x}) = \min_{y'} \left\{ O(y') + \sum_{d_t'=0}^{\infty} p_t'(d_t') \left[\begin{array}{l} U\left(w_1 - d_t'\right)^+ + E\left(d_t' - w_5\right)^+ + \\ H\left(\left(w_5 - d_t'\right)^+ + y'\right) + \\ B\left(\left(w_5 - d_t'\right)^+ + y'\right) + \\ f_{t+1}\left(\begin{array}{l} \left(x_2 - \left(d_t' - w_1\right)^+\right)^+, \\ \left(x_3 - \left(d_t' - w_2\right)^+\right)^+, \\ \left(x_4 - \left(d_t' - w_3\right)^+\right)^+, \\ \left(x_5 - \left(d_t' - w_4\right)^+\right)^+, \\ y' \end{array} \right) \end{array} \right] \right\} \quad (0.4)$$

5. Results

The utility of the dynamic programming approach to ordering and inventory management was tested by using the model to solve the daily ordering problem faced by CBS NS/PEI and comparing the results of the model against the operations of the actual system. To undertake this it was necessary to collect a representative data sample, prove the model in trial applications, and then compare the model's results to the actual system.

5.1 Data

Data was collected from a variety of primary sources within the Nova Scotia platelet supply chain. Inventory transactions were collected for all platelet units collected, produced, shipped, disposed, or outdated by CBS NS/PEI. All information regarding platelet unit movement, excluding donor identifier was obtained for the period Jan 1, 2002 – Oct 30, 2003. Similar transaction level data was collected from the two tertiary care centres in the province (the IWK Health Centre and the Queen Elizabeth II Health Sciences Centre). Hospital data covered the period from Jan 1, 2002 – Oct 30, 2003 and excluded only patient identifiers (names, hospital numbers, and insurance numbers). Transaction level data from the platelet producer and two major consumers in the province was then used to create a relational database in Microsoft Access. Altogether, the

database contains a complete list of all platelet units collected, produced, shipped, transfused, or disposed in the provinces of Nova Scotia and PEI. Complete transaction data from collection through transfusion or disposal is available for 70.3% of all platelet units (i.e. those units flowing through the two tertiary centres). Data for units flowing through non-tertiary sites is available up until such time as the units are shipped from the producer to the consumer. Since non-tertiary centres do not regularly keep stocks of platelets, we assume in our model that all units shipped to non-tertiary sites are transfused immediately upon receipt. This assumption corresponds to an "order only as necessary" policy common for non-tertiary sites.

The Access database was validated by comparing reports derived from the populated database against summary data produced independently by CBS and the tertiary hospitals. CBS issues and disposals, as well as receipts and transfusions at the participating hospitals, were compared to equivalent database reports for the period from January to August of 2002.

Table 1 shows issues data extracted from the database and corresponding levels reported by CBS. The average difference between database output and reported units issued was 0.1%; monthly differences did not exceed 0.4%. A similar set of tests was run on CBS disposal data. The average difference was 1.2% and monthly differences did not exceed 6.7%, are based on average monthly volumes of 1517 units issued and 321 units disposed in total.

Table 1: Units Shipped Actual vs. Database

Month	Units Shipped (Actual)	Units Shipped (Database)	Difference
January	1609	1610	-0.1%
February	1213	1209	0.3%
March	1363	1363	0.0%
April	1158	1158	0.0%
May	1771	1764	0.4%
June	1830	1831	-0.1%
July	1683	1685	-0.1%

Cost data was collected from both the platelet producer and platelet consumers. Operational inventory-related costs were determined for the platelet supplier from direct observation of work cycles, analysis of transportation and shipping data, management reports, and, where no other data existed, expert opinion. Table 2 summarizes cost data used in the model.

Table 2: Inventory Costs

Item	Type	Cost
Order	Fixed	21.85
	Variable	0
Expedite	Fixed	100.00
	Variable	0
Holding	Fixed	0
	Variable	0.05
Disposal	Fixed	10.00
	Variable	0.45

5.2 Testing

The accuracy of the model proposed in Equations (0.5) and (0.6) is a function of the planning horizon (T) and the bucket size (n). As $T \rightarrow \infty$ and $n \rightarrow 1$ the accuracy of the model will improve, obtaining the optimal solution when $T=\infty$ and $n=1$. Unfortunately, as T increases and n decreases, the time required to run the model also increases. See Table 3a–3c for a description, solution results, and run times of a pilot run of the dynamic programming model on a small, simple problem.

Table 3a: Parameter Values (Pilot Run)

Parameter	Value
Demand:	Uniform(0,20)
Initial Inventory	(0, 0, 20, 0, 0)
Maximum Inventory	40
Maximum Order	20

Table 3b: Bucket Size and Planning Horizon vs. Run Times (Pilot Run)

	Bucket Size			
Horizon	1	5	10	20
1	0:00:00	0:00:00	0:00:00	0:00:00
2	0:00:00	0:00:00	0:00:00	0:00:00
3	0:00:10	0:00:00	0:00:00	0:00:00
4	0:00:31	0:00:00	0:00:00	0:00:00
5	0:02:33	0:00:01	0:00:00	0:00:00
6	0:31:03	0:00:03	0:00:02	0:00:00

Table 3c: Bucket Size and Planning Horizon vs. Expected Average Daily Cost (Pilot Run)

	Bucket Size

Horizon	1	5	10	20
1	0.50	0.50	0.50	0.50
2	*12.18*	*12.18*	*12.18*	*12.18*
3	*13.11*	*13.05*	*12.69*	*12.71*
4	*13.97*	*13.70*	*13.17*	*12.61*
5	*14.70*	*14.47*	*14.08*	*13.14*
6	*16.19*	*15.69*	*15.05*	*13.26*

Tables 3 show solution times increase as both bucket size decreases and planning horizon increases. All run times shown in Table 3b were completed on a 2 GHz computer with 1024 MB of memory running Windows XP. The programming language used to code the model was MS Visual Basic 6.0. Problems with large run times (in bold type) in Table 3b exceeded available RAM memory. In these runs physical disk space was utilized, via a database, in place of arrays in memory to store intermediate problem results. As a result of the requirements to physically read and write to disk, solution time for these runs is much larger than for other runs.

The quality of the solutions returned by the model (Table 3c) also increases as bucket size decreases and the planning horizon increases. The italicized figures represent runs where the model returned a solution value of y=20. The figures in the table represent the model's estimate of average daily inventory costs. As the planning horizon increases, the average expected inventory cost associated with the optimal solution to the problem converges to a value of $16.19. From this observation, we can conclude that for a sufficiently large problem solution horizon and a sufficiently small bucket size an optimal (or near optimal) solution can be found.

5.3 Comparison Results

The model was then compared in a simulated environment to the function of the real world system upon which it is modelled. The period between January 15, 2003 and March 15, 2003 was selected for the comparison, since this period represents an era of relatively normal operations for the blood producer and blood consumers in the platelet supply chain.

The model was initialized with the actual on-hand inventory vector observed at the platelet producer on January 15, 2003. The model was then run to determine a recommended order size for that day. The model experienced the same demand for platelets as was experience by the platelet producer. (Demand here includes all shipments of platelets to hospitals, inventory losses due for quality control testing, and regular production losses.) The model filled demand, if units were available, from available stock. If units were not available, an expedite

order was placed. The day then ended. All remaining inventory was aged one day. Holding costs and disposal costs were then determined. Once all transactions were complete, the daily cost for running the inventory system were tallied and recorded. Time advanced to the next day and the simulated ordering process repeated. The actual system, during the period used in the comparison test, experienced daily demand that ranged from 15 to 125 units. Inventory levels fluctuated between 32 and 192 units. A total of 143 units outdated during this period. No expedited units were required during this period. The average daily inventory cost experienced by CBS NS/PEI during this period, as determined by the cost structure in Table 2 was $25.98. Table 4, by comparison, shows the average daily inventory costs that would have been experienced by CBS NS/PEI, had inventory decisions been based on the recommendations from the dynamic programming model.

Table 4: Average Daily Inventory Cost vs. Bucket Size and Planning Horizon

	Bucket Size		
Horizon	10	20	30
3	50.40	43.07	27.13
4	24.50	24.20	25.51
5	21.33	24.05	24.17

As can be seen from Table 4, the dynamic programming model produces solution values that outperform the manual solution in instances where the bucket size is small (i.e. n < =20) or the planning horizon is long (T>= 4). At a bucket size of 10 and a planning horizon of 5, the model provides an 18% improvement over the actual system when measured by average daily inventory cost. A paired t-test comparing model results to actual indicates that this value is significant at a level of α =0.02. In addition to the lower average daily inventory cost, the model produces a lower number of outdates (2.83/day for the actual system; 1.37/day for the model). Neither the actual system, nor the model, experienced any shortages over the test period.

Table 5: Run Times (secs) vs. Bucket size and Planning Horizon

	Bucket Size		
Horizon	10	20	30
3	18.20	1.73	0.68
4	50.28	4.43	1.47
5	172.00	10.28	2.78

Table 5 shows the times required to generate these solution values. From this we can see that only modest computational requirements (<3 minutes) are necessary to generate a good solution value for the practical problem facing a platelet

producer. Accordingly, we conclude that it is possible to use a dynamic programming framework to solve the platelet inventory ordering problem.

6. Conclusions

In this paper a dynamic programming framework is adopted for solving the perishable inventory problem faced by platelet producers. A review of the literature shows that a dynamic programming approach to platelet inventory management has been proposed, but never implemented, due to concerns over intractability when a practical problem is solved. We adopt a simplification in which orders and demand are aggregated into larger units ("buckets") as a method of reducing the problem search space and hence improving problem tractability. We demonstrate in a pilot that the quality of the solution obtained depends on the size of the bucket and the length of the time horizon. We then show that this approach can be applied to a practical problem. With modest run times (less than 3 minutes per day), it is possible to generate decisions that will decrease costs by at least 18% while maintaining lower outdate and shortage rates.

References

1. Brodheim, E., Hirsch, R. and G. Prastacos, 1976. Setting Inventory Levels for Hospital Blood Banks. *Transfusion*, 16:63–70.
2. Brodheim, E. and G. Prastacos, 1979. A Regional Blood Management System with Prescheduled Deliveries. *Transfusion*, 19:455–462.
3. Canada. Constitution Act. Statute, Government of Canada, 1867. (Downloadable from http//:www.http://laws.justice.gc.ca/en/index.html).
4. Canadian Blood Services, 2002. Governance Structure, Web Site, Canadian Blood Services, Ottawa. (Downloadable from website http://www.bloodservices.ca)
5. Cohen, M.A., Pierskalla, W.P, Sassetti, S., and J. Consolo, 1979. An Overview of a Hierarch of Planning Models for Regional Blood Bank Management. *Transfusion*, 19:526–534.
6. Friedman, B.A., Abbott, R.D., and G.W. Williams, 1982. A Blood Ordering Strategy for Hospital Blood Banks Derived from a Computer Simulation. *American Journal of Clinical Pathology*, 78:154–160.
7. Fries, B.E., 1972. Optimal Ordering Policy for a Perishable Commodity with Fixed Lifetime. *Operations Research*, 23:46–61.
8. Hesse, S.M., Coullard, C.R., Daskin, M.S, and A.P. Hurter, 1997. A Case Study in Platelet Inventory Management. *Proceedings of the 6th Industrial Engineering Research Conference*. Edited by B. Bidanda and S. Jaydale. Atlanta: Institute of Industrial Engineers.

9. IBM. Performance Review of Canadian Blood Services: Final Report. Policy Paper. IBM, October 15, 2002. (Downloaded from website http://www.bloodservices.ca).
10. Katz, A.J., Carter C.W., Saxton P., Blutt J., and R.M. Kakaiya, 1983. Simulation Analysis of Platelet Production and Inventory Management. *Vox Sang*, 44:31–36.
11. Kendall, K.E. and S.M. Lee, 1980. Formulating Blood Rotation Policies with Multiple Objectives. *Management Science*, 26:1145–1157.
12. Nahmias, S., 1975. Optimal Ordering Policies for Perishable Inventory. *Operations Research*. 23:735–749.
13. Nahmias, S., 1977. On Ordering Perishable Inventory When Both Demand and Lifetime are Random. *Management Science*, 24:82–90.
14. Nahmias, S., 1978. The Fixed Charge Perishable Inventory Problem. *Operations Research*, 25:630–640.
15. Nahmias, S., 1982. Perishable Inventory Theory: A Review. *Operations Research*, 30:680–708.
16. Pink, J., Thomson, A., and B. Wylie, 1994. Inventory Management in Sydney Public Hospital Blood Banks. *Transfusion Medicine*, 4: 237–242.
17. Popp, W. and H. Vollert, 1985. Methods of Strategic Planning for Blood Services. *Haemotology*, 18:151–163.
18. Prastacos, G.P., 1981. Allocation of a Perishable Product Inventory. *Operations Research*, 29:95–107.
19. Prastacos, G.P., 1984. Blood Inventory Management: And Overview of Theory and Practice. *Management Science*, 30:777–800.
20. Pierskalla, W.P., Roach, C.D., 1972. Optimal Issuing Policies for Perishable Inventory. *Management Science*, 18:603–614.
21. Sirelson, V., Brodheim, E., 1991. A Computer Planning Model for Blood Platelet Production and Distribution. *Computer Methods and Programs in Biomedicine*, 35:279–291.
22. Veinott, A.F., 1965. Optimal Policy for a Multi-Product, Dynamic Non-Stationary Inventory Problem. *Management Science*, 12:206–222.

A VIRTUAL CLINIC USING VR AND DISCRETE-EVENT SIMULATION TECHNIQUES

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Abstract: This paper presents a prototype of a virtual clinic especially developed using VR techniques and Discrete-Event Simulation. Virtual Clinic is able to study many important points as: flow of patients, distribution of materials, and allocation of human resources.

1. Introduction

Operational Research (OR) is a field that has produced a great amount of new tools to improve the way to structure and to think about existing problems that happen in several segments such as industry, education, environment and health. The OR methods are usually developed through formal and abstract models that seek a mathematical or logical description of some of the main characteristics of the real system being studied. Modeling is the art of building and uses such models as tools for the analysis of alternative policies and evaluation of operations

All models are basically tools for learning. They enable the study of systems that do not exist, so as to predict complicated consequences of actions and development and to simulate experiments that are impossible or too costly to perform in reality [1]. Virtual Reality allows users to interaction naturally and intuitively with the virtual environment and its components. Thus, a Virtual Reality Model helps the Operational Research Analyst (or the final user): to see and to understand the simulation results´ performed and to allow that analyst to train personnel in special care in a simple and efficient manner [2].

The 3D scenery or the Virtual Clinic was proposed and developed using VR techniques and Discrete-Event Simulation to show many important points as: flux of patients, distribution of materials, and allocation of human resources. A model of the admission system is used to evaluate the effect of changes and variations in the flow of patients and allocation of human and material resources.

2. The Virtual Clinic

This health care system operation problem is complex and its multidiscipline characteristic involves a close contact with a wide range of activities - other than medical - including pure and applied science, technology, and economic organization. Medicine is a subject devoted exclusively to ministering to human

needs. While clinical knowledge and ability are paramount there are many real and urgent problems in organizing the restricted resources available in a clinic or a hospital environment so as to provide the community with the greatest possible benefit [3].

Admission system is considered as an important factor in controlling the costs, and increasing the effectiveness of the medical care provided. Handling of such a problem is difficult because clinic or a hospital environment administration has little information about the demand for services, and the duration of service. The flow of patients should be predicted and controlled to match the human and material resources available in the near future [1].

The construction of the virtual clinic layout was planned in such a way that the admission sector of patients does not interfere with the work routines of the care of patients which are already operating. There is a special site for the control over the admission with a different entrance/exit way and employees do that.

In this study, the patients were admitted before being introduced to this system under study. The virtual clinic does not attend to emergency. The plan of construction of virtual clinic allows creating of emergency attendance as a part of this system in the future. The virtual model has two rooms of medical care and one receptionist room. It offers care to patients in two eight-hour shifts, and two doctors in each shift supply the medical care.

3. Visual Simulation

One of the most important areas of present day technology is visualization. Graphic computing allows the models to be seen by their users in a more meaningful way and more elegantly. An animation has the capacity to communicate the essence of a simulation model [4] that possesses such characteristics as:

- Optimization of a program of simulation;
- Assistance in suggesting improvements in operational procedures or in the control of the logistics of the system; and
- Makes possible the technical training of personnel.

Even so, one animation is not complete and definitive. In particular, it does not substitute the careful statistical analysis of the output necessary for a simulation. In this case, the entire systems must be considered as valid. The changes in the logic of the problem are not interactive; it is necessary that a complete correspondence exist between the elements of the model and the elements that

are described visually on the computer screen. 3-D Visual Simulation not only is a more elegant way to visualize the problem under study, but also makes it easier for the user to see the results in a more realistic way [3].

4. Virtual Reality

The term "Virtual Reality" refers to the experience of interacting with computational systems that present a "virtual world" with simulated signals and sounds. A virtual world, i.e., a 3-dimensional environment created in a computer, is built up based on 3-dimensional graphics and audio elements. VR techniques allow for the creation of applications where a person can be immersed in a 3-dimensional environment experiencing the "real" problem [5] and having feelings very similar to those that would be felt under the true situation [2].

A virtual world is not "recorded" beforehand, it is generated in real time as the user navigates and interacts with the model. The appearance of the image reacts in accordance with the actions that are taken: whatever direction one looks, in whatever direction one moves, whatever object that one handles. The most efficient experiments with the Virtual Reality take the user closer to the data in such a way that identification with the real world is immediate [6], [2].

By means of the Virtual Reality Techniques, one tries to minimize the barrier between the simulation and the user. In these applications, the "liberty to stroll" exists, where the user may choose an angle (a better position from which to view the system), not being restricted to just some pre-defined points of view [7]. Besides this, the placement of a user in a simulated environment is, normally, much more cost-effective than placing him in a real physical environment [8], [2].

VRML [9] is the abbreviation for the 3-D standard developed to function on the Internet and stands for *Virtual Reality Modeling Language*. VRML is platform-independent language that permits the creation of 3-D scenarios wherever one might walk, visualize objects from whatever angle, and also interact with them [10]. The language was conceived to describe interactive simulations with multiple participants in virtual worlds available on the Internet and linked to the World Wide Web. VRML has a set of characteristics that make its utilization of powerful and efficient visualization tool [6]. Among them, the most important to be emphasized are low cost, hyperlink, interactivity, user-friendly browser interface and so on.

In this study, it was exploring some of the characteristics listed above, introducing in the most realistic way, the day-a-day situations that may occur during the work tasks in these care givers of the virtual clinic.

5. Methodology

Several methods are available that may be used to execute a single simulation. However, the use of a program in the development stage and simulation makes rapid development possible by means of a defined standard structure [3], [11]. This study presents development stages, discrete simulation (formulation module and simulation module), interface between discrete simulation and visual simulation, and lastly, the generation of environments in VRML [12].

The following conditions were assumed for the development of the problem:

- Objective: Simulate the care of patients;
- Environment – Patients, receptionist, and doctor (There is a special site for the control to the admission with a different entrance/exit way and employees do that. Thus in this paper, the patient is admitted before being introduced to this system under study);
- Hypotheses: The arrival of patients is independent of the situation of the system. All patients have the same time distribution of the time of stay;
- Distribution: Poisson (rate of arrival and exit);
- Exponential (care-giving).

5.1 The Formulation Module

Formulation is an important step for the simulation experiment [11]. The formulation used in this work aids in the creation of a life cycle for all entities, making the necessary tools available for the interconnection of the entities and make it possible to confirm its own integrity. A life cycle represents the relationship among entities, activities, and queues. The formulation of the problem was done using the MULTISIM program [11] that, using its own algorithms, provides an interface with the simulator. The stage of formulation of a problem has three basic modules: Entities Module, Activities Module and Queues Module.

In the Entities Module, the entities and their respective life cycles are created. The life cycle is basically a succession of alternating and successive queues and activities, the last queue being, out of necessity, the first queue, thus closing the cycle. All the Entities may be seen in Figure 1.

Figure 1: Entities

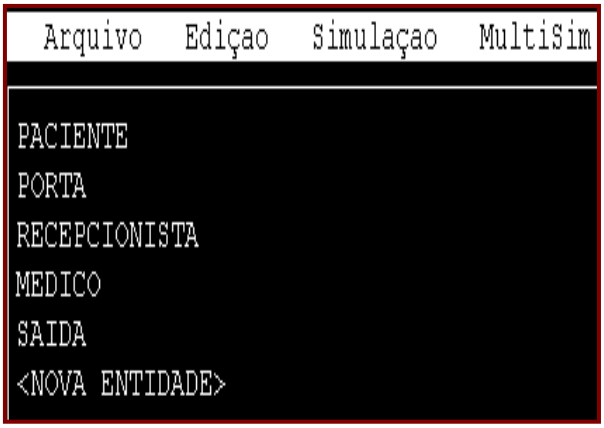
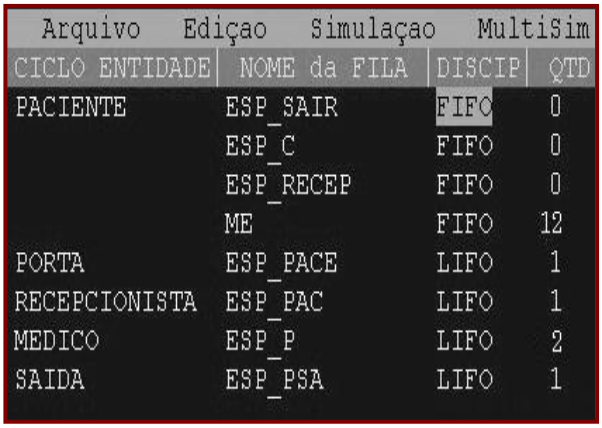
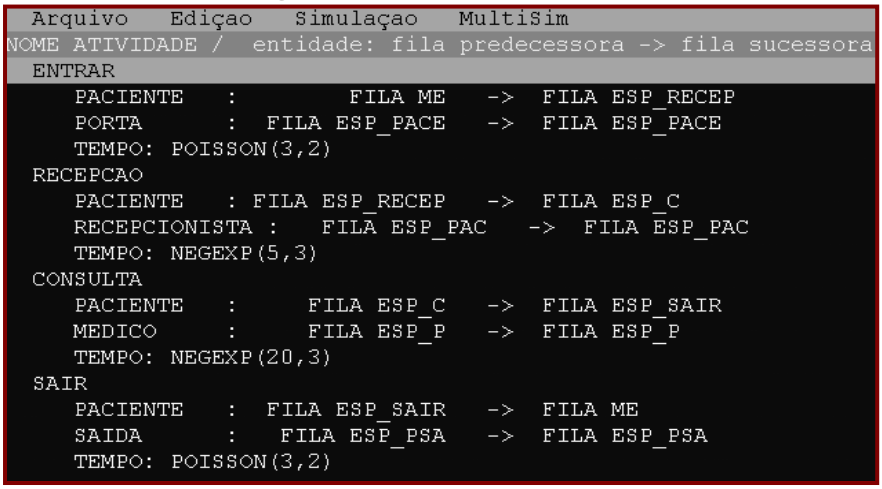


Figure 2: Queues Module



The Activities Module strings together all of the information coming from the entities module. At this point, one may confirm that the formulation is correct. For all of the activities, the entities involved are shown along with the preceding and succeeding queues. The program is interactive and permits changes in the entities module. The Activities Module may be seen in Figure 3.

Figure 3: Activities Module



The Queues Module is designed to show the queues belonging to the life cycle of the entities involved and thus permits the specification of the initial conditions. This module completes the formulation of the problem. The Queues Module may be seen in Figure 2.

5.2 Simulation Module

The simulator used was Simul [13], a computational system for Discrete Event Simulation that is comprised by two modules written in Turbo-Pascal language: a library of pre-defined routines for Discrete Event Simulation and an executive program structured according to the Three-Phase Method.

The user must fill out all questions inside the executive module questionnaire of this system considering all problem idiosyncrasies under study. The simulator has its own random number generator that uses the Method of Linear Congruence [2], which is used by most of the generators available nowadays. It also has functions and procedures that generate random values for distributions such as Normal, Negexp (exponential), Poisson, Erlang, Uniform and so on.

5.3 Interface Between The Discrete Simulation and Visual Simulation

The transition of the data requires setting up of specific positions for the principal entity being simulated. Such positions were acquired by being read directly from the data output of the simulation generated. Thus, starting at the interface, one may construct the trajectory of patients throughout the visual simulation. The organization of data for an animation is accomplished in accordance with the problem following the researcher criteria making the formulation process. Therefore, there are not general rules for this purpose, just a particular rule that fits how the viewer is to be used. The table with the transition data may be seen in the Table 1.

Table 1: Transition Data

Patient	Arrival	Reception	Medical Care	Exit	Doctor
1	415	416	480	482	2
2	419	421	483	519	2
3	422	423	491	591	1
4	425	429	520	563	2
5	429	439	564	601	2
6	433	445	592	606	1
7	438	448	602	606	2
8	447	455	607	642	2
9	451	456	607	662	1
10	465	473	643	693	2
11	482	483	663	680	1
12	485	495	681	703	1

5.4 3D Visual Model

Once the discrete simulation has been executed and the generation of the data for its animation done, the 3-D visual model representing the generated results may be constructed. For this phase the software 3DS Max™ was used [14]. The

steps executed for the construction of the visual model were the following: creation of the objects, insertion of lights and cameras, render and animation.

Throughout the process of setting-up the scenario, besides the objects constructed and the software resources themselves, some objects from other libraries [15], [16] were also used.

5.5 VR Model

At this stage one VRML model that reflecting the situations that occurred during the simulation was generated. The environment constructed in VRML came directly from the discrete simulations that were generated initially. The model was converted into environment in VRML after the creation of animations, thus the initial integrity of the simulation was maintained. The complete overview of the 3-D scene may be seen in Figure 4.

Figure 4: The Virtual Clinic

It is internal, composed of a reception room (A); two rooms for medical care, side by side (B,C); two restrooms for patients (male and female) (D,E); admittance room (with own reception room) (F); kitchen (G); employee bathroom (H); corridor (I); medical entrance separated (J); patients entrance (K) and medical relax room (L).

The next step now is the visualization of the model in VRML in software (browser/plugins) like that Blaxxun™ [17] or Cortona™ [18], which allows navigation into the model in a more interactive manner. Thus, by means of navigation into the environment, one may learn as well as perceive the diver's possibilities in the simulation.

6. Evaluations

The methodology used in this study permits a dynamic and complex system such as a clinic to be divided and modeled in a simple manner. It heps the OR analyst to present in a clearer and more objective form, thus reducing the barrier that exists between the analyst and the final user. This methodology can be easily applied to other environments and situations.

The integrity of the discrete simulation model was maintained in all processes steps described in this study. The input data for the visual simulation were obtained directly from the data resulting from the discrete simulation. Thus, the integrity of the generated VR models was preserved as well.

Some advantages may be cited that were obtained with the construction of this model in VR:

- The presentation of facilities for the OR analyst at the interface and navigation in the simulated environment;
- Unrestricted changes in view points;
- Increased realism of the environment;
- 3D compression of the physical space and its limitations during the simulation and
- Possibility of distributing the model in study groups over the Internet: thus making possible a wider disclosure of the Simulation that was made.

7. Conclusions

The study demonstrated the potential of the purpose approach; the major benefits provided by Virtual Reality application are the preservation of model integrity and the better visualization model. The virtual model showed that at low cost the interaction between Visual Simulation and the VR Techniques could clarify complicated situations in the daily practice. This is the first step in the virtual clinic; it would be interesting in the future to make a visual simulation of the section of admissions and emergency, too.

8. References

1. Gabcan, L. and M.J.F. De Oliveira, 2002. *3D Visual Simulation Applied to a Thorax Disease Hospital Project***,** presented at EURO XXVIII, Rio de Janeiro, July 29–31.
2. Gabcan, L., Santos, C.L.N., and L. Landau, 2003. *Virtual Reality as a Training Tool in a Hospital Simulation,* 2003 Summer Computer Simulation Conference, July 20–24, 807–812, Montreal, Canada.
3. Gabcan, L., 2000. *Representação Visual 3D de um Setor para a Nova Unidade do Instituto de Doenças do Tórax (IDT)*, MSc. Thesis, COPPE/UFRJ, Rio de Janeiro, Brasil.
4. Law, A.M. and W.D. Kelton, 1991. *Simulation Modeling and Analysis*, Singapore, 2nd Edition, *McGraw-Hill*.
5. Santos, C.L.N., 2001. *Ferramentas de Visualização Antropomórficas através do uso de Realidade Virtual Aplicadas a Engenharia Offshore*, D.Sc. (COPPE/UFRJ), Rio de Janeiro, Brasil.
6. Santos, C.L.N. and L. Landau, 2003. *Considerations about the Anthropomorphic User Interface to Improve the Collaborative Visualization Environments into Petroleum Applications*, Advanced Simulation Technologies Conference, Florida, USA.
7. Santos, C.L.N., Bacoccoli, G., and L. Landau, 2001. *A Review about the Anthropomorphic Visualization Environments Applied to Offshore Engineering*, The International Workshop on Harbour, Maritime & Multimodal Logistics Modeling and Simulation - HMS2001, Marseilles, France.
8. Santos, C.L.N., Cunha, G.G., Mello, L.F.N, and L. Landau, 2000. *Simulations at Petroleum Industry using Virtual Reality Techniques*, The International Workshop on Harbour, Maritime & Multimodal Logistics Modelling and Simulation – HMS200, Portofino, Italy.
9. WEB3D Consortium, 2002. *The VRML97 Especification*, retrieved from http://www.web3d.org
10. Santos, C.L.N., Cunha, G.G., and L. Landau, 2001. *Use of VRML in Collaborative Simulations for the Petroleum Industry*, The 34th Annual Simulation Symposium, Seattle, USA.
11. De Oliveira, M.J.F., 1999. *3D Visual Simulation Platform for the Project of a New Hospital Facility*, In Monitoring, Evaluating, and Planning Health Services: ORAHS'98, World Scientific Publishing, p. 39–52, Singapore.
12. Gabcan, L., Santos, C.L.N, De Oliveira, M.J.F., Cunha, G.G., and L. Landau, 2002. *Utilização de Técnicas de Realidade Virtual na Visualização de Simulação de Atendimento em Hospital,* I Workshop de Realidade Virtual e Visualização Científica do Laboratório de Métodos Computacionais em Engenharia–LAMCE/PEC/COPPE/UFRJ, http://www.lame.ufrj.br/GRVa/wrv2002.

13. Saliby, E and M. Pimentel, 1991. Simul: Um Sistema Computacional para a Simulação a Eventos Discretos em Turbo-Pascal, Rel, *COPPEAD*, Rio de Janeiro.
14. Da Silva, J.L., 2002. *3DS Max 4.2: Utilizando Totalmente*, Editora Érica, São Paulo, Brasil.
15. Mister Collection CD-Rom – Modelos para 3D Studio nº6, *Raven Multimídia*, Brasil.
16. Products of the Platinum Technology Inc., http://www.platinum.com.
17. Blaxxun Technologies, http://www.blaxxun.com
18. ParallelGraphics*, Cortona VRML Client,* http://www.parallelgraphics.com/N.B.

MODELS FOR PREDICTING CRITICAL BLOOD PRODUCT SHORTAGES[2]

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Abstract: The paper describes a study to develop prototype simulation models to predict the likelihood, and assess the subsequent medical consequences of, blood product shortages. The models account for uncontrollable factors such as random donation and patient demand, as well as policies controlling blood product expiries and hospital restocking. The complexities in blood type matching and issuing policies which depend on inventory levels were captured where appropriate. The study was conducted in three settings: urban, semi-urban and rural. The model quantifies the hourly inventory patterns of blood centers and specific hospitals, as well as predicting the risks of shortages and subsequent medical consequences of these shortages. The model was validated against inventory levels and outdates and was considered to be sufficiently accurate by the blood bank and hospital staff for use of the model as a decision support tool.

1. Introduction

Blood is a body tissue that carries oxygen and nutrients to all parts of the body and carries away waste products. Blood is composed of many components (red cells, white cells, platelets and plasma), each of which has a separate function. Red blood cells carry oxygen to tissues and are responsible for the removal of carbon dioxide through the lungs. Transfusions of red blood cells help accident victims, surgical patients and people with anemia. Platelets, which cause blood to clot and help control bleeding, are used to treat leukemia and cancer patients. All of blood components are perishable; lifetimes varying from 5 days for platelets, 35 days for whole blood, 42 for red blood cells and one year for plasma. [1]

Not all human blood is identical. Since 1940, blood has been categorized into four types: A, B, AB, and O. Additionally, each group can be subdivided by rhesus factor (positive or negative), resulting in eight distinct groups; O+, O-, A+, A-, B+, B-, AB+ and AB-. Blood types in the Canadian population vary from 38% (O+) to 0.5% (AB-). Blood transfusions are required for a variety of medical procedures ranging from emergencies, to elective surgeries to cancer treatments. When transfusion is necessary, it is always preferable to transfuse patients with their own blood type. However, depending on a patient's blood type, it may be possible to transfuse a different type. Table 1 illustrates the blood type substitution preferences.

[2] This work was supported by Canadian Blood Services.

Table 1. Blood Type Substitution Preferences.

Donor	Patient							
	A+	B+	AB+	O+	A-	B-	AB-	O-
A+	1		2		3*		6*	
B+		1	3			3*	7*	
AB+			1				5*	
O+	2	2	4	1	4*	4*	8*	2*
A-	3		6		1		2	
B-		3	7			1	3	
AB-			5				1	
O-	4	4	8	2	2	2	4	1

This table indicates which blood types each patient is able to accept and the order of blood type preference. The asterisks indicate that a female patient of childbearing age cannot accept this blood type.

In Canada, blood transfusions are required at a rate of one per minute. The Canadian Blood Services (CBS) is the sole provider of blood and blood products in Canada. CBS maintains a number of regional blood centers. Regional Blood Centers are responsible for collecting, testing, and producing blood products as well as maintaining a sufficient stock of product to meet demand, without excessive outdates. Whole blood is collected from volunteers and then transported to a blood centre where it is processed, screened, tested and separated into components. Hospital blood banks operate as independent inventory locations, each storing a stock of ready inventory and issuing blood products to satisfy transfusion requests of physicians. Hospital blood banks issue requests to their nearest regional centre to replenish stock. CBS collects approximately 803,000 units of whole blood annually and processes it into the components and products that are administered to thousands of patients each year. [1]

Because of the random nature of supply and demand, demand occasionally exceeds supply. Since shortage and blood product outdates are undesirable, the efficient management of blood products is of great importance to CBS, hospitals, patients, and society as a whole. Blood management issues are likely to become even more critical in Canada over the next five years as demand is expected to exceed one million units by 2006. [1] Accordingly, a simulation study was carried out to quantify the risk of shortages and their consequences, for red blood cells and platelets.

Three representative locations were selected for inclusion in this study: a major urban centre (Sunnybrook and Women's College Health Science Center, supplied by the Toronto Blood Center), a semi-urban location (Kingston General Hospital, supplied by the Ottawa Blood Center), and a rural location (Prince

George Regional Hospital, supplied by the Vancouver Blood Center). The two key distinguishing factors between these three locations are product travel times between the blood center and hospital and the percentage of urgent requests. The travel times vary between a few minutes in an automobile for urban setting, to several hours by airplane in rural settings. The hospitals selected in the study have a high amount of 'urgent requests' for blood, requests which if not meet could result in a patient fatality. These hospitals are more susceptible consequences of a shortage. At each center, 10% of the combined requests of all hospitals in the region were urgent in nature. At the study hospitals, 86% of requests from Sunnybrook are urgent, 42% at Kingston and 44% of requests at Prince George are urgent.

The following sections examine the data used in the simulation study, methodology used, the models developed, the results, validation procedure and recommendations.

2. Literature Review

Recognizing that the management of blood is critical, numerous researchers have given blood inventory management considerable attention. Over the past 35 years a number of models have been developed and successfully implemented and a significant amount of literature exists on the subject of perishable inventory systems. Most models deal with a sub-problem of the inventory model for example; re-ordering points [2], optimal inventory levels [3], crossmatching [4], or hospital allocation[5]. In addition, these models have several different objective functions; determining optimal issuing policies [6,7], minimizing outdating [8], meeting hospital demand [5] or meeting two different demand patterns [9].

Very few simulation studies of perishable inventories exist. The earliest was conducted by Jennings in 1973 in which he used a simulation model to determine outdate and shortage curves in order to establish an inventory ordering policy. His models also account for inter- hospital transfers. [7] Goh built simulation models which he used to validate his approximations for a blood bank performance measures (outdate rate, shortages rate, average age of inventory and average number of units in inventory). [9]

Some researchers have provided overviews of the relevant literature in blood management. The overviews most often referred to are those of Prastacos [10] and Nahmias [11]. More recently Goyal and Giri reviewed the latest advances in modeling of deteriorating inventory. [12]

3. Data

Data was collected at all participating hospitals and centers. The two centers for which a Red Blood Cell model was built, Vancouver and Toronto, similar data was collected. The type of data collected included; the number of units of red blood cells received daily, volume distribution by condition (e.g. trauma, surgery, cancer) and by gender, percentage of demand which is urgent, packaging damage, and product expiries. For the two corresponding hospitals (Sunnybrook and Prince George) data pertaining to the following was obtained; number of units of Red Blood Cells received daily, volume distribution by condition (e.g. trauma, surgery, cancer) and by gender, percentage of demand which is urgent, packaging damage, and product expiries were collected.

The platelet model was built for the Ottawa Blood Center and Kingston General Hospital. From the Ottawa Blood Center, the following data was gathered; volume of daily requests, volume of platelets orders which were issued (by medical condition and blood type), product expiry and waste. From the Kingston General Hospital, data such as; the volume of platelets issued by medical condition, issue times, number of pools of platelets requested, standard order sizes and product expiries were collected.

4. Approach

A simulation approach was adopted for this problem, because the complexities introduced by blood product substitution (as illustrated in Table 1) and inventory reduction policies (as illustrated in Table 2) made an analytical approach intractable.

Table 1 illustrates blood substitution preferences. Wherever possible, patients should be transfused with a blood product that matches their own blood group. However, where exact products matches are not available, substitution is possible. For example a patient of blood type A+ can accept blood of type A+, O+, A-, O- . (The order of preference shown in Table 1 is primarily designed to manage inventories; medically substituted products are practically equivalent.) An asterisk in the cell indicates that for female patients of child-bearing age, it is preferred that they do not receive blood of that particular type.

Table 2 is an example of inventory reduction rules that are in place at the Toronto Blood Centre. Each blood center has a unique set of rules, which depend on average volume. These rules outline the operational practice of reserving inventory when stock level is low to ensure that a blood center will have enough stock on hand in case of emergency. For example, an order for 100

units of O+ when a 25% reduction was in place would generate a shipment of 75 units to the requesting location.

Table 2: Sample Inventory Reductions for non-bleed requests.

Group	No Reduction Required	25% Reduction	50% Reduction	75% Reduction	Emergency Issue
O+	>350	300-350	250-300	200-250	<200
A+	>280	230-280	180-230	150-180	<150
B+	>100	85-100	70-85	55-70	<55
AB+	>50	40-50	30-40	20-30	<20
O-	>120	110-120	100-110	90-100	<90
A-	>100	90-100	80-90	70-80	<70
B-	>30	25-30	20-25	15-20	<15
AB-	>15	12-15	10-12	8-10	<8

5. Methodology

Six possible models were considered during the pilot project; one model for each product (red blood cells and platelets), and three possible hospital settings (urban, semi-urban and rural). However, the priority was given to developing the Toronto red blood cell model and the Ottawa platelet model. Work proceeded on both fronts in parallel, with greater emphasis on the completion of the red blood cell model, as it could also be used as a possible basis for the platelet model. The Toronto red blood cell model was then modified for the Vancouver red blood cell model. In each model, the participating hospital was modeled in detail while patients from other hospitals in the region were aggregated into a common demand point supplied directly by the blood center.

The following three sections describe the development of the models.

a. Product Flow

The first step in developing the models was obtaining an understanding of the flow of the blood through the blood banking system. Together with staff at the hospital blood banks and the regional blood banks a flow diagram was developed. A conceptual version of the product flow is described in Figure 1.

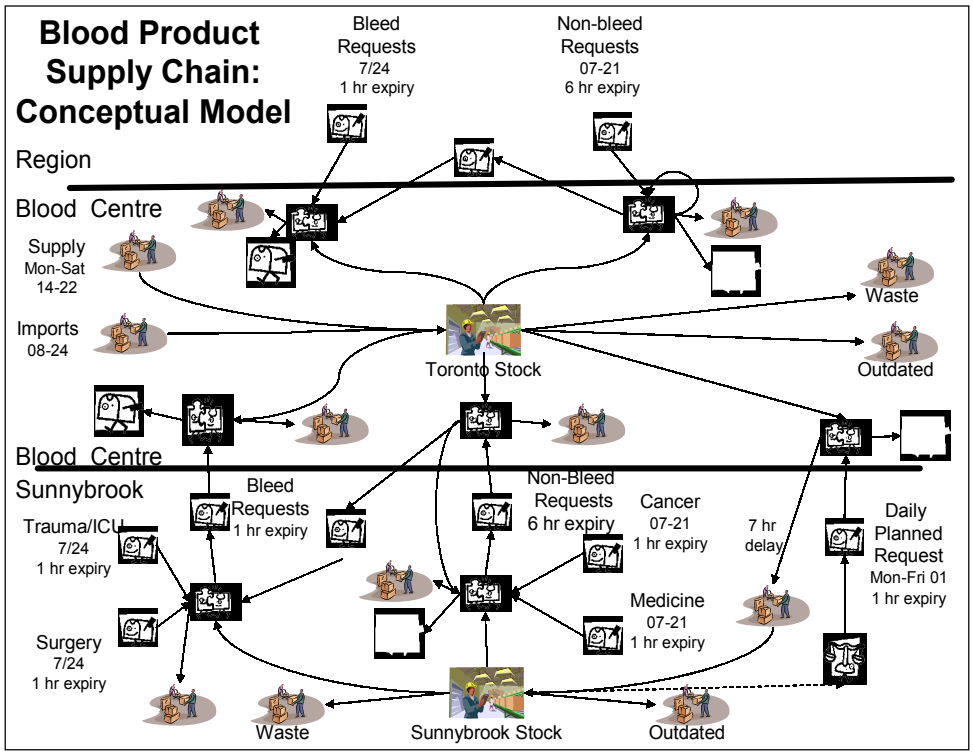
As illustrated in Figure 1, blood product arrives into a centre through voluntary donors (either at the center itself or in mobile collection units) or is imported from other regional blood centers. The transportation from the collection units to the center and processing times are accounted for by deducting this time from the shelf life of the blood product. The product is stored in a storage facility,

where if not taken by its shelf life, it will outdate (expire). Each center encounters some wastage. Requests for product are filled by a first-in-first-out procedure. There are three types of requests; daily planned, non-bleed and bleed. Daily planned requests follow a set order schedule, which the hospital determines based on historical data. This request fills up the hospital inventory which is to be used to meet anticipated demand. Should the hospital demand exceed its inventory, the hospital makes a direct request to the blood center, and depending on the need of the patient, this request is either bleed (urgent) or non-bleed (non-urgent). To simplify the model, all regional hospital requests were aggregated. The hospital inventory stock fills individual patient requests.

The volume, urgency and blood type of patient requests vary. The only processing times included in the model are transportation times between the blood centre and the hospitals, and the length of time a request for blood product remains active before it is declared unsatisfied. Both of these times were treated as a deterministic factor in the model.

Availability of a blood product or substitute to meet a particular request is a complex function involving numerous elements. These elements include the transit time of product between a center and hospital, the details and timing of the requests of other patients vying for the same product, inventory reduction policies, the number of times other non-bleed patients have been unsatisfied.

Figure 1: Conceptual View of Product Flow for Red Blood Cells in Toronto



b. Supply and Demand

Blood product enters the system after testing on specific days of the week over a period of several hours. The data from the blood centers recorded only total daily inputs, not the specific times within this period. Discussion with staff report that units come into inventory one at a time randomly over the period. The model assumes the arrival times are uniformly distributed over the period, which is equivalent to exponentially distributed inter-arrival times [13]. This same approach was used to model the time of use of the blood products at the hospitals. For each hospital and medical condition, periods of use were identified (for example 07-21), and within each a Poisson process was assumed with a rate based on actual data. In addition, where significant, arrival and demand rates were adjusted based on weekday and hourly patterns observed in the data. Distributions of volumes per transfusion were obtained with standard distribution-fitting software within acceptable confidence levels.

c. Medical Consequences of Shortages

While the simulation model is able to assess the probability that a patient cannot be supplied with a given blood product, the key question of clinical impact must be addressed. To classify the medical impact of shortages three levels of consequence were defined;

- Level 1 (High) – Potentially fatal outcome or serious injury.
- Level 2 (Medium) – Minor, transient injury
- Level 3 (Low) – No ill effects, no harm.

Within each level, three scenarios were considered;

- Mismatch vs. shortage
- Bleed vs. non-bleed patients
- Condition of non-bleed patient

A mismatch occurs when the exact product request could not be satisfied, but a substitute product was available. In most cases, while there is a preference for the specific blood product, the clinical outcome of a substitution in the vast majority of cases can be classified as Level 3. In very few cases, the substitution might cause a Level 2 injury. A shortage is assumed to occur when neither a requested product nor its substitute could be provided.

A bleed patient is defined as a patient who requires a blood transfusion urgently. Examples include trauma patients and intensive care patients. A non-bleed is

defined as a patient who requires a blood transfusion, but for whom the need is not considered urgent. Generally, these are patients who are receiving cancer treatment, or a routine surgical procedure.

For non-bleed patients a shortage generally does not indicate a Level 1 injury. Only if these patients endure repeated shortages are they escalated to Level 1. The escalation depends on the medical condition of the patient. For example, if an anemic ICU non-bleed patient did not receive the requested blood type or its substitutes within 24 hours (attempts are made every hour), these patients will sustain a Level 1 injury, however a chronic anemic non-bleed patient is able to endure a shortage for one week before encountering a Level 1 injury. For red blood cells, escalation is assumed to occur automatically after a patient is left unsatisfied for a preset number of days. For platelet patients, only a percentage of unsatisfied non-bleed patients escalate within that same time period. Bleed patients generally incur a Level 1 injury on the first shortage event.

The escalation of non-bleed patients, however, also depends on patient specific characteristics. For example a patient with severe acute anemia, chronic anemia, or having just completed surgery, will escalate more rapidly than other patients. For patients requiring platelets escalation depends on whether the patient has a low platelet count (less than 10), a 10–50 count, or a platelet dysfunction.

6. Verification Issues

Once the conceptual model, as described in Section 4 was validated before Blood Center staff and hospital staff the SIMUL8 software program was used to construct the simulation model. The simulation was run on a 2.4 GHz computer with 512 MB of memory running Windows XP.

The starting inventories were populated with average starting inventory levels over the period of interest. As there was no need to delay the collection of output statistics, a warm-up period was not required. The study required that the number of close calls be computed over a specific month. Since the study dealt with terminating simulations there was no need to derive an alternate run length. For the red blood cell models, this time period was reduced to one week in order to allow a larger number of runs within reasonable computation time. Before any decisions are based on these shorter runs, the run length would be extended to the full month period. As there was no formal accuracy requirement, five runs were used to derive confidence intervals. In cases were these intervals were too wide, the number of runs was increased to 20. In all cases the resulting confidence intervals were acceptable.

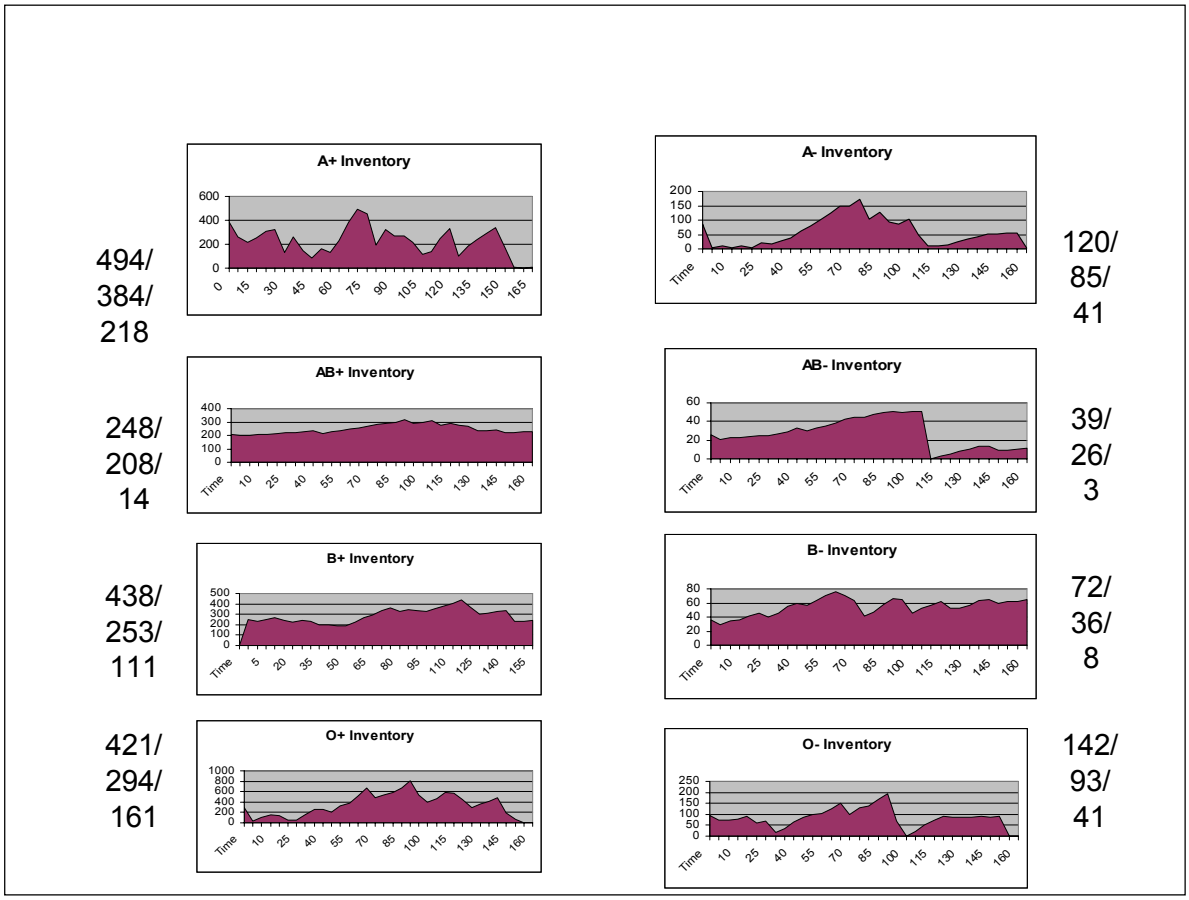
7. Validation

One of the difficulties in testing the simulation for reasonableness is that there is no actual data for the key statistic of interest: unsatisfied bleed requests or 'close calls'. Thus when the model reported a number of close calls it could only be compared with anecdotal incidents that blood centre and hospital staff could recollect.

A Turing test on the hourly inventory levels (Figure 2) and number of close calls was considered sufficient by the client. Plans are under way for collection of 'close calls' during the summer of 2004, at which time a more formal validation may be undertaken.

The only formal validation was carried for the number of outdated platelets (red cells were fully utilized before they have a chance to outdate). Actual outdates were within the 95% confidence interval of average model values, i.e. 25 pools vs. 23.3±2.7 at KGH, and 47 pools vs. 52.8±10.3 at the blood centre.

Figure 2: Forecasted inventory values at the Toronto Blood Centre. The figures on each graph also show the historical maximum, average and minimum inventory levels.



8. Results

The scope of the funded study was to quantify the risk of a blood shortage and the resulting medical impact on the patient. Additionally this study was used as a pilot project to explore the power of quantitative methods in this challenging area. To determine the possibility of shortages, the number of 'close calls'- the number of patients suffering from a Level 1 injury which could not be satisfied - were captured for each setting. Table 3 reports the number of close calls for red blood cells or platelets at each location. In practice, blood substitute products are used in these cases.

Table 3: Number of unsatisfied bleed request by location.

		Single Runs					5 Run Trial		20 Run Trial	
Model	**Location**	**1**	**2**	**3**	**4**	**5**	**Average**	**99% CI**	**Average**	**99% CI**
Toronto Red cells	TBC	4	1	2	0	8	24.6	0 – 62.7	12.1	3.4 – 20.7
	Sunnybrook	4	4	16	0	6				
Vancouver Red Cells	BC&Y	0	1	0	1	0	0.4	0 – 2.2	-	-
	PGRH	0	0	0	0	0	0	0 – 0	-	-
Ottawa Platelets	OBC	0	0	0	0	0	0	0 – 0	0	0 – 0
	KGH	3	0	1	2	2	1.4	0 – 4.5	1.25	0.5 – 2.0

Models are for different time frames and conditions; therefore inter centre comparisons are inappropriate. In those instances where the results are consistently zero, longer runs and more trials are required to generate close call events, as the probabilities are too low to be captured with these limited runs.

The multi-run trial results include all Toronto close calls, including Sunnybrook. The difficulty of separating the results is related to the fact that, unlike PGRH and KGH, a bleed request at Sunnybrook that cannot be met from hospital inventory does not immediately result in a close call. This occurrence is a result of travel times. Sunnybrook Hospital is located in an urban setting which a Blood Center easily accessible. An unsatisfied bleed request at Sunnybrook is rerouted to the Toronto Blood Centre, where it joins other bleed requests. The hospitals in the semi-urban and rural locations are unable to obtain urgent requests from their blood centers because the travel times are too great. The 20 run trials were only performed for cases with significant numbers of close calls.

9. Recommendations

Based on the positive reception of the model by the Canadian Blood Services and the analysis of possible model application, the following courses of action are recommended.

1. Use the models developed in this pilot to minimize platelet close calls and outdates by optimizing the volume and timing of KGH standing orders, and include the impacts of:
    a. Alternate freshness policies for filling standing orders,
    b. Using 5, 6 and 7 day old platelets – as last resort only,
    c. Using 5, 6 and 7 day old platelets as common practice.

2. Use the models to minimize the overall number of red cell close calls at Vancouver, Ottawa and Toronto by optimizing the allocation of total current imports into the centers, and include the impact of weekly starting inventories at each centre.

3. Initiate a pilot study to include multiple centers into one model that would dynamically redirect imports in response to inventory levels.

10. Future Work

Once the model results were deemed to be acceptable, the model can be used to compute the impact of many input variations on key statistics such as average close calls for red cells, and average close calls and outdates for platelets. In addition to sensitivity results, it becomes possible to optimize operational decisions. Such computer models can be extremely valuable to complement extensive experience, and reduce the need for risky, costly and time consuming field trials.

Discussions with the lab managers and the participating hospitals identified a number of studies that could lead to actual benefits for CBS and could be readily performed with the models developed to date:

i. Vary the volume, delivery and freshness of the platelet standing (set) orders to determine their impact on close calls and outdates.

    Benefit: Platelet outdates at the Kingston General Hospital have been known to be relatively high. The model may be able to identify a different standing order which would reduce these levels, without increasing the risk to KGH patients.

    Feasibility: Standing order volumes, delivery times are input data to the model and can be readily changed without further development. Similarly changing the criterion from freshest to oldest platelets requires a single parameter change. The purchase of optimization add-ons may be required to reduce the number of model runs.

ii. Retain outdated platelets for up to 3 additional days, for use in case of shortages, and determine the impact on close calls and outdates.

Benefit: Recent medical reports indicate that it may be safe to use platelets beyond their current 5 day expiry. This study would support a change in practice to keep platelets for up to 3 additional days. They would only be used during shortages in decreasing order of freshness. This study would then identify the number of true close calls (if any) when even 7 day old platelets were unavailable.

Feasibility: Minor development work required.

iii. Vary the allocation of current total imports of red cells into the Vancouver, Ottawa and Toronto blood centers, within feasible ranges, to determine the impact on the individual centre and total number of close calls.

Benefit: Each of these centers relies to various degrees on imports from exporting centers (e.g. Calgary), and often request increased transfers. This study would determine the relative impacts of reallocation on close calls. These will also be a function of the starting weekly inventories at the various centers. It would help CBS in taking a more national view for managing its inventories, facilitate more transfers between centers and ultimately support the leveling of risk of shortages across Canada.

Feasibility: This study would require that the red cell model be applied to the Ottawa area. Based on the pilot experience in modifying the red cell model from Toronto to Vancouver this is not seen as a major development effort. It would require additional data collection in the Ottawa area. Given the experience accumulated during this pilot study this is not seen as a major effort, and may provide additional unforeseen local benefits to the Ottawa Centre and KGH.

iv. Initiate a pilot project to include several centers into a single red cell simulation model, including rules for dynamic transfers between centers in response to local inventory levels.

Benefit: This pilot project would focus on non-scheduled transfers, based on the dynamic inventory levels at each centre. Such a study could significantly assist a national dispatcher to develop operating policies for initiating such transfers.

Feasibility: This is a major development effort, feasible but significantly more involved than the previous studies.

References

1. Canadian Blood Services, 2002. http://www.bloodservices.ca/. Accessed on December 1, 2002.
2. Fries, B., 1975. Optimal Ordering Policy for a Perishable Commodity with Fixed Lifetime, *Operations Research,* 23:46–61.
3. Chazan, H. and Gal, S., 1977. A Markovian Model for a Perishable Product Inventory, *Management Science,* 23:512–521.
4. Jagannathan, R. and Sen, T., 1991. Storing Crossmatched Blood: A Perishable Inventory Models with Prior Allocation, *Management Science,* 37:251–266.
5. Sapountzis, C., 1989. Allocating Blood to Hospitals, *The Journal of the Operational Research Society,* 40:443–449.
6. Pierskalla, W and Roach, C., 1972. Optimal Issuing Policies for Perishable Inventory, *Management Science,* 18:603–614.
7. Jennings, J., 1973. Blood Bank Inventory Control, *Management Science,* 19:637–645.
8. Kendall, K. and Lee S., 1980. Formulation Blood Rotation Policies with Multiple Objectives, *Management Science,* 26:1145–1157.
9. Goh, C., et. al., 1993. Two-stage Perishable Inventory Models, *Management Science,* 39:633–649.
10. Nahmias, S., 1982. Perishable Inventory Theory: A Review, *Operations Research,* 30:680–708.
11. Prastacos, G., 1984. Blood Inventory Management: And Overview of Theory and Practice, *Management Science,* 30:777–800.
12. Law, A. and Kelton, D., 2000. *Simulation Modeling and Analysis,* 3rd Edition, McGraw Hill, Boston.

ALLOCATING HIV PREVENTION RESOURCES IN A MULTI-LEVEL DECISION MAKING FRAMEWORK: A PROPOSED MODEL

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Abstract: Investment in HIV prevention averts loss of life, human suffering, as well as negative social and developmental consequences. Funds targeted towards HIV interventions are commonly allocated using equity-based criteria and often traverse several levels of distribution. Optimizing the use of these funds narrows the gap between need and funding. Given two levels of distribution, upper and lower, this research questions whether an optimal allocation at the upper level yields a better outcome than an optimal allocation at the lower level. We consider a problem consisting of two lower level regions. Each region is divided into two subpopulations, high risk and low risk. Each subpopulation is modeled, using a system of differential equations, as a four-compartment epidemics model in which the population is divided by disease state and maturity. Since the purpose of HIV prevention programs is to reduce the incidence rate, "new infections" is the outcome measure and the objective function aims to minimize the number of new infections. Practically, this is achieved by reducing the effective contact rate and the rate of mother to child transmission, which are a function of the allocated budget. We suggest four methods of solving the resource allocation problem, combining all possibilities of equity and optimal allocation methods, at both upper and lower levels of decision making.

1. Introduction

Of the 60 million HIV infection cases that have occurred over the last 20 years, 95% are in developing countries [1]. The average life expectancy in sub-Saharan Africa in 2002 was reported as 47 years, while without AIDS it would have been 62 years [2]. In addition, sub-Saharan African countries are losing their manpower to the AIDS, and most of those impaired by the disease are at the prime of their working years. It is expected that by 2005, Zimbabwe, Botswana and South Africa will have lost, respectively, 19%, 17%, and 11% of their workforces to the disease [2]. AIDS strains productivity, adds costs and diverts the productive resources in developing countries thereby destabilizing their economies and healthcare systems. The extent of the epidemic is still increasing in Africa: in Botswana, HIV prevalence among pregnant women in urban areas rose from 38.5% to 44.9% between 1997 and 2001, while, in Zimbabwe, it rose from 29% to 35% between 1997 and 2000 [2]. Within specific age groups, prevalence rates can even be higher — as high as 55.6% among 25–29 year-old women attending antenatal clinics in urban areas of Botswana, in 2001 [2].

Investment in HIV prevention may avert loss of life, human suffering, as well as negative social and developmental consequences. It is estimated that an annual budget of US$9.2 billion is required to run valuable prevention and care programs in low- and middle-income countries [3]. Although funding has increased it remains insufficient to curtail the epidemic [2]. A better understanding of the current resource allocation models used and the introduction of optimization techniques would likely taper the gap between funding needs and availability.

When resources are allocated towards epidemic prevention, they usually cross over several levels in decision making before reaching the level of the intervention program itself. For example, the Joint United Nations Program on HIV/AIDS (UNAIDS) allocates their annual budget across 60 countries. At a lower level, those countries distribute their portion of the funding towards organizations judged appropriate. In turn, those organizations will redistribute the funds towards specific HIV prevention and treatment programs.

Equity based allocation methods such as proportional to number of HIV/AIDS cases in different subgroups [17] is the most commonly used resource allocation method for distributing funds towards HIV prevention. For example, in the United States, federal HIV prevention funds are allocated to community planning groups (CPG) using equity based allocation heuristics [15, 18]. Little information about the criteria used to make allocation decisions is given by the main suppliers of funding for HIV/AIDS interventions in Africa such as the WorldBank, the United States Agency for International Development (USAID) and the Global Fund to fight AIDS, Tuberculosis and Malaria. While equity criteria may be useful for allocating funds for AIDS treatment, it is not appropriate in indicating the need for prevention services. Equity based allocation methods indicate the current state of the epidemic, rather than the direction in which it is headed [19]. Also, equity allocation conceivably rewards areas which report higher caseloads and use their resources ineffectively [19].

According to fundamental health economic principles, resource allocation among multiple interventions should be done in increasing order of cost-effectiveness ratios until a budget constraint is encountered [4, 5]. Unfortunately, this theory does not enable complexities such as minimum or maximum program funding levels, increasing or diminishing marginal returns, mutual exclusivity of programs and interaction of program outcomes to be addressed. To address the issue of program divisibility, Weinstein and Zeckhauser [6] provide a binary integer model for program selection, that is a program is either fully implemented or not at all. Stinnett and Paltiel [7] develop a mixed integer programming formulation which addresses issues of program

divisibility and returns to scale. These techniques are applicable to a one-time allocation at the start of the time horizon and they do not consider epidemic growth. Zaric and Brandeau [8] developed a multi-period resource allocation model for epidemic control programs and demonstrate the benefit of allowing for reallocation of resources over a time horizon.

More thorough resource allocation models for epidemic control have been researched. Sanders elaborates a control theory approach where the objective is to find the control function which minimizes, over time, the cost of control plus the cost associated with the number of individuals who become infected [9]. Other control theory approaches are surveyed by Wickwire [31].

Simulation-based techniques have been used to compare a set of resource allocation alternatives [10–12]. For example, Brandeau et al. developed a compartmental epidemic model to evaluate the costs and effects of a number of strategies for screening women of childbearing age [13]. Kahn [10] developed a simulation-based model to assess the benefits of targeting HIV-prevention funds to non-interacting population. Rauner et al. [11] use discrete event simulation to select interventions aimed at reducing vertical transmission of HIV in developing countries.

Several approaches are based on nonlinear optimization formulation of the epidemic control problem. In this case, the problem is consists of deciding the amount to be invested in several interventions in order to optimize total the health benefits, subject to a budget constraint [14]. Kaplan and Pollack use a non-linear optimization formulation and seek to maximize the number of infections averted using a dynamic programming method for determining production functions [15]. With a focus on short time horizons, Zaric and Brandeau propose approximations for allocating resources for epidemic control [16]. Nonlinear optimization approaches are summarized by Zaric [14].

In this study, we question whether an optimal allocation of HIV prevention funds at an upper level yields a better outcome than an optimal allocation at the lower level. We propose to compare the impact of using simple resource allocation heuristics such as equity based allocation against using optimal allocation, given two levels of decision-making, upper and lower, in the context of sub-Saharan Africa. HIV policy models have been studied, but most are focused on developed countries where modes and rates of transmission, the available resources and the cost-effectiveness of interventions are not comparable that of developed countries. In addition, this research is novel in its inclusion of both sexual contact and vertical transmission as modes of HIV transmission and in its evaluation of the impact of more than one level of

allocation decision. This study is intended to help policy makers in governments, public health agencies and non-government organizations make informed decisions regarding AIDS policy modeling and budget allocation.

2. Proposed Methodology

Overview

Vertical transmission takes place when an infected woman transmits the HIV virus to her baby during pregnancy, labour or breastfeeding, it also known as mother-to-child transmission. Vertical transmission is responsible for the vast majority of the world's HIV-infected children, of which over 90% live in sub-Saharan Africa [20]. The probability of vertical transmission during pregnancy and labour lies between 15% and 30% when there is no attempt to prevent the transmission. There is an additional risk of transmission of approximately 15% associated with breastfeeding [21].

Condom distribution, treatment of sexually transmitted diseases, and blood safety measures are among HIV prevention interventions that are known to be cost-effective [23, 24]. The administration of antiretroviral agents and substitution of formula feeding for breastfeeding are demonstrably cost-effective in reducing the chance of vertical transmission [22]. In this study we consider the impact of both investing in the reduction of unsafe sexual contact as well as investing in the reduction of vertical transmission.

The upper level decision in our allocation network is consists of determining the funds to invest in two regions, Region 1 and Region 2. Each region is in turn divided into a high risk subpopulation and a low risk subpopulation. Within each subpopulation, the lower level allocation decision consists in determining the amounts to allocate towards interventions aimed at reducing HIV transmission rates resulting from unsafe sexual contact, and reducing vertical transmission.

Production Functions

Epidemic control models should consider epidemic progression. For a given epidemic, a production function is used to define the effect of investing in relevant intervention programs onto the epidemic's progression. Basic economic theory defines a production function, $f(\boldsymbol{v})$, as the level of output that can be achieved from input amounts $\boldsymbol{v} = (v_1, v_2, \ldots v_n)$ [30]. In the context of HIV prevention, production functions will translate the amounts invested in prevention programs into a reduction in the sufficient contact rate or the rate of vertical transmission. We use the linear production function stated in (1) to

define the relationship between investing in prevention programs and a reduction in the contact rate, λ.

$$\lambda(x) = a_{ij} - \sum_{n=1}^{N} b_{ijn} x_{ijn} \qquad (1)$$

In equation (1), x_{ijn} is the amount invested in intervention n aimed at reducing the contact rate in subpopulation i of region j, a_{ij} is the contact rate at the start of horizon in subpopulation i of region j and b_{ijn} is a variation of the cost-effectiveness ratio of investing in intervention n aimed at reducing the contact rate in subpopulation i of region j.

We use an analogous production function to define the function associated with the rate of vertical transmission. The appropriate function parameters are obtained through an extensive search of the cost-effectiveness of different prevention programs.

Modelling the epidemic

We use a non-linear system of differential equations which draws on the structure of a SI (susceptible-infected) model with sufficient contact rate, λ, vertical transmission rate, m, and varying population size, to define the epidemic model. This way of defining an epidemic model has been widely used elsewhere [25–29]. The epidemic model is necessary to determine the impact of investing in HIV prevention interventions and the outcome measure is the number of new infections. Each of the four subpopulations in the allocation network is itself modelled as a four-compartment epidemic model where the subpopulation is divided by disease state (infected or not) and maturity (mature or not). The epidemic model is defined mathematically, as follows:

$$S'(t) = -\lambda I(t)S(t) - \delta_S S(t) + \gamma U(t) \qquad (2)$$

$$I'(t) = \lambda I(t)S(t) - \delta_I I(t) + \gamma V(t) \qquad (3)$$

$$U'(t) = -\delta_U U(t) + \beta_S S(t) + (1-m)\cdot\beta_I I(t) - \gamma U(t) \qquad (4)$$

$$V'(t) = -\delta_V V(t) + m\cdot\beta_I I(t) - \gamma V(t) \qquad (5)$$

In equations (2) to (5), S(t), I(t), U(t) and V(t) represent the number of susceptible adults, infected adults, uninfected children and infected children, respectively, at time t. We assume that the infected children, V(t), were infected by vertical transmission and are too young to transmit the virus. Likewise, the uninfected children, U(t), are young and cannot contract the virus through sexual contact. Uninfected children and infected children will migrate to their

corresponding adult compartments at a rate of γ which is the inverse of age at which children will become sexually active.

The death and birth rates are noted respectively by δ_i and β_i where the index i represents the compartment. We suppose the death rate in the infected children compartment, δ_v is far greater than δ_u, the death rate of the uninfected children compartment. Also, we assume that the probability of vertical transmission, noted by m, includes the probabilities of transmission during pregnancy, labour and through breastfeeding.

Individuals migrate from the susceptible to infected adults compartment based on λ, the sufficient contact rate. A sufficient contact is defined as a sexual encounter that results in the infection of a susceptible adult by an infected adult and we assume that λ represents all forms of sexual contact.

Closed-form analytic solution for the model specified by (2)-(5) are not known. So, as defined in (6), we estimate the number of new infections between time zero and time T using third degree Taylor series approximation. In time horizons of up to 10 years, it has been demonstrated that such approximations produce valid estimations for the new infections function. This approximation will be used in the objective function of the optimization model.

$$\int_0^T \mathrm{NI}(t) \approx \frac{T^1}{1!} \cdot \mathrm{NI}(0) + \frac{T^2}{2!} \cdot \mathrm{NI}'(0) + \frac{T^3}{3!} \cdot \mathrm{NI}''(0) \qquad (6)$$

where:

$$\mathrm{NI}(t) = \lambda \mathrm{I}(t)\mathrm{S}(t) + m \cdot \beta_1 \mathrm{I}(t) \qquad (7)$$

$$\mathrm{NI}'(t) = \lambda \mathrm{I}'(t)\mathrm{S}(t) + \lambda \mathrm{I}(t)\mathrm{S}'(t) + m \cdot \beta_1 \mathrm{I}'(t) \qquad (8)$$

$$\mathrm{NI}''(t) = \lambda \mathrm{I}''(t)\mathrm{S}(t) + 2 \cdot \lambda \mathrm{I}'(t)\mathrm{S}'(t) + \lambda \mathrm{I}(t)\mathrm{S}''(t) + m \cdot \beta_1 \mathrm{I}''(t) \qquad (9)$$

Optimization model

The goal of the objective function is to minimize the number of new infections subject to a budget constraint. To minimize the number of new infections, the allocation of funds towards reducing λ and m must be optimal. Given a global budget, the upper level allocation model consists in determining the amounts to allocate to Region 1 and to Region 2 that minimize the total number of new infections in both regions.

The allocation model for a specific region j is expressed as follows:

$$\text{Min}_{xij,yij} = \sum_i \text{NI}_j(x_{ij}, y_{ij}) \quad (10)$$

$$\text{subject to:} \quad \sum_i (x_{ij} + y_{ij}) \leq \text{B}_\text{j} \quad (11)$$

$$a_{ij} - b_{ij}\, x_{ij} \geq \lambda_{min} \quad i=1,2 \quad (12)$$

$$p_{ij} - q_{ij} y_{ij} \geq m_{min} \quad i=1,2 \quad (13)$$

$$x_{ij}, y_{ij} \geq 0 \quad i=1,2 \quad (14)$$

where the index *ij* represents subpopulation *i* of region *j*. The decision variables x_{ij} and y_{ij} represent the amount allocated towards reducing λ and *m*, respectively, in subpopulation *i* of region *j*. The budget allocated to region *j* is noted by B_j. For subpopulation *i* of region *j,* the sufficient contact rate at the start of the horizon is noted by a_{ij} and the rate of vertical transmission at the start of the horizon, is noted by p_{ij}. The lowest possible sufficient contact rate is noted by λ_{min} and the lowest possible rate of vertical transmission is noted by m_{min}.

Equity Model

In the equity-based heuristic, the global budget is allocated proportionally based on HIV prevalence and population size of the regions at the start of the horizon. Comparable equity allocation models are examined [15].

The upper level allocation model, which determines the portion of the global budget to allocate to each region, is defined as follows:

$$\text{B}_j = \mathbf{B} \times \frac{\text{I}_j(0) + \text{V}_j(0)}{\sum_j (\text{I}_j(0) + \text{V}_j(0))} \quad (15)$$

where **B** is the global budget available and the region is noted by the index *j*. The number of infected adults and the number of infected children, in region *j*, at the start of the horizon, are noted $\text{I}_j(0)$ and $\text{V}_j(0)$, respectively.

The regional budgets are then allocated proportionally towards λ and *m* of the high-risk and low-risk subpopulations, based on prevalence in the adult and children compartments. The allocation model for a specific region *j* is expressed as follows:

$$\text{B}_{ij} = \text{B}_j \cdot \frac{\text{I}_{ij}(0) + \text{V}_{ij}(0)}{\sum_i (\text{I}_{ij}(0) + \text{V}_{ij}(0))} \quad i=1,2 \quad (16)$$

$$\text{B}_{\lambda ij} = \text{B}_{ij} \cdot \frac{\text{I}_{ij}(0)}{\text{I}_{ij}(0) + \text{V}_{ij}(0)} \quad i=1,2 \quad (17)$$

$$B_{mij} = B_{ij} \cdot \frac{V_{ij}(0)}{I_{ij}(0) + V_{ij}(0)} \qquad i=1,2 \quad (18)$$

where the index *ij* represents subpopulation *i* of region *j*. The number of infected adults and the number of infected children, in subpopulation *i* of region *j*, at the start of the horizon, are noted $I_{ij}(0)$ and $V_{ij}(0)$, respectively.

The budget allocated to region *j* as determined by the upper level allocation model and is noted by B_j. The allocation to subpopulation *i* of region *j* is noted by B_{ij}. The budgets allocated to reducing the sufficient contact rate and the rate of vertical transmission, in subpopulation *i* of region *j*, are noted $B_{\lambda ij}$ and B_{mij}, respectively.

3. Discussion

In this study we propose a model for examining the impact of equity based allocation of HIV prevention funds versus an optimal allocation of HIV prevention funds in an epidemic model with two levels of decision making. We suggest four methods of solving the allocation problem in order to compare the equity based heuristic against the optimal allocation model. The first method, Optimal-Optimal, consists in minimizing the total number of new infections throughout the upper and lower levels of the allocation network. The second method, Optimal-Equity, consists in solving the lower level allocation with the equity model and using those results to then solve the upper level allocation using the optimal model. The third method, Equity-Optimal, consists in solving the upper level allocation using the equity model and then solve the two lower level problems optimally. The fourth method, Equity-Equity, consists in solving the upper and lower level problems using the equity model.

Preliminary results suggest that while the Optimal|Optimal option minimizes the total number of new infections, the Equity|Optimal option represents an improvement over the number of new infections in the Optimal|Equity option. However, further analysis is required to establish the robustness of the proposed model and draw firm conclusions.

As a future direction for the suggested model, we recommend several improvements. The accommodation of multiple time periods in the optimization model would enable budget allocations over several time periods and the effects of the investments could diminish over time if they are not replenished. Also, the objective function is nonlinear and neither convex nor concave, in general.

An adequate non-linear solver should be used to obtain the best results, otherwise, other optimization techniques such as genetic algorithms or simulated annealing, which do not require convex or concave objective functions, should be investigated. Further, the production functions could be extended to consider, for example, minimum or maximum program funding levels, increasing or diminishing marginal returns, mutual exclusivity of programs and interaction of program outcomes. Lastly, as the average life expectancy of HIV infected children is less than the age of sexual maturity, the distribution within the infected children compartment would be non-homogenous and inclined towards the younger age groups. This issue could be addressed by further stratifying the children compartments by age group.

In spite of the suggested improvements, we view the proposed model as a pioneering step in the evaluation of resource allocation models for control of infectious diseases given multiple levels of allocation decision.

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References

1. Vas, A., 2001. AIDS now fourth biggest killer worldwide, report says. *Br Med J,* 323:1271.
2. UNAIDS, 2002. *Report on the Global HIV/AIDS Epidemic 2002.* UNAIDS, Geneva, Switzerland.
3. Schwartlander, B., Stover, J., Walker, N., Bollinger, L., Gutierrez, J.P., McGreevey, W., Opuni, M., Forsythe, S., Kumaranayake, L., Watts, C., and S. Bertozzi, 2001. Resource needs for HIV/AIDS. *Science,* 292:2434–2436.
4. Drummond, M.F., O'Brien, B., Stoddart, G.L, and G.W. Torrance (Ed.), 2000. *Methods for the Economic Evaluation of Health Care Programmes, Second Edition.* Oxford University Press: New York.
5. Paltiel, A.D. and Stinnett, A.A., 1998. Resource allocation and the funding of HIV prevention. In Holtgrave, D.R. (Ed.), *Handbook of Economic Evaluation of HIV Prevention Programs.* New York, Plenum Press, p. 135–152.
6. Weinstein, M. and Zeckhauser, R., 1973. Critical ratios and efficient allocation. *J Publ Econ,* 2:147–157.
7. Stinnett, A.A. and Paltiel, A.D., 1996. Mathematical programming for the efficient allocation of health care resources. *J Health Econ,* 15:641–653.

8. Zaric, G.S. and Brandeau, M.L., 2003. Dynamic resource allocation for epidemic control in multiple populations. *Math Med Bio,* 19:235–255.
9. Sanders, J.L., 1971. Quantitative guidelines for communicable disease control programs. *Biometrics,* 27:883–893.
10. Kahn, J.G., 1996. The cost-effectiveness of HIV prevention targeting: how much more bang for the buck? *Am J Public Health,* 86:1709–1712.
11. Rauner, M.S., Brailsford, S.C., and S. Flessa, 2003. Using discrete-event simulation to select affordable intervention programs for vertical HIV transmission in developing countries. In Anderson, J.G. and Katzper, M. (Ed.) *Proceedings of the 2003 International Conference on Health Sciences Simulation*. The Society of Computer Simulation International, USA, p. 59–64.
12. Stover, J.M., 2000. Influence of mathematical modelling of HIV and AIDS on policies and programs in the developing world. *Sex Transm Dis,* 27:572–578.
13. Brandeau, M.L., Owens, D.K., Sox, C.H., and R.M. Wachter, 1993. Screening women of childbearing age for human immunodeficiency virus: a model-based policy analysis. *Management Science,* 39:72–92.
14. Zaric, G.S., 2003. Resource allocation for control infectious disease epidemics. *Comments Theor Biol,* 8:475–496.
15. Kaplan, E.H. and Pollack, H., 1998. Allocating HIV prevention resources. *Soc Econ Plann Sci,* 32:257–263.
16. Zaric, G.S. and Brandeau ,M.L., 2001. Resource allocation for epidemic control over short time horizons. *Math Biosci.* 171:33–58.
17. Beehary, G., Schwab, N., Akhavan, D., Hernandez, R., and C. Paredes, 2002. *Optimizing the allocation of resources among HIV prevention interventions in Honduras*. HNP Discussion Paper Health Nutrition and Population Family of the World Bank's Human Development Network. Washington DC, USA.
18. Johnson-Masotti, A.P., Pinkerton, S.D., Holtgrave, D.R, Valdiserri, R.O. and M. Willingham, 2000. Decision making in HIV prevention community planning: an integrative review. *J Community Health,* 25:95–112.
19. Ruiz, M.S., Gable, A.R., Kaplan, E.H., Stoto, M.A., Fineberg, H.V., and J. Trussell (Ed.), 2001. *No Time to Lose. Getting More from HIV Prevention*. National Academy Press: Washington DC.
20. UNAIDS, 2000. *AIDS epidemic update*, *December 2000*. UNAIDS, Geneva, Switzerland.
21. De Cock, K.M., Fowler, M.G., Mercier, E., de Vincenzi, I., Saba, J., Hoff, E., Alnwick, D.J., Rogers, M., and N. Shaffer, 2000. Prevention of mother-to-child HIV transmission in resource-poor countries - Translating research into policy and practice. *JAMA,* 283:1175–1182.

22. Soderlund, S., Zwi, K., Kinghorn, A., and G. Gray, 1999. Prevention of vertical transmission of HIV: analysis of cost effectiveness of options available in South Africa. *Br Med J,* 318:1650–1655.
23. Creese, A., Floyd, K., Alban, A., and L. Guinness, 2002. Cost-effectiveness of HIV/AIDS interventions in Africa: a systematic review of evidence. *Lancet,* 359:1635–1642.
24. Walker, D., 2003. Cost and cost-effectiveness of HIV/AIDS prevention strategies in developing countries: is there an evidence base? *Health Pol Plann,* 18:4–17.
25. Capasso ,V. (Ed.), 1993. *Mathematical Structures of Epidemic Systems.* Springer-Verlag: Berlin.
26. Bailey, N.T.J. (Ed.), 1975. *The Mathematical Theory of Infectious Diseases and its Applications, Second Edition.* Charles Griffin and Company: United Kingdom.
27. Zaric, G.S., Brandeau, M.L., and P.G. Barnett, 2000. Methadone maintenance treatment and HIV prevention: A cost effectiveness analysis. *Management Science,* 25:1013–1031.
28. Tchetgen, E., Kaplan, E.H., and G.H. Friedland, 2001. Public Health Consequences of Screening Patients for Adherence to Highly Active Antiretroviral Therapy. *JAIDS,* 26:118–129.
29. Edwards, D.M., Shachter, R.D., and D.K. Owens, 1998. A dynamic HIV-transmission model for evaluating the costs and benefits of vaccine programs. *Interfaces,* 28:144–166.
30. Mas-Colell, A., Whinston, M.D., and J. Green (Ed.), 1995. *Microeconomic theory.* Oxford University Press: New York.
31. Wickwire, K., 1977. Mathematical models for the control of pests and infectious diseases: A survey. *Theor Popul Bio,* 11:182–238.

SURGICAL WOUND INFECTION

Logistic regression on surgical procedures performed at Sarah Hospital, Brasilia, 1995 to 1999

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1. Introduction

Surgical wound infections account for about 15% of all hospital infections and are considered an important public health problem, due to the increase of morbidity, mortality, and hospital costs. Surgical wound infections can be attributed to risk factors inherent to every patient (such as pathologic condition, age, coexistence with other sites infections, etc.) or to a break of surgical technique and/or post surgical care, among other factors. The objective of this paper is to carry out an analysis of the influence of some risk factors on the occurrence of surgical wound infections.

2. Material, Definitions and Methods

12,146 surgical procedures were analyzed retrospectively; the operations were performed in a Rehabilitation Hospital (Sarah Hospital, Brasilia) during five successive years (1995 up to 1999). The analysis used a logistic regression where surgical infection was considered as the dependent variable, and the independent variables were: patients' age, physical condition, class of surgical wound, duration of the procedure, use of antibiotic prophylaxis, and complexity of the procedure.

Patients' physical condition was classified using the ASA (American Society of Anesthesiology) index, which starts from number one (patient in good health and physical condition) and increasing progressively according to the pathological or physical condition of the patient. This index is assessed by anesthesiologists, some days before the operation.

The class of the surgical wound follows the standard NNISS (National Nosocomial Infection Surveillance System) classification into the following four classes: clean, clean-contaminated, contaminated, and infected, according to the anticipated levels of intraoperative microbial contamination.

Complexity of the procedure is classified using a weighting related to the procedure code. Classifications zero or one correspond to a very low complexity procedure.

Duration of the procedure corresponds to the time elapsed since the first skin cut is realized up to the last suture point. The definition of surgical wound infection follows the norms of CDC (Center for Diseases Control, USA).

The regression analysis was performed by SPSS software, using the *forward method* that included one variable at each iteration step, choosing the variables that have significant contribution to the explanation of the event.

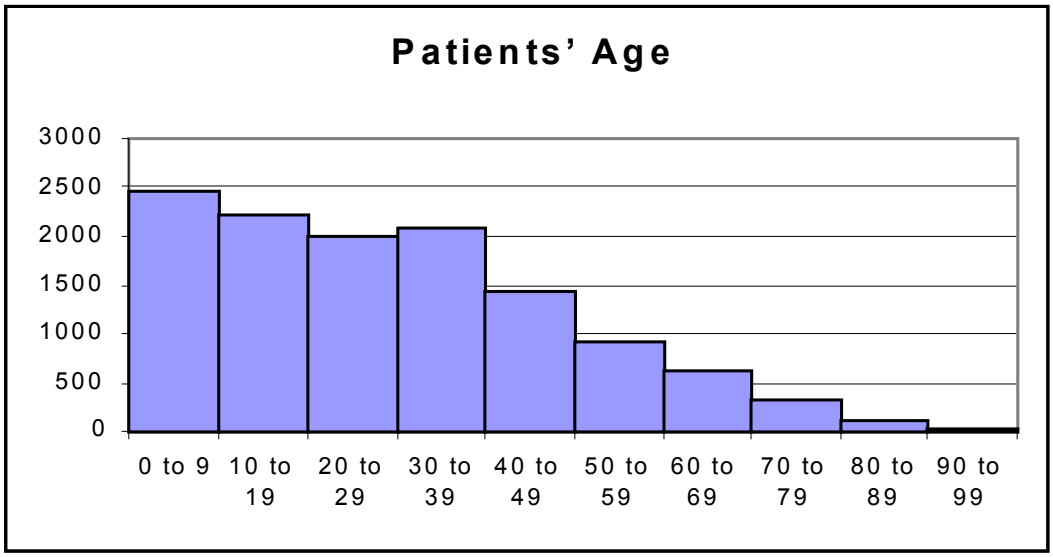
3. Description of the Population

Most patients (54.8%) are less than 30 years old (Table 1 and Figure 1).

Table 1: Patients' Age

Age Group	Freq.	%
0 to 9	2457	20.2%
10 to 19	2197	18.1%
20 to 29	2003	16.5%
30 to 39	2067	17.0%
40 to 49	1432	11.8%
50 to 59	938	7.7%
60 to 69	607	5.0%
70 to 79	319	2.6%
80 to 89	105	0.9%
90 to 99	21	0.2%
Total	12146	100.0%

Figure 1: Patients' Age



Most patients (91.5%) were classified as ASA I or ASA II (Table 2 and Figure 2).

Table 2: Distribution of ASA score

ASA	Freq.	%
I	5551	45.7%
II	5562	45.8%
III	937	7.7%
IV or V	93	0.8%
V	3	0.0%
Total	12146	100.0%

Figure 2: Patients' ASA

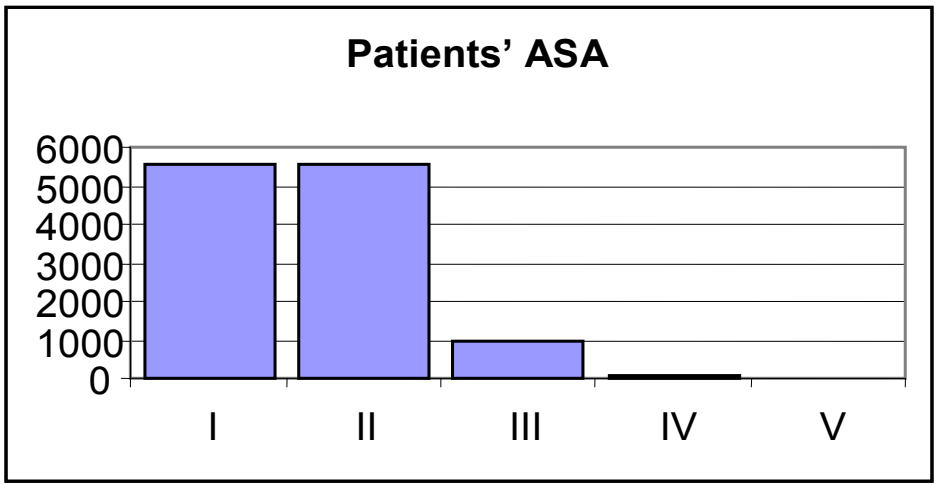


Table 3: Surgical Procedures by Specialty

Specialty	Freq.	%
Orthopedics	6221	51.3%
Neurosurgery	1641	13.6%
Plastic surgery	1341	11.0%
Thoracic surgery	623	5.1%
Maxillo-facial surgery	451	3.7%
Urology	404	3.3%
Oncology	381	3.1%
Gastroenterology	297	2.4%
Vascular	225	1.9%
Others	562	4.6%
Total	12146	100.0%

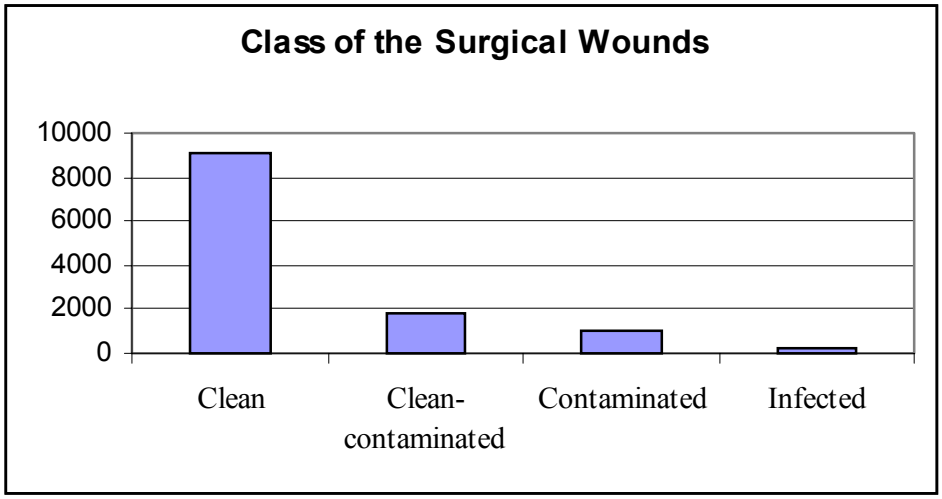
Orthopedic surgeries account for more than half of the total (Table 3).

Table 4: Class of Surgical Wounds

Wound class	Freq.	%
Clean	9074	74.6%
Clean-contaminated	1794	14.8%
Contaminated	1077	8.9%
Infected	201	1.7%
Total	12146	100.0%

Most surgeries (74.7%) were classified as clean surgeries (see Table 4 and Figure 3).

Figure 3: Class of the Surgical Wounds



4. Results of Regression Analysis

The following tables show the results of the regression analysis, with the regression coefficients, the force of the regression (measured by the value of R) and the degree of significance. Table 5 shows the variables retained by the best model, for all the surgeries as a whole.

Table 5: Global Regression

Variable	Coefficient	R	p
Antibiotic prophylaxis	0.5891	0.0827	0.0000
Complexity of the procedure	0.2584	0.0825	0.0000
Duration of procedure	0.2212	0.1334	0.0000
Wound class	0.2332	0.0559	0.0002
Constant	-4.8883		

The model chosen for all surgeries excluded patients' age and the ASA index. In the following Tables 6 and 7 we show the results of the regression analysis performed for orthopedic and neurosurgery procedures, respectively.

Table 6: Orthopedic Surgery (6,214 cases)

Variable	Coefficient	R	p
Antibiotic prophylaxis	0.7677	0.1073	0.0000
Complexity of the procedure	0.1698	0.0488	0.0107
Duration of procedure	0.2832	0.1020	0.0000
Constant	-4.4709		

Table 7: Neurosurgery (1,639 cases)

Variable	Coefficient	R	p
Complexity of procedure	0.4164	0.1101	0.0021
Duration of procedure	0.1353	0.0851	0.0110
Constant	-4.6644		

5. Discussion

Complexity and duration of the procedure were retained, both in the global analysis and in the analysis of orthopedic surgery and neurosurgery. So, both variables seem to be the best global predictors for surgical wound infection (SWI). The classification of surgical wound was only significant in the global analysis.

The use of antibiotic prophylaxis was considered a good predictor for SWI in the global analysis, as well as in orthopedic surgery. As far as antibiotic

prophylaxis is concerned, procedures with prophylactic administration of antibiotics have showed a higher SWI (this conclusion can be made due the positive signal of the coefficient). Schnoring and Brock (2003), Ferraz (1992), Young and Lawner (1987), and Auerbach (2001) have concluded, either in their papers or through meta-analysis of some other papers, that antibiotic prophylaxis reduced the surgical infection rate; on the other hand, d'Amico et al. (2001) and Knight et al. (2001), among others, have reported results similar to our findings.

One reason for this contradictory finding may be that doctors would prescribe the prophylaxis to patients at greater risk of infection. We think that our results need a deeper investigation and that there is a need for standardization of the administration of antibiotic prophylaxis, according to the characteristics of every hospital

Freitas and Campos (2000) published a paper where age and ASA score were significant predictors of SWI; however the duration of the operation and the wound class were not significant in the regression performed by this author.

In our study, patients' age was not retained in any of the regressions performed; one reason for this may be that most patients (55%) are less than 30 years old.

The same reason may account for the fact that the ASA score was not retained as an explanatory variable, since 92% of all patients classified as ASA I or ASA II.

In our patients, duration of operation seems to be the most important risk factor for SWI. However some papers, such as Freitas and Campos (2000) or Ferraz (1992), did not agree with our results.

6. Conclusions

In our study we have found out that duration of anesthesia seems to be a good predictor for SWI. This variable was not included in the model, since it depends on the duration of the procedure. The influence of the duration of anesthesia on SWI has to be confirmed by another retrospective case-control study. Horn (2002) reported a higher rate of SWI with the use of patient-controlled anesthesia (PCA), suggesting that an additional study must be carried out in order to elucidate the possible immunological effects of PCA pumps (or, indirectly, the use of prolonged analgesia).

Literature findings seem contradictory; however, groups of patients and procedures are quite different and so we think that every hospital must have its

own standardization process, particularly as far as antibiotic prophylaxis is concerned.

References

1. Auerbach, A., 2001. Prevention of Surgical Site Infections. In *Making Health Care Safer*, p. 221–230.
2. D'Amico, D.F., Parimbelli, P., et al., 2001. Antibiotic prophylaxis in clean surgery. *J Chemother*, 13(1):108–111.
3. Ferraz, E.M., 1992. Wound Infection Rates in Clean Surgery: a potentially misleading risk classification. *Infec Control Hosp Epidemiol*, 13:457–462.
4. Freitas, P.F., Campos, M.L. et al., 2000. Aplicabilidade do índice de risco do sistema NNIS na predição da incidência de infecção do sítio cirúrgico em um Hospital Universitário do Sul do Brasil. *Rev Ass Med Brasil*, 46(4):359–362.
5. Horn, S.D., Wright, H.L. et al., 2002. Association between patient-controlled analgesia pump and postoperative surgical site infection in intestinal surgery patients. *Surg Inf*, 3(2):109–118.
6. Pessaux, P., Msikas, S. et al., 2003. Risk factors for postoperative infectious complications in colorectal abdominal surgery: a multivariate analysis based on a prospective multicenter study. *Arch Surg*, 138(3):314.
7. Knight, R., Charbonneau, P. et al., 2001. Prophylactic antibiotics are not indicated in clean general surgery cases. *Am J Surg*, 182(6):682–6
8. Lee, E.S., Santili, S.M. et al., 2000. Wound infection after infrainguinal bypass operations: multivariate analysis of putative risk factors. *Surg Inf*, 1(4): 257–263.
9. Schnoring, M., Brock, M., 2003. Prophylactic antibiotics in lumbar disc surgery: analysis of 1030 procedures. *Zentralbl Neurochir,* 64(1): 24–29.
10. Young, R.F., Lawner, P.M., 1987. Perioperative antibiotic prophylaxis for prevention of postoperative neurosurgical infection. *J Neurosurg*, 66(5):701–705.
11. Consensus Paper on the Surveillance of Surgical Wound Infection, 1992. *Infect Control Hosp Epidemiol*, 13:599–605.

LIVER TRANSPLANT MODELS – A REVIEW AND MORE…

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Abstract: There are a limited number of livers available for liver transplantation and a growing number of eligible patients in the UK. Therefore, there are strict criteria for placing patients on the transplant waiting list and further conditions for the allocation of donated livers. The key limitations of existing models are that they do not consider the implications of allocating on an individual basis and they do not consider patient assessment policies for joining the waiting list. This paper concludes that the UK would benefit from a model which evaluates waiting list selection and criteria for allocating livers on a national basis. The proposed model will use discrete event simulation and mathematical programming techniques to describe the progress of patients, through the selection and transplant process. This model will evaluate various policies to understand the dynamics of allocation further, from an individual and aggregate basis, which will aid in identifying the desired features that an allocation system should contain.

1. Background

Although many new technologies [1] are being researched, liver transplantation is currently the only reliable treatment for people with badly damaged livers. The number of people requiring a liver transplant is increasing [2], [3] but despite government awareness campaign's [4], the supply of livers in the UK has remained fairly constant from 1995 to 2001 [5]. The main source of livers is from cadavers and recently the cadaver donor pool has been declining, making livers a scarce resource [4].

Equity measures convey the overall fairness of how the livers are allocated. They may be represented in various ways (e.g., as waiting times, as the percentage of patients transplanted within groups), across a range of categories (e.g., disease type, geographical region, gender). The figures obtained for each equity measure must be of comparable magnitude across groupings to resemble a fair process with respect to that particular category.

Utility measures help us to determine the overall usefulness of the allocating system. They can be measured as the total number of Life Years (LYs) gained or as the total number of Quality Adjusted Life Years (QALYs) gained. Process and outcome measures include the total costs incurred, the number of transplants performed, the number of donated organs that are wasted, and the number of patients to benefit from transplant, or to suffer from acute rejections, chronic rejections, or recurrence of liver disease. These measures are general indicators of the effectiveness of the system.

In reality there are many conflicting views and ethical issues [6] surrounding what is considered to be a fair or effective allocation process.

(i) A survey published in 1998 [7] which questioned the general public, family doctors and gastroenterologists about their views on allocating donated livers to potential recipients of liver allografts, established that the priorities of the public differ from those of the medical profession. The public tended to prioritise on a more emotional basis and rank patients with antisocial behaviour lowest. Whereas, the gastroenterologists and doctors and considered overall outcome, work status and the likelihood of working post transplant as key criteria when allocating the livers.

(ii) The overall gain in LYs or QALYs is dependent on the disease type being treated, so trying to maximise these two measures may lead to certain disease types with poor prognosis (e.g., cancer) not being treated at all. This actually resembles one of the main trade-offs; should patients who will benefit the most be transplanted, or should those who are more ill and therefore arguably in more need of a transplant but less likely to survive for as long, be allocated the liver. This is an important ethical issue and there is much debate on what is the correct rule to apply.

The above example helps to illustrate that sometimes you need to prioritise measures into relative importance, and that this is sometimes a hard decision to make.

2. Problems for Consideration

The following issues are ones that any liver allocating procedure should seek to understand and resolve.

2.1 Supply and Demand

The number of deaths from chronic liver disease has been increasing for the last 30 years, particularly in the last 10 years [8]. In recent years the gap between donations and the number of patients requiring a transplant has been widening [3], [4]. Though the exact figures are unknown, this gap is set to increase further for the following reasons:

- Improvements in surgical techniques and new immunosuppressive regimens leading to the possibilities of treating patients who have less promising prognoses [9].
- The increase in the number people falling ill from chronic liver diseases, such as, Hepatitis C, Alcoholic Liver Disease, Non Alcoholic Fatty Liver Disease and Hepatocellular Carcinoma [10], [8].

- Possible further declines in cadaver organs and the limited scope for live donors because of the risks involved.

Cadaver livers come from those who die young (under 50 years of age) without damaging their livers. Even if more people could be encouraged to donate [7], [9] it would only have a moderate impact on the disparity between supply and demand.

Another issue is that the regional supplies of and demands for liver organs are uneven. It is arguable that each region should obtain a fair share of the livers that become available according to need, however currently this is difficult to judge since the length of waiting list (WL) depends on what patients the different units decide are suitable to join the WL. If the same criteria for selecting patients that join the WL were incorporated in all regions and units then equity between regions and units could be increased. At the same time, the distance and time [11], [12] involved between procurement and transplant can influence the graft survival chances and the length of survival of the patient post transplant. Ideally we want a system that provides a fair proportion of livers to every region with respect to the proportion of liver disease patients that the regions look after, under the objectives of minimising the distance and time the liver allograft travels between operations.

2.2 Assessment/Selection

The assessment phase is the stage at which a decision is made as to whether a patient should be put on the transplant WL subject to pre-defined suitability criteria. Various tests and interviews are carried out to determine if the patient is likely to benefit from an operation. If their liver disease was induced due to alcohol, for example, special requirements of abstinence may have to be met and a judgement made as to the likelihood of the patient continuing to abstain post transplant [13]. If the patient has Hepatocellular Carcinoma then selection is also based on the extent and size of lesions. This phase is important because it helps in establishing whether or not a patient is likely to benefit from a transplant and indicates if the donated liver will be used effectively. It is also an important part of this study since it forms a key aspect of how the livers are rationed.

2.3 Allocation

Once patients are on the WL they are in competition for the livers available. In the UK, a patient must have a compatible blood type (as depicted in figure 1) to the donors [14], for each donated liver, however there are choices concerning

how to allocate with respect to better weight matching, matching based on donor and patient risk groupings and shorter distance.

Figure 1: ABO Blood Type Compatibility

		Donor Blood Type			
		O	A	B	AB
Patient Blood Type	O	✓	×	×	×
	A	✓	✓	×	×
	B	✓	×	✓	×
	A B	✓	✓	✓	✓

2.4 Donor and Patient Risk Groupings and Other

Past experiences have shown that marginal liver transplantation (where there is doubt as to whether the organ will function adequately e.g., donors of age 60 years or over, with hypotension, that were obese and so the liver has excess fat) results in poorer survival. This is a particular problem for patients that are most ill since their recovery in the post transplant phase is severely affected.

There are also issues regarding whether or not opting in (informed consent – where people have to volunteer to become donors), opting out (presumed consent – where all members of the public are automatically considered as donors and they must state otherwise if they do not want to be), or some policy in between these extremes [15], maximises the number of actual donations. In theory the opt out system should result in the best donation figures, however there is some debate as to whether this is true and how ethical this policy is.

Other problems that will require investigating include:

- The future use of split liver transplants (where a liver is split into two and therefore two patients can benefit from transplants) and live transplants;
- The effects of forcing identical patient-donor blood group matching as opposed to compatible blood groups;
- Policies in different countries concerning donors;
- How allocating livers is different from most other health care problems since it is not currently constrained by money issues.

3. Liver Transplantation in the United States

3.1 Specific Characteristics

The problems outlined previously are also characteristic of the American liver transplantation process. The supply of livers does not meet the demand [3] and

much recent work has attempted to establish how best to prioritise patients on the WL [12], [16], [17], [18], [19] in the form of policy analysis. The assessment of patients and allocation of livers play important roles in the dynamics of how the whole liver transplantation process operates.

Some issues are amplified due to the size of America, such as, providing geographical equity [12]. The private health care system that exists in America incorporates several separate companies that procure organs and others that transplant organs, which adds to the organisational complexity of the liver allocating problem [12].

3.2 Previous Developments

Several studies have attempted to model liver transplantation in America focusing mainly on who to allocate to and how to prioritise patients on the WL [12], [16], [17], [18], [19]. The CONSAD model [20] and the model developed by Howard [16] both carried out liver allocation policy evaluation. Howard compared a few rationing rules using a simulation model that considered loss of health and equity measures for each rule, under various demand-to-supply ratios.

3.3 Current Practice

In the US the United Network for Organ Sharing Liver Allocation Model (ULAM) [12], [17], [18] is currently in operation and patients are chosen to join the WL and for transplant based on their Model for End Stage Liver Disease (MELD) score [21], which determines the severity of their illness and their prognosis without transplantation. ULAM was initially developed to aid with comparing several policies and in 2000 it was updated to provide a model which was flexible, responsive, able to provide vast amounts of data to its end-users and was also clinically more acceptable [12]. The model is constantly updated and it incorporates many issues including distance measures (procurement to transplant) and provides several utility and equity measures.

3.4 The Future

More recently, a group based in Pittsburgh [19] have been developing another simulation model with the aims of (i) providing a clinically robust model which could enable the user to compare potential allocation policies, in terms of given objectives, and (ii) creating a model which would separate the modelling of the biology and natural history of the disease from the allocation and selection mechanism.

In 2002 the basic model was successful in incorporating the natural history of diseases independently of any particular patient priority scheme; however, the model incorporates 5 broad diagnostic categories and the authors indicated that the model also faces drawbacks concerning the availability and completeness of data.

In terms of allocation policies none of the models attempt to establish optimal allocations at the time a liver is procured based on a range of goals, neither do they consider the policies employed within the assessment phase.

4. Liver Transplantation in the UK

4.1 The Current UK System

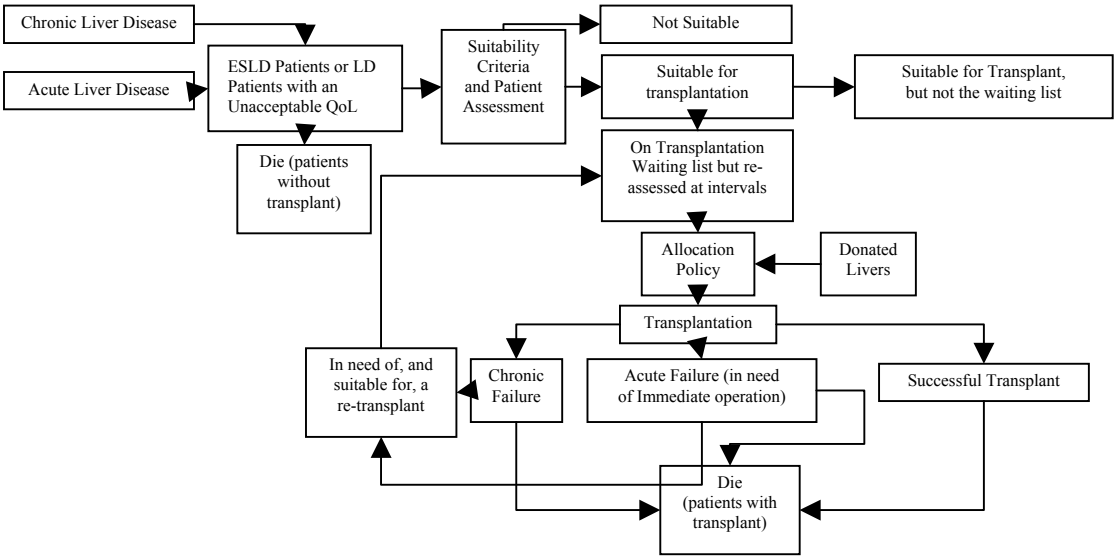
Figure 2 depicts the current process that a liver disease patient in the UK may go through, to obtaining a transplant, once they are diagnosed with acute or chronic liver disease. The diagram shows how acute and chronic liver disease patients first progress to End Stage Liver Disease (ESLD) or to an unacceptable Quality of Life (QoL), then they are assessed for suitability for transplant, and if judged suitable then they wait until a donated liver is allocated to them. If the patient is not currently suitable, they can be reassessed when their disease status changes. The outcome of the transplant may be:

(i) Chronic Graft Failure – patient reassessed for suitability of rejoining the WL;
(ii) Acute Graft Failure – patient rejoins the WL and most obtain another transplant;
(iii) Successful Transplant.

At any stage the patient may die. The key stages at which deaths should be compared are: Death Post Transplant and Death Pre Transplant.

Two important types of patients exist in this system: Super Urgent (SU) and Routine. SU patients have a prognosis of 72 hours survival without transplantation, whereas the Routine ones are those who have an unacceptable QoL or those that are expected to die within a year, if they do not receive a transplant. SU patients take priority over the Routine patients.

Figure 2: A Flow Chart to illustrate the Possible Stages That a Liver Disease Patient May Be in



It is believed that some patients who might be suitable for transplant are not put on the WL because their chances of receiving a transplant were considered slim—a consequence of supply not meeting demand.

4.2 Future Trends in Supply and Demand

Several government awareness campaigns [4] have been implemented but have not resulted in increasing supply, in the UK, between 1995-6 and 2000-1 [5].

4.3 Assessment for the transplant waiting list

The current suitability criteria [13] for transplantation are documented and are intended to ensure that the WL remains in balance with donors and exist to encourage consistency between units. Broadly the criteria are:

(i) Patients should be considered for transplantation if they had an anticipated length of life (in the absence of transplantation) of less than one year or an unacceptable quality of life. This is judged by the teams that assess patients at the liver transplant units.

(ii) Patients should be accepted for transplantation only if they have an estimated probability of being alive 5 years after transplantation of at least 50% with a quality of life acceptable to the patient.

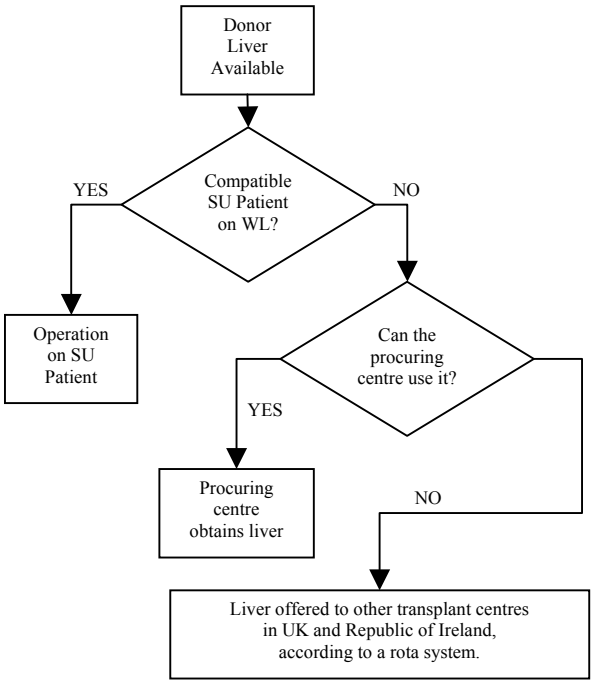
However the final decision as to who is classed suitable for a transplant is very subjective and remains dependent on the unit the patient is assessed at. The unmet need is hard to quantify since once a patient is turned away, liver units may not keep their records. Also it is not known how many patients would be

suitable for a transplant but who are not referred to a transplant centre. Also, since survival rates are improving [22], point (ii) allows many more patients onto the WL and therefore potentially requires revision.

4.4 Regional Supply and Demand

Figure 3 shows how a donated liver is currently allocated [14], with respect to location. Initially, the liver may be allocated to any compatible SU patient. If none exist then routine patients are allocated the liver, initially within the procuring unit, if no compatible patients exist within the procuring unit, then the other centres are offered the organ through a rota system.

Figure 3: A Flow Chart to Represent the Rules on how Livers are allocated to Centres



Therefore the current approach tries to ensure some degree of geographical equity. Under these rules however, if a certain unit procures significantly more livers then they will perform significantly more transplants than the other units. From the unit perspective this will seem fair, but for patients elsewhere it will not.

4.5 Allocation

Currently the procedure depicted in figure 3 is implemented in allocating the transplant. Patients are compatible if their blood group matches (as defined in figure 1) with the donors' and they have a similar body weight to the donor [13],

[14]. If there are any ties then the length of time the patient has been on the WL for is considered.

4.6 Donor and Patient Risk Groupings

The liver transplant units currently try not to allocate marginal livers [15] to the sickest patients. However, there are no set criteria for distinguishing who is too ill for a certain type of donated liver.

5. LiverSim

LiverSim [23], [24] is the only model that has been developed to evaluate liver allocation within the liver transplantation system in the UK. LiverSim is a discrete event simulation model which runs in Simul8. It provides an economic evaluation of the liver transplantation process under the patient prioritisation policies of: high wait, low wait, high age, low age, high PI[3], low PI, and Groups[4]. For each policy several outputs are calculated: total costs with and without transplantation, LYs gained with and without transplantation, and Incremental Cost Effectiveness Ratios (ICERs), where:

$$ICER = \frac{\text{Incremental Costs}}{\text{Incremental Effectiveness}} = \frac{\text{Total costs with transplantation - Total costs without transplantation}}{\text{Life years gained with transplantation - Life years gained without transplantation}}$$

The policies found to be the most cost effective [23], [24], from the results obtained, were low age and groups, meaning that allocating using severity of illness measures and to the younger members of the WL, is best.

There are limitations with this model, as it only incorporates two disease types (alcoholic liver disease and primary biliary cirrhosis). The model only considers patients from the Royal Free Hospital and it only investigates the cost-effectiveness of the system. Therefore, it leaves many problems unanswered concerning how to allocate livers fairly and most effectively. The model also excludes SU patients from its analysis, which is an important omission since SU patients affect allocations and overall outcomes greatly.

1. PI = clinical severity defined in terms of prognostic indices at the time of listing.
2. Groups = Patients were ranked in order of clinical severity and placed into four groups (A, B, C, D = more severe patients). Patients in group D were given a lower priority for a donor organ than patients in the other groups.

Other models in the UK have also attempted to find the optimal timing for transplant with respect to certain diseases [25].

6. Proposed Model

Below is an outline of how this research will aid in developing models that will investigate the problem of allocating livers within the UK and selecting patients to join the WL, under technique headings. The techniques that will be implemented include Discrete Event Simulation (DES), Mathematical Programming, and various Statistical Analyses.

6.1 Discrete Event Simulation

To evaluate the impact of certain selection policies and allocation policies with respect to various equity and outcome utility measures, a DES model implementing the *Patient Oriented Simulation Technique* (POST) [26], [27] will be constructed. POST has already been effectively implemented in other health care settings such as diabetes [28], chronic heart disease [29], and renal failure [30], [31].

The simulation model will investigate the processes of patient assessment and allocating livers, taking into account: supply and demand (both the various increasing demand trends and the regional issues), cadaver and live transplants, through evaluating equities and utilities under a range of allocation policies. It will also allow for comparisons between patients who are transplanted and those who are not so fortunate.

6.2 Mathematical Programming

To aid with examining policies concerning liver allocation to individuals that should be investigated in the simulation model, several mathematical programs that allocate optimally under varying constraints and objectives will be devised. Goal programming is the most appropriate since there are many objectives (utilities) and constraints (equities and constraints) within the liver allocation process. The utilities and constraints will also have differing importance, so being able to allocate various weights to each is an important part of the formulation. For example, patient-to-donor weight constraints and patients-to-donor blood type matching are important constraints and *must* be respected while age constraints and waiting times are of slightly less significance.

6.3 Integration of Simulation and Mathematical Programming

The results that are obtained from the mathematical programs will be analysed and any policy implications will be further tested using the simulation model.

6.4 Statistical Analysis

Statistical analysis techniques will be implemented in obtaining survival distributions for incorporation within the DES. Regression techniques will be used in attempting to predict overall outcomes of transplantation, based on donor and patient risk groupings, retrospectively and to aid in identifying what variables actually influence overall outcome, with and without transplant.

6.5 Conclusions

The overall model will help with understanding the dynamics of the process a liver disease patient may go through towards receiving a transplant. It will demonstrate how allocation and selection policies directly influence overall system outcomes and show what happens when the policies are varied.

Analysis will also be carried out to establish how different allocating procedures (e.g., using the MELD score to prioritise patients, allocating livers nationally or locally) would affect the overall outcomes of patient equity, the utility of the system and of the donated livers.

References

1. Strong, R.W., 2001. *Liver transplantation: current status and future prospects,* Journal of the Royal College of Surgeons Edinburgh, 46, February 2001, p. 1–8.
2. Neuberger, J., 1997. *Allocating donor livers,* Editorial of BMJ, 314:1140 (April 19).
3. Neuberger, J., 1999. *Liver Transplantation,* Editorial of Q J Med; 92:547–50.
4. Neuberger, J., 2003. Should Liver Transplantation Be Made Available to Everyone? – The Case Against*, Archives of International Medicine*, 163:1881–3
5. UK Transplant Activity, 2001 *Section 5 Liver Activity,* p. 35–41. http://www.uktransplant.org.uk/statistics/transplant_activity/uk_trans_activity2001_html/uk_tx_a2001_35.htm *(last accessed: April 2003)*
6. DuBois, J.M., 2002. Organ Transplantation: An Ethical Road Map, *The National Catholic Bioethics Quarterly*, Autumn 2002, 2(3) http://www.lifeissues.net/writers/dub/dub_01organtransethics4.html *(last accessed: May 2003)*

7. Neuberger, J., Adams, D., MacMaster, P., Maidment, A., and M. Speed, 1998. Assessing priorities for allocation of donor liver grafts: survey of public and clinicians, *BMJ*, 317 18/07/98 172–5.
8. Annual Report of the Chief Medical Officer 2001. *Liver cirrhosis – starting to strike at younger ages,* p. 16–9.
9. Neuberger J., and O. James, 1999. Guidelines for selection of patients for liver transplantation in the era of donor-organ shortage, *The Lancet*, Vol. 354, Nov. 6 1999, 1636–9.
10. Alcohol – can the NHS afford it? *Recommendations for a Coherent Alcohol Strategy for Hospitals,* Royal College of Physicians, February 2001.
11. Stahl, J., Schaefer, A.J., Kong, N., Shechter, S., Roberts, M., and S. Gazelle. *Organ Transplant Regions – What Is Their Optimal Size and Distribution? A Framework for Analysis* (submitted for publication), http://www.ie.pitt.edu/~schaefer/Papers/OrganRegions.pdf *(last accessed: May 2003)*
12. Harper, A.M., Taranto, S.E., Edwards, E.B., and O.D. Daily, 2000. *An Update on a Successful Simulation Project: The UNOS Liver Allocation Model,* In Proceedings of the 2000 Winter Simulation Conference.
13. UK Transplant Liver Transplant Services. *Donor Organ Use – Protocols and Guidelines for Adults undergoing Cadaveric Liver Transplantation* Published Nov. 1999, Revisions March 2000 and April 2001 http://www.uktransplant.org.uk/about_transplants/organ_allocation/liver/national_protocols_and_guidelines/protocols_and_guidelines/protocols_and_guidelines_for_adult_liver_transplantation.doc *(last accessed: April 2003)*
14. UKT Liver Advisory Group. *Donor Organ Sharing Scheme – Operating Principles for Liver Transplant Units in the UK and Republic of Ireland* First published: July 1999, Last Amended October 2002 http://www.uktransplant.org.uk/about_transplants/organ_allocation/liver/liver_organ_sharing_principles/oss_liver_11-2002-1.doc *(last accessed: April 2003)*
15. Neuberger, J., Liver Transplantation*, Journal of Hepatology,* 32(suppl. 1):198–207.
16. Howard, D.H., 2001. Dynamic Analysis of Liver Allocation Policies, *Clinical Decision Making*, 21(4):257–266.
17. Pritsker, A.A.B., Martin, D.L., Reust, J.S., Wagner, M.A., Wilson, J.R., Kuhl, M.E., Allen, M.D., Daily, O.P., Harper, A.M., Edwards, E.B., Bennett, L.E., Roberts, J.P., and J.F. Burdick, 1995. *Organ Transplantation Policy Evaluation,* In Proceedings of the 1995 Winter Simulation Conference.
18. Pritsker, A.A.B., Daily, O.D., and K.D. Pritsker, 1996. *Using Simulation to Craft a National Organ Transplantation Policy,* In Proceedings of the 1996 Winter Simulation Conference.

19. Kerke, J., Angus, D.C., Bryce, C.L., and M.S. Roberts, 2002. *Incorporating Biology into Discrete Event Simulation Models of Organ Allocation,* In Proceedings of the 2002 Winter Simulation Conference, p. 532–6.
20. CONSAD Research Corporation 1999 (Update: 09/10/99). *National Organ Allocation Policy for Transplantation – National Liver Allocation System Model,* http://www.consad.com/projects/liverta.htm *(last accessed: May 2003)*
21. Wiesner, R., Edwards, E., Freeman, R., Harper, A., Kim, R., Kamath, P., Kremers, W., Lake, J., Howard, T., Merion, R.M., Wolfe, R.A., and R. Krom, 2003. The United Network for Organ Sharing Liver Disease Severity Score Committee Model for end-stage liver disease (MELD) and allocation of donor livers, *Gastroenterology,* 124: 91–6.
22. UK Transplant Support Services Authority (UKTSSA) *Liver Transplant Audit 1985-1995, Transplant Survival Analysis*, p. 24–9. http://www.uktransplant.org.uk/statistics/general_statistics/liver/audits/liver24-29.pdf *(last accessed: April 2003)*
23. Baldwin, L.P., Eldabi, T., Paul, R.J., and A.K. Burroughs, 2000. *Using Simulation for the Economic Evaluation of Liver Transplantation,* Proceedings of the 2000 Winter Simulation Conference, p. 1963–70.
24. Eldabi, T., 1999. *Simulation Modelling: Problem Understanding in Healthcare Management,* Ph.D. Thesis, Brunel University.
25. Christensen, E., Gunson, B., and J. Neuberger, 1999. Optimal timing of the liver transplantation for patients with primary biliary cirrhosis: use of prognostic modeling, *Journal of Hepatology*, 30:285–92.
26. Davies, R. and R.M. O'Keefe, 1989. *Simulation Modelling with Pascal* Prentice Hall Int.
27. Davies, R., O'Keefe, R.M., and H.T.O. Davies, 1993. Simplifying the modelling of multiple activities, multiple queuing, and interruptions, a new low level data structure, *ACM Transactions on Modeling and Computer Simulation,* 3(2):332–46,
28. Davies, R., Brailsford, S., Roderick, P.J., Canning, C., and D. Crabbe, 2000. Using Simulation modelling for evaluating screening services for diabetic retinopathy, *Journal of Operational Research Society*, 51(4):476–85.
29. Davies, R., Cooper, K., and P. Roderick, 2002. *Simulation of policies for prevention and treatment in coronary heart disease,* Health Sciences Simulation 2002, Western simulation Multiconference, San Antonio, p. 134–8.
30. Davies, R. and P.J. Roderick, 1998. *Simulation Used in Conjunction with Randomised Control Trials to Evaluate the Costs and Benefits of a New Drug,* Proceedings of the 1998 Winter Simulation Conference, Washington, 1578–85.

31. Davies, R. and P.J. Roderick, 1998. Planning resources for renal services throughout the UK using simulation, *European Journal of Operational Research*, 105(2):285–295.

EVALUATING THE NEW DIAGNOSIS & TREATMENT CENTRES IN THE UK

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Abstract: The UK Government has introduced a new class of hospitals that are intended to deliver diagnostic and "routine" elective services but that will not deliver emergency or "non-routine" elective services. We are involved in a multi-disciplinary evaluation of these Diagnosis and Treatment Centres as a mode of service delivery. The introduction of these hospitals provides several potential mechanisms for improving the efficiency of service delivery in terms of the throughput of patients. We will discuss the modelling approaches that we are using to evaluate whether these potential benefits can be realised.

1. Introduction

A new class of health care centres that are dedicated to the delivery of diagnostic and routine elective services are being introduced in the UK. Some of these DTCs (Diagnosis and Treatment Centres) are newly built hospitals whereas others are housed in existing acute hospitals. The Clinical Operational Research Unit (CORU) is working with colleagues from the University of Southampton and the Centre for Health Informatics and Multi-professional Education at University College London to evaluate DTCs as a new mode of service delivery. The research evaluation will study DTCs from a number of perspectives including Change Management, Organisational Development and Knowledge Management. CORU's activity will focus on the impact that DTCs have on the throughput of patients and the efficient use of capacity.

An important element of the operation of a DTCs is that a firm commitment is given to patients regarding the date for their diagnosis appointment or admission to hospital. In previous papers [1,2] we have used mathematical modelling to investigate capacity required to operate such booked admission systems. A key feature of this work is the major role played by unpredictable variability in hospital operation. This is a commonplace notion in Operational Research, the general rule being that the more unpredictable variability there is in a system, the more likely it is that operational emergencies will occur, particularly if systems operate close to capacity. Depending on the context, such operational emergencies might include unacceptable computer network delays, road traffic gridlock or bed crises.

The problem presented by unpredictable variability is not so much the variability but the fact that it is unpredictable. If one can somehow predict variations, system design can take account of this and compensate. For example,

we know ahead of time that winter months bring an increase in admissions for respiratory conditions. This is predictable variability and sensible planning takes account of it.

The introduction of DTCs offers an opportunity to reduce the level of unpredictable variability in the health service. This paper outlines the mechanisms by which the introduction of DTCs may improve the efficient use of capacity and the mathematical modelling tools that CORU plan to employ to evaluate whether the potential benefits can be realised. Hypothetical examples are given to illustrate the models described. The next section describes the effect of unpredictable variability on estimating capacity requirements within healthcare.

2. Modelling Capacity Requirements

In this section we discuss some of the basic notions related to mathematical estimates of resource need. Unfortunately health service planning terminology can be ambiguous, for example the term ‘capacity’ can have different meanings depending on the context and the degree of refinement with which it is estimated.

Our mathematical models of in-patient care are based on a simplifying assumption that a ward or unit has a fixed number of ‘beds’ which corresponds to the maximum number of patients who can simultaneously be in-patients. Further we assume that an episode of patient care occupies a whole number of days and that during that time, the patient concerned effectively occupies a bed during the whole of the period. This ignores admissions and discharges at different times of day. Although the results of our models give capacity requirements in terms of "beds", this is viewed as a surrogate measure for overall resource needs, including staff and equipment.

The main features of our models are as follows:

We assume that patients are categorised into a number of distinct groups. This might be done according to a Health Related Group (HRG) categorisation, or by using some other system.

The number of **admissions** is specified for each patient group for each day of a repeating planning cycle, typically a week.

The **length of stay** distribution for different patient groups are specified based on data derived frequency distributions rather than mathematical distributions and the assumption is made that the length of stay of patients are independent.

Methods from standard **probability theory** are then used to calculate the distribution of bed requirements for each day in the cycle, assuming that no admissions are cancelled by the hospital.

These distributions are then used to **estimate the level of operational emergencies** that the hospital would face if a fixed number of beds were available.

3. Modelling Variations in Bed Demand

We use the following notation:

Suppose that there are *H* categories of patients, each category having its own characteristic length of stay distribution. These may be thought of as being different HRGs although in principle other categories could also be used incorporating factors such as age and co-morbidity.

We assume that there is a fixed admissions planning cycle of duration C days. Typically this will be the 7-day week, although other planning cycles may be preferred.

For $1 \le c \le C$ and $1 \le h \le H,$ suppose that $N_{h,c}$ is the number of elective booked admissions planned for day *c* of the planning cycle who are from category *h*. Note that we assume cyclic operation whereby the same pattern of elective admissions are planned from one cycle to the next.

Variation in length of stay is a central feature of our analysis and we reflect this using probability distributions associated with the patients' length of stay. For $1 \le c \le C, 1 \le h \le H,$ let p_{cj}^{h} denote the probability that a patient from category *h* booked to be admitted on day *c* of the planning cycle is still an in-patient *j* days later. Note that in the simplest case we might assume that these length of stay distributions do not depend the day of admission, however we allow for the possibility that factors such as the occurrence of weekends may influence discharge decisions.

It is notationally convenient to assume that p_{cj}^{h} is defined and has the value 0 for values of j that are negative.

We are interested in estimating bed demand and how this varies during the planning cycle depending on the parameters discussed above. We stress that this is different from a typical queuing theory analysis that would take into account

the consequences of sufficient capacity being unavailable. Our intention is to estimate the demand for beds that would follow from a particular pattern of admissions rather than to examine the consequences of whether this demand can be met. In these circumstances, results from a previous paper [2] can be extended to derive closed form analytical expressions for the mean and variance for the number of patients requiring beds on a given day of the planning cycle depending on the factors discussed above.

A central and simplifying feature of our analysis is that the assumption of cyclically repeating admissions means that the steady state probabilities concerning the level of demand are also cyclic. Also, one can reinterpret length of stay survival distributions in cyclic terms. A concrete example helps to motivate the particular form taken by our formulae for bed demand. Suppose a planning cycle of one week. Suppose that each week there is a single admission from a single HRG and that this always occurs on a Monday. The expected bed demand for each Monday is the sum of contributions corresponding to the current admission, the admission on the previous Monday, the admission the week before etc. In order to derive an analytical expression for this expectation, one simply adds terms in the length of stay survival distribution corresponding to 0 days, 7 days, 14 days etc. Equally, to determine expected bed demand on a Tuesday, one sums the survival distribution terms corresponding to 1 day, 8 days, 15 days etc.

Extending this notion to the more general case, $X^h_{d,i}$ the contribution to the mean bed requirements on day *d* of the cycle from an admission on day *i* of the cycle of a patient from group *h*, is given by:

$$X^h_{d,i} = \sum_{w \geq 0} p^h_{i,(wC+d-i)} \tag{1}$$

Note that given the general definition of $p^h_{i,j}$, terms of this series for which the second subscript is negative are zero.

Then μ_d, the total mean bed requirements on day *d* of the cycle, is simply given by:

$$\begin{aligned} \mu_d &= \sum_{h=1}^{H} \sum_{i=1}^{C} N_{h,i} X^h_{d,i}. \\ &= \sum_{h=1}^{H} \sum_{i=1}^{C} N_{h,i} \sum_{w \geq 0} p^h_{i,(wC+d-i)}, \qquad 1 \leq d \leq C. \end{aligned} \tag{2}$$

Similarly, the contribution to the variance of the number of beds required on day *d* of the cycle from a single admission on day *i* of a patient from group *h*, $Y^h_{d,i}$, is given by:

$$Y^h_{d,i} = \sum_{w\geq 0} p^h_{i,\,wC+d-i}(1-p^h_{i,\,wC+d-i}) \qquad (3)$$

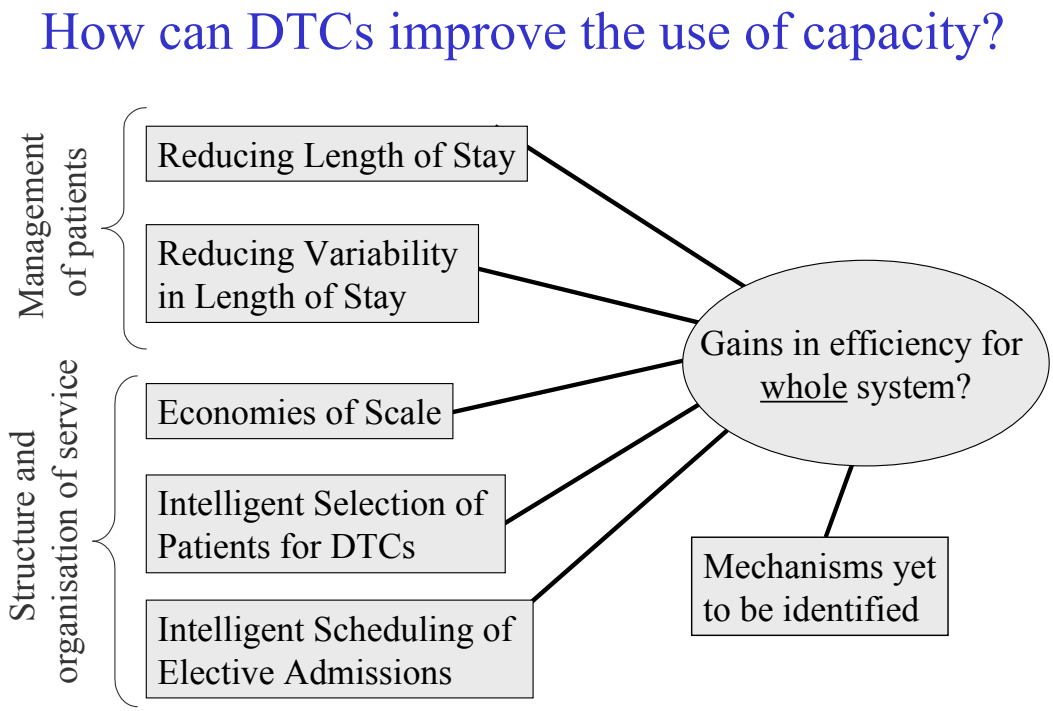
and σ^2_d, the variance of the bed requirements on day d of the cycle, by

$$\sigma^2_d = \sum_{h=1}^{H}\sum_{i=1}^{C} N_{h,i} Y^h_{d,i}\,.$$
$$= \sum_{h=1}^{H}\sum_{i=1}^{C} N_{h,i} \sum_{w\geq 0} p^h_{i,\,wC+d-i}(1-p^h_{i,\,wC+d-i}), \qquad 1\leq d\leq C. \qquad (4)$$

4. Mechanisms for Improving Efficiency in the Use of Capacity

Part of the motivation behind DTCs is to improve efficiency by delivering some healthcare services in an environment less prone to the effects of unpredictable variability. For instance, booked admissions systems have been shown to reduce patient non-attendance rates [3]. The other potential mechanisms for increasing throughput and making more efficient use of capacity offered by the introduction of DTCs are as follows (see Figure 1).

Figure 1: The potential mechanisms for increasing throughput and the efficient use of capacity offered by the introduction of diagnosis and treatment centres



One expectation is that improved management of patient care pathways will reduce the length of stay (LOS) for patients treated in DTCs compared to the

same patients if treated in a non-DTC environment. This has obvious implications for being able to increase throughput for a given level of capacity.

In addition to reducing LOS, there is scope for improved management of patients to reduce variability in LOS, which could give rise to less fluctuations in capacity requirements and an attendant increase in throughput.

Referring all patients with a particular treatment need to one DTC may introduce capacity requirement benefits due to economies of scale. Put simply, the proportion of capacity required to cater for unpredictable fluctuations in capacity requirements decreases with increasing scale.

Emergency admissions, a major source of unpredictability, are intended to play little or no part in the operation of most DTCs. Furthermore, selecting distinct groups of patients with particular LOS characteristics (if possible) and using separate pools of capacity to treat them (either DTC or Non-DTC) has great potential for reducing unpredictable variability in length of stay. That said, separating streams of patients goes against arguments based on the economies of scale.

Another potential mechanism for reducing unpredictable fluctuations in capacity requirements is to make use of the LOS characteristics of different patient groups into consideration when scheduling admissions of patients to a hospital department.

5. Illustrative Analysis

Consider a hypothetical health economy where elective orthopaedic surgery services are delivered by two hospitals. For the sake of simplicity, assume that only two types of operation, total knee replacements and arthroscopies, are provided and that demand for each is the same. The length of stay distributions used for the two operations were based on data from the UK NHS Health Episode Statistics. The modelling techniques described in the previous section were used to calculate the number of beds required to avoid operational problems on at least 95% of weekdays for a number of scenarios. The different scenarios reflect different ways in which the delivery of services could be delivered and were chosen to illustrate the potential benefits of different aspects of DTC operation. Each was based on a throughput of 20 patients per week. Table 1 gives a brief description of each scenario and its estimated capacity requirements.

Table 1: The capacity required for a throughput of 20 orthopaedic patients per week for different service configurations.

Scenario	Description	Total capacity Requirements
Baseline	Two hospitals - each admitting two patients per-weekday without regard to case mix.	30 beds
Economies of scale	One hospital - each admitting four patients per-weekday without regard to case mix.	28 beds
Patient selection	Two hospitals - one admitting two patients per weekday for arthroscopy, the other admitting two patients per weekday for total knee replacement.	28 beds
Combined	One hospital admitting two patients per weekday for arthroscopy and two patients per weekday for total knee replacement	26 beds

6. Discussion

The introduction of DTCs to the UK NHS offers an opportunity to reorganise the delivery of elective services and could potentially lead to a more efficient use of hospital capacity and thus increase the throughput of patients. This paper has discussed some of the mechanisms for this potential increase in system efficiency and illustrated the effect of these with the results of an admittedly simplistic mathematical modelling exercise.

Given the scope of DTCs to select the services that they deliver and, to a lesser extent, the patients that they offer treatment to, it is essential to assess the impact of the introduction of DTCs on the non-DTC environments that deliver emergency and non-routine services. To reflect this, the basis of the mathematical modelling part of the evaluation of DTCs will be a whole systems view of the delivery of services within a given health economy. Rather than ask whether DTCs deliver the services they offer efficiently, we will attempt to assess whether the introduction of DTCs can lead to a more efficient use of capacity within the health economy as a whole.

References

1. Gallivan, S., Utley, M., Treasure, T., and O. Valencia, 2002. Booked in-patient admissions and capacity: mathematical modelling study, *British Medical Journal,* 324:280–2.
2. Utley, M, Gallivan, S., Treasure, T., and O. Valencia, 2003. Analytical methods for calculating the capacity required to operate an effective booked

admissions policy for elective inpatient services, *Health Care Management Science,* 6:97–104
3. Kipping, R., Meredith, P., McLeod, H., and C. Ham, 2000. *Booking Patients for Hospital Care: a progress report.* Second Interim report from the evaluation of the national booked admissions programme first-wave pilots. Retrieved from www.bham.ac.uk/hsmc.

MEDICAL STAFF SCHEDULING

SCHEDULING DOCTORS FOR NIGHT DUTY

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Abstract: In this paper we deal with the problem of scheduling doctors to night duties at hospitals. Every month, doctors usually work several night duties in addition to their usual day duties in Japan. The appropriate number of doctors and skill level must be assigned to every night duty while balancing the workload among the doctors. The constraints of this problem are of block-angular structure. This structure consists of diagonal blocks of constraints for a specific doctor that can be dealt with independently without a set of linking constraints. We deal with this problem as a variant of the nurse-scheduling problem and we solve it by an algorithm based on the 'Subproblem-centric approach' for nurse scheduling. This algorithm obtains good schedules efficiently.

1. Introduction

In hospitals, emergency medical care and nursing are needed around the clock, so therefore, in Japan, doctors usually work several night duties in addition to their usual day duties every month. The scheduling for this is usually carried out by one of the doctors involved and although it is independent of day duty scheduling it is considered difficult. The main reason for this is that the scheduler has to assign the appropriate number of doctors and skill level to each day as well as balance the doctors' workload. Although the study of nurse scheduling began as early as the 1970's [9, 11, 12] and has continued [1–8, 10], doctor scheduling for night duty has not been dealt with as a mathematical problem. This might be because night duty is usually considered as standby work rather than regular work.

Doctors are usually grouped according to their specialty and skill. Days in a scheduling period are also grouped into two or three groups e.g. Sundays, Saturdays and weekdays, because the number of night duties that a doctor works in each 'day-group' must be considered as well as the number in total. In addition there are some work patterns that may adversely affect the doctors' health and are therefore not permitted, e.g. consecutive night duties or an on-off-on pattern.

In this paper, this problem is dealt with as a variant of the nurse scheduling problem and it is solved by an algorithm based on the *Subproblem-centric approach,* which is proposed for nurse scheduling [7], although this problem has no rotation. After describing a model for scheduling doctors for night duty and the algorithm that solves this problem, the computational results are shown,

where the algorithm obtains good schedules efficiently for a real scheduling problem in a hospital.

2. Model

When we make a schedule for staff involved in medical care or nursing, we have to satisfy essentially two different types of constraints. One maintains a certain level of skill for each shift and the other concerns the workload for each staff. There is a trade-off between these types of constraints e.g. when a skilled member staff is continuously given a busy schedule, although it is good for the skill level of the shift, it can be extremely mentally and physically tiring for the staff. The formulation of scheduling doctors for night duty considers this relationship. This formulation is shown after explanation of the notation.

Notation

$M = \{\text{doctor1, doctor2, …, doctor}\, m\}$: the set of doctors involved.

$N = \{1,2,\ldots,n\}$: the set of days in the scheduling period.

$R = \{r \mid r$ means a skill/specialty/etc group$\}$.

$G_r = \{i \mid i$ means a doctor belonging to group $r\}, r \in R$.

$Q = \{q \mid q$ means a Sundays/Saturdays/ weekdays/etc group $\}$, $N_q \subseteq N$, $q \in Q$: the subset of days in the scheduling period.

$F_1 = \{(i,j),\ i \in M,\ j \in N \mid$ doctor i must work on day $j\}$.

$F_0 = \{(i,j),\ i \in M,\ j \in N \mid$ doctor i cannot work on day $j\}$.

a_{rj} and b_{rj}, $r \in R$, $j \in N$ are the lower bound and the upper bound respectively for the number of doctors belonging to group r working on day j.

c_{iq} and d_{iq}, $i \in M$, $q \in Q$ are the lower bound and the upper bound respectively for the number of night duties on the day-group q for doctor i.

$P_h = \{(k_1,k_2,\ldots,k_h),\ k_1,k_2,\ldots,k_h \in \{0,1\} \mid$ a doctor cannot work $(k_1,k_2,\ldots,k_h)$ pattern, where 1 represents a day-on and 0 represents a day-off $\}$, $h \in \{2,3,\ldots\}$, e.g. $(1,1)$ means consecutive night duties and $(1,0,1)$ means only one day-off between two night duties.

decision variable x_{ij}, $i \in M$, $j \in N$ equals 1 if doctor i works on day j, otherwise 0, although $x_{ij}, j \le 0$ represents a fixed schedule in the previous month and it is not decision variable.

Formulation

(1) $\quad a_{rj} \le \sum_{i \in G_r} x_{ij} \le b_{rj} \qquad\qquad r \in R,\ \ j \in N$

(2) $c_{iq} \le \sum_{j \in N_q} x_{ij} \le d_{iq} \qquad i \in M,\ q \in Q$

(3) $x_{ij} = \tau \qquad (i,j) \in F_\tau,\ \tau \in \{0,1\}$

(4) $\sum_{\alpha=1}^{h} (2k_\alpha - 1) x_{i,j-h+\alpha} \le \sum_{\alpha=1}^{h} k_\alpha - 1 \qquad i \in M,\ j \in N,$

$(k_1, k_2, \cdots, k_h) \in P_h,\ h \in \{2,3,\cdots\}$

(5) $x_{ij} = 0 \ \ or \ \ 1 \qquad i \in M,\ j \in N$

Constraint (1) is for maintaining a certain level of skill for each day, where the number of doctors belonging to a specific group working on a particular day must be within a given range. Constraint (2) is or the workload for each doctor, where the number of night duties on a specific day-group for each doctor must be within a given range. Constraint (3) is for the fixed schedule. When doctor i must work on day j $x_{ij} = 1$, and when doctor i cannot work on day j $x_{ij} = 0$. Constraint (4) avoids the patterns that are not permitted for health reasons, where doctors cannot work pattern $(k_1, k_2, \ldots, k_h)$, e.g. the pattern $(1,0,1)$ means that only one day-off between two night duties is not permitted.

The constraints of this problem can be divided into two groups as mentioned above; constraints (1) and the others. These are of Block-angular structure. This structure consists of diagonal blocks of constraints for a specific doctor who can be dealt with independently without a set of linking constraints, i.e. constraints (1).

There are usually no other constraints or goals other than those mentioned above which could be deemed important enough to deal with due to the larger problem of having a lack of staff. Even if there were a requirement different from the above-mentioned constraints or even if there were a goal, the requirement could be dealt with as a variant of either one of two types of constraints with a small impact on the computational complexity by the approach. This is proposed in the next section.

3. Subproblem-centric approach

The Subproblem-centric approach is based on the decomposition of a problem into subproblems when constraints are of Block-angular structure. It improves the objective function by repeatedly solving subproblems, where the objective function includes minimizing violations for the linking constraints.
Therefore, when we solve scheduling doctors for night duty, we first define z as the degree of violations for the linking constraints as follows:

$$z = \sum_{r \in R} \sum_{j \in N} \alpha_{rj}^{-} + \sum_{r \in R} \sum_{j \in N} \beta_{rj}^{+}$$

where,

α_{rj}^{-}: the amount below the lower bound a_{rj} for the number of doctors belonging to group r working on day j.

β_{rj}^{+}: the amount above the upper bound b_{rj} for the number of doctors belonging to group r working on day j.

Next, we set a subproblem for each doctor. For a given trial solution, *subproblem* i finds the optimal schedule for doctor i given that the other doctors' schedules are specified in the current trial solution. The formulation for the subproblem and Subproblem-centric approach are shown as follows:

<u>*Subproblem i*</u>

(6) *Minimize* $z = \sum_{r \in R} \sum_{j \in N} \alpha_{rj}^{-} + \sum_{r \in R} \sum_{j \in N} \beta_{rj}^{+}$

subject to

(7) $\sum_{i \in G_r} x_{ij} + \alpha_{rj}^{-} - \alpha_{rj}^{+} = a_{rj} \qquad j \in N$

(8) $\sum_{i \in G_r} x_{ij} + \beta_{rj}^{-} - \beta_{rj}^{+} = b_{rj} \qquad j \in N$

(9) $c_{iq} \le \sum_{j \in N_q} x_{ij} \le d_{iq} \qquad q \in Q$

(10) $x_{ij} = \tau \qquad (i, j) \in F_\tau, \ \tau \in \{0,1\}$

(11) $\sum_{\alpha=1}^{h} (2k_\alpha - 1) x_{i \cdot j-h+\alpha} \le \sum_{\alpha=1}^{h} k_\alpha - 1 \qquad j \in N,$

$(k_1, k_2, \cdots, k_h) \in P_h, \ h \in \{2,3,\cdots\}$

(12) $x_{ij} = 0 \ \ or \ \ 1 \qquad j \in N$

(13) $\alpha_{rj}^{-}, \alpha_{rj}^{+}, \beta_{rj}^{-}, \beta_{rj}^{+} \ge 0 \qquad r \in R, \ j \in N$

<u>*Subproblem-centric approach*</u>

Starting from an appropriate trial solution, e.g. a dummy schedule for each doctor that specifies his/her schedule as days off only, we solve a problem through two phases. In the contractive phase, we solve each subproblem for doctors still assigned a dummy schedule. Then we accept the best solution from the results in those subproblems. This process is continued until all of the dummies are resigned. In the improvement phase, we solve each subproblem for all doctors. Then we accept the best solution from the results. This process is

continued until the objective value is zero while avoiding the creation of a loop e.g. by ignoring the specific schedule that produced the current trial solution from future subproblem solving processes.

4. Algorithm

In the algorithm based on the Subproblem-centric approach, we use a simple branch-and-bound for the subproblem at each iteration. We divide the scheduling horizon into periods of appropriate numbers of days in order to enumerate all the feasible patterns for each period for each doctor, for example, 4 periods of 7 days and 1 period of 2 days. The short patterns satisfy the constraints for the pattern that is not permitted and the constraints for the fixed schedule of the doctor within the period.

The branch-and-bound branches by selecting a pattern among the untested patterns associated with the period that can reduce the value of z the most. It calculates the lower bound of z by using short patterns in the periods that are not fixed while ignoring the constraints (2) and (4) for the short patterns.

In order to speed up the algorithm, in the improvement phase, this branch-and-bound algorithm stops as soon as a solution with an objective value of less than the value of the current trial solution is found, and the solution is employed as the next trial solution without solving the remaining subproblems for that iteration.

In addition, for each set of data, we have to check the balance between supply and demand in total before solving problems. Therefore, we have to ensure the following conditions.

$$\text{(14)} \quad \sum_{j \in N_q} a_{rj} \leq \sum_{i \in G_r} d_{iq} \qquad q \in Q, r \in R$$

$$\text{(15)} \quad \sum_{j \in N_q} b_{rj} \geq \sum_{i \in G_r} c_{iq} \qquad q \in Q, r \in R$$

5. Computational results

Under the conditions shown in (14) and (15), solutions have been obtained by the algorithm for the January 2003 schedule of the obstetrics and gynecology department in a hospital in Tokyo. The set of data and the results are the following.
Table 1 shows whether a doctor belongs to each group or not. 1 denotes the doctor belongs to the group, where skill (1) is the group of doctors with the highest level of skill. Table 2 shows the lower bound and the upper bound for

the number of doctors belonging to a specific group working on a particular day. It shows that there has to be at least 1 doctor from each specialty, and at least 1 doctor from skill (1) in total. Table 3 shows the lower bound and the upper bound for the number of night duties on a specific day group for the doctor. Non-permitted patterns were ‘consecutive night duties’ and ‘only one day-off between two night duties’. There was no fixed schedule in January. It was not necessary to consider the end of the previous month’s schedule because it was the first month of the year. It should be noted however, that this is unusual as consideration for the previous month’s schedule is usually required.

This problem was solved while changing the lengths of short patterns. Table 4 is the resulting schedule when dividing the scheduling horizon into 7 periods of 4 days and 1 period of 2 days. A star sign means a night duty. Figure 1 shows the running time as a function of lengths of short patterns (computer: Power Edge, Pentium III, 1 GHz, Linux 7.1). This graph shows that lengths less than 10 are efficient.

When these resulting schedules were seen by the scheduling doctor, she agreed that the algorithm could obtain practical schedules. Then the doctor also wanted there to be at least 1 doctor from skill (1) or (2) from each specialty working each night duty, although there was a lack of doctors of skill (2) in obstetrics. Therefore, we added the following constraint to the original constraints: From gynecology, there must always be at least 1 doctor from skill (1) or (2). From obstetrics, there must be at least 1 doctor from skill (1) or (2) on Sundays and holidays.

The algorithm obtained a schedule that satisfied this constraint for each day except one for gynecology and took 3 minutes 22 seconds. When given a longer time to process, that is 99 minutes, it was able to obtain a schedule that satisfied all the constraints.

Table 1: Doctor groups (1: if the doctor belongs to the group, 0: otherwise).

		Group											
	Doctor	0	1	2	3	4	5	6	7	8	9	10	11
	A1	1	1	0	1	0	0	1	0	0	0	0	0
	B1	1	1	0	1	0	0	1	0	0	0	0	0
	C1	1	1	0	1	0	0	1	0	0	0	0	0
Gynecology	D2	1	1	0	0	1	0	0	1	0	0	0	0
	E2	1	1	0	0	1	0	0	1	0	0	0	0
	F3	1	1	0	0	0	1	0	0	1	0	0	0
	G3	1	1	0	0	0	1	0	0	1	0	0	0
	H3	1	1	0	0	0	1	0	0	1	0	0	0
	I1	1	0	1	1	0	0	0	0	0	1	0	0
	J1	1	0	1	1	0	0	0	0	0	1	0	0
	K1	1	0	1	1	0	0	0	0	0	1	0	0
Obstetrics	L2	1	0	1	0	1	0	0	0	0	0	1	0
	M3	1	0	1	0	0	1	0	0	0	0	0	1
	N3	1	0	1	0	0	1	0	0	0	0	0	1
	O3	1	0	1	0	0	1	0	0	0	0	0	1

	Group Name
0	alldoctors involved
1	gynecology
2	obstetrics
3	skill(1)
4	skill(2)
5	skill(2)
6	gynecology-(1)
7	gynecology-(2)
8	gynecology-(3)
9	obstetrics-(1)
10	obstetrics-(2)
11	obstetrics(3)

Table 2: The lower bound and the upper bound for the number of doctors belonging to a specific group.

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Group			H	H	H	H	H	M	T	W	T	F	S	S	H	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F
0	alldoctors involved	a_{rj}	4	4	4	4	4	3	3	3	3	3	3	4	4	3	3	3	3	3	4	3	3	3	3	3	3	4	3	3	3	3	3
		b_{rj}	4	4	4	4	4	3	3	3	3	3	3	4	4	3	3	3	3	3	4	3	3	3	3	3	3	4	3	3	3	3	3
1	gynecology	a_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		b_{rj}	3	3	3	3	3	2	2	2	2	2	2	3	3	2	2	2	2	2	3	2	2	2	2	2	2	3	2	2	2	2	2
2	obstetrics	a_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		b_{rj}	3	3	3	3	3	2	2	2	2	2	2	3	3	2	2	2	2	2	3	2	2	2	2	2	2	3	2	2	2	2	2
3	skill(1)	a_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		b_{rj}	2	2	2	2	2	1	1	1	1	1	1	2	2	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1
4	skill(2)	a_{rj}	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0
		b_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	skill(3)	a_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		b_{rj}	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
6	gynecology-(1)	a_{rj}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		b_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	gynecology-(2)	a_{rj}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		b_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	gynecology-(3)	a_{rj}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		b_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	obstetrics-(1)	a_{rj}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		b_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	obstetrics-(2)	a_{rj}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		b_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	obstetrics-(3)	a_{rj}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		b_{rj}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

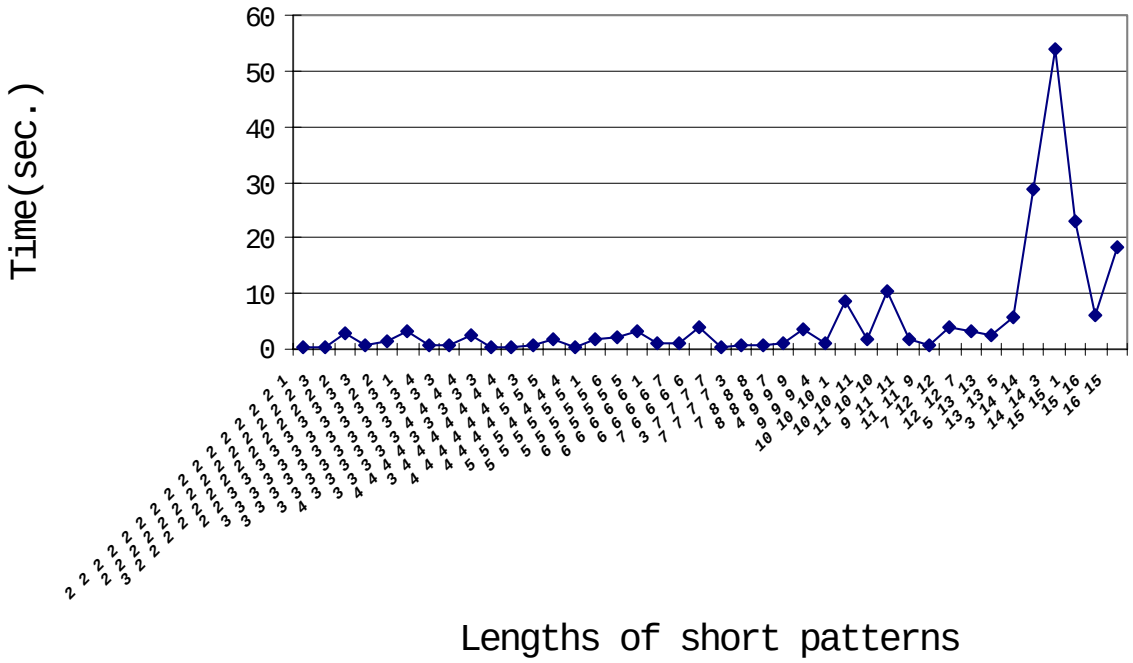
Table 3: The lower bound and the upper bound for the number of night duties on a specific day group for the doctor.

		Total		Sundays		Saturdays	
	Doctor	c_{ig}	d_{ig}	c_{ig}	d_{ig}	c_{ig}	d_{ig}
Gynecology	A1	3	4	0	0	0	0
	B1	5	7	2	3	1	2
	C1	5	7	2	3	0	0
	D2	5	7	2	3	0	0
	E2	5	7	2	3	1	2
	F3	6	8	2	3	1	2
	G3	6	8	2	3	0	0
	H3	6	8	2	3	1	2
Obstetrics	I1	2	4	2	3	1	2
	J1	5	7	2	3	0	0
	K1	5	7	2	3	0	0
	L2	5	7	2	3	0	0
	M3	5	8	2	3	0	0
	N3	6	8	2	3	0	0
	O3	5	8	2	3	1	2

Table 4: The resulting schedule (*: a night duty)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31			
		H	H	H	H	H	M	T	W	T	F	S	S	H	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F			
	Doctor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total	Sundays	Saturdays
G	A1														*						*											*	3	0	0
G	B1	*			*			*				*					*					*				*							7	2	2
G	C1					*				*				*						*				*				*			*		7	3	0
G	D2			*			*				*			*						*					*				*				7	3	0
G	E2	*			*								*						*				*						*			*	7	3	1
G	F3			*				*					*			*			*			*				*			*				8	2	2
G	G3	*								*				*			*				*			*			*			*			8	3	0
G	H3		*			*			*			*			*			*							*			*					8	2	1
O	I1				*						*								*								*						4	2	1
O	J1		*			*			*				*					*							*				*				7	3	0
O	K1			*			*									*				*			*							*			6	2	0
O	L2		*			*			*						*			*									*				*		7	3	0
O	M3			*							*			*							*			*			*					*	7	3	0
O	N3		*				*			*			*			*				*			*					*					8	3	0
O	O3	*			*			*				*					*					*				*					*		8	2	2
Group	0	4	4	4	4	4	3	3	3	3	3	3	4	4	3	3	3	3	3	4	3	3	3	3	3	3	4	3	3	3	3	3			
Group	1	3	1	2	2	2	1	2	1	2	1	2	2	3	2	1	2	1	2	2	2	2	1	2	2	2	1	2	2	2	1	2			
Group	2	1	3	2	2	2	2	1	2	1	2	1	2	1	1	2	1	2	1	2	1	1	2	1	1	1	3	1	1	1	2	1			
Group	3	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1			
Group	4	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0	0	1	1	1	0	0	1	0	1	0	1	0	1	1	1	1			
Group	5	2	2	2	1	1	1	2	1	2	1	2	2	2	1	2	2	1	1	1	2	2	1	2	1	2	2	2	1	1	1	1			
Group	6	1	0	0	1	1	0	1	0	1	0	1	0	1	1	0	1	0	0	1	1	1	0	1	0	1	0	1	0	0	1	1			
Group	7	1	0	1	1	0	1	0	0	0	1	0	1	1	0	0	0	0	1	1	0	0	1	0	1	0	0	0	1	1	0	1			
Group	8	1	1	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	0			
Group	9	0	1	1	1	1	1	0	1	0	1	0	1	0	0	0	1	0	1	1	1	0	0	1	0	1	0	1	0	1	1	0	0		
Group	10	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0			
Group	11	1	1	1	1	0	1	1	0	1	1	1	1	1	0	1	1	0	0	1	1	1	1	1	0	1	1	1	0	0	1	1			

Figure 1: Running time as a function of lengths of short patterns (DELL PowerEdge, Pentium III, 1 GHz, Linux 7.1).



6. Conclusion

In this paper, it is realized that the nurse-scheduling model that is proposed in [7] can also deal with scheduling doctors for night duty and the algorithm based on the Subproblem-centric approach can obtain good solutions at a speed that is efficient enough for it to be used in a real scheduling problem. This result shows the possibility that the algorithm based on this approach can be applied to other scheduling problems that have to consider the skill level of the term on a work shift.

In this paper, however, only two sets of data for only one month was dealt with and the constraints were not so tight because it was January. It is, therefore, desirable that many types of data sets are applied to the algorithm. In addition, discussion and comparison with other heuristics or general solvers for the integer-programming problem are interesting and desirable. This is because scheduling doctors for night duty has a far smaller number of constraints than those of nurse scheduling, i.e. there is the possibility that it can be solved by simpler algorithms.

Finally, in order to make it easier to use this algorithm, a computer-aided decision support system has been developed which includes a user-friendly interface. When this support system was introduced, doctors and nurses

commented, “This support system can be very useful in big hospitals where they have to consider the skill of the team for every night shift because of the many kinds of doctors and patients”. When making a schedule with the system for the first set of data above, a feasible schedule could be obtained in 20 minutes (this time includes the initial set up time for entering the doctors’ information and the system parameters). Once the system has been set up, the doctor need only enter the monthly data. This means a schedule could be produced in approximately ten minutes rather than the usual several hours by hand.

References

1. Aickelin, U., Dowsland, K.A., 2000. Exploiting problem structure in a genetic algorithm approach to a nurse rostering problem. *Journal of Scheduling,* 3:139–153.
2. Dowsland, K.A., 1998. Nurse scheduling with tabu search and strategic oscillation. *European Journal of Operational Research,* 106:393–407.
3. Dowsland, K.A., Thompson, J.M., 2000. Solving a nurse scheduling with tabu search and strategic oscillation. *Journal of the Operational Research Society,* 51:825–833.
4. Ikegami, A., Niwa, A., and M. Ohkura, 1996. Nurse scheduling in Japan. *Communications of the Operations Research Society of Japan,* 41:436–442 (in Japanese).
5. Ikegami, A., Niwa, A., 1998. An efficient approach to nurse scheduling - Implementation for a 2-shift case. *Journal of the Operations Research Society of Japan,* 41:572–586 (in Japanese).
6. Ikegami, A., 2000. Improvement on the 2-shift nurse scheduling algorithm. *Journal of the Operations Research Society of Japan,* 43:365–381 (in Japanese).
7. Ikegami, A., Niwa, A., 2003. A Subproblem-centric Model and Approach to the Nurse Scheduling Problem. *Mathematical Programming,* Series B 97:517–541.
8. Jaumard, B., Semet, F., and T. Vovor, 1998. A generalized linear programming model for nurse scheduling. *European Journal of Operational Research,* 107:1–18.
9. Li, L.X., Benton, W.C., 1996. Performance measurement criteria in health care organization: Review and future research directions. *European Journal of Operational Research,* 93:449–468.
10. Millar, H.H., Kiragu, M., 1998. Cyclic and non-cyclic scheduling of 12 h shift nurses by network programming. *European Journal of Operational Research,* 104:582–592.
11. Siferd, S.P., Benton, W.C., 1992. Workforce staffing and scheduling: hospital nursing specific models. *European Journal of Operational Research,* 60:223–246.

12. Smith-Daniels, V.L., Schweikhert, S.B., and D.E. Smith-Daniels, 1988. Capacity management in health care services: Review and future research directions. *Decision Sciences,* 19:889–919.

OPTIMIZATION OF NIGHT SHIFTS SCHEDULING IN HOSPITALS

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Abstract: The scheduling problem consists in assignment of doctors in a hospital to night shifts. The assignment must respect specific conditions and simultaneously should assure the proportional occupation of all the doctors. Moreover, the assignment to all-day weekend shifts and holiday shifts is worked out on paper. The scheduling should even respect doctors' personal priorities for night shifts. The paper includes the case study of Faculty Hospital of Charles University, Prague, where the shifts must be provided with six doctors of predetermined specializations. Each doctor, being on duty last night, must not be included in the following two night shifts, except weekends and holidays. For this problem we tried to implement an optimization model with binary variables. Nevertheless, we found out that it is questionable to incorporate all the conditions in the model in order to receive an acceptable solution in a short time. That is why we developed a special information system to solve the problem together with supporting the communication between all doctors and the head doctor, who is responsible for the whole scheduling process. In the system, heuristic method is used to roster doctors. The information system is successfully implemented in the before-mentioned hospital.

1. Introduction

The process of scheduling night shifts in hospitals can be a very difficult and time-consuming task for responsible persons—usually chief doctors of clinics. In large clinics this task may take several hours or even the whole day of time of a very experienced doctor each month. This time could certainly be spent more efficiently if the clinic had available a computer support system for scheduling the night shifts. Management of the Faculty Hospital with a request to build a support system that will be able to help them to schedule the night and weekend shifts contacted Department of Econometrics, the University of Economics, Prague. The Faculty Hospital is one of the largest hospitals in Prague and even in the Czech Republic. It has almost 50 clinics with more than one thousand doctors and two thousand beds. All the clinics must assign doctors for night shifts to several workplaces depending on their specialization. One of the largest clinics in the hospital is the surgery clinic with around 40 doctors. The problem of scheduling was analysed for this clinic but the proposed support system is general and can be used at any other clinic without any modification.

In the system it was necessary to take into account many conditions given by the requirements of the hospital management and the chief doctors of the clinics. The most important of them are discussed in the following list:

1. Workplaces

The number of workplaces to roster the doctors for the night shifts in the clinic is fixed - seven for the surgery clinic (chief doctor of the shift, traumatic department, ICU 1 (intensive care unit), ICU 2, ICU 3, ambulance 1, ambulance 2). Each workplace is described with respect to the assigned doctor by its specialization, attestation, etc. That means the doctor assigned to the shift at the workplace must satisfy all its requirements. Moreover, the group of doctors on the shift must respect some other conditions – e.g. it should contain at least one doctor of the given specialization, at least a minimum number of expert doctors with the second stage of attestation, etc.

2. Specializations of doctors

Each doctor is described by his/her specialization that influences his/her assignment to the workplaces. In the surgery department there are six basic specializations of doctors – general surgery, traumatology, pectoral surgery, internal surgery and anaesthetics. Among the doctors in the night shift at the surgery clinic there must be at least one doctor with pectoral, general surgery and neurology specializations.

3. Preferences of doctors

The scheduling of night shifts must respect important personal preferences of doctors (absence in hospital given by really important personal or service reasons) and should respect personal wishes of doctors. Each doctor can express his/her preferences in the positive or negative sense in the middle of the previous month.

4. The number of shifts

While the number of shifts of doctors is not limited, it is required to be equal to all doctors in a long time period. Moreover, it is necessary to provide the appropriate balance between the number of weekend and holiday shifts and standard night shifts.

5. Weekend shifts

The weekend shifts have three basic modes:

- a doctor is assigned to the shift from Friday afternoon till Monday morning,
- a doctor starts the shift on Saturday morning and ends it on Monday morning (on Friday night there is another doctor is on the shift),
- a doctor has a shift from Saturday morning till Sunday evening and Friday night and Sunday night are covered by another one.

6. Intervals between shifts

Intervals between two consecutive shifts during the week (except weekend) should be at least 48 hours.

7. Preventing joint shifts

The system of scheduling night shifts should respect requirements that two or more doctors cannot be on the shift due to technical or personal reasons on the same day.

The presented list illustrates the basic (but not all) requirements that must be taken into account in the process of building the month schedule of night shifts.

2. Optimization and heuristic approach to night shifts scheduling.

Scheduling of night shifts is a complex problem that can be modelled generally by means of two different approaches. The first of them is based on building the optimization model that can be formulated as a standard linear programming model with integer (mostly binary) variables where various optimization criteria can be taken into account. The optimization model has several disadvantages among which the most important ones are the following:

- The model can hardly involve all the requirements that have to be taken into account in the process of scheduling; trying to extend the model by further requirements makes it too complex and often unsolvable by standard optimization techniques.
- The model contains, depending on the scheduling time period and the number of doctors, at least one thousand binary variables and several hundreds of constraints; to find the optimal solution of such a large model may be an extremely time-consuming process even if professional optimization researchers are employed.

On the other hand, the heuristic approaches cannot give the decision maker the optimal solution (or in special cases only). However, they are very flexible and, depending on their quality, offer solutions that are usually accepted very well. They need not be too complex and can be realized in quite a simple way in any programming language. The major advantage, comparing the heuristics to the optimization techniques, consists in providing the solution in much shorter time, which is one of the most important factors influencing the real application of the model. That is why we decided to solve the problem of scheduling night shifts in the Faculty Hospital in Prague by using our original heuristic that was successfully programmed and integrated into the larger decision support system being now verified in the hospital. The applied heuristic procedure and developed support system will be discussed in more detail in the next section of the paper. In this section below we present the basic structure of the optimization model that was tested and results of which were not always satisfactory because of very long time of computing the optimal solution and the incompleteness of the model with respect to the requirements of the management of the hospital and the responsible doctors.

1. Variables

The optimisation model contains variables x_{ij}, i = 1,2,...,*r*, j = 1,2,...,*n*, where *r* is the number of doctors available for scheduling and *n* is the number of days for which the shifts are planned. The number of days is usually 62 (two months). In the surgery clinic the number of doctors was 36, which means the total number of variables is up to 2232. All the variables of the model are binary and they express if the i-th doctor is assigned and is on the shift in the j-th day (value 1) or not (value 0).

2. Constraints

Constraints of the model ensure fulfilling the basic requirements of the decision maker presented in the introductory section of the paper. Constraints

$$\sum_{i \in M_k} x_{ij} = 1, \qquad j = 1,2,...,n, \qquad k = 1,2,...,s,$$

where *s* is the number of workplaces and M_k, *k* = 1,2,..., *s* is the set of doctors that can be assigned to the workplace *k*, ensure that each workplace will be occupied exactly by one doctor. Constraints

$$\sum_{i \in A_k} x_{ij} \; \leq = \geq 1, \quad j = 1,2,...,n, \qquad k = 1,2,...,t,$$

where *t* is the number of different specialisations of doctors and A_k, *k* = 1,2,..., *t* is the set of doctors belonging to the specialisation *k*, ensure the required number of doctors with the specialisation *k* on the shift. The sign ≤ = ≥ means that exactly one of the given relations is used for each specialisation.

The two basic groups of constraints must be completed by further ones that express the remaining requirements of the problem. Some of them can be modelled very simply (preventing joint shifts, intervals between shifts), while others are questionable (different modes for weekend shifts).

3. Objective function

Objective function of the model can be formulated by different ways. We tried to work with the following two formulations:

1. Minimise the sum of negative preferences of doctors.
2. Minimise the maximum number of shifts for doctors within the planned period.

As we stated before, the optimization approach was rather the study with the aim to verify the possibility of its using in our application. The main emphasis was on the proposed heuristics that is presented in the following section.

3. Optim Solution: a heuristic based system for night shift scheduling

Optim Solution is a heuristic night-shift system for the Faculty Hospital in Prague divided into two basic procedures - Optim Brain and Optim Menu. These procedures are supposed to solve difficult criteria job schedule for 1 to10 workplaces in the hospital and for 1 to 62 daytime periods according to the doctors' priorities for every day and priorities for selected workplace respectively workplaces. One doctor can work only for one concrete workplace during the concrete night shift. The doctor's night shifts can be spread among several workplaces during the specific time period. For example, it is possible to select two workplaces as primary ones and some other as secondary ones. In most cases only one primary workplace is used for doctors. Doctors with some secondary workplaces are supposed to have a night shift there only in such a case when no other doctor from this workplace is available. A group of doctors with primary workplace priority belongs to every workplace – mostly five or six doctors per workplace. Every doctor is supposed to select his priorities in the *Optim Menu* procedure according to his particular needs for each day as follows:

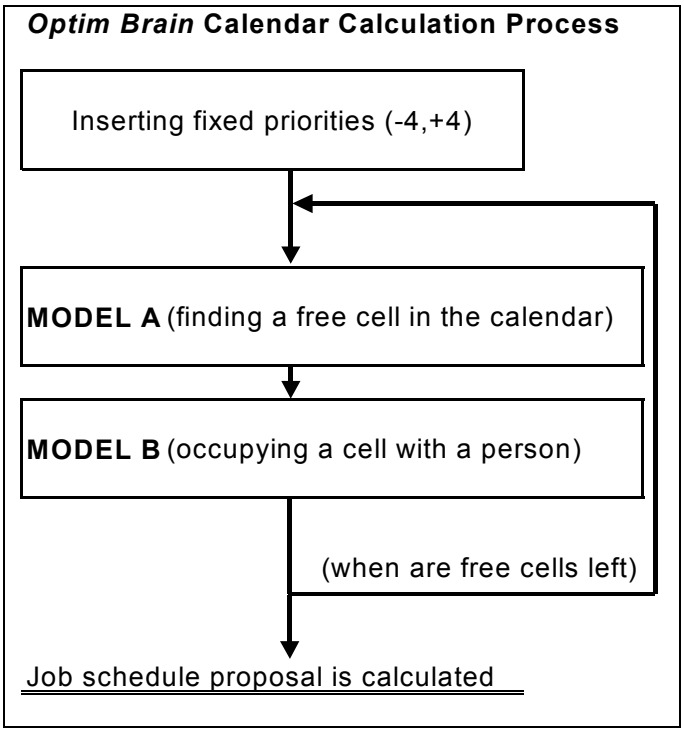
–4	The highest negative priority (the night shift is forbidden)
–3	He/she must not work this day (e.g. holiday or other absence in the hospital)
–2	He/she strongly does not prefer this day (night shift)
–1	He/she slightly does not prefer this day (night shift)
0	He/she does not care about the night shift (a neutral preference)
+1	He/she slightly prefers to have the night shift
+2	He/she strongly prefers to have the night shift
+3	The night shift is absolutely necessary
+4	The highest positive priority (he/she will have the night shift with certainty)

The priorities –4 and +4 cannot be used directly by doctors but by these priorities the chief doctor (a responsible person) can express the absolute necessity or restriction of night shifts for a doctor. These doctors' priorities are loaded by *Optim Brain* procedure when the *Job Schedule* administrator creates the shift schedule.

The basic structure of *Optim Brain* is on Figure 1. It is possible to select several useful options, modify the priorities and calculate possible priority conflicts. It is also possible to recalculate the shift schedule proposal using different shift schedule calculation paths of the calculation routine by modifying particular priorities or by changing calculation options. After the shift schedule calculation

process is finished, the program makes *Shift schedule* that can be exported to XML or to an Excel XLS file.

Figure 1: Optim Brain Calculation Process



Night Shift Conditions

Special rules are given to *Optim Solution* for calculating the night shift schedule. It is not possible to have night shifts in two consecutive days without 48 hours break during workdays. (24 hours break only in emergency cases). The consecutive night shifts are allowed only during the weekends and during the national holidays.

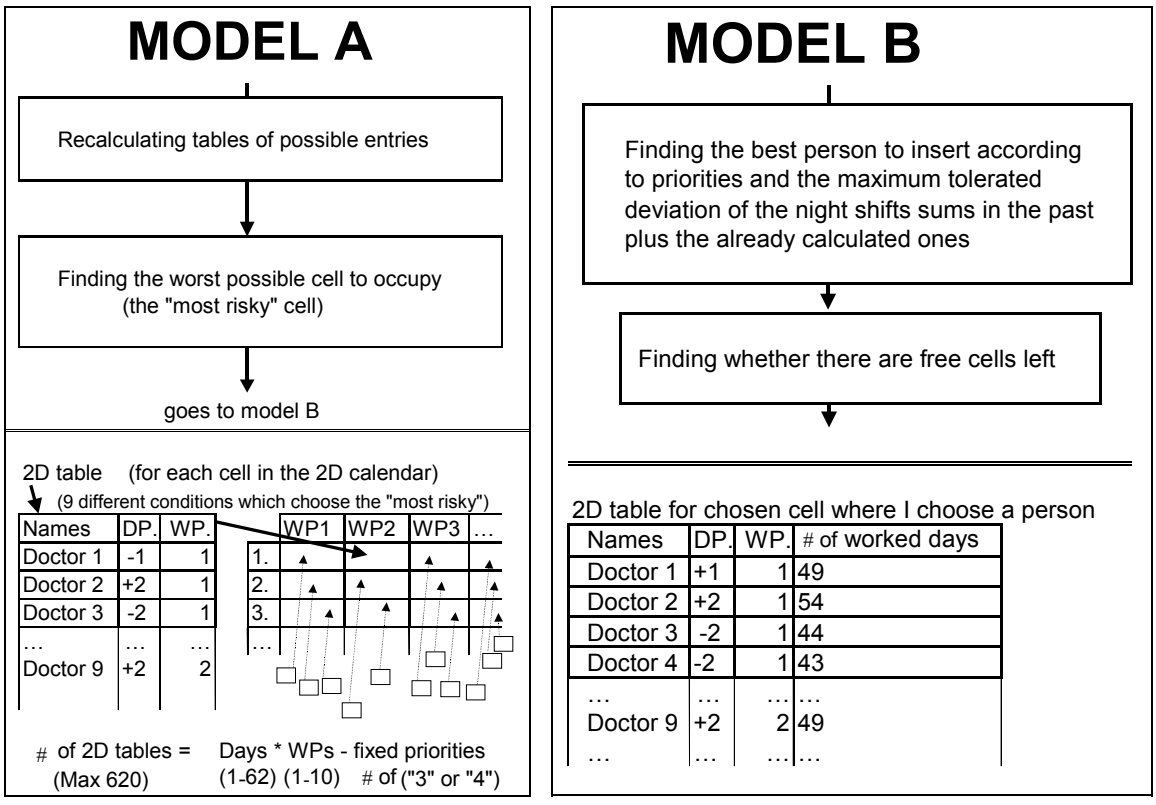
Optim Brain Calculation routine

Calculation routine is made as a VBA procedure in MS-Excel. As the calculation process is very complex, it is necessary to simplify the process into models A and B. This makes it easier to understand its general function. First of all, the fixed priorities are inserted. Repeating both the models, A and B, follows this. Each cycle occupies one job schedule cell, which was selected in model A and occupied by selected doctor in model B. The repeating process is finished when no free job schedule cells remain. Figure 2 shows the structure of models A and B.

The calculation routine in model A recalculates a table with possible entries for every cell in the night shift job schedule. It means it is necessary to calculate up to 620 tables for each cycle.

After the recalculation process is done, the program proceeds to the second part of model A and finds the most suitable cell for occupying by model B. This selection of the suitable cell is calculated using nine different conditions. These conditions are basically set according to the program function needs and philosophy of advancing specific calculated parameters. The change of these conditions can influence the process of calculation, i.e. which cell is selected. It starts with a number of possible entries and continues by comparing the priorities, finding the lower number of doctors with primary workplace for the selected cell, checking the deviations among the numbers of doctors' insertions according to the maximum allowed deviation selected in the program options, using other methods to determine the right cell, etc. These specific conditions can be used to fit different ways how to schedule the shifts in different hospitals.

Figure 2: Optim Brain calculation routine



After the most suitable cell is selected, the program moves to model B, where the given cell's 2D table with possible entries is examined in order to find the right person. It uses doctors' day priorities and their sum of insertions stored separately in three different types of days (workdays, weekends, holidays).

Doctors with their primary workplace priority are selected always as the first ones. Then, the doctors with 24-hour break during the workdays can be selected. When no doctor is available from the primary workplace, a doctor will be inserted as the secondary one. After a doctor is inserted, the program checks whether some other steps in order to schedule remaining days are necessary. If there are no free cells in the job schedule remaining, the procedure offers the final schedule report to the chief doctor.

After the shift schedule proposal is made, it is possible to change some priorities and run a recalculation for different results or to make the final corrections (to change some doctor, to switch some shifts, etc.) All these corrections cause recalculation of the sums of night shifts. Before the final schedule is accepted, the total numbers of shifts for all the doctors are added to their total count of shifts.

4. Conclusions

Scheduling of night shifts in hospitals, discussed in the paper, is the real application of assignment models. Quantity of the conditions and complexity of specifications make harder the solution of a discrete model corresponding to the research project. Since the generation of an optimal solution is impracticable, the use of heuristic algorithms is considered as a suitable alternative for the needs of the hospital. Although the heuristic system *Optim Solution* has been developed for the surgery department of the Faculty Hospital in Prague, it can be used without any complex modifications for the requirements of other departments of the hospital. The experience of the surgery department in using the system in shift operations shows the advantage of modelling the process and it is an appropriate challenge for other departments and even other hospitals to use it. The more complex conditions and requirements, the more useful the system will be in practice.

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References

1. Blazewicz, J., Ecker, K.H., Pesch, E., Schmidt, G., and J. Weglarz, 1996. *Scheduling computer and manufacturing processes*, Springer, New York.

2. Dlouhý, M., Pelikán, J., 2001. Measuring Trends in Productivity of Hospitals by Data Envelopment Analysis, In: H. Vomáčková (Ed.), *Economic chances in 3rd millennium*. TU Liberec, p. 45–47.
3. Jablonský, J., 2002. *[Operations research: quantitative models for economic decision making]* (in Czech), Professional Publishing, Prague.
4. Pelikán, J., 2001. *[Discrete models in operational research]* (in Czech), Professional Publishing, Prague.
5. Nemhauser, G.L., Wolsey, L.A., 1998. *Integer and Combinatorial Optimization*, John Wiley, New York.

PATIENTS

DEVIL'S ADVOCACY AND PATIENT CHOICE

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Abstract: The London Patient Choice Project is a pilot scheme concerned with involving patients in the decision about where their hospital treatment will take place. Prior to implementation, the organisers of the project decided to seek Operational Research advice, although they were not quite sure what it had to offer them. As a first step, it was decided to carry out a short scoping study in order to establish where Operational Research might best be focussed. Part of this short study involved a Devil's Advocacy exercise to identify potential operational problems that might occur once the patient choice scheme was introduced. In the event 13 different scenarios were identified which could cause major problems, few of which had occurred to the organisers. This paper discusses some of these findings illustrating how Operational Research can be applied even in circumstances when there are no data available.

1. Introduction

The United Kingdom is currently introducing policy to promote patient choice and as part of this an extensive pilot project is being carried out known as the London Patient Choice project. This paper discusses a short term research exercise commissioned by the organisers of the London Patient Choice project to explore the potential for applying Operational Research methods to investigate problems that might arise prior to implementation. This involved adopting the role of Devil's Advocate and constructing exemplar vignettes, based on OR insight, to illustrate potential problems that might provide barriers to success.

Although such work provided deep insights, the short time scales of the research project precluded deeper follow-up of the example vignettes that were identified. Thus, while this paper gives examples of system behaviour that might pervert the intentions of the patient choice policy, it was not feasible to explore what remedial actions could be taken to prevent or minimise the effects of such behaviour if it were indeed to emerge.

The use of mathematical modelling is relatively uncommon in Health Services Research in the UK and some of the techniques used are somewhat alien to health care planners. This is particularly the case in relation to the project carried out for the organisers of London Patient Choice, since it was based on little more than the written information describing the pilot choice project and conversations with some health care professionals involved. Given the short

time scales of the project, there was neither the opportunity to collect data nor to observe the patient choice process in action.

In view of this, it was decided to use exemplar vignettes for identifying potential system deficiencies. This method is basically concerned with constructing counterexamples, a technique that is used frequently in pure mathematics, rather more than in other scientific disciplines (although experiments that didn't give the expected result have frequently led to key discoveries in Science). The rationale behind the search for counterexamples is based on the notion that it can often be as valuable to know what isn't true as to know what is. Furthermore, falsehood can be established far more easily than truth. It is Operational Research folklore that "If you want to find out what works, first find out the options that don't work and then discard them". Thus the study sought to identify problem scenarios associated with patient choice so that remedial action could be taken prior to implementation.

The examples that were constructed were based on examining the consequences of patient choice from a mathematical modelling perspective. This led to a presentational difficulty since it would not help to clarify issues for the clients by presenting example vignettes in mathematical terms as they would have difficulty in assimilating such information. Instead, we adopted a format whereby each vignette was given in terms of a pen portrait of a set of circumstances in which the adoption of patient choice could lead to operational problems or unexpected or counterintuitive system behaviour. The use of the term 'Cautionary Tales' has been used to describe this collection of vignettes since hopefully most have a 'moral' in that they indicate a lesson that may be learnt. In the event, some thirteen separate cautionary tales were identified. Here only two will be described.

2. Cautionary Tale 1

There are examples of system behaviour in fields other than health care where it is counter-productive to offer system users the right to choose. One such example goes by the name of Braess's Paradox[1] which was discovered in relation to road traffic systems.

It is not surprising that if one has a road network and if its users have free choice about which routes they use, then there might be a minority of road users who are disadvantaged, for example, those who live close to roads that are popular and thus congested. The novelty of Braess's Paradox is that it gives an example whereby the effects of user choice conspire so that it is not just the minority who are penalised, nor even the majority, but *all* users who suffer.

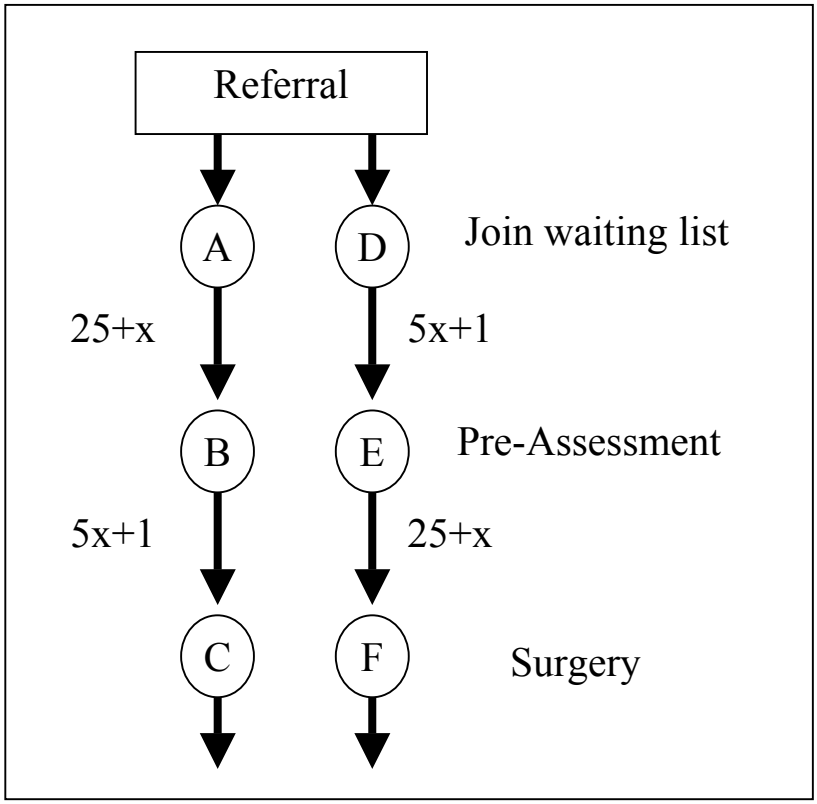
Whether such pathological behaviour could occur in relation to choice within health care is not clear, although potentially it could, which can be shown by a simple illustrative example. Whether such odd system's behaviour would follow the introduction of choice is hard to assess, although possibly this is because no one has yet thought to investigate the issue.

Following the ideas of Braess, we consider a rather simplistic representation of the operation of a health care system shown schematically in the Figure 1. Here we assume that a homogeneous group of patients are treated surgically in one of two different Trusts.

It is assumed that three patients per week are referred to each Trust. The Trusts have adopted different ways of managing their waiting lists for initial pre-surgical assessment and for subsequent surgery, although for the same throughput, both have the same overall 'processing time'. The waiting times in each part of the care pathway are assumed to depend upon the number of patients treated per week (denoted by x in Figures 1). In general, mathematical formulae for waiting times are complex, but here simple linear formulae will be used for illustration purposes (the complexity of individual formulae does not affect the nature of the paradox). These formulae are shown alongside the links of Figure 1.

Since three patients per week are referred to each Trust, the overall 'processing time' for the two Trusts are identical for each patient (44 time units).

Figure 1: Schematic diagram of pathways in a health care process in which there is no patient choice. Formulae indicate delays dependent on flow x.



Now consider the situation where patient choice is introduced (Figure 2). Two choices are permitted. Patients are allowed to decide which of the two Trusts they will attend for pre-operative assessment. Also, following pre-operative assessment, patients are permitted to switch to a different Trust for their surgery.

If three patients per week continue to use each Trust, using routes A-B-C and D-E-F through the care pathway, the total processing time would be 44 time units per patient. However, it wouldn't take long before a patient from the right hand branch discovered that a quicker way through the system would be to opt for the left hand branch following pre-operative assessment. Assuming that no other patients switched, then the overall processing time for this patient would be made up of (15+1) units waiting for pre-operative assessment and (20+1) units awaiting surgery. Note that there would now be 4 patients using the link B-C, hence the longer wait of 21 units. The overall waiting time for this patient would thus be 37 units, an improvement compared with the previous 44 units. The configuration of flows with three patients per week using routes A-B-C and D-E-F is thus not stable, since patients would have an incentive to switch to another route through the system.

If all patients make choices that minimise their own personal overall processing time, then there will be an equilibrium only if the routes chosen through the care pathway network are all individually better that any alternative route that is available. This equilibrium is achieved if four patients take the route D-E-B-C, one patient takes the route D-E-F and one patient takes route A-B-C. This configuration of flows is illustrated in Figure 3. With this configuration, all patients have the same total processing time, 52 units. It can easily be verified that any patient who wishes to deviate from this, would suffer a longer overall delay.

The overall effect of introducing patient choice in this circumstance is thus to increase delays for all patients using the system from 44 units to 52 units.

Figure 2: Schematic diagram of pathways in a health care process in which patient choice is allowed. Formulae indicate delays dependent on flow x.

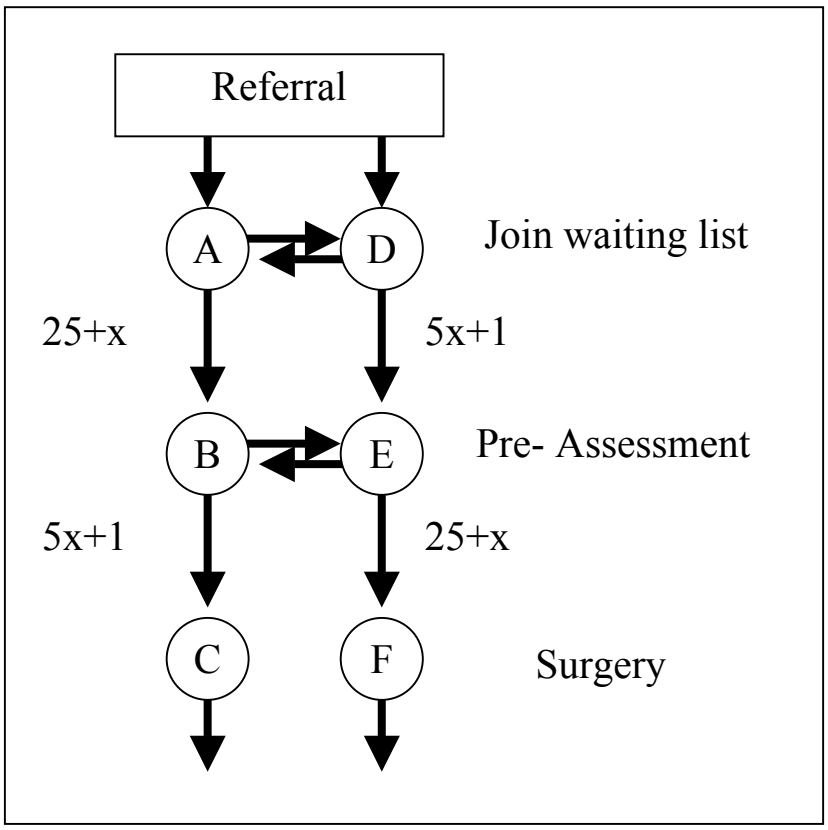
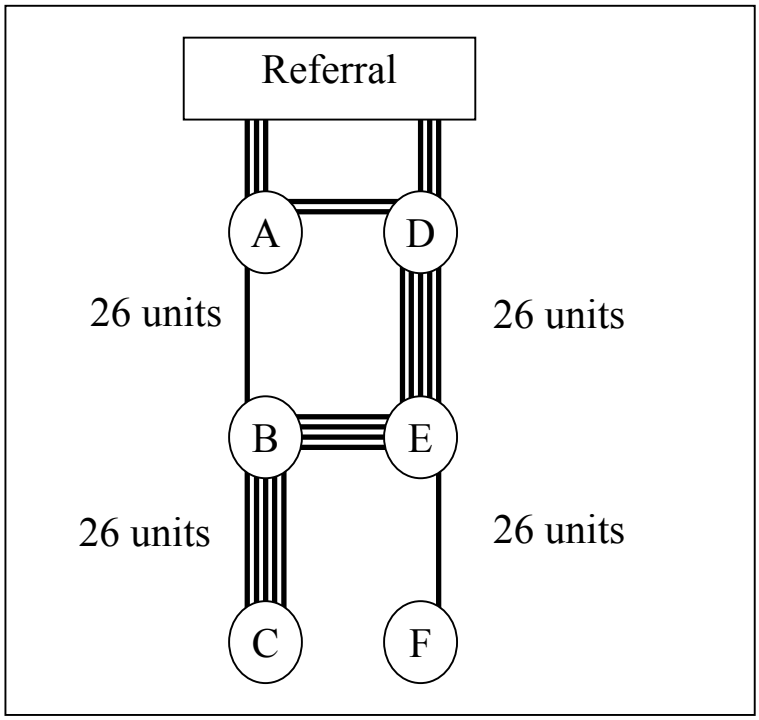


Figure 3: The equilibrium configuration whereby no patient can switch to a different route without incurring greater delay. Units of delay are displayed.



We claim no credit for concocting these particular examples, since they are very much due to Braess, indeed those interested in the original traffic context of Braess's work should simply view Figures 1, 2 and 3 as though they represent road networks rather than health care processes.

3. Cautionary Tale 2

From an Operational Research viewpoint, it is a commonplace notion that the more unpredictable variability there is in a complex queueing system, the more likely it is that there are operational problems particularly if the system operates close to capacity. We have previously discussed this in relation to variability in length of stay [2,3]. Here we discuss another aspect of unpredictability that patient choice can bring.

Our example is based on the following analogy with the airline industry. Suppose an airline decides it will offer first class passengers a choice between a fish or meat dinner. Market research has shown that 50% of passengers prefer fish and 50% prefer meat. If each plane carries 14 first class passengers would it be reasonable to stock 7 meat meals and 7 fish meals, which is the expected pattern of choice? Clearly not. If the airline is serious about providing choice, then to be absolutely certain that all choices are available then 14 meat and 14 fish meals need to be stocked. If any less are stocked, then it is possible that all

passengers may coincidentally ordered the same thing. Thus to be certain of offering choice to all, the airline must carry 100% reserve stock of meals over and above the number that will be eaten.

This is perhaps extreme since the probability of all passengers ordering the same thing is tiny. Let us suppose that the airline wants to reduce costs and is prepared to accept say a 5% chance that stocks are insufficient. An elementary application of the binomial theorem can be used to show that the aircraft still need to stock 10 fish and 10 meat meals. This represents 42% reserve capacity.

Transforming these notions into healthcare terms is straightforward. In the course of the project, a general analysis was carried out assuming that there are a number of receiving Trusts, and several classes of patients, individuals in each class having the same *a priori* probability distribution determining the Trusts they opt for. For example, these may correspond to patients from the same geographical area. Full details of this exercise are omitted for the sake of brevity.

The results of this general analysis can be illustrated in the case where there are just two Trusts, Trust A and Trust B, and a single class of K patients making choices between these. If Trust A and Trust B are comparable in terms of quality and accessibility, it might be reasonable to assume a 50-50 chance that any given patient would opt for Trust A. Assuming this is the case, then the probability distribution of number choosing to be treated in Trust A is an approximation to the normal distribution with mean value $\frac{K}{2}$ and standard deviation $\frac{\sqrt{K}}{2}$.

This mean value is precisely what one would estimate from a back of an envelope calculation. The estimate of the standard deviation is more informative since this quantifies the ‘unpredictable variability’ introduced by choice.

The power of this finding is that it provides a unified means for addressing a key question concerning the number of care episodes that a Trust needs to plan for in order to participate in a Patient Choice scheme. By analogy with the aircraft catering example cited above, it is unlikely that Trusts would wish to provide for all possible patterns of patient choice that might conceivably occur.

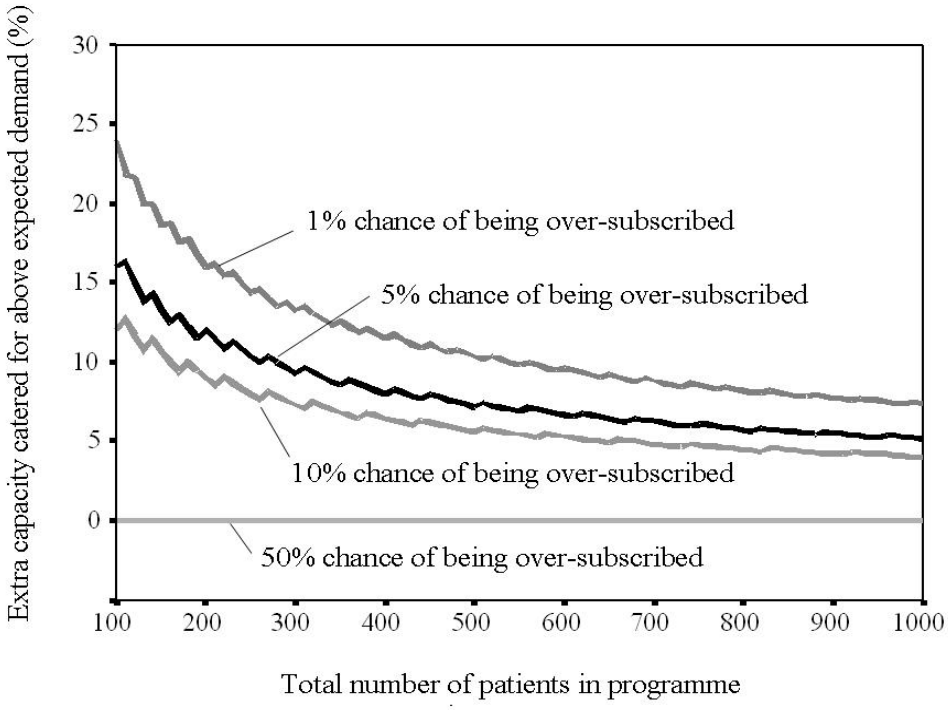
More likely, it would seem sensible to cater for the majority of cases and accept the fact that an ‘operational emergency’ might possibly occur whereby more patients opt for treatment at the Trust than have been planned for. A balance

needs to be struck between the cost of providing for care episodes and the probability of being oversubscribed.

Figure 4 shows levels of provision for episodes of care that the Trust A must plan for depending on the chance deemed acceptable that the Trust would be oversubscribed.

Different levels indicated in the graph correspond to different levels of probability that the given level of provision would be insufficient. The base line case, where the Trust caters for exactly half of the estimated choice patients, would be oversubscribed with a probability of 50%. Other levels in Figure 4 shows the additional number of episodes that need to be catered for, expressed as a percentage of the baseline 'expected' number of episodes.

Figure 4: An example of the extra episodes that a hospital Trust should cater for in order to avoid being over-subscribed. Percentage comparisons are made with a base-line expected number of episodes based on the number of patients choosing between the Trust and one other alternative assuming both are equally attractive options.



Clearly, if the managers of Trust A have a strong wish or a strong financial incentive to avoid being oversubscribed, then they must plan to provide for considerably more episodes of care than would occur on average. Equally, so too must the managers of Trust B. Thus in spite of the fact that the total number

of patient care episodes for the two Trusts combined is unaltered by offering patient choice, the total number of episodes that must be planned for is considerably higher.

4. Discussion

This paper has discussed a number of scenarios to illustrate the potential for hidden pitfalls in systems design, counterintuitive systems response and other factors that might subvert the intentions of patient choice policy

These examples have been devised primarily to alert those organising the London pilot study of patient choice to potential problems at an early stage. However, they also serve another important role in that they indicate areas where application of Operational Research methods may assist the implementation of such policy.

A major design problem is that patient choice implicitly promotes change from a system where there are relatively few decision makers (at least as regards the paths that patients take through the system) to a system where there are thousands (the patients and the many people involved in informing them). Unfortunately, this has the potential for promoting unexpected and counterintuitive systems behaviour that may well have a deleterious effect on the health care system as a whole. These go well beyond Tower of Babel effects, although the scope for promoting miscommunication is large. Introducing massively dispersed decision making would almost certainly have a major effect on the organisational structure and operational effectiveness of the health care service. Whether these effects would be beneficial is far from clear, although the relative ease with which it has been possible to devise the problematic scenarios described in this report is not a good sign.

The second illustrative example indicates that there are circumstances whereby individual Trusts might need to provide for substantially more episodes of patient care than are likely to occur on average. What is more, much of this additional provision would not actually be used.

This has a potentially large effect on hospital financial planning and remuneration structures. With the two Trusts example, considering the overall system, for effective choice to be offered, both Trusts must make provision for more treatment episodes than they might expect to attract on average. Thus between the two Trusts, there would need to be provision for more treatment episodes than would actually occur. If remuneration to a Trust is based purely on the number of episodes of care they actually provide, then one or both Trusts are likely to make a financial loss in terms of resources used providing for episodes

of care that did not occur. Further, within the terms of this example, the scale of such financial losses and which Trust incurs them are governed by chance.

It should be said that the example given concerning patients choosing between two Trusts both of which are equally attractive options is in a sense a worst case scenario. If there were a marked preference for one Trust rather than the other, then the standard deviation for the number choosing each Trust (and hence the inherent uncertainty), would be smaller.

It should be noted that this modelling makes no specific use of any time frame nor do we specify what this time frame should be. This very much depends what the Trust needs to know in terms of its planning. On the one hand, it may be negotiating the number of episodes it is prepared to accept during the course of a year. In this case, the 'expected' number of episodes might be relatively large, thus the reserve that needs to be catered for would be relatively small in percentage terms. On the other hand, if the Trust is concerned with more detailed planning, it might be more concerned with the number of episodes it must plan for during say a two month period. Here, the 'expected' number of cases would be much smaller and the degree of over-provision correspondingly larger.

These results, and many others, were presented to the clients in the form of vignettes referred to as cautionary tales in the form of short stories outlining a particular set of circumstances and a boxed comment box summarising the moral or lesson to be learned. This is the first time that the authors have used such a method in a formal report to clients and, according to their feedback, it proved remarkably effective.

References

1. Braess, D., 1969. Über ein Paraadoxon aus der Verkehrplannung, *Unternehmenforschung*, 12:258–263.
2. Gallivan, S., Utley, M., Treasure, T., and O. Valencia, 2002. Booked inpatient admissions and hospital capacity: mathematical modelling study, *BMJ,* 324:280–282.
3. Utley, M., Gallivan, S., Treasure, T., and O. Valencia, 2003. Analytical methods for calculating the capacity required to operate an effective booked admissions policy for elective inpatient services, *Health Care Management Science,* 6:97–104.

PATIENT SATISFACTION IN GENERAL PRACTICE: SOME METHODOLOGICAL ISSUES AND APPLICATIONS

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Abstract: In Italy, General Practice is the medical service most used by the population; it represents both patients' initial contact with and first impression of the National Health Service. It is estimated to constitute about 90% of formal care. In this context patients' opinions can make an important contribution to the quality improvement process, given that they are the best evaluators and reporters of the soundness of care received. In the present study, after developing a valid and reliable questionnaire of satisfaction, a postal survey was carried out in a Local Health District of the Marche Region in order to assess the potentiality and limits of the instrument. The analysis of the levels of patient satisfaction - both regarding single items as well as the domains covered by the questionnaire - allowed the identification of some strengths and weaknesses of the service investigated. For this purpose, we furthermore developed a "priority index" that allows us to identify aspects of the service to be improved. Finally, the use of multilevel analysis highlighted certain characteristics of General Practitioners and their patients that influence the level of satisfaction.

1. Introduction

General practice, or general medicine, is among the services offered by the National Health Service (SSN) to all citizens. Italy has adopted a model revolving around the general practitioner, who is freely chosen by citizens/patients and who has the responsibility for providing non-specialist care which includes prescribing drugs, referring patients to specialists and co-ordinating care support services. Doctors may choose to become part of a group surgery practice, in order to cope with periods of absence for professional in-training, illness and holidays etc. in the most efficient manner. During non-G.P. surgery hours: nights and holidays, care is covered by other doctors (known as the *guardia medica* - emergency medical service physicians) who guarantee the coverage of so-called "care continuity."

General practice, in all its forms, has been defined in many ways. It is certainly not only fundamental in terms of the therapeutic outcome of its services but also the role it plays with individuals; it must by definition dedicate great attention to the dynamics of patient relationships.

The G.P. system plays a strategic role in the co-ordination and running of health service; it represents both patients' initial contact with and first impression of the National Health Service (N.H.S.), being the first level of contact between patients, their families, the community and the Service. It is estimated to cover 90% of all formal health care (Campbell, Ramsay, Green, 2001), confirming its

key role. The assessment of the impact of this service is therefore critical and the image that patients have of it, represents a key component of their satisfaction with the whole Service.

Quality deficits undeniably occur and therefore have to be coped with by the G.P. Quality improvement consciousness is due, in part, to the N.H.S's clear response to less than satisfactory service in terms of the standards reached, the degree of variability and the level of responsibility of the health professionals in the field. In this process, an important aspect will be represented by the assessment of service quality, with the patient remaining at the centre of all its steps. His assessment is the most direct way of measuring some of the facets of care such as: **accessibility, communication, interpersonal factors, and the possibility of having a continuous relationship with the same doctor**. Bergman (1994) showed that satisfaction continues to be one of the principal criteria for assessing the operator. Indeed, the notable increase in the use of instruments to measure satisfaction as well as the results that emerge from assessing quality require greater attention in research development and analysis. Nevertheless, while some progress can be seen in the design of satisfaction instruments in the hospital field (Rubin, 1990; Carey, Seibert, 1993), research does not yet allow us to measure the principal problems in G.P. offices/surgeries. Moreover, the centrality of the G.P. surgery suggests the fact that many meetings (between health professionals and patients) take place in these surgeries, suggests the need to develop suitable methodologies to extend the breadth of patient satisfaction research.

The present work illustrates the results of a survey on the perceived quality of G.P. services in the context of a Local Health District (ASL) in the Marche Region. The specific aims of this study can be thus summarised:

- Development of a valid and reliable satisfaction questionnaire, aimed at identifying and measuring the key characteristics of perceived quality in the G.P. field.
- A survey to be carried out to assess the validity and reliability of a proposed survey instrument.
- Examination of the level of patient satisfaction for each area and for each item of the questionnaire used.
- The development of appropriate criteria to guide the efforts made to improve quality relative to the problems identified.
- The identification, through multivariate analysis, of some physician and patient characteristics that may influence the level of satisfaction.

It is hoped that, through this empirical work combined with the other measurements of outcomes of care, administrators and operators will be able to get useful to the continuous improvement of G.P. services. Another outcome

that is to be hoped for is that patients will find information in this paper that will help to orient their choice between physicians.

2. Methodology

2.1 The instruments used

When aiming to assess the level of satisfaction towards a service through judgements formulated by a client, it is important to consider all the aspects that contribute to the generation of a patient's single opinion. Weiss (1988) tried to identify the main factors that influence patient satisfaction in general practice, distinguishing four areas:

- Patient characteristics (socio-demographic aspects, state of health, expectations, personal attitude, etc.)
- Factors relative to the doctor (personality traits, professional competence, art of caring, etc.)
- Doctor/Patient relational aspects (clarity and completeness of communication, outcome of the visit, etc.)
- Structural factors associated with the environment where the service is provided (accessibility, the building's appearance, length of visit etc.)

The above elements can predispose the patient towards feelings of satisfaction or dissatisfaction. In the present case, the primary challenge was the difficulty in measuring these characteristics, apart from the normal socio-demographical variables; thus, we experimented with an approach to investigate the main determinants of patient satisfaction in our specific context.

2.1.1. The questionnaire for the doctor

The questionnaire is divided into two parts. The first includes the socio-demographic picture of the doctor to which a few items have been added regarding the typology and number of patients in their care as well as information regarding their geographical location and the total number of diagnostic-pharmaceutical prescriptions given. The whole of the second part consists of an instrument borrowed from literature and known as *Maslach Burnout Inventory* (MBI) (Sirigatti, Stefanile, 1993). This instrument is used to analyse the perception that professionals have of their own work and the relationships they have with the people with whom they come into contact.

2.1.2. The patient questionnaire

The core of the patient questionnaire comes from a critical and simplified revision of one of the best-known instruments used in the literature: the General Practice Assessment Survey (GPAS, 1999), adapted herein to better reflect the

specific characteristics of G.P. service providers and users.

The resulting instrument was divided into domains, each of which is further specified in topic items that call for a judgement of the service on a five-point scale (very bad, bad, fair, good, excellent). The most obvious addition to the content of the basic instrument regards the items related to the continuity of care between surgeries where the doctors form a group practice, and the so-called emergency medical service (guardia medica). Moreover, an indicator of overall satisfaction was added, as well as a section for extensive comments. A total of 29 items of satisfaction divided into four areas were used.

Furthermore, exploratory factor analysis was utilised to reveal the underlying structure and construct validity of the above question set. Factor analysis allowed the redistribution of the items into three distinct domains: **accessibility, service functioning, continuity of care**.

Besides the domains cited, the questionnaire included another three sections. The first summarised the respondent's socio-demographic profile, while the second assessed his/her psychophysical state of health using an instrument widely used in the literature: the Short Form 12 (SF-12) (Apolone et al., 2001). The final section of the patient questionnaire attempted to assess the Health System as a whole, that is, an evaluation detached from the care aspects of the patient's own G.P. In the absence of specific episodes, the judgements may in fact be influenced by preconceived ideas.

2.2 The selection of patients

From a methodological point of view, the ideal sample for this type of survey should be made up of **"actual"** users of the general practice service (Williams, Calnan, 1991), represented both by those using G.P. surgery services and those receiving such services in their own home. It was furthermore necessary to take into consideration: those patients who do not use the service or use it sporadically, "**routine**" users who habitually seek psychological comfort from consultations with physicians, and people who do not possess adequate cognitive abilities to properly judge the service. It was therefore decided to opt for a random sample taken from every doctor's patient list.

We will now describe the organisational details of the survey: at the date on which the data were gathered the population under consideration (enrolled as G.P. patients) was 43,923. The first challenge faced was protecting the privacy of the patients in the survey; to guarantee this, the data regarding them were gathered by mail. The use of this procedure proved particularly appropriate for

this kind of survey, as it guaranteed a uniform way of gathering data from samples spread over a quite extensive geographical area.

With regards to the doctors' data, these were gathered directly from their Local Health District representative, who developed a privacy system in which the physicians were assigned numerical codes. The Health Unit then provided a whole data bank of patients, whose irrelevant information had been suitably removed and in which the name of the doctor had been substituted by his previously mentioned numerical code. In turn, we modified the physicians' code system by complete permutation. The resulting "double-blind" operation guaranteed the privacy of both patients and doctors.

2.3 The Pilot Study

Before beginning the survey itself, it was decided to carry out a more limited pilot study. The latter had two objectives. On one hand, it aimed at assessing the feasibility of the survey in logistic terms: the time necessary for delivery and replies, the response rates, costs, etc. On the other, it also aimed at determining if the respondents would experience any difficulties in filling in the questionnaire.

Thus, a pilot study doctor was chosen at random from the list of physicians available, questionnaires were then sent out and returns awaited. If the latter were sporadic (20-30 days after despatch) a reminder was sent containing a new copy of the questionnaire, in the event that the first one had been thrown away. As a result, the number of returns—initially only 25%—more than doubled. The above piece of information was extremely valuable, because it allowed us to plan out in advance everything necessary for the survey, considerably reducing the time needed to carry out the survey itself. Regarding the question of the clarity and comprehensibility of the questionnaire format, the pilot study did not suggest that its topic items contained ambiguities or redundancies; thus, only some slight adjustments were made. For this reason it was also possible to incorporate the pilot study data into the overall survey data set.

2.4 The Survey

The people chosen to be part of the samples were selected randomly from the patient register at each site and on each doctor's register. The number of respondents chosen was constant for each sample, equalling about 100 units (with the exception of those patients under the care of a physician with a low number of patients). Each questionnaire was assigned the doctor's code number before being sent off, in order to link up his/her data with his/her own patients. Then the packets were made up.

The survey packets contained a letter signed by the General Manager of the Health District, in which the reasons behind and aims of the survey were explained; a copy of the questionnaire and a pre-paid stamped envelope for its return. In all, 3,460 questionnaires were sent out, with the whole procedure, including the pilot survey, lasting for about three months. During the said period, the questionnaires returned were selected and checked in order to eliminate any formal errors.

3. Results

3.1. Participation in the survey

Of the 3,460 questionnaires sent, 1,553 were returned completed. The average response rate among physicians was 43.9%, with a range of 12.7%–65.7%. The lower value is clearly anomalous (σ=9.8). Only a minimal number of questionnaires had to be eliminated due to the fact that they did not contain enough information for correct use.

3.2 Representativeness of the samples

The first problem that we had to face regarded the representativeness of the sample. Due to the way in which the survey was carried out, the characteristics of those who replied were not distinguishable from those who did not. For this reason, the comparisons were carried out between groups of respondents and groups of patients in each doctor's care.

The above-mentioned comparisons were made after an obvious selection was effected, utilising the same criteria as in the samples (a population limited to between 18 and 80 years of age). The only socio-demographic variables available for comparison (and therefore chosen) were those of sex and age. Regarding sex, the analysis allowed us to identify a substantial correspondence of samples to the population to which reference is made. However, the same could not be said for age variables. In fact, about one sample in four was significantly dissimilar to the population, presenting a higher average age. The analysis carried out on the distribution by age of the data collected highlights the larger inclination of young people and the elderly to not send back the questionnaire.

3.3. Validity and reliability of the measurements

The validity of the questionnaire, conceived as 'the capacity to actually measure patient satisfaction in General Practice', was assessed with regard to two

aspects: content validity and construct validity. Regarding the former, all the aspects of General Practice covered by our instrument reflect the priorities of patients in the main components of the service investigated. The care aspects studied, in fact, seemed relevant for the patients in the sense that a large proportion of them had opinions about and experiences to relate regarding all the domains analysed. On the other hand, the construct validity refers to the appropriateness of our instrument in measuring the concept underlying the items in the questionnaire that represent its major themes. Factor analysis was used to assess this type of validity, in order to identify of those satisfaction dimensions that were actually perceived by the patients. On the other hand, we deemed it unnecessary to submit the present tool to reliability tests, given that there was no reason to doubt the methodology's soundness in terms of the normal standards suggested by the literature for temporal stability and internal cohesion (Grol, Wensing, 2000)

3.4 G. P. Socio-demographic characteristics

Of certain interest is the analysis of the questionnaire items aiming to measure the syndrome of emotional exhaustion, depersonalisation and professional dissatisfaction that is referred to in the literature by the term burnout (Sirigatti, Stefanile, 1993). Given that the persistence of such syndromes leads to negative repercussions for the profession, we retained it necessary to describe the situation among the doctors investigated and include these data in the predictive models for patient satisfaction. The data obtained allowed us to show how, in the present sample, emotional exhaustion is very low and depersonalisation is almost absent. Meanwhile, the professional satisfaction index is close to the highest possible level. Thus, the portrait of a satisfied health professional is revealed by the present survey, even if G.P. doctors do at times declare themselves to be exhausted by the demands of their profession.

3.5 Socio-demographic characteristics of respondents

We will not describe the characteristics of the respondents in detail, but will engage in a limited analysis of their psychophysical state of health as it is depicted by the fore-mentioned instrument SF-12. The two indexes that it produces, which will shortly be incorporated into the models that interpret the satisfaction levels, show average values that are lower than those of the reference population (which is, however, American) and a variability that is slightly higher.

3.6. Analysis of satisfaction judgements

In order to analyse the level of patient satisfaction, we thought it best to summarise the distribution based on the mean of satisfaction judgements, quantified as follows: 0 (very bad), 0.25 (bad) 0.50 (fair), 0.75 (good), 1 (excellent) (Leti, 1983; Delvecchio, 2001; Vian, 2002).

From Table 1 we can note how some certainly more inadequate aspects are linked to the continuity of care in the "emergency medical service" (guardia medica) component (survey items D27, D28 and D29). These data likely stem from the way in which that service is structured, and also perhaps from the limited professional experience of those working for that service. Thus, clients who use the service do not on average encounter the elements of readiness and competence that they are probably used to in their relationship with their own G.P. physicians. Moreover, in the emergency medical care context relative to the present study there exist problems of transferring patients' medical history data from and to other doctors. Perhaps it is now time to adopt individual medical records, which are structured in way similar to those used in hospitals for acute patients; such records could be consulted (with obvious limits imposed for privacy) and updated by anyone who intervenes in a patient's clinical history. On another front, the data gathered regarding the presumed scarce interest of doctors in their own patients' state of health also raises concerns (D23). The interpersonal component on which the relationship of trust between should and patient should be primarily based seems to be inadequate. Other elements of low satisfaction are related to waiting times for office/surgery visits (item D7) and the difficulty in reaching the surgery (item D1). More specifically, it may be assumed from the verbal comments gathered that waiting times can be in part attributed to overly limited office hours and the interruption of physicians' examination of patients by pharmaceutical company representatives. However, despite these undeniable impediments to quick consultation with G.P.s, the main reason for long office waits is overuse of the service by patients. The elderly are particularly likely to seek comfort in visits to their general practitioner, though the nature of that reassurance is often more psychological than physical. However the question remains of how to properly judge the demand for services like the above-mentioned reassurance; although inappropriate, they must nevertheless be assessed.

We will now turn to examining less problematic aspects, and note, with pleasant surprise, that these are linked to the **simplicity of the explanations received (D9), to the respect of privacy (D19) and the willingness of the doctor to give information and advice by telephone. (D8)**.

An integral part of quality assessment is the process of obtaining and referring correct feedback on the information collected. The referral of feedback can occur at two different moments: on a macro level, implementing business strategies which aim to improve the organisation's own service; on a micro level, pointing out the need for corrective actions to individual doctors, with the aim to overcome the inadequacies discovered. Regarding the former feedback opportunity, a well-established and widely used tool in similar studies is the analysis of the performance-importance of single items (Drain, 2001; Gessell, 2001). In these cases, with the adoption of the concept of improvement priority that is typical of the quality improvement approach, the available information is used to construct two distinct classifications around the single items: one based on the level of satisfaction, the other relative on the importance that a single aspect has in the overall concept of the caring process. The information is used in order to develop an indicator the values of which summarise the priority level of improvement intervention, as revealed by the patients' assessment.

Let us now return to the general question. If we substitute survey item D30 with an overall expression of the opinion that patients hold of their General Practitioner, a measure of "vicinity" between this and the single items can be obtained as a coefficient of rank correlation (Fabbris et al., 1993). The result provides us the information necessary to assess its importance. Following this methodology, the higher the correlation rank, the greater the importance of that particular aspect.

Given that a high priority for improvement must necessarily correspond to high importance, whilst a low priority for improvement must correspond to a high level of satisfaction, we have all the elements necessary to develop a **Priority Index**. This was derived by **adding the score rank of importance and the reverse rank of the level of satisfaction**. Questions at the top of the priority index list are characterized by low scores in the satisfaction (high score rank) and high correlation (high correlation rank), reflecting poorly scoring service aspects that patients deem important in their evaluation of quality. In our study, the priority index shows that the greatest need for improvement of overall satisfaction is related to the following issues: **capacity of the doctor to discover disorders, length of visit, the completeness of the explanations received, the involvement of the patient in the choice of treatment, the trust that the patient has in his/her own doctor.** These are the items that must be addressed when considering corrective actions to improve the quality of service and overall patient satisfaction. If targeted corrective actions are to be undertaken, they must be communicated to each doctor on an individual level, whilst respecting privacy needs. One of the possible methods that can be used to refer feedback to the individual health professional is to identify his/her position with respect to the distribution of colleagues' positions. Quartile distribution, for

example, is appropriate to this scenario. It must be remembered that the positions indicated must be interpreted from a comparative point of view and not as a total assessment. In conclusion, they must be interpreted within a prospective of benchmarking that, in this case, refers to the median behaviour of the professionals as a reference value.

Table 1: Level of satisfaction for the services received. Adult respondents (n=1553) (in brackets the minimum and maximum values are indicated excluding those with less than 10 respondents)

AREAS /Items	Overall satisfaction	Min-Max
ACCESSIBILITY OF SERVICE		
D1-Ease in arriving at office/surgery	**0.63**	(0.48-0.81)
D2-Ease of access to office/surgery	**0.74**	(0.48-0.88)
D3-Waiting room Appearance	**0.71**	(0.30-0.82)
D4-Office/Surgery Cleanliness	**0.76**	(0.53-0.87)
D5-Information received	**0.69**	(0.51-0.84)
D6-Respect of hours	**0.69**	(0.40-0.83)
D7-Office/Surgery waiting times	**0.51**	(0.24-0.68)
SERVICE FUNCTIONING		
D8-Willingness of doctor to advise by phone	**0.77**	(0.64-0.90)
D9-Simplicity of answers received	**0.78**	(0.67-0.89)
D10-Waiting times for home visits	**0.68**	(0.49-0.79)
D11-Knowledge of state of health	**0.71**	(0.56-0.82)
D12-Doctor's capacity to discover disorders	**0.69**	(0.51-0.83)
D13-Capacity to refer to specialists	**0.68**	(0.47-0.92)
D14-Registering of state of health	**0.74**	(0.53-0.85)
D15-Trust	**0.71**	(0.54-0.84)
D16-Capacity to listen	**0.73**	(0.50-0.83)
D17-Capacity to reassure	**0.71**	(0.55-0.83)
D18-Ease in confiding personal problems	**0.62**	(0.53-0.72)
D19-Respect for privacy	**0.77**	(0.68-0.85)
D20-Completeness of explanations received	**0.67**	(0.55-0.80)
D21-Involvement in treatment choice	**0.69**	(0.56-0.84)
D22-Following up illness at home	**0.69**	(0.54-0.90)
D23-Doctor's interest in state of health	**0.51**	(0.28-0.70)
D24-Serenity of doctor's manner	**0.74**	(0.57-0.85)
D25-Length of visit	**0.68**	(0.52-0.80)
CARE CONTINUITY		
D26-Usefulness of group office/surgery	**0.67**	(0.50-0.84)
D27-Capacity of discovering disorders	**0.43**	(0.29-0.57)
D28-Speed of visits	**0.51**	(0.29-0.65)
D29-Link with own G.P.	**0.42**	(0.23-0.58)
SYNTHESIS OF SATISFACTION		
D30-Overall judgement	**0.70**	(0.54-0.80)

3.7 Analysis of the verbal comments

The analysis of the questionnaire section dedicated to verbal comments shows that about a quarter (24.1%) of the respondents expressed negative comments on some aspect of G.P. service. A further 10.6% pointed out other inefficiencies of the health system (continuity of care, health centres, hospitals, etc.).
The resultant image of the G.P. that emerges from these comments is basically one of a professional who is not very attentive to the patient; indeed, the latter appears to be seen more as a sick person than a human being. All this does not necessarily have to seem to be in contradiction with the results from the structured parts of the questionnaire, in which indicators of greater satisfaction with the doctor emerged. The only difference that emerges from the comparative analysis is linked to the way in which the criticism is made: the verbal comments are definitely more direct and bitter. In the end, the priorities are generally and substantially the same.

3.8 Towards a better understanding of patient satisfaction

Our survey has pointed out sources of dissatisfaction that focus on specific aspects of the service under investigation. Therefore, it is our duty to look further into the satisfaction or dissatisfaction judgements linked to the experience of using G.P. services. In particular it will be possible to observe if the judgements expressed on this service are correlated to the socio-demographic-cultural aspects of the patients and physicians, as well as the specificity of the context studied.

The tool that best lends itself to the above-mentioned aim is multiple regression analysis; considering that the data are nested (each patient must be referred to his/her own doctor), the variant used is a **multilevel approach** (Kreft, De Leeuw, 1999; Zaccarin, Rivellini, 2002). The variables utilised in the interpretative models are expressed on different scales, however this fact leads to important problems in their use. To overcome this drawback at least in part - we chose to carry out some transformations on the original variables, in order to allow more correct use. In particular, after the transformation of satisfaction assessment in metric values, we reduced the asymmetry of distribution using a Box-Cox transformation. The use of regression on the survey items regarding ‘Accessibility of surgeries’ (D1-D5) did not give encouraging results. The multilevel analysis shows how, on average, 12% of the variability is explained at the doctor level. On average, the predictors used account for 14% of the variability explained (R^2=0.10-0.17). Going into further detail, the transversal presence of block C items on the questionnaire is clear (biased attitude towards the health service). The indicators of patient mental and physical disabilities are predictably positively correlated to the ease of arriving at the surgery (item D1).

The same methodology was used to analyse the continuity of care (items D26-D29). Here, the average amount of variability relative to the subdivision between different doctors decreases to 2.7%. The average value of R^2 coefficients is 0.10 with a range of 0.07-0.14. The models present a nucleus of common predictors, including some items relative to patient trust in the National Health Service and in particular in General Practice services. The age of the respondent is also a common predictor.

Let us now deal with the variables directly attributable to the physician. Here, the results of the multilevel technique show how on average about 9% of the variability is attributable to the nested of the patients. In this case the average value of R^2 coefficients is 0.24 with a range of 0.12-0.36. This is not very comforting, although it is similar to other well-known studies in the literature (for example: Gesell, 2001; Kreft, De Leeuw, 1999).

Finally, we describe the behaviour of the general satisfaction item (D30). Given that the aspects of the service provided, together with the specific behaviour of the doctor must, in this case, necessarily induce the patient to formulate a short-term judgement of its relative quality, the resulting analysis will be "internal" (so to speak); furthermore, the predictor blocks will be made up of the single items of satisfaction (D1-D29). This is the only model (table 2) among the numerous ones proposed that explains a significant amount of variability (R^2=0.69) and unambiguously shows that the variables relative to the "care experience" have a prevailing role with respect to that of "context".

Moving ahead: if we address the specificity of the predictors, we may see that, in order of importance, these are: **trust placed in the G.P.** (D15), **length of visit** (D25), **the habit of following up the course of the illness at home** (D22), **diagnostic ability** (D12), **information on office/surgery opening times** (D5), **waiting time in the office/surgery** (D7), **completeness of explanations received** (D20), **the habit of staying informed about the patient's state of health** (D23) **and the Serenity of doctor's manner** (D24). In order to make the comparison easier, all the variables have been normalised.

It seems therefore that general satisfaction emerges from a coherent picture actually based on specific characteristics of the patient-doctor relationship.

Table 2: Multilevel analysis with the item of general satisfaction (D30) with the G.P. as dependent variable. Results of the regression

Predictors	**Coefficient** (sign.)
Constant	**0.061** (0.000)
D5-Information received	**0.089** (0.000)
D7-Office/Surgery waiting times	**0.074** (0.000)
D12-Doctor's capacity to discover disorders	**0.128** (0.000)
D15-Trust	**0.217** (0.000)
D20-Completeness of explanations received	**0.060** (0.026)
D22-Following up illness at home	**0.136** (0.000)
D23-Doctor's interest in state of health	**0.057** (0.003)
D24-Serenity of doctor's manner	**0.057** (0.018)
D25-Length of visit	**0.137** (0.000)

4. Conclusion

Our work has attempted to provide a complete report on G.P. services within the context of a local National Health District in the Italian Marche Region. The tool adopted herein, having been proven valid and reliable, is comprised by four multiple item scales addressing the main areas of primary care activities (access to care, functioning of the service, continuity of care provided by patient's usual doctor). A final item relates to overall satisfaction with the care received.

Furthermore, the questionnaire includes a number of additional variables related both to some of the doctor's characteristics - including **burnout** - as well as the patient's; particular reference is made to the measurement of psychophysical health. Although the information generated by this work holds undeniable value for management, a drawback is that it only reflects the problems that patients encounter during care. Thus, in order to better direct service improvement, the present research has included a "priority index"; that highlights service areas in which performance improvement effort should be made to obtain the greatest increases in satisfaction while making the most efficient use of limited resources.

Finally, it has been proved that some "external" factors influence the level of satisfaction. In fact, the overall judgement of satisfaction is greatly influenced by the care experience that, with its own contribution, makes the individual variables of doctor and patient uninfluential. This type of analysis allows us to identify aspects and behaviour that increase the level of satisfaction, distinguishing between those which require intervention with improvement

policies and those, such as the age of the patient, which will always be elements of differentiation in the client population.

References

1. Apolone, G., Moscono, P., Quattrociocchi, L., Gianicolo, E. A. L., Groth, N., and J. E. Ware Jr., 2001. *Questionario sullo stato di salute SF-12. Versione italiana*, Guerini e Associati Editore, Milano.
2. Bergman, R., 1994. Study: Employers consider cost over quality in health purchases, *Hospitals and Health Networks*, 54.
3. Campbell, J.L., Ramsay, J., and J. Green, 2001. Age, gender socio economics, and ethnic differences in patients' assessment in primary care, *Quality in Health Care*, 10:90–95.
4. Carey, R.G., Seibert, J.H., 1993. A patient survey system to measure quality improvement: questionnaire reliability and validity, *Medical Care*, 31:834–835.
5. Delvecchio, F., 2001. *Statistica per la ricerca sociale*, Cacucci, Bari.
6. Drain, M., 2001. Quality improvement in primary care and the importance of patient perceptions, *J Ambulatory Care Management*, 24(2):30–46.
7. Fabbris, L., Capiluppi, C., Giancotti, G., and A. Meneghello, 1993. *Statree 1.0*, Edizioni Summa, Padova.
8. Gesell, S., 2001. A Measure of Satisfaction for the Assisted-Living Industry, *Journal for Health Care Quality*, 23, 2 March/April.
9. GPAS, 1999. *National Primary Care Research and Development Centre*, University of Manchester.
10. Grol, R., Wensing, M., 2000. Patients evaluate general/family/practice, The Europep instrument. *European Society of General Practice/Family Medicine*, Nijmegen.
11. Kreft, I., De Leeuw, J., 1999. *Introducing multilevel modelling*, SAGE Publications, London.
12. Leti, G., 1983. *Statistica descrittiva*, Il Mulino, Bologna.
13. Rubin, H.R., 1990. Can patients evaluate the quality of hospital care? *Medical Care*, 47:265–326.
14. Sirigatti, C., Stefanile, C. (a cura di), 1993. MBI Maslach Burnout Inventory, *O. S. Organizzazioni Speciali*, Firenze.
15. Weiss, G.L., 1988. Patient satisfaction with primary medical care. Evaluation of Sociodemographic and predispositional factors, *Medical Care*, 26(4):383–392.
16. Williams, S.J., Calnan, M., 1991. Key determinants of consumer satisfaction with general practice, *Fam. Practice*, 8:237–242.
17. Zaccarin, S., Rivellini, G., 2002. Multilevel analysis in social research: an application of a cross-classified model, *Statistical Methods & Applications*, 11:95–108.

18. Vian, F., 2002. *Statistica di base*, Edizioni Summa, Padova.

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Although the work has been carried out in close collaboration by the two authors, in the publication paragraphs 1, 2, 3.1–3.6 can be attributed to Alberto Franci and 3.7, 3.8 to Mario Corsi. The conclusions are the joint work of the two authors.

The questionnaire utilised is available from the authors upon request.

INFORMATION SYSTEMS

AN INFORMATION SUPPORT SYSTEM TO IMPROVE CANCER TREATMENT

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Abstract: Cancer is responsible for over one hundred thousand deaths per year in Brazil. The national health care organization has undergone a series of reforms in recent years and there is a challenge to implement advanced clinical tools to achieve quality. The management of cancer treatment is a long and complex process. The reduction of the patient's waiting time to start cancer treatment plays an increasingly important role in the treatment of this chronic illness. The objective of this paper is to describe the development and the implementation of an information support system specially designed for the Brazilian National Cancer Institute (INCA). The system provides secure access to key information about cancer treatment process and intends to bridge the gap between the doctor, the manager and the patient. The goal is to provide, in real time, an accurate disease status and to evaluate the treatment flow process. It is argued that information is crucial to improve the accessibility to treatment and quality of the service. This information support system is proven to be a useful and convenient tool for decision-making.

1. Introduction

The National Cancer Institute (INCA) is an agency under the direct administration of the ministry of health, associated with the health care secretariat. INCA has five specialized hospital units, in the state of Rio de Janeiro and is a large group practice with over 650 staff and physicians-in-training, plus an allied 3,200 health staff providing medical and assistance services for cancer and related diseases. They offer services of diagnosis confirmation, evaluation of the tumor extension, treatment, rehabilitation and palliative care. The practice sees over 50,000 outpatients per year and has approximately 350 inpatient beds with over 13,000 hospital admissions per year [1,2].

Brazilian health and care organizations are now receiving requirements from their customers, government and regulatory bodies with regards to clinical information and other related systems that should be implemented. Any environment focusing on the accessibility to the treatment of a chronic illness like cancer could avoid medical errors and fragmentation of the care delivery. The integration of key data helps the evaluation of medical procedures and protocols improving the cancer treatment. The ability to generate valuable information is a competitive advantage, enabling health care organizations to

operate more efficiently. The effective data management and the translation of the data into information produce substantial benefits. It is clear that this initiative is a driver for quality improvement.

There has never been a more challenging time to discuss issues of services improvement using information, knowledge and technology. Accessibility and quality of health services was the subject of the 28th ORAHS meeting. An earlier paper presented at this conference contributed for the reduction of the patient's waiting time to start cancer treatment [3]. This waiting period corresponds to the time interval between the patient's registration and the execution of therapeutic procedures such as surgery, radiotherapy applications and chemotherapy. The adopted methodology was to analyze the patient's flow, evaluating the access alternatives and the use of the available human and material resources. A simulation model was used to identify the bottlenecks and to evaluate alternatives for the allocation of resources improving the access and decreasing the time between the ordering cancer diagnosis exams and its effective accomplishment.

This paper describes the development and the implementation of an information support system, specially designed to INCA. This system affords secure access to key information about the whole cancer treatment process. The goal is to offer, in real time, an accurate disease status and to evaluate the treatment flow process. The system intends to overcome a high number of adverse events occurring in this care center. It focuses on the treatment flow of this chronic illness and intends to avoid possible medical errors by reducing fragmentation in the health care delivery system through the automation of the patient record.

A case study is presented here to evaluate the potential of this new system to support decision-making at INCA. The goal is to show how this tool can be used to straightforward the treatment of thousands of patients combining medical and managerial information. The ability to research various conditions by evaluating medical procedures and protocols is essential to improve the efficiency and quality in a cancer treatment center.

A literature review on information support systems brings interesting issues with regards to the kind of functionality this type of system should offer. An earlier attempt to actually use information to support health and care operations was made by M. De Oliveira [4]. Based upon data from Scottish hospitals an information support system was designed. The system was able, through data mining, to record and reconstruct the past history of medical procedures and generate useful information to the hospital administration. It is noticeable the value of information to support decision-making at that stage. There are also, in the literature, references to family of other support systems that provides easy

access to high-level information and integration with other sources such as spreadsheets and databases.

A. Kastelein and A. Looijen [5] discuss some changes and experiences in the application of information technology in health care management. They explored the gap between the idealized design of support systems and the information needs of hospital managers at directorate level. A recent review of models of the health and care systems operation points to earlier initiatives towards improving performance, efficiency and decision in medical practice [6]. Advanced clinical information systems, however, are hard to be implemented. A linkage between decision support systems and reflections about the future developments can be found elsewhere [7, 8].

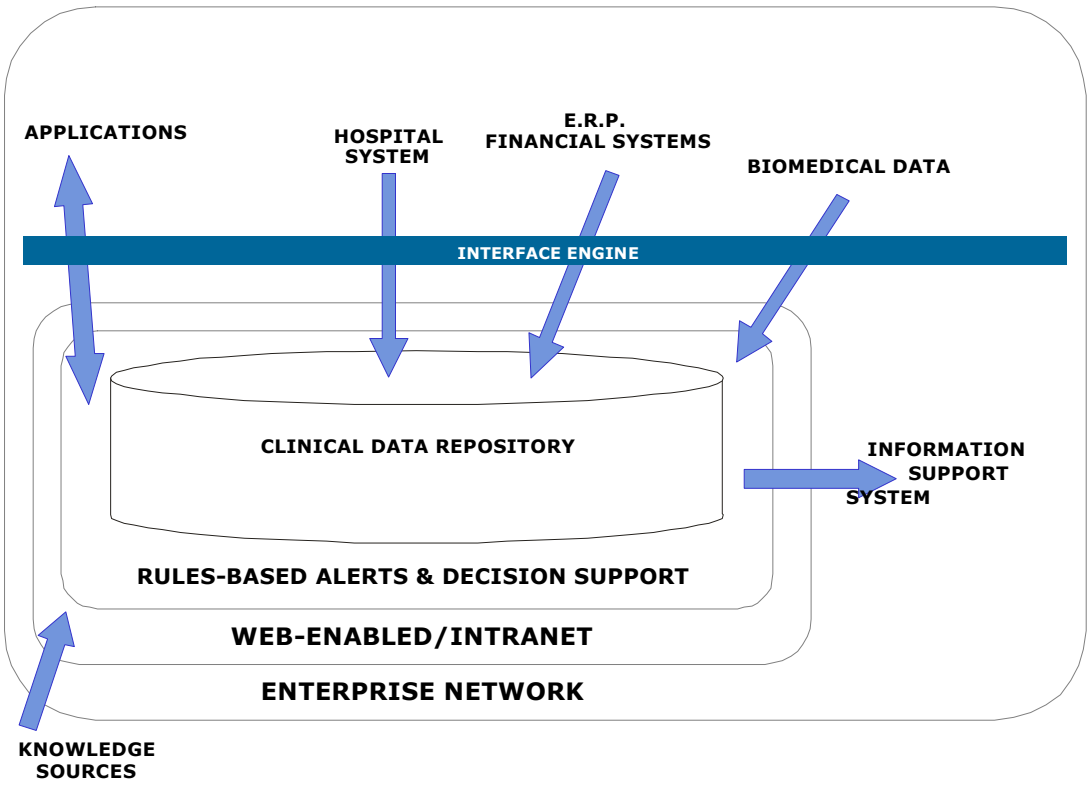
2. The Project

The project to develop and deploy the information support system took approximately 3 years. The process of documentation has evolved, over the years, from handwritten typed notes and reports to the electronic capture of information. The system architecture is composed by the following systems:

- Admission;
- Radiology and laboratory;
- Surgery, radiotherapy and chemotherapy;
- Biomedical and epidemiological data;
- Enterprise resource planning and financial;
- Other applications and knowledge sources.

The present vision of INCA is to significantly contribute to the practice, education, and research through excellence in information support systems, processes and technology. The existing structure feeds the clinical data repository, which is the base to build the information system. The current architecture of the system is shown in Figure 1.

Figure 1: The INCA information systems architecture



The information support system was developed using the INCA intranet. This network provides a safe access to key benefits of an e-health strategy that is the use of emerging information and communication technology to improve and enable healthcare. This solution includes enhanced collaboration between physicians and managers, simplifying the physician work, and empowering managers with sophisticated and cost-effective applications on the Web architecture. All the information is protected by secure polices ensuring strong patient privacy. Each user has its own access profile.

The primary goal of the project is to offer an accurate status of the patient treatment. The solution allows the user access key information, such as admission details, orders, scheduling, test results and follow-up care, reflecting the natural flow of the services. The implementation of the system was made in two stages. The first stage was to replace the manual data collection process. The users are now able to see and share standard data with other users, in real time, rather than produce and maintain their own statistics. The second stage was to evaluate and to promote changes in the clinic workflow process. Historically, patients had to wait days to be called on for their appointments. With the new design, managers know exactly where the patient needs to be and at what time, streamlining the process even more.

A great effort was made to provide information, communication and training in order to adjust the staff to the new approach. The staff and other users soon realized the benefits of the new system enabling easy and effective data entry. The reduction of the patient's waiting time to start cancer treatment plays an increasingly important role in the treatment of this chronic illness. The main point is that most users are very pleased with the present information system. In addition to supporting the combined medical and managerial benefits, the system provides useful reports and trend analysis that integrates medical and queue information.

Some physicians have been uneasy to offer support for they realized that this new technology would take over their previous scheduling method. Some of them were reluctant to accept that someone from a different department started to be involved in the planning of their working routine. It is clear that every working routine have "secrets and tricks" with regards to balancing the time spent with patients and administrative workload. However, in order to achieve quality, each department had to define the desired standard in order to contribute to the improvement of the service as a whole.

It is noticeable that managers have evolved their capabilities in medical procedures, by using this new concepts and tools. Now, they are able to evaluate to a greater level, important details of the patients´ flow within the hospital, associated to the clinical and administrative information. Some pieces of information on the follow-up of the cancer patient are essential to ensure that the patient receives an efficient and clinically correct deference by the physicians in charge of the treatment. This system also guarantees that the research protocols for complex cases are addressed. The use of electronic records and flow evaluation helps to verify if the appointment and exam schedules follow an appropriate sequencing.

As health care organizations embark on strategic and capital planning, these processes now include a major emphasis on the introduction of information technology in order to improve the medical care. It is apparent that the focus of information systems is shifting from the largely financial purpose to a clinical realm.

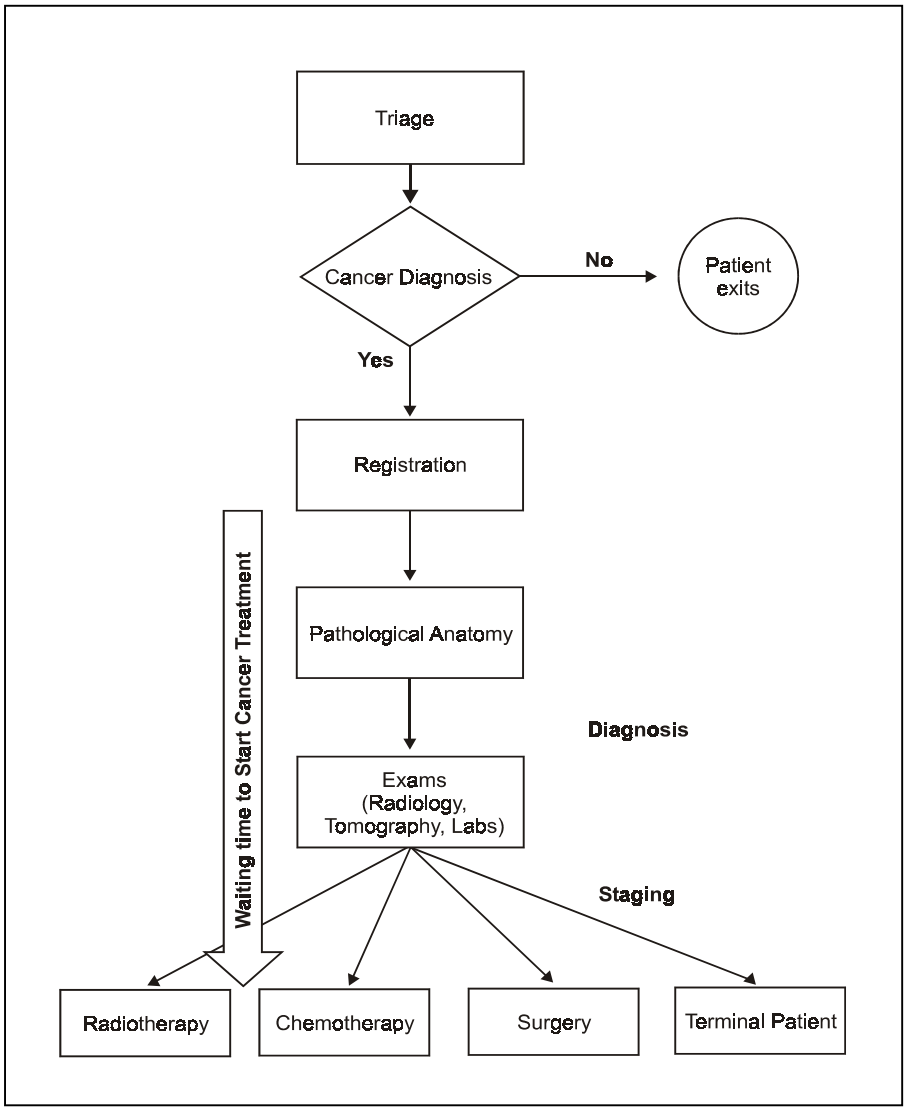
3. The Information System

The information support system, as described in this paper, is a suite of modules specially designed for the management of the attendance of patients. The system has become one of the main available tools to support decision-making at several administrative levels ranging from clinics to the directory of the different

INCA hospitals. The system follows the flow of all the patients from the registration to the discharge. All the details related to the demand, identification, preliminary pathological anatomy exams, clinical pathology, radiology, among others, are provided in order to easy the detection of the localization and evolution of the illness.

The cancer treatment follows a well-known flow. The localization of the tumor, stage and diagnosis is usually identified after a batch of preliminary activities. Figure 2 shows a sequence of activities that corresponds, predominantly, to a surgery application of radiotherapy and chemotherapy.

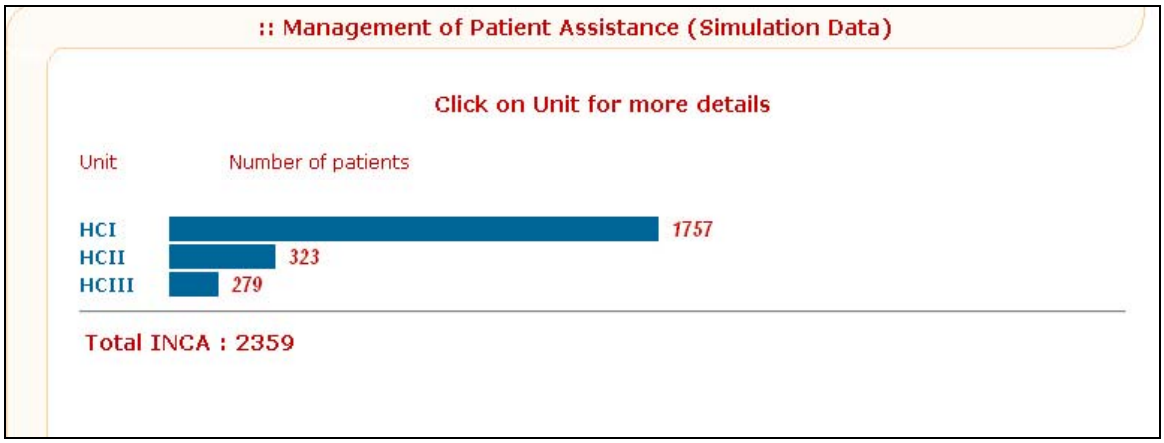
Figure 2: The treatment flow



The information in the Disease Management Module (DMM) is available from the more aggregated level to the more specific one. The first available information in the system is the number of patients who are waiting for the

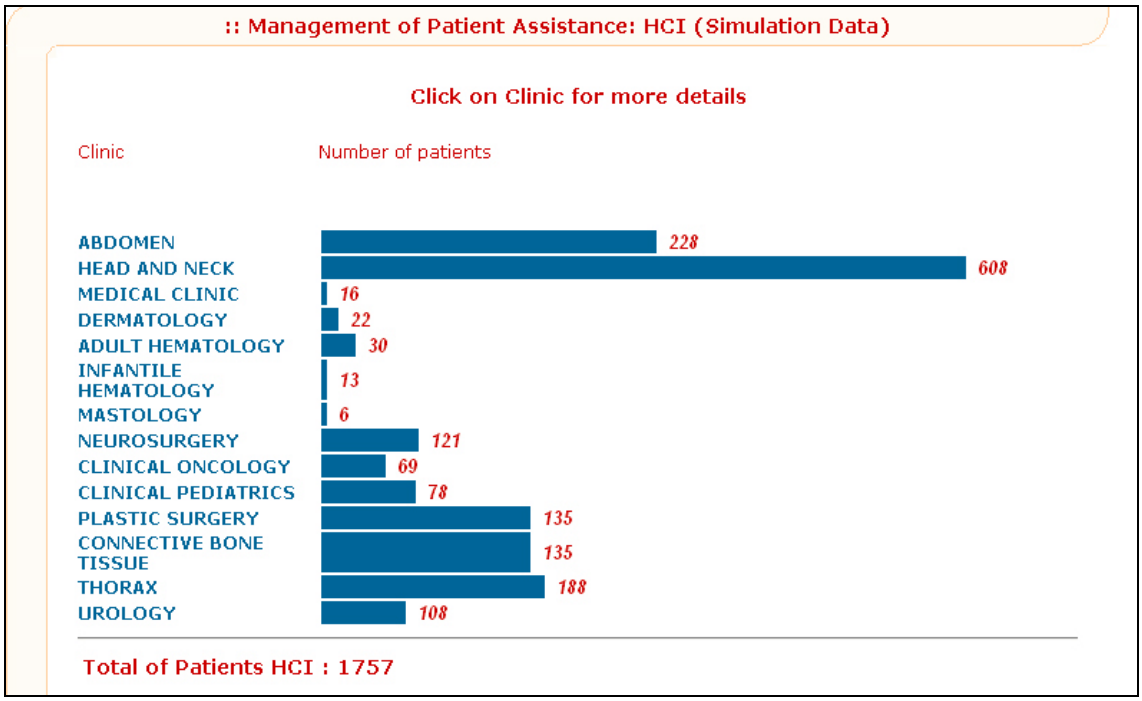
beginning of the treatment. For example, the physician can start his search from the analysis of the size of the queue, looking for a particular patient and following the history of each patient from the waiting line being able to see fine details such as the result of specific exams. This information is available for each hospital unit at INCA. It is segmented by 3 hospitals HC1, HC2 and HC3 as demonstrated in Figure 3.

Figure 3: The size of the waiting list for a particular hospital unit



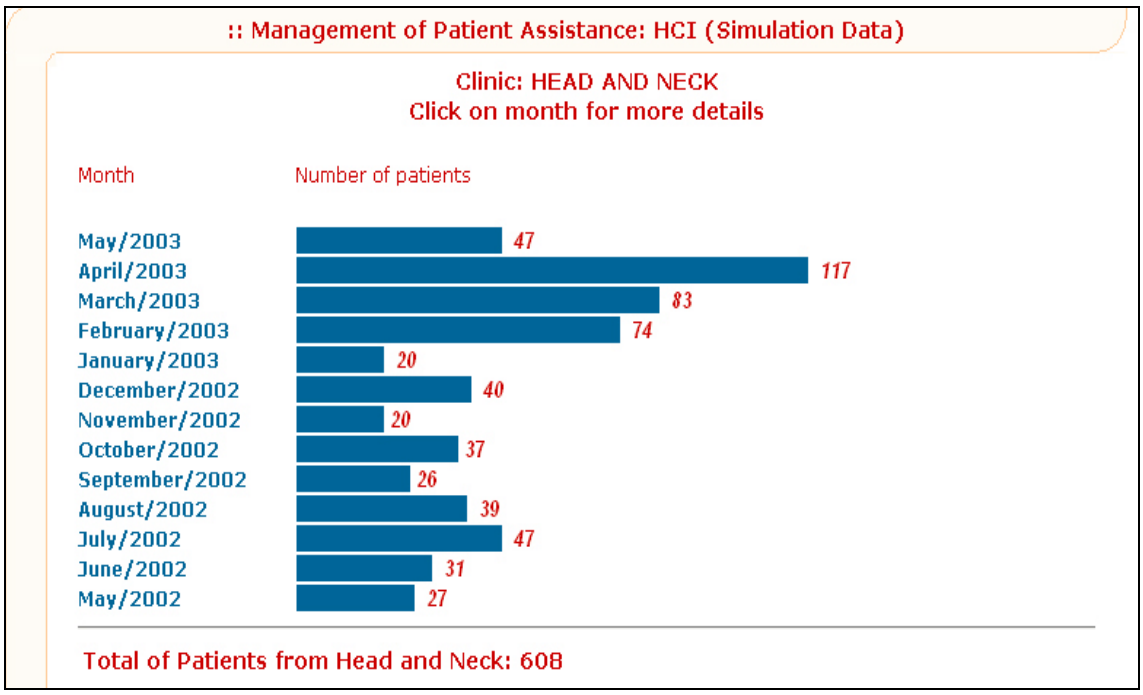
The manager can select, according to his security profile access, a unit to be analyzed by drilling down to the level of segmentation that shows the size of the queue in each specialty as is shown in Figure 4.

Figure 4: The waiting list for the clinical specialty



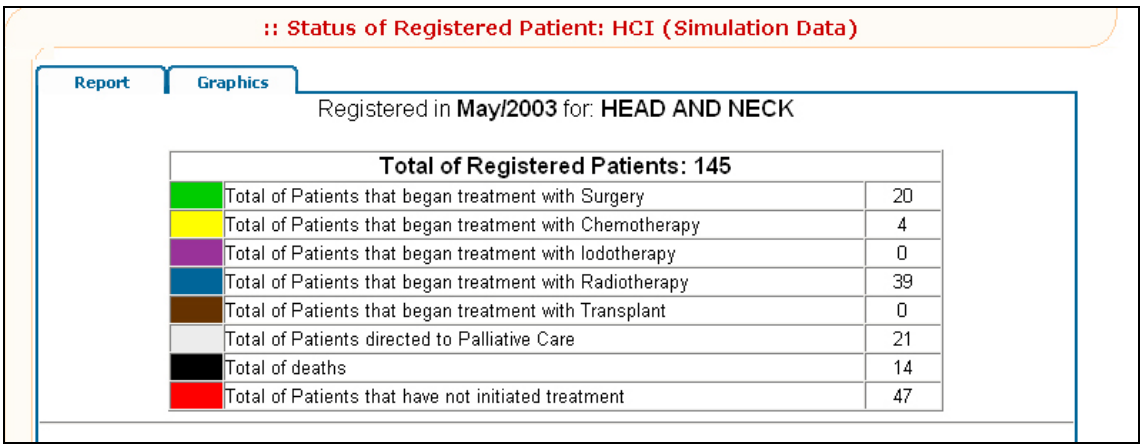
It is possible now to have the profile of the demand. The size of the waiting list, for example, is a very important parameter to evaluate the quality of cancer treatment. By using this information system, the user is able to analyze the status of a particular clinic. Figure 5 shows, the size of the waiting list, over the period of one year for the head and neck clinic. It can be seen that there was 117 patients on the waiting list on April 2003. It is important to notice that this information was not available to the managers before the implementation of the system.

Figure 5: The size of the waiting list for the head and neck clinic per month



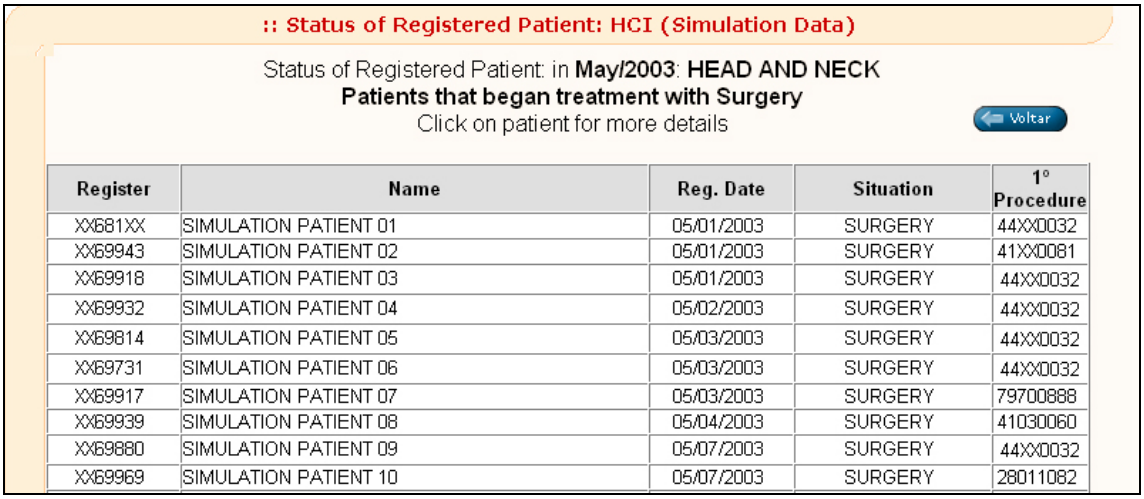
It is also possible to access the information about the registered patients. Let us select a particular month of interest and identify the distribution of the registered patients according to different forms of treatment. Figure 6 shows the number of patients that began treatment in different units, and points to the total number of patients that have not initiated the treatment. This is very important information because time is essential to reduce the mortality in cancer treatment.

Figure 6: The status of the registered patients at the head and neck clinic



It is possible to see that about 32%, out of group of 145 registered patients, have not initiated the treatment yet. The death rate is about 10% in this group. It is clear that, with the new advances in the cancer research, there are better chances of cure if the patient receives treatment in an earlier stage of the disease. It is now possible to drill down to a list of patients by selecting a specific treatment and verify the status of the registered patients. Figure 7 shows the data for the patients that began treatment with a surgery, in the head and neck department.

Figure 7: The list of patients that began treatment with surgery



Register	Name	Reg. Date	Situation	1° Procedure
XX681XX	SIMULATION PATIENT 01	05/01/2003	SURGERY	44XX0032
XX69943	SIMULATION PATIENT 02	05/01/2003	SURGERY	41XX0081
XX69918	SIMULATION PATIENT 03	05/01/2003	SURGERY	44XX0032
XX69932	SIMULATION PATIENT 04	05/02/2003	SURGERY	44XX0032
XX69814	SIMULATION PATIENT 05	05/03/2003	SURGERY	44XX0032
XX69731	SIMULATION PATIENT 06	05/03/2003	SURGERY	44XX0032
XX69917	SIMULATION PATIENT 07	05/03/2003	SURGERY	79700888
XX69939	SIMULATION PATIENT 08	05/04/2003	SURGERY	41030060
XX69880	SIMULATION PATIENT 09	05/07/2003	SURGERY	44XX0032
XX69969	SIMULATION PATIENT 10	05/07/2003	SURGERY	28011082

The Electronic Medical Record (EMR) contains all the relevant information about patients. It also includes details of specific exams, dates of appointment and registration. The user is able to access information on each exam or appointment by clicking on an item of the EMR. It is possible to search the patient records in a great level of details. All the pertinent information becomes

available on the detailed exam screen. Figure 8 shows a sample of the results of a particular exam.

Figure 8: The sample of the exam result of a particular patient

INCA - INSTITUTO NACIONAL DE CÂNCER

Patient: **SIMULATION PATIENT - 9999999** // Sex: **M** // Age: **54**
Request Date: **06/24/2003** // Result Date: **07/01/2003**
Result Closing Date: **07/01/2003** - **10:56**
Exam Description: **LARINGOSCOPIA**// Doctor: **José**

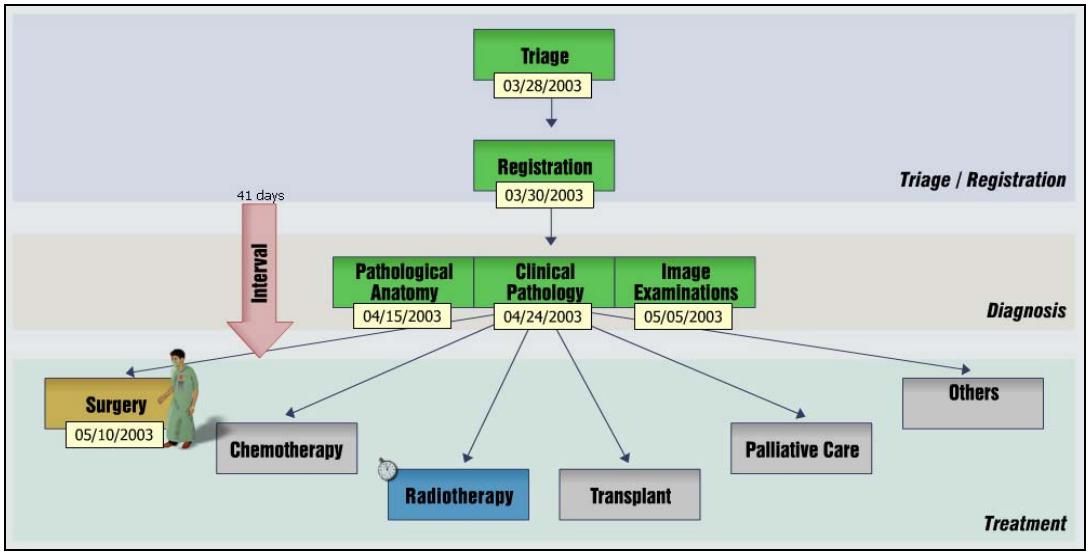
RESULT NUMBER: 247676 - Exam Date: 05/10/2003

U.S. ABDOMINAL

THERE IS AN INTENSE FOCUS OF FDG UPTAKE IDENTIFIED IN THE POSTERIOR ASPECT OF THE LIVER, NEAR THE MIDLINE, MEASURING APPROXIMATELY 6.2cm IN TRANSVERSE DIMENSION BY 5.4cm IN AP DIMENSION, WITH MEAN SUV MEASUREMENTS IN THE RANGE OF 4.5 TO 5.5. THERE IS A SMALLER FOCUS OF ABNORMAL FDG UPTAKE SEEN IN THE HYPERTROPHIED LEFT LOBE OF THE LIVER, MEASURING 3.3cm TRANSVERSE BY 2.8cm AP, WITH OVERALL LESS GLUCOSE UPTAKE AND MEAN SUV MEASUREMENTS OF 2.5 TO 3.5. THERE IS ALSO BILATERAL MILD UPTAKE OF ACTIVITY NOTED ALONG THE POSTERIOR PLEURAL ASPECT OF BOTH LUNGS. NORMAL UPTAKE AND EXCRETION OF ACTIVITY BY BOTH KIDNEYS IS NOTED. NO DEFINITE ABNORMAL FOCUS OF UPTAKE IS IDENTIFIED IN THE LINGS.

Another interesting feature of the information system is the possibility to create the patient's treatment flow from the clinical data repository. That is a totally new approach, which allows users to examine, in a visual fashion, the evolution of the treatment. This module a very useful tool to support decision-making with regards to the care provided to individual patient. The doctors are able to synthesize, in one screen, the past, the present and the future events of the patient treatment history, being able to evaluate the stage of the treatment. The sequence of events, the dates and the duration of each event are very important to understand the structure of the treatment. Figure 9 shows an example of the flow of treatment for a particular patient.

Figure 9: The treatment flow of a particular patient



This information system increases the trace ability and is totally patient-oriented. It is possible to see, in an animated fashion, the details of the flow of a particular patient over the treatment process. The doctor in charge of the case is able to follow a particular patient or a group of patients step by step in their cancer treatment. Based upon the easily available information, one is able to detect and/or predict possible problem in the treatment flow. Understanding the flow of the treatment, evaluating the constraints and managing the bottlenecks could be a possible way to improve the quality of the treatment [10]. This environment will enable managers to consider priorities related to the stage of the disease and treatment.

4. The Simulation Model

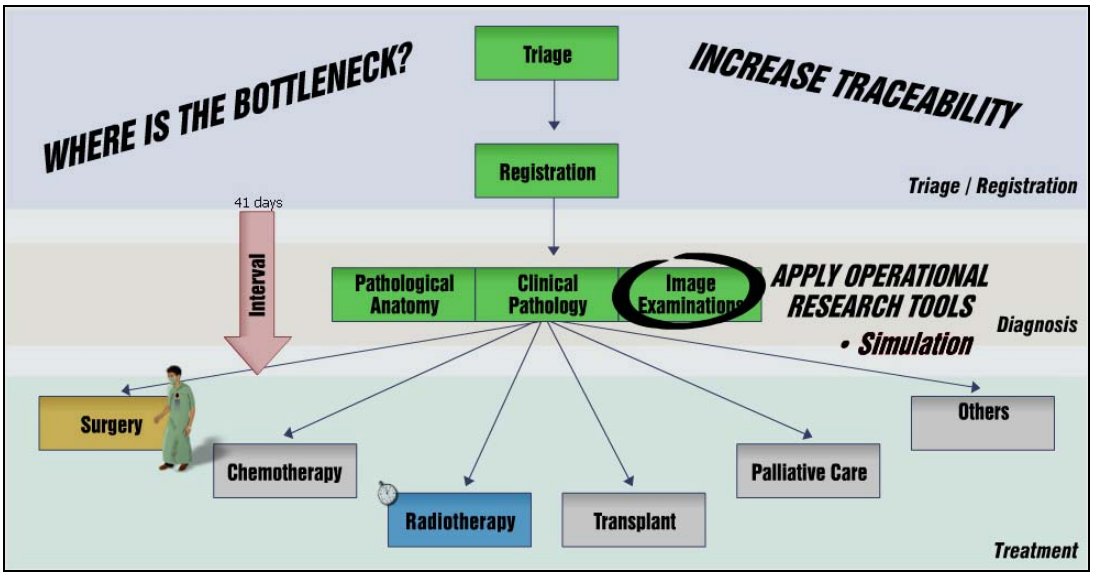
A previous paper, written by the authors describes a simulation experiment made at the image examination sector of one of the hospitals of the INCA complex [3]. The objective of the model is to contribute to the reduction of the patient's waiting time in the service. The adopted methodology is to analyze the patient's flow in this reference hospital evaluating the access alternatives and the use of available equipment. The exercise is useful to identify bottlenecks and evaluate alternatives for the allocation of resources improving the level of access and decreasing the time between the ordering cancer diagnosis exams and its effective completion.

The arrival of patients to the radiology department is gathered from the present information support system. The model evaluates scheduling patterns and typical situations such as observed in practice. Three different arrival schedules are proposed for the radiology patients. The main activities evaluated include:

- Reception
- Patient preparation
- Medical examination
- CT examination;
- Image scan
- Film production

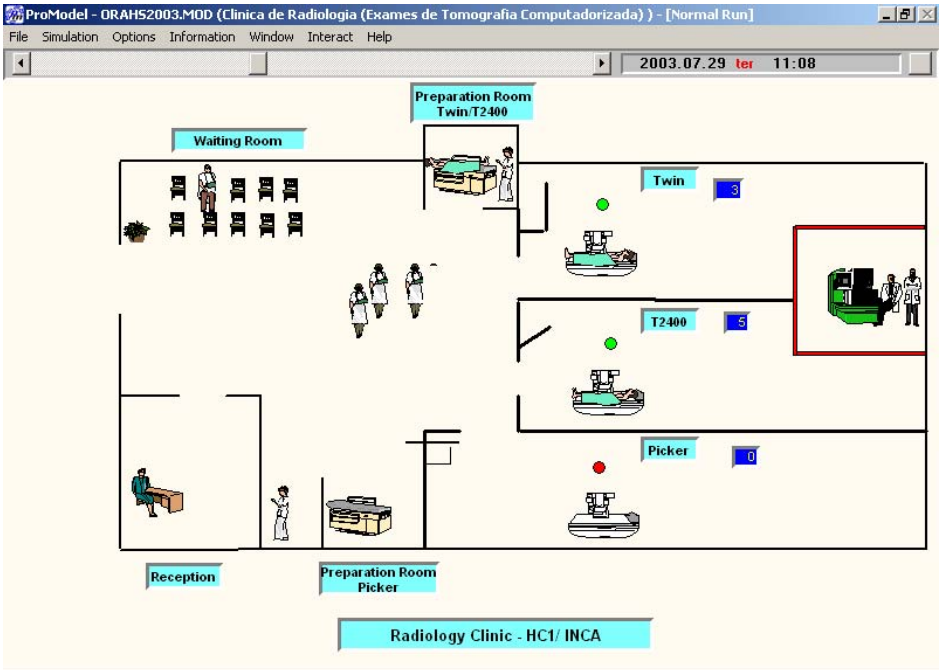
The advantages to use information systems to provide data for operational research models can be found elsewhere [3, 4, 9]. The requirement of a continuous evaluation of the activities of the radiology department suggested the inclusion of the simulation model as another module of the information system, as it can be seen in Figure 10.

Figure 10: Operational Research Tools



In this way the model could be used to investigate alternative scenarios. Figure 11 shows the screen of a model that represents the flow to perform image exams in the radiology facility. The objectives are to evaluate the reduction of the waiting time between the image exam schedule, its execution and the dimensioning of the human and material resources [3]. The target is to increase the capacity to complete image exams.

Figure 11: Simulation Experiment



5. Conclusions

The information support system proposed here represents a significant step towards improving the quality of the cancer treatment at INCA. The disease management tool has caused a significant impact in different areas of the hospitals, enabling information exchange between key sectors. It provides logistical support to identification of the patients, evaluation of the case, follow-up of the treatment, improving the longitudinal care. The data on how a particular patient receives cancer treatment from month to month or year to year was not easy to be gathered before the implementation of the system.

The creation and implementation of the new system has changed the entire workflow process at INCA. The ability to integrate data is a competitive advantage, enabling a more efficient operation of the hospital care. From a clinical point of view, one can identify the characteristics of patients demanding special attention. Proactive problem identification involves alerts and reminders for patients who are at-risk. The power of changing behavior by sharing information about longitudinal patient history demonstrates tangible benefits. Among other improvements, the resources are better utilized and the patients' management became more organized. Despite a natural initial resistance to changes, most physicians feel that the new development will be a long-term success.

The strategy of the solution implemented intends to bridge the gap between the doctors, the managers and the patients, with regards to the level of information available. Information is crucial for decision-making in administrating hospital regulations and enhancing medical treatment. Through the integration the new available technology and daily clinical information, managers are now able to take decisions based on pieces of information that doctors would normally keep with their personal records.

Future developments are likely to include a greater emphasis on disease management, protocols and more sophisticated logical rules as additional types of clinical data become available. Currently, the analysts are working towards the integration of the system with other services. As time progresses, the project measurements continue to show positive results for both the facility and patient.

6. References

1. National Cancer Institute, 2002. *INCA, Annual report 2002*, Rio de Janeiro.

2. National Cancer Institute, 2003. *INCA, Rio de Janeiro*. Available at http://www.inca.gov.br/.

3. Gonçalves, A.A. and M.J.F. De Oliveira, 2004. The use of simulation to improve cancer treatment access, In: M.J.F. De Oliveira (Ed.), *Accessibility and Quality of Health Care - Proceedings of the 28th ORAHS meeting*, Peter Lang, p. 149–161.
4. De Oliveira, M.J.F., 1982. *The use of information in planning hospital admissions with special reference to Glasgow Western Infirmary 1977-79,* Ph.D. Dissertation, Strathclyde University, Glasgow.
5. Kastelein, A. and A. Looijen, 1996. Executive information support systems and health care management, In: Kastelein, A, Vissers, J., van Merode, G.G., and L. Delesie (Ed.), *Managing Health Care Under Resource Constraints,* Proceedings of the 21st ORAHS meeting, Eindhoven University Press, Eindhoven, p. 213–219.
6. Lagergren, M., 2002. Modeling as a tool to assist in managing problems in health care, In Boldy, D., Braithwaite, J., and I. Forbes (Eds.), *Evidence based management in health care: The role of decision support systems*, Australian Studies in Health Service Administration, 92:17–36.
7. Braithwaite, J., Whelan A., and I. Forbes, 2002. Decision support systems and where they go from here: The normative and the realizable, In D. Boldy, J. Braithwaite and I. Forbes (Ed.), *Evidence based management in health care: The role of decision support systems*, Australian Studies in Health Service Administration, 92:137–143.
8. Drazen, E.L., Metzger, J.B., Ritter J.L., and M.K. Schneider, 1995. *Patient care information systems,* Springer Verlag, New York.
9. Côté, M.J., 1999. Patient flow and resource utilization in an outpatient clinic, *Socio Economic Planning Sciences,* 33:231–245.
10. Breen, A., Burton, T., and D. Aron, 2002. Applying the theory of constraints in health care: Part1 – The Philosophy, *Quality Management in Health Care*, 10:3.

LOGISTICS INFORMATION SYSTEMS IN HOSPITALS: SYSTEM REQUIREMENTS

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Abstract: Nowadays, there are several studies in areas such as medicine, economics, administration, engineering, sociology, among others, which have substantially contributed for the understanding of health organizations. In this context information systems, adjusted to hospital necessities, are strongly united for planning, organizing, coordinating and controlling this kind of business. In relation to hospital logistics, modern management techniques, integrated to well-defined information systems, are basic tools to support management and logistics systems regarding decision processing. This article analyzes *Pontificia Universidade Católica do Paraná's* (PUCPR - Catholic University) health system structure, called *Aliança Saúde*, consisting of four hospitals, a medicine distribution center and a health insurance plan. It also evaluates the information system integration in relation to all key elements involved in the logistics structure. Interviews realized with participants of this process highlight deficiencies in relation to administrative aspects as well as the inefficient utilization in relation to existing computational resources. The need to adopt an integrated information system for implementing inventory policies is very clear, specially to boost the use of administration techniques according to the expected health system efficiency for organizing and controlling the supply chain. This article presents a proposition of logistics information system requirements to the *Santa Casa de Misericórdia* hospital (a public beneficiary hospital), one of PUCPR's system units, classified as clinic and budget control, standardization and subdivision of inventory control and distribution, purchase policy support, cost control, integration and communications facilities.

1. Introduction

Hospital services present basic differences in relation to other types of activities [1], especially regarding their complexity. The main purpose of hospital services is to preserve human life, therefore quality assurance, which express efficiency for the various types of demand, is desired, always taking available resources and the social aspect of it into consideration. The complex organizational structure, the nature of services rendered and low budgets contribute for hospital management difficulties [31].

A collection of processes is part of hospital services driven for the re-establishment and maintenance of people's health [1]. Like other productive processes, activities that support such processes represent a considerable part of the global cost of a hospital. Daniel [3] has checked and concluded that for each US$1.00 spent in the acquisition of supplies there is an additional US$0.70 to US$1.00 in distribution logistics. Due to these facts, rationalization of resources and the improvement of logistics efficiency in a hospital are relevant, in special

to the Brazilian context, where the public health system presents serious administration inefficiency [4].

Despite of all health system difficulties, the increasing public awareness has resulted in a growing demand for quality services, along with lower service costs. This has forced the health sector to search for new techniques and methodologies that can minimize complexities regarding hospital management. Borba [2] says that hospitals have two alternatives to improve their client expectations, i.e., improve available capacity or increase productivity of the existing system. The first alternative faces cost reduction barrier and lack of resources. This way, productivity increase of the existing system, based on reduction of costs, along with improved logistics efficiency, is presented as the possible alternative to be adopted.

For achieving productivity gain and logistics efficiency, some studies have proposed the use of rationalization techniques and optimization, originally developed within production engineering. However, Vries, Bertrand, and Vissers [5] emphasize that the use of traditional planning, programming and production control techniques, seeking hospital logistics efficiency, does not completely fit in the hospital context if some perspectives and basic features, which are specific to hospitals, are not taken into consideration, which are different from general procedures.

Ferreira et al [6] emphasize that the volume of information and the number of processes executed in daily tasks of a hospital require fast and flexible controls, so the task repetition and waste, caused by the lack of rationalization in processes are avoided. It is also mentioned that the data processing designed to fulfill the needs of the specific organization, mainly supported by information systems, is an auxiliary tool for planning, organizing, coordinating and controlling this organization, further than presenting medium- and long-term advantages, either in relation to costs or the improvement of quality level of services provided to patients.

Novaes [7] highlights that well defined information systems, properly integrated with modern management techniques, are basic tools for supporting the decision process and management of logistics systems. A hospital unit may be characterized as a complex logistics system, where human and physical resources and information need to be coordinated and integrated, which due to the current complexity of these systems, is only possible through the use of information systems and support to select a management process [8].

Further than what presented above, the studies regarding information systems are important under several aspects:

- historically, information has never been so important as it is today and, as a consequence, methodological system development studies become a main priority for the creation of information systems for helping the management process of organizations [17];
- it is not a matter of just focusing the techniques developed in computers for creating information systems; an inter-disciplinary approach with applied social sciences is also necessary, specially regarding management studies, because it is in this specific field where the organization theory is concentrated [9];
- in the worldwide scenery, where organizations aimed for high performance, integration and expansion are found, there is the need of a new organizational focusing, in which information must flow with maximum agility and flexibility possible [10]. Systemized studies of information systems must be integrated with these expectations, for the lack of such studies leads to administration unawareness regarding consequences of decisions taken for defining data processing resources [11].

This article has the purpose of presenting the necessary information system requirements for supporting the supply logistics management process of a health system. For achieving this, the health management process concept was explored, with emphasis to processes inherent to hospital supply logistics, relating it with a hospital information system. The requirements, presented by literature, of an information system, which supports hospital and logistics management process, are supported. The requirements of an information system that supports the supplying logistics operation of a health system specific for the city of Curitiba, Brazil, were proposed.

2. Theoretical Fundaments

2.1 Hospital Management

Hospitals are organizations with a great number of different positions and duties, great diversity of units, independent departments, interference on the way public/private financing is presented, constant pressure for quality improvement and reduction of costs [1], [32]. Castelar, Mordelet and Grabois [4] sustain that health service organizations are complex structures the components of which are: development of systems, organization of programs, economic support, management and supplying of services.

Currently there are works within the areas of Medicine, Economy, Administration, Engineering, Sociology, among others, which have contributed for the knowledge of health organizations [12]. That is why, currently, the functioning of health systems and services, mainly in hospitals, takes into consideration several management and evaluation concepts which promote the quality and efficiency of its activities.

Castelar, Mordelet and Grabois [4] say that, for an efficient organization management, such as hospitals, it is demanding, on the part of managers, the same level of professionalism required for medical activities. It is also highlighted that an important feature of the health service production is how strong the human element is, either as a service provider or as a user. This implies that this process is rich in social-economic, cultural and even psychological components, which are not easily found in any other sector.

Pijl and Smits [13] highlight that, currently, modern hospitals are providing professional services instead of products. To do so, hospitals have a high-quality technological infrastructure to sell medical services. Authors also mention that such structure is under pressure, including financial limitations in its budgets due to social changes and political reasons. That is why hospitals are adopting a market-driven orientation.

Mintzberg's typology, characterize hospitals as professional organizations [4], [13], where the work is performed by specialists with autonomy to develop it. Pijl and Smits [13] denote that hospitals can also be seen as organizations based on high technology and intensive information processes. Such organizations are not generally hierarchically structured bureaucracies, but frequently based on democratic control mechanisms with institutionalized influences of their stakeholders in decision processes [33].

Castelar, Mordelet, and Grabois [4] suggest a management proposition based on their study of French organizations, with some specific features of Brazilian hospitals, which respect the organizational principles of professional services:

- hospitals must settle their assistance objectives, following *Sistema Único de Saúde's* (SUS = Single Health System) guidelines of the Brazilian government;
- the management must be based on the evaluation of results with the definition and accompaniment of indicators which must combine information originating from assistance and administrative areas. Indicators must consider aspects based on quality and productivity point-of-view, such as taxes related to procedures, infections, hospital re-admissions, medium-term hospital

permanency, occupational rate, information regarding production and consumption of material, etc;

- the management structure must be divided into centers of responsibility in such a way that performance, regarding products and/or supplies, be physically and financially quantified;
- the definition of objectives must integrate different existing competencies, however, keeping the necessary autonomy for each service;
- the lateral communication must be valued between the several areas of a hospital;
- it is necessary to define a management team formed by headmen of all different hospital areas and types of services;
- a greater degree of specialization must be developed in certain management areas, in a compatible way in relation to the hospital's complexity level;
- technology incorporation criteria must be developed based on cost-benefit concept. In environments where resources are scarce, this definition becomes relevant.

According to Pijl and Smits [13], the most recent answer of modern hospitals is network management reorientation. In this type of organization, the hospital is seen only as a piece introduced in a detailed network of health care. That is why the main focus of management is the greater coordination among its inner and external processes. In this specific case, authors, the redesign of processes and the management of supply chain can be used to improve efficiency of hospital services. This way hospital structures tend to change from management of abilities to management of networks or, according to Mintzberg, from hierarchic management and a formal kind of control to management through networks and collective control [34].

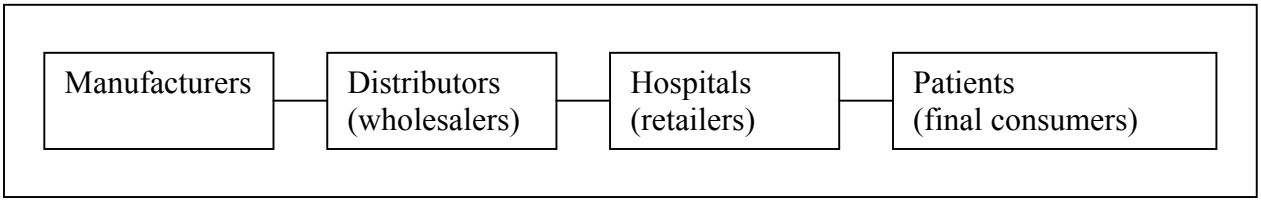
2.2. Hospital Logistics

Supply logistics is one of the basic activities of entrepreneurial logistics, and focusing in a continuous and organized flow, it is at the beginning of it, supplying the need of different kinds of material and also production, allowing the logistics cycle to be complemented with distribution. Ballou [14] defines entrepreneurial logistics as the integration of material administration or supplying logistics and physical distribution.

In hospital context, the supply or distribution chain is configured as presented in Figure 1. In this chain, the hospital plays the role of a retailer, providing several types of service aggregated to the product, for clients (patients). These services, aggregated to products acquired directly from manufacturers or wholesalers

(distributors), are made effective and result in the good health of final consumers (patients).

Figure 1: Hospital Supply Chain



SOURCE: Correia Neto and Oliveira [15]

Supply logistics functions, or administration of material, within hospital context, follow the same principles of other types of organizations, with the exception of some features which must be better valued, such as, intangible cost related to the lack of medicines/material at the moment of need. Castelar, Mordelet, and Grabois [4] highlight that logistics services are part of health services as a whole, providing all necessary material for the medical assistance and, consequently, creating a favorable environment for an adequate patient treatment. That is why modernization and proper functioning of logistics in hospitals are basic quality factors for providing health services. Correia Neto and Oliveira [15] explain that tolerance to errors in the flow of hospital products cannot exist and that "In the distribution chain of hospital products, factories, distributors and hospitals must be aware of patients needs, the last link of this chain. Mismanagement of it causes a strong impact on the patients care's level. It is, above all, a chain which involves a critical mission on the human health."

2.3 Information Systems and Logistics

Laudon and Laudon [16] explain that an information system is part of an organization and is formed by three components: technology, organization and people. Campos Filho [35] goes beyond, emphasizing that the information system is based on a four-component structure, with the purpose of understanding the organization objectives:

- information (formatted data, images, audio and free texts);
- human resources (which collect, store, retrieve, process, spread and use information);
- information technologies (hardware and software);
- work schemes (methods used).

The information technology caused a strong impact on logistics and on the supply chain [15]. This is due, mainly, because logistics itself presents various

information elements in its structure configuring, this way, a long information flow [18]. In this flow, the analysis of transactions reports and logistics elements, along with structured techniques, allow the determination of important control features, such as the definition of inventory, for example. That originated logistics information systems, which are subsystems of management information systems, or of integrated management system, which provide all necessary information for logistics activities of an organization [14], [18].

As mentioned above, Laudon and Laudon [16] explain that an information system is part of an organization and is formed by the composition of three components: technology, organization and people. That is the reason authors suggest an approach, for information system projects, which relates its technical aspects, people involved in the process as a whole, and the natural process for the resolution of problems – adapted from the Simon's model for analysis of decision process: analysis of environment and understanding of problems, identifying possible courses of action and deciding for one of them [19]. This model is expanded to contemplate stages of solution project and its implementation.

An information systems project can be driven to: the construction of specific systems and adapted to the needs of the organization, in this case, developed by the own organization; the selection and purchase of packages which have already been developed, consolidated and properly tested and validated, which require few or no adaptation at all; or the third-party process of the development. For each type of the project, stages are differentiated, as well as the roles of people involved.

For development projects there are some approaches, which have been already consolidated in the software engineering, also known as development methodologies. A methodology is a group of techniques and tools that allow standardization of the system development process through specification of the footsteps that must be followed [20]. The most ancient and widely used is the life cycle methodology. In this methodology, the development is viewed as a set of different and defined stages, each one representing different activities, with specific start and ending. However, despite this methodology is largely used and accepted as efficient, there is no standard for the division of system projects into defined stages [36].

Some approaches have been studied as alternatives to traditional life cycle, such as prototyping, interactive construction and heuristic development. Their

similarities are regarding the difficulties users have to define their information requirements, and on the part of system analysts, to understand user's environment. However, independently of the methodology used, other factors have been observed as important ones for the development of systems, such as, for example, the fact that there must be an intrinsic need of the system on the part of users, and also there must be a high level of their participation in the process [21].

3. Methodology

This work has adopted the qualitative method of research which, among the main features, are: the direct source of data in this type of research is the natural environment, and the key instrument is the researcher; the qualitative research is descriptive and researchers who use this method tend to make inductive analysis [22].

This work followed the structure of an exploratory study and, according to Selltiz et al. [37] is classified as analysis of literature, analysis of experiences and analysis of examples. According to Gil [23] exploratory studies usually involve bibliographic and document approach, non-standard interviews and case studies. This way, the work has been divided into two stages: research in secondary sources and the case study. Research in secondary sources occurred through bibliographic review about subjects related to researched theme, document analysis and analysis of a reference model—a public hospital in the State of São Paulo, Brazil, where there is an information system already implemented that supports supply logistics operation. Pozzebon and Freitas [41] are certain that case studies can be applied on the information system because they allow the study of such systems in their natural environment and the generation of theories based on praxis, further than making it possible to understand the nature and complexity of ongoing process.

The population researched through the work included employees of the *Santa Casa de Misericórdia de Curitiba's* data processing department; employees of pharmacy and storage departments, responsible for the distribution of medicines/material within the hospital; employees of PUCPR's purchase department; employees of the pharmaceutical products supplying and processing station pertaining to *Aliança Saúde*; and decision aspects involved on the hospital's and *Aliança Saúde's* logistics processes.

The sample obtained among the population was intentional. This type of sample, according to Goode and Hatt [38], provides “freedom to choose on the part of the interviewer, with the restriction that certain informant's features represent the area or the group which has been investigated.” Therefore, an intentional international relationship among the sample's elements is necessary, according to certain features established in the plan and in presented hypothesis [24].

At the *Santa Casa de Misericórdia de Curitiba* (a beneficiary hospital) the employee in charge of the hospital's data processing department, the two leading pharmacists, the two leading storage room administrators and the administrative managers of the hospital were selected. At the purchase department, which is part of PUCPR's finance department, the following personnel was selected: the department's manager and one of the employees in charge of the purchase operational procedures, such as organization of documents and selection of suppliers and estimates. At the Pharmaceutical Products Supplying and Processing Station the two pharmacists in charge of the logistics support to *Aliança Saúde* were selected. Eventually, at Aliança Saúde, the superintendent general, responsible for the *Aliança Saúde's* administration, was selected, totaling eleven people.

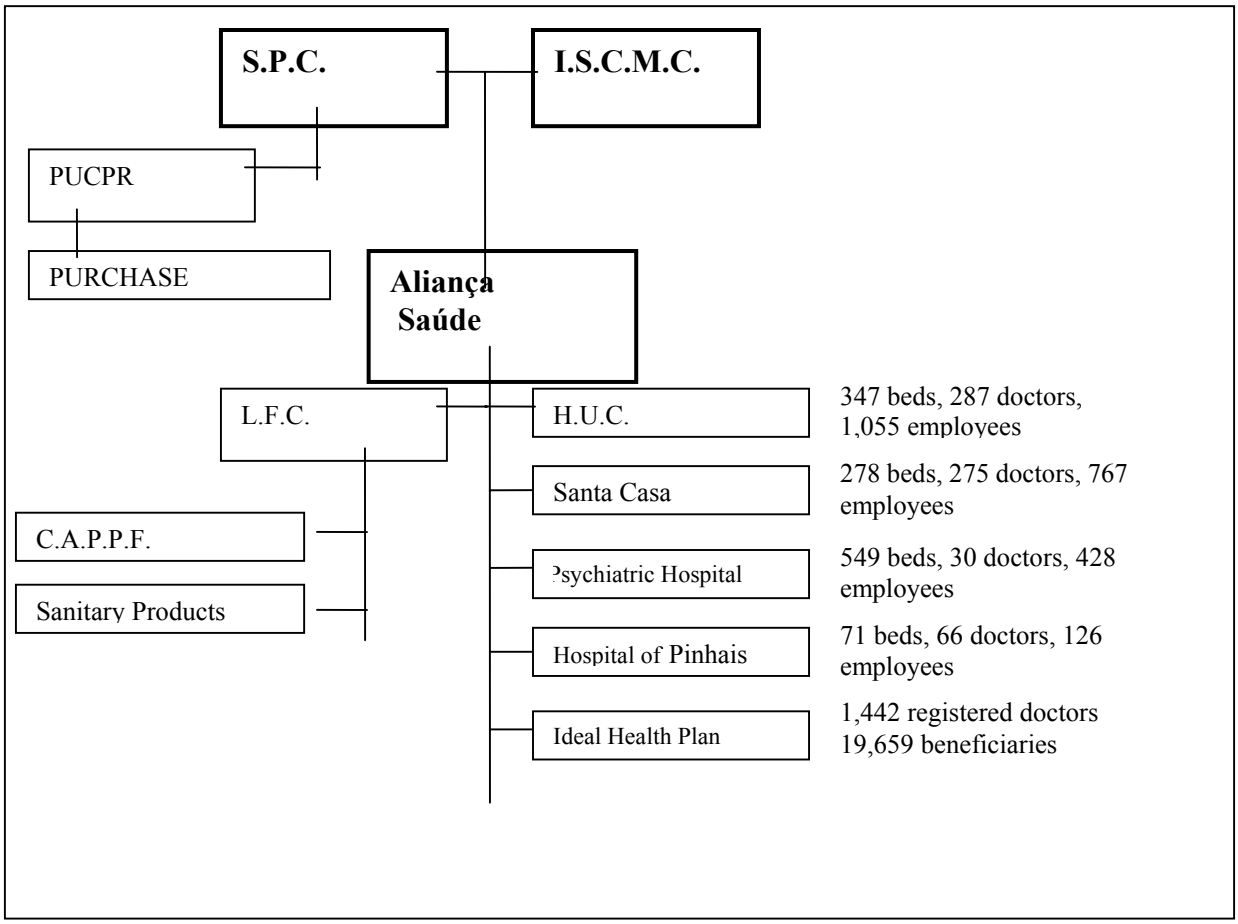
4. The ALIANÇA SÁUDE and the SANTA CASA DE MISERICÓRDIA

The *Pontifícia Universidade Católica do Paraná* (PUCPR), administered by the *Sociedade Paranaense de Cultura* (SPC) has been working in the health segment since 1959, when *the Faculdade de Ciências Médicas do Paraná* was incorporated. In 1977, the "Hospital Cajuru" was acquired by the SPC and became the *Hospital Universitário Cajuru e Pronto-socorro Municipal* (university hospital and a municipal emergency hospital). In 1999, the *Irmandade Santa Casa de Misericórdia de Curitiba* (ISCMC), a non-profit hospital network with philanthropic purposes, transferred the control of two of its hospitals and a health care plan to the SPC. It was created, then, a company called *Aliança Saúde*, which responsibility, apart from unifying the system administration, is to unify the system administration. In 2001, the control of another ISCMC hospital is transferred to the system. Figure 2 shows the current structure of *Aliança Saúde's* system. The history of hospitals are very different – for example: the *Santa Casa de Misericórdia de Curitiba*, a non-profit organization, was inaugurated by the emperor Dom Pedro II in 1880, the Psychiatric Hospital was inaugurated in 1903 and *Hospital Cajuru* belonged to the Federal Railway Company.

Detailing of the Aliança Saúde system and SPC structure:

- *Sociedade Paranaense de Cultura* (SPC) (cultural society of Paraná) – in charge of administrion of the *Pontifícia Universidade Católica do Paraná* (PUCPR) (Paraná's Catholic University);
- *Irmandade Santa Casa de Misericórdia de Curitiba* (ISCMC)(a beneficiary hospital) – institution that provides support to the *Casa de Misericórdia de Curitiba* (also known as *Hospital de Caridade*(charity hospital)), to the *Hospital Psiquiátrico Nossa Senhora da Luz* (psychiatric hospital), to the *Hospital e Maternidade Nossa Senhora da Luz dos Pinhais* (maternity hospital) and to the *Plano de Saúde Ideal* (health care);
- *Aliança Saúde* – in charge of administration of *Hospital Universitário Cajuru* (HUC)(university hospital), of hospitals linked to *Irmandade Santa Casa de Misericórdia de Curitiba* (ISCMC)(beneficiary hospital) and to *Laboratório Farmacêutico Cajuru* (LFC);
- *Laboratório Farmacêutico Cajuru* (LFC) – responsible for the *Central de Abastecimento e Processamento de Produtos Farmacêuticos* (CAPPF) (pharmaceutical products supply center) and for the production of sanitary products;
- *Central de Abastecimento e Processamento de Produtos Farmacêuticos* (CAPPF) (pharmaceutical products supply center) – also known as central laboratory, is responsible for supporting the supply logistics of the *Aliança Saúde's* hospitals network, with the main purpose of organizing the acquisition of medicines and material through the supervision of orders, standardization and effective needs, further than centralizing and periodically distributing medicines/material for hospitals.

Figure 2: ALIANÇA SAÚDE'S STRUCTURE



SOURCE: ALIANÇA SAÚDE / PUCPR [40]

5. Requirements for the Information System

5.1 Hospital logistic management and its relation with the information system

Fleury, Wanke, and Figueiredo [18] performed a multi-case study in 10 companies with the purpose of analyzing the development stage of logistics administration. One of the points taken into consideration in the analysis was the level of utilization and the importance of information systems. In these cases it is checked if systems used in the material/supplies and commercial areas are a priority in relation to management of logistics system found in companies researched. As for the importance of such systems, the research has revealed that the control of inventory, purchases, sales predictions, processing of orders and monitoring of performance are among the five most important and best quality ones [18]. According to statements of interviewed people, the quality of information systems operating in researched companies is not the expected by logistics professionals. Table 2 presents the areas of application where systems are considered most important.

Going beyond the logistics scope of information systems in hospitals, Castelar, Mordelet, and Grabois [4] characterize the importance of an information system equal to expectations of hospital management. At this specific subject, authors check the need of similar companies researched by Fleury, Wanke, and Figueiredo [18] regarding the quality of use in information systems for supporting management activities.

Table 1: Areas of Application of Information Systems

Areas of application	**Information systems**
Commercial	Processing of orders
	Reception of orders
	Electronic transmission of orders
	Financial support
Material/supplies	Inventory control
	Purchases
	Prediction of sales
Transport	Freight
	Routing and programming
Performance analysis	Profitability
	Performance monitoring
Storage	Reception of on-line orders

SOURCE: Fleury, Wanke and Figueiredo [18]

In a research made with 2,752 European hospital managers, the fact that technology can substantially influence hospital activities and services became evident, according to what is shown in Table 3. According to Pijl and Smits [13], the use of information technology in diagnosis and treatment increments the development of clinic and hospitals networks and health care processes. In this context, communication processes present themselves as critics in the improvement of interconnections between demands and health care providers.

Table 2: Implementation of Information Technology Selected By European Hospitals in 1998

IT resources implemented	Preference (%)
Reimbursement computerized procedures	86
Executive information systems	79
Communication between hospital departments	74
Computerized medical records	68
Electronic library	65
Electronic storage of radiological images	64
Computerized medical and nursing planning	63

SOURCE: Pijl and Smits [13]

Still according to Castelar, Mordelet and Grabois [4], the most important support instrument for hospital services is the local data processing structure that must keep equipment and programs in good operating conditions in all sectors, connected by networks which allow the creation or improvement of information systems regarding management, and the creation of an information circuit through an interconnected network. As for the information systems within a hospital, some questioning is still necessary [4]:

- Who is where? Allowing to locate and identify a patient in a clear and precise way, further than showing his/her real-time location;
- Who does what? For clinic personnel it means the group of analytic steps, either diagnosis and/or therapeutics, protocol or not, and for administrators it is a flow of information related to management needs;
- How? It allows refining of hospital production analysis.

For management information it is known, as mentioned above, that a management information system is not frequently found in Brazilian hospitals. Information found in a systemized way almost always reveals classical indications of hospital services, which are insufficient for ideal management. Castelar, Mordelet, and Grabois [4] propose some reports for supporting management: hospital services bulletin with daily schedule of services in each clinic or unit of the hospital; hospital activities report, quantifying activities such as appointments and emergency cases, data about admittance, among others,; diagnosis and therapeutic support, such as laboratory exams and X-rays, physiotherapy sessions, etc; administrative support; results report quantifying hospital revenues and expenses, enabling the checking of operational result and unitary cost of daily hospital expenses for an admitted patient.

Due to the constant changes of information systems supporting health operations, these systems are frequently fragmented. “History shows that there is a tendency, in several countries, to restrict the possibility of constituting a single system which would be the single source of all health information” [9]. The constant search for integration among all systems is noticed, the purpose of which is to avoid data collection duplicity and excessive work for health professional; factors which, among others, have resulted in lack of credibility and liability of information systems [9]. These initiatives are related to the attempt for designing a hospital information system, which is totally integrated, reflecting all information needs on the part of people involved in health organizations.

Lillehaug [25] emphasizes that a hospital information system (HIS) can be characterized as the complete integration of information available in a hospital. The system must enable all professionals to evaluate their own activities. A hospital equipped with an efficient information system will benefit in terms of quality and costs after this information are made available.

However, such availability of information on the part of the hospital information system does not assure the correct use of it. The first problem pointed out is the fact that several departments implement their own systems, independently, with the excuse that each one of them has its own requirements, and the consequence of it is the great difficulty of communication among them. These same problems are detected in the attempt for integrating administrative and clinic information systems. This case is known as patchwork, characterized as "of difficult integration". The author presents a case study in a British hospital having approximately 40 independent systems, which are unable to communicate with each other [25].

5.2 A Requirements Proposal for the Information System and Comments

Table 4 shows all elements desired by interviewed people, independent of the number of statements in an information system focused on supply logistics administrative scenery of the *Santa Casa de Misericórdia de Curitiba* and *Aliança Saúde*. The requirements were subdivided into six groups for organization purposes: clinic and budget control; standardization and subdivision; inventory and dispatching control; purchase policy support; cost control and communication and facilities integration.

The interviews show an anxiety for a standard hospital information system, integrated and adjusted to current organizations features. The integration of

patients clinical information, through data processing and automation of medical prescriptions, registering and orders among all hospital *Aliança Saúde's* units sectors, and the administrative duties and techniques related to logistics management, mostly referring inventory control, costs, support to purchase policies and distribution processes, are among the main desired features by people involved in analyzed processes. Some topics regarding automation and standardization of operations through the use of support equipment, such as bar code reader, and the use of a bar coding system of all information related to medicines, material and patients, are also commented. Such points are also highlighted by pertinent literature and related articles, as fundamental for the improvement of performance and quality of health services.

Table 4: Information System Requirements for Supporting *Santa Casa de Misericórdia de Curitiba* and A*liança Saúde's* Logistics

Clinic and budget control	**Support to purchase policy**	**Integration and communication facilities**
▪ Electronic prescription and requisition	▪ Purchase programming	▪ Integration with other units
▪ Intervention protocols	▪ Control and availability of ordering procedures	▪ Purchasing X hospitals integration
▪ Balance control of estimates at the moment of requisition	▪ Registration of products and suppliers	▪ CAPPF X hospitals integration
▪ Medicine interactions	▪ Classification and listing of products and suppliers	▪ Purchasing X CAPPF integration
▪ Electronic records	▪ Automatic suppliers selection	▪ Integration with interning procedures
▪ Electronic use confirmation	▪ Quotation control	▪ Patient information
Standardization and subdivision	▪ Quotation history	▪ Integration with exclusive suppliers
▪ Bar code	▪ Automatic registering of quotations return	▪ Inventorying centers X other sectors integration (HR, revenue, etc.)
▪ Code standardization	▪ History of negotiations	▪ Availability of debt payment to suppliers
▪ Salt standardization	▪ Purchase orders generation	▪ Single and integrated system
▪ List of standard products	▪ History of purchases	▪ Accesses with safety policy
▪ Tracing	▪ Generation of supply authorizations	
▪ Subdivision control	▪ Control and availability of quotations and purchases procedures	
Inventory and dispensing control	▪ Electronic communication among hospitals, purchases and suppliers	
▪ Accurate control of inventory	▪ Delivery positions	
▪ Accurate control of consumption history and predictions	▪ Registering of non-conformities during deliveries	
▪ Ordering stations	▪ Order time control	
▪ Automatic ordering	**Cost control**	
▪ Safety inventory	▪ Acquisition cost	
▪ ABC curve	▪ Order cost	
▪ Control of lots and expiration date	▪ Idle inventory cost	
▪ Return control	▪ Inventory cost	
▪ Expiration control at reception	▪ Cost due to lack of inventory	
▪ Loss control	▪ Cost of emergency purchases	
▪ Automatic authorizations	▪ Cost referring items temporarily taken from other units	
▪ Automatic medicine suggestions per expiration date	▪ Registering of price corrections indexes	

SOURCE: Moreira [42]

It is important to highlight that there have been differentiated evaluations, although complementary, in relation to basic requirements for an information system for the supply logistic scenery of the *Santa Casa de Misericórdia de Curitiba* and the *Aliança Saúde*. The *Santa Casa's* pharmacy and storage department employees showed more interest regarding data input, prescriptions, requisition and record automation. In this case, administrative instruments focusing logistics management efficiency, such as cost control and safety inventory control techniques, order stations, ABC curve, among others, were not taken into consideration. These topics were only acknowledged by the hospital management, by CAPPF's employees and PUCPR's purchase department as being fundamental for such a system.

Besides, however, several problems related to inventory control, such as negative inventories, were detected. There were also frequent situations when lack of material was registered, mainly because employees of *Santa Casa de Misericórdia de Curitiba* inventory center order material only when shelves are empty. This results in a great accumulation of emergency orders. There are also cases when supplies are ordered, inventory center employees add an unnecessary safety margin. This margin frequently originates an additional inventory that generates extra costs and possibility of loss of products due to validity reasons. This implies difficulties regarding organization, planning and control of inventory and distribution process on the part of inventory center employees.

The lack of material, specifically, can result in severe problems for a hospital pharmacy [26]. Gonzalo Neto [27] has a study regarding the causes that lead to the lack of material in hospital inventory centers. For the author, these causes can be identified in three different groups: structural causes, organizational causes and individual causes. Among organizational causes, the lack of ability, personnel updating programs, control, planning, routine and rule not properly established, are highlighted.

Portella [28] emphasizes that among other types of organizations, the hospital medical area may be one of the most complex ones. In this scenery, inventories have to be assured for any type of situation, however, in a planned way, for the remaining material in inventory cannot be liquidated. The author stands for better logistics procedures, based on strategies that must be included in every health care company priority goal, i.e., the efficient circulation of products, the efficient and ordinary collection of information and the efficient management of prescriptions. Such actions are not only related to technology or to techniques, but fundamentally to organizational discipline and specific behavior.

Particularly to the aspects of integration and availability of information in order to interact with internal and external environment of Santa Casa de Misericórdia de Curitiba and Aliança Saúde, the interviewed people demonstrated desire for a single, standard and totally integrated system. The integration must be among all units, the purchasing sector and the CAPPF. In the hospitals, the integration among departments must be among pharmacy/warehouse and other sectors, e.g., internment and billing sectors. Among the units, the integration must be with the CAPPF in a central role. This, due to the attributions of the supply center which are essentially linked to supervision of material's movement among the hospitals. Among purchase department and the hospitals, the purchase department must have completely access to the warehouses' inventory control.

I believe that we should have an integration among the hospitals and the CAPPF and, so, with the other hospitals' departments would be possible get performance indicators, e.g., consumption controls among the hospitals. However, it wouldn't be interesting that the hospitals could check their warehouses among themselves. That could create loss of control in the moment that a hospital would request borrowing of materials without CAPPF knowledge. (CAPPF´s pharmaceutical)

The adoption of a single, integrated and standard system, is justifiable because according to Fischer [43], "to implant any information system in health care, is needed a structured information base, consolidated and useful to whole involved professionals in health care" And, as verified in the interviews, there is a worry in making available information to the suppliers for a major approach among them. In this case, with an objective of partnerships among suppliers, distributors and hospitals, the share of goals, strategies and even some financial information could actually improve the supply channel [44].

Furthermore, thinking in a possible adoption of electronic purchases, is verified that as big as the integration of the electronic systems and procedures of purchases, bigger will be the integration of the delivery channel [45]. Correia Neto and Oliveira [15] point out some advantages in adopting electronic purchase and, consequently, a major approach among the supply chain's elements: to improve distribution channel's efficiency, specially in communication among participants; to reduce or eliminate mistakes, to reduce operational costs related to requests; to make easier the trace of goods through distribution channel; to improve the services to the final consumer; to allow that purchasers involve themselves more with strategic issues and relationship with suppliers than with repetitious tasks; to create a platform in real time in order to create business.

6. Conclusions

Generally speaking, technological innovation is imperative for a company to be part of the current turbulent environment, allowing it to help improve its strategic performance. However, the use of technology itself does not result in values [15]. Zuboff [29] asserts, “if a company is committed to fully take advantage of data processing, organizational innovations are necessary for supporting technological innovations”.

The author also states that people use several means to learn about it with their own work, and after the moment their tasks are automated through data processing equipment, they search for ways to check such tasks with actions performed before computers were used. This way they are convinced they are doing things correctly. Thus, it is necessary to have full control of administrative techniques related to logistics processes management, be part of the formation of people involved in current processes, which is not always a reality – at the hospital pharmacy there are pharmacists with extreme concern regarding the pharmaceutical techniques craft, but with administration difficulties.

That is the reason why it is possible to check that, for the correct and effective implementation and acceptance of an information system with requirements contemplated by what has been exposed in this work, it is necessary an investment in management training directed to employees involved in daily work of inventorying centers in hospitals associated to *Aliança Saúde*. This is also sustained by Zuboff's statement [29]: “... intellective qualification becomes a prerequisite for operating, with competence, the new environment controlled by the computer. Those who still do not have it may feel lost”.

Another factor to be taken into consideration is the effective participation and generation of incentives to the use of computer on the part of high and medium management levels. According to Humphrey [39] managers must “…elaborate challenging objectives, monitor progress and insist on their execution”. Factors such as commitment degree, support and cohesion on the part of the board of directors, along with the constant participation during implementation period, negatively or positively influence the process. The company's board commitment has to be driven towards development of human and financial resources, management of crisis and investment in training and vast communication [30].

Regarding logistics context of *Santa Casa de Misericórdia de Curitiba* and *Aliança Saúde*, a deficiency was detected regarding the vision and praxis of management instruments for inventory, costs and other management tools focusing planning, coordination, execution and logistics control of actors involved in the *Santa Casa de Misericórdia de Curitiba's* logistics process. Parallel to it, the scarce use of technological resources and currently existing information at the hospital was also detected. That is the reason why information stored and made available by information systems are not liable and do not reflect the reality in several aspects.

The desired requirements, on the part of people interviewed, for a system focused on the support to logistics and hospital management of scrutinized organizations, were presented in Table 4. It was possible to notice that, for all features mentioned, there are registers and indications in researched literature and articles. Thus, the mentioned requirements support planning, coordination, control and execution of activities focused on the operability and management supply logistics of *Santa Casa de Misericórdia de Curitiba* and *Aliança Saúde* [42].

References

1. Gonçalves, E. L., 1983. *O hospital e a visão administrativa contemporânea*. São Paulo: Pioneira, p. 52.
2. Borba, G. S. de, 1998. *Desenvolvimento de uma abordagem para a inserção da simulação no setor hospitalar de Porto Alegre.* Porto Alegre. 195 f. Dissertação (Mestrado em Engenharia de Produção) – Programa de pós-graduação em Engenharia de Produção, Universidade Federal do Rio Grande do Sul.
3. Daniel, W., 1997. Applying just-in-time systems in health care. *IIE Solutions*, 29(8):32.
4. Castelar, R. M., Mordelet, P., and V. Grabois, 1995. *Gestão hospitalar: Um desafio para o hospital brasileiro.* [S.I.]: Èditions Ècole de La Santé Publique.
5. Vries, G. de, Bertrand, W. M., and J. M. H. Vissers, 1999. Design requirements for health care production control systems. *Production Planning & Control,* 10(6):559–569.
6. Ferreira, J. A. et al., 2002. Informatização em hospitais de grande porte. *Revista de administração em saúde*, 4(15):17–24.
7. Novaes, A. G., 2001. *Logística e gerenciamento da cadeia de distribuição.*

Rio de Janeiro: Campus.

8. Austin, C. J., Boxerman, S. B., 1995. *Quantitative analysis for health services administration.* Michigan: AUPHA Press / Health Administration Press.
9. Carvalho, A. de O., Eduardo, M. B. de P., 1998. *Sistemas de informação em saúde para municípios.* Série Saúde e Cidadania. São Paulo: Faculdade de Saúde Pública da Universidade de São Paulo.
10. Freitas, H. M. R. de, Pozzebon, M., 1996. Construindo um EIS (enterprise information system) da (e para a) empresa. *Revista de Administração.* São Paulo, 31(4):19–30.
11. Costa, A. L., Oliveira, M. M. B., 1999. Sistema de informação para prescrição e distribuição de medicamentos: o caso do Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto. *Revista de Administração*, São Paulo, 34(3):44–55.
12. Miyagi, M. M., Miyagi, P. E., and M. Kisil, 2002. Modelagem e análise de serviços de saúde baseados em redes de Petri integradas. *Revista Produção.* 11(2):23–39.
13. Pijl, G. van der, Smits, M., 1999. Developments in hospital management and information systems. *Proceedings of the 32nd Hawaii International Conference on System Science*.
14. Ballou, R. H., 1993. *Logística empresarial*. São Paulo: Atlas.
15. Correia Neto, J. F., Oliveira, F. C., 2003. Avaliação do *e-procurement* como meio de formação de alianças estratégicas nos hospitais de Fortaleza. In: 3 ES - ENCONTRO DE ESTUDOS EM ESTRATÉGIA, 1., Curitiba. *Anais...* Curitiba, 2003. 1 CD-ROM.
16. Laudon, J. P., Laudon, K. C., 1999. *Sistemas de informação.* Rio de Janeiro: LTC, 4 ed.
17. Martins, L. W., 2001. *Uma proposta de configuração de sistema de informações executivas para gestão universitária: o caso da universidade do oeste de Santa Catarina*. Florianópolis, 177 f. Dissertação (Mestrado em Administração) – Curso de pós-graduação em Administração, Universidade Federal de Santa Catarina.
18. Fleury, P. F., Wanke, P., Figueiredo, K. F., *Logística empresarial: a perspectiva brasileira*. Coleção COPPEAD de Administração – Centro de estudos logísticos. São Paulo: Atlas, 2000.
19. Simon, H. A., 1972. *A capacidade de decisão e de liderança.* Rio de Janeiro: Editora Fundo de Cultura, 2. ed.
20. Schmitz, E., Silveira, D., 2002. Uma Metodologia de Desenvolvimento de

Sistemas de Informações em Empresas de Pequeno e Médio Porte. In: ENANPAD – ENCONTRO NACIONAL DOS PROGRAMAS DE PÓS-GRADUAÇÃO EM ADMINISTRAÇÃO, 26., Salvador. *Anais...* Salvador, 1 CD-ROM.

21. Watson, H. J. et al., 1995. Development practices for executive information systems: findings of a field study. *Decision support systems.* 14:171–184.
22. Triviños, A. N. S., 1987. *Introdução à pesquisa em ciências sociais: a pesquisa qualitativa em educação.* São Paulo: Atlas.
23. Gil, A. C., 1999. *Métodos e técnicas de pesquisa social.* São Paulo: Atlas, 5th ed.
24. Richardson, R. J., 1999. *Pesquisa social: Métodos e técnicas.* São Paulo: Atlas.
25. Lillehaug, S., 1998. Requirements for integrating effective decision support in Hospital Information Systems. *Journal of Couseware Engineering*, 1:21–30.
26. Berman, H. J., Weeks, L. E., 1979. *Administração financeira de hospitais*. São Paulo: Livraria Pioneira Editora.
27. Gonzalo Neto, V., 1998. *Gestão de recursos materiais e de medicamentos*. Série Saúde e Cidadania. São Paulo: Faculdade de Saúde Pública da Universidade de São Paulo.
28. Portella, A., 2001. *Padronização e custos – uma questão de logística hospitalar.* Available em: http://www.guiadelogistica.com.br/ Acesso em: 24 de out. 2001.
29. Zuboff, S., 1994. Automatizar/informatizar: as duas faces da tecnologia inteligente. *Revista de administração de empresas*, 34(6):80–91.
30. Silva, A. C. L.; Teixeira, L. A. A., 2002. Implantação de processo de desenvolvimento de *software*: um estudo empírico. In: ENANPAD – ENCONTRO NACIONAL DOS PROGRAMAS DE PÓS-GRADUAÇÃO EM ADMINISTRAÇÃO, 26., Salvador. *Anais...* Salvador, 1 CD-ROM.
31. Hames as cited in Borba, G. S. de, 1998. *Desenvolvimento de uma abordagem para a inserção da simulação no setor hospitalar de Porto Alegre.* Porto Alegre, p.1, 195 f. Dissertação (Mestrado em Engenharia de Produção) – Programa de pós-graduação em Engenharia de Produção, Universidade Federal do Rio Grande do Sul.
32. Novaes as cited in Miyagi, M. M., Miyagi, P. E., Kisil, M., Modelagem e análise de serviços de saúde baseados em redes de Petri integradas. *Revista Produção.* 11(2):23–39, 2002.
33. Lawrence and Dyer as cited in Pijl, G. van der, Smits, M., Developments in

hospital management and information systems. *Proceedings of the 32nd Hawaii International Conference on System Science,* 1999.

34. Mintzberg and Glauberman as cited in Pijl, G. van der, Smits, M., Developments in hospital management and information systems. *Proceedings of the 32nd Hawaii International Conference on System Science,* 1999.
35. Campos Filho as cited in Martins, L. W., 2001. *Uma proposta de configuração de sistema de informações executivas para gestão universitária: o caso da universidade do oeste de Santa Catarina*. Florianópolis, p. 48, 177 f. Dissertação (Mestrado em Administração) – Curso de pós-graduação em Administração, Universidade Federal de Santa Catarina.
36. Necco, Gordon, and Tsai as cited in Watson, H. J. et al., Development practices for executive information systems: findings of a field study. *Decision support systems.* 14:171–184, 1995.
37. Selltz et al. as cited in Costa, A. L., Oliveira, M. M. B., Sistema de informação para prescrição e distribuição de medicamentos: o caso do Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto. *Revista de Administração,* São Paulo, 34(3):44–55, 1999.
38. Goode and Hatt as cited in Martins, L. W., *Uma proposta de configuração de sistema de informações executivas para gestão universitária: o caso da universidade do oeste de Santa Catarina.* Florianópolis, 2001, 177 f. Dissertação (Mestrado em Administração) – Curso de pós-graduação em Administração, Universidade Federal de Santa Catarina.
39. Humphrey as cited in Silva, A. C. L., Teixeira, L. A. A., Implantação de processo de desenvolvimento de software: um estudo empírico. In: ENANPAD – ENCONTRO NACIONAL DOS PROGRAMAS DE PÓS-GRADUAÇÃO EM ADMINISTRAÇÃO, 26., 2002, Salvador. *Anais...* Salvador, 2002. 1 CD-ROM.
40. ALIANÇA SAÚDE / PUCPR, Relatório Anual, Santa Casa de Misericórdia de Curitiba / Brasil, 2001.
41. Pozzebon and Freitas as cited in Martins, L. W., *Uma proposta de configuração de sistema de informações executivas para gestão universitária: o caso da universidade do oeste de Santa Catarina.* Florianópolis, p. 4, 2001, 177 f. Dissertação (Mestrado em Administração) – Curso de pós-graduação em Administração, Universidade Federal de Santa Catarina.
42. Moreira, V. R., 2003. *Uma proposta de requisitos para um sistema de informação voltado ao apoio à logística de suprimentos hospitalar: O caso da Santa Casa de Misericórdia de Curitiba/Aliança Saúde.* Curitiba. 143 f.

Dissertação (Mestrado em Administração) – Programa de Mestrado em Administração, Pontifícia Universidade Católica do Paraná.

43. Fischer as cited in Borba, G. S. de, *Desenvolvimento de uma abordagem para a inserção da simulação no setor hospitalar de Porto Alegre.* Porto Alegre, 1998. 195 f. Dissertação (Mestrado em Engenharia de Produção) – Programa de pós-graduação em Engenharia de Produção, Universidade Federal do Rio Grande do Sul.
44. Cunningham, W. A., Wilson, J. W., 1992. Stockless inventory systems for the health care provider: Three successful applications. *Journal of health care marketing.* 12(2):39–45.
45. Neef as cited in Correia Neto, J. F., Oliveira, F. C., Avaliação do e-procurement como meio de formação de alianças estratégicas nos hospitais de Fortaleza. In: 3 ES - ENCONTRO DE ESTUDOS EM ESTRATÉGIA, 1., 2003, Curitiba. *Anais...* Curitiba, 2003. 1 CD-ROM.

THE CZECH REPUBLIC

HEALTH SYSTEM OF THE CZECH REPUBLIC 1990–2002

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1. Introduction

The Czech Republic, formerly part of Czechoslovakia (1918–1992), is a Central European country with 10.2 million inhabitants. The health system of the Czech Republic underwent radical changes during the 1990s. After the overthrow of the communist government in 1989, wide social reforms including health reforms were expected. The tax-financed national health service was seen as a health system that offered a low quality of health care, poor consumer satisfaction, and low economic efficiency. Radical health reforms were proposed and implemented very quickly.

2. The End of National Health Service 1990–1992

After the political changes in 1989, between 1990 and 1992, first health reform proposals were prepared. During that initial period the command-and-control system was removed. The patients gained a free choice of providers, which had been restricted under the communist regime. At that time the health sector had been underfinanced and the share of total health expenditures of the gross domestic product was 5.4% (1992). The medical chambers were founded; the law enabled setting up of private practices; the necessary health insurance legislation was prepared.

3. The Era of Public Health Insurance 1993–1996

The new era began in January 1993 when the universal health insurance replaced the tax-financed system. The health expenditures jumped to 7.3% of the gross domestic product in 1993. The separation of purchasing and provision functions was introduced. The purchasing function was placed into the hands of newly established health insurance funds, which are autonomous public organizations that collect insurance contributions and purchase services from the providers. Due to financial problems, 18 smaller insurance funds established between 1993 and 1997 had to be abolished (Jaroš and Kalina, 1998). Nine health insurance funds (2003) now compete for enrollees. The health insurance market is dominated by the General Health Insurance Fund of the Czech Republic, which covers around 70% of population (2003).

At the beginning of the 1990s, the mass privatization of providers was seen as the main remedy for inefficiency. Currently, the majority of primary and specialized outpatient care providers are private, mostly as independent practices. On the other hand, the privatization of hospitals was stopped and the majority of hospitals are now under the control of regions and municipalities. The hospitals run their own outpatient departments, so there are two networks of outpatient services. Operating under fee-for-service reimbursement and with no problem in securing contracts from health insurance funds, the hospitals have tried to expand their outpatient services. Such a strategy postponed a financial crisis in the hospital sector by gaining additional income from outpatient and laboratory services with low marginal costs.

In the newly established universal health insurance system, the services were paid by fee-for-service with no co-payments and no gate-keeping. The services were reimbursed according to the List of Health Services, which sets the relative point values for each service, whereas the monetary value of point had initially been set by the individual fund. The point value of a given service is based on the estimated time and material costs, but also on the lobbying power of an individual medical specialty. Drugs were reimbursed according to the price list. Since drugs must be paid, the production of more services with more prescriptions leads to a lower total reimbursement for providers. Later, the system of reference prices according to therapeutic categories came into operation. Because the difference between a reference price and drug price (if the latter is higher) has to be paid out-of-pocket, physicians prescribe more carefully so as not to lose patients.

It should be noted that the market-like incentives have changed the behavior within the medical profession. The initial data from the health insurance funds showed that privatized physicians generated greater volume and consumed more resources than those who stayed to work as salaried public employees (Massaro, Nemec, and Kalman, 1994). The weak regulation of service volume and unregulated contracting brought about the over-utilization of services and the building of new excessive capacities, and ultimately threatened the economic stability of the health sector. As a defense, the health insurance funds gradually decreased the monetary value of point. The value of point was set according to the financial situation of the funds, irrespective of the real cost of service. Decreasing the fees simply transferred the financial problems back to the providers and did not address the wider systemic problems. The funds also delayed the reimbursement a few weeks or months, which again solved their financial problems by shifting them onto the providers. Later, the funds adopted the strategy of dividing the total expenditures into separate expenditure categories according to the type of providers (e.g. general practitioners, specialized outpatient services, inpatient services, and so on).

4. The Era of Regulation 1997–2002

In July 1997, a new version of the List of Health Services was published. The providers argued that their fees were lower than the real costs, but the health insurance funds countered that they would not be able to pay the fees. In that situation, the List of Health Services was rejected and the budgets were agreed upon as a provisional measure to avoid a financial crisis in the health sector. Nobody expected that the provisional budget regulation would become a permanent strategy of cost containment. In July 1997, the open-ended system was suddenly replaced by tight regulation. The changes in the reimbursement system, which started the third period of health regulation, made the essential modification of economic incentives for health providers. The end of the fee-for-service system removed the financial incentives for over-utilization; instead, the motivations to minimize the volume and cost of services became an economically rational behavior of physicians. As another step for cost containment, negotiations between the health insurance funds and the organized groups of providers at the national level were introduced by Act no. 48/1997 Coll. The objective of negotiations is to set fees and percentage growths of expenditure ceilings. The negotiated reimbursement system may be changed every six months according to negotiation cycles.

The general practitioners are now paid by capitation, with a combination of fee-for-service for certain services. The specialists in outpatient services are still paid by the fee-for-service system, but with tight time limits and expenditure ceilings, which in practice means budgeting of specialized outpatient services. The gate-keeping function of general practitioners or the co-payments at the point of service is not enforced, so a patient can contact a specialist directly without a referral. Such behavior is, however, much harder, because specialists try to limit the number of patients in order to stay within the time limits and expenditure ceilings. The negative results of budgeting are waiting lists and possible corruption related to these lists. The introduction of some co-payments regulating the excessive demand and generating additional resources was highly recommended (e.g., OECD 2003). Dental services are reimbursed according to the price list and represent the least regulated sector. The dentists have been able to stay within the total budget for dental services, which may be related to the fact that they earn a part of their incomes from out-of-pocket payments for above-standard services and materials. The reimbursement of hospital services is based on the simple per-case system with expenditure ceilings, which in reality means historical budgets. The outpatient services delivered in hospital are considered as a part of the hospital budget and paid by fixed sums. The different regulatory conditions for the independent and the hospital-based outpatient physicians create conflicts between these two groups of physicians.

5. Conclusion

The combination of open-ended fee-for-service reimbursement, the lack of active contracting policy and the privatization of services leads inevitably to serious financial problems. It may appear to be a paradox, but the privatization process needed strong governmental control and adequate time for all the actors in the health system (providers, health insurance funds, as well as government itself) to understand the nature of privatization. Latent problems of the health system manifest themselves regularly and are solved by ad hoc subsidies from the national budget. The appropriate design of incentives in the reimbursement system and the active, need-based purchasing are what matters even more regardless of the type of ownership.

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References

1. Dlouhy, M., Mariel, P., 1999. La Sanidad en la Republica Checa despues de nueve anos de democracia. *Osasunkaria: revista vasca de salud publica y gestion sanitaria*, 17:23–27.
2. Jaroš, J., Kalina, K., 1998. *Czech Health Care System: Delivery and Financing*. Prague: Czech Association for Health Services Research 1998.
3. Massaro, T. A, Nemec, J., Kalman., I., 1994. Health system reform in the Czech Republic. Policy lessons from the initial experience of the general health insurance company. *JAMA*, 271(23):1870–4.
4. NERA (National Economic Research Associates), 1996. *The Health Care System in the Czech Republic*. London.
5. OECD, 2003. *OECD Economic Surveys: Czech Republic*. Paris.
6. European Observatory on Health Care Systems, 2000. *Health Care Systems in Transition: the Czech Republic*. Copenhagen.

CHANGES IN THE ORGANIZATIONAL STRUCTURE OF CZECH HOSPITALS

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Abstract: As an important component of the Czech health care system, Czech hospitals have been central to the process of reform. Since the beginning of 1990s Czech hospitals have gone through several phases, such as transformation, privatization or restructuring, recently having been subject to the public administration reform. The situation has changed since 1990 when all hospitals were solely state-owned, while nowadays there various different forms of ownership appeared and there is a tendency to autonomous hospitals. The aim of this paper is to outline the contemporary trends of the legal organizational system of in-patient care in the Czech Republic and its links to the public administration reform and social changes.

1. Introduction

In the Czech Republic as well as in other developed countries, hospitals are an important component of the health care system and they become central to the reform process. Generally, there are several reasons why hospitals are so important—they account for a considerable proportion of the health care budget; their position in the health care system means their policies determine the accessibility of specialists' services, thus having a major impact on the overall health; technological and pharmaceutical developments as well as more attention given to evidence-based health care mean that services provided by hospitals can potentially make a significant contribution to the health status of the population.

Hospital is „an institution which provides beds, meals and constant nursing care for its patients while they undergo medical therapy at the hands of professional physicians. In carrying out these services, the hospital is striving to restore its patients to health"(McKee and Healy, 2002, p. 5). Apart from their key function, i.e. to treat patients who are ill, hospitals can also serve as an important setting for teaching and research activities, they can actively support the health care system, be an important source of local employment and play several important social roles.

In the Czech Republic, a lot of attention is continuously paid to the health care system and to hospitals in particular, mostly due to the changes that have taken place over the past thirteen years as the country has been going through the transformation process towards becoming a democratic state. Yet, the process has not been finished yet and problems that have to be solved continuously appear in the health care system. These specific problems are combined with

other aspects, such as demographic changes (ageing, fertility, migration), changing patterns of sickness rate, higher public expectations of health care standards, new developments of health technologies (pharmaceuticals, material resources, technological equipment and methods of treatment).

There have been several trends to be recognized in the Czech hospitals since 1990s, which started to appear in the Western European countries at least ten years earlier. Similar to their Western European counterparts, nowadays even Czech hospitals have been experiencing phenomena such as a decline of the number of hospitals, decline of acute beds, decline of average length of stay in acute care hospitals, growth of hospital admissions, de-institutionalization, replacement of hospital resident care by day care, technological development, and the development of clinical knowledge.

2. Reforms 1990–1999

Since the beginning of 1990s the hospital health care has gone through several phases, such as transformation, privatization or restructuring, recently having been subject to the public administration reform. To understand the development of relations between the legal system, stakeholders' activities and other related effects within the Czech health care system, it is important to look at the initial phase, i.e. transformation. It is at this early beginning where many causes of current problems can be traced.

In 1990 and 1991, when the country went through the democratization process, dramatic liberalization of health care system took place. The principle of free choice of health care facility was established. Large regional and district health authorities were dismantled. In 1991 new legislation was approved, namely the General Health Insurance Act (Act no. 550/91 Coll.) and the Act on the Health Insurance Fund (Act. no. 551/91 Coll.). Since then, the health care system has moved towards a compulsory social insurance model, with a number of insurers financing the health care providers on the contractual basis. This does not seem to have caused any adverse effects on the health status of the Czech population. For the most part, the indicators are showing positive trends (life expectancy increase).

Between 1990 and 1992, both district and regional institutes of national health were dissolved and the health care facilities gained a high degree of legal and economic autonomy. The state health administration was incorporated into the district authorities in the form of health offices. Unfortunately, neither legal nor financial powers of these offices were clearly defined. The district health offices are not under the direct supervision of the Ministry of Health, but of the Ministry of Interior, while the Ministry of Health provides methodological

guidance. However, from the legal point of view the district health offices were responsible for ensuring that accessible health services were provided within their areas.

Another significant change taking place at the beginning of 1990s was the transition of budgetary organizations to contributory organizations, which gave the hospitals a higher level of economic autonomy. The General Health Insurance Act (Act No. 550/91 Coll.) established not only a new framework for health insurance as a new instrument for financing of health care services, but it also created a space for contracts to be concluded between hospitals and health insurance funds.

The situation has changed since 1990 when all hospitals were solely state-owned, while nowadays there are different forms of ownership and there is a tendency to autonomous hospitals. As a result of social changes after 1989, a gradual reform of the Czech health care system took place with demonopolization and decentralisation as its main principles. Some legal changes that were supposed to enable the privatization of the health care institutions were being carried out since 1991. In 1992 the plan to privatize all hospitals (except the large ones) was announced. This policy was supposed to result in a "new" organizational structure of the Czech hospitals that would be transformed into the form of business companies. While at that time there was a legal framework enabling the denationalization of hospitals in the form of business companies, there was no legal regulation that would enable the denationalization of hospitals in the form of non-profit organizations. This was not possible until 1995 when the Act on Public Benefit Organizations (Act no. 248/1995 Coll.) was passed. However, the Act is rather general and it would be still necessary to pass a special legal regulation enabling the denationalization of hospitals.

The supply aspects of health care services (acute care trends, workforce changes etc.) were not subject to active state interventions. The optimal structure of the health care system was supposed to be achieved by the bankruptcy of health care institutions unable to survive on the free market. A large number of privatization projects of hospitals based their "business plans" on the presumption that they would succeed in the competitive environment, obtaining a higher number of patients, reaching higher turnover and then using the available profit to pay off bank loans in several years (see Košek, 1999). The situation was similar within the sector of the health insurance institutions the formation of which was facilitated at the beginning of 1993. Two thirds of the newly established health insurance companies went bankrupt by 1996 and their liquidation was a great burden to the state budget. At present there are nine health insurance companies in the Czech Republic.

In 1996 the Czech government decided to put an end to the privatization process of hospitals because it appeared that the whole plan could not be carried out without significant negative consequences and the banks were not willing to lend money for high-risk privatization projects. Moreover, the situation of those small hospitals that had been already transferred to limited companies gave raise to a question whether it is possible to finance such institutions by public funds while allowing their owners to draw a possible profit from those hospitals.

In the mid-nineties the health care system was in a serious balance crisis. A large number of hospitals were showing a deficit reaching up to tens or hundreds of millions Czech Korunas. The same balance crisis appeared also in the sector of health insurance companies (as described above). In some respects, the situation can be compared to what happened in the Czech banking sector. It was under those circumstances that the state shifted a focus of its health care policy from the demand aspects to the supply ones.

3. Public Administration Reform

Since 2000 the public administration reform has been going based on the principle of decentralization. The main aim of the reform has been to improve and modernize the public administration and to bring it closer to the public. The reform consists of three stages: (1) reform of district public administration, (2) reform of central public administration, and (3) a modernization of the public administration activities.

The public administration reform had a two-fold impact on hospitals: first, the change of ownership of district hospitals and second, the change of the responsible funding bodies of district hospitals. Under the bounds of the reform it was necessary to cope with the state possession that came under the district offices provinces and where district offices acted as responsible funding bodies or owners. The public administration reform has not represented just the transfer of public administration to local authorities but also the change of the ownership and related change of the legal status of the original institutions.

The new legislation is appropriate for the managing of region possession in terms of autonomy in which the regions follow their interests and meet their aims. However, in the case of the hospitals that provide public goods, in public interest, guaranteeing basic human rights for health, the legislation appears insufficient. The state lays down a duty of insurance and tax payments but at the same time it renounces its responsibility for the control of these resources in relation to public needs. There is a danger that the protection of public interest will disappear (public accessibility of hospital care, public rights).

Decentralization has been a major feature of the Czech health care reform but its implementation has not been completed yet. The task of financing health care has been delegated to the health insurance funds, which are under the state supervision. Some regulatory functions have been devolved to the former district health offices at district level. These include issuing of authorisation to private physicians and health facilities. Professional chambers are responsible for issuing licenses to health care professionals. At the moment, a number of clinics but only small-sized hospitals have been privatised. Most hospitals still have been owned by the state (regional or specialized hospitals) or by regions/municipalities (smaller hospitals).

The preferred method of decentralizing health care provision has been through privatization. This has been achieved within various sections of the health care system. The great majority of primary health care providers in the Czech Republic are now private, mainly renting community-owned buildings, offices and surgeries. The spa resorts and pharmaceutical companies are also private and the vast majority of pharmacies have been privatized as well. Following the break-up of local, district and regional health institutes, i.e. the previous owners of state hospitals, the ownership of small-size hospitals was transferred to regions and municipalities. Yet the situation is likely to change soon. Many municipalities have already announced their intention to shift the organizational status of hospitals, the most proclaimed form being the joint-stock company.

In view of the health care legislation and legal regulations, the organizational status of Czech hospitals can be divided into three types. Firstly, the hospitals established by non-state institutions have no specific form according to the law, but it is obligatory for them to be registered as non-state health care facilities. Secondly, the hospitals established by regions or municipalities have the organizational form of contributory organizations, but recently they also have the possibility to transform themselves into joint-stock companies. Thirdly, university hospitals and some other hospitals are coming under the responsibility of the Ministry of Health and they have the form of contributory or budgetary organizations.

As it does not seem there will be a new legislation to define a special status for hospitals, the current situation is likely to remain unchanged, i.e. hospitals are to be owned by a mix of public-private subjects, such as the national government, regions and municipalities, as well as private non-profit and profit organizations. Yet, due to the recent changes resulting of the public administration reform, the proportion of various organizational forms of hospitals is likely to shift in favour of more joint-stock companies being established.

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References

1. Bennet, S., 1994. *The Mystique of Markets: Public and Private Health Care in Developing Countries*. PHP departmental publications No. 4.
2. Bowling, A., 1997. *Research Methods in Health: Investigatng Health and Health Services*, Open University Press, Buckingham.
3. Saltman, R.B., Figueras, J. (Ed.), 1996. *European Health Care Reform: Analysis of Current Strategies.* Copenhagen, WHO.
4. Feachem, R., 2000. *Heath systems: more evidence, more debate*. WHO Bulletin 78/6/2000.
5. Háva, P., Stožický,A., Goulli, R., Vyskočilová, O., and L. Krákorová, L., 2003. Problémy hospodaření okresních nemocnic. In *Zdravotní politika a ekonomika*. Analytická, hodnotová a koncepční východiska zdravotní politiky II. Institute of Health Policy and Economics, Kostelec nad Černými lesy.
6. Háva, P., Kružík, L., 1994. Průběh privatizace v českém zdravotnictví In Potůček, M., Purkrábek, M., and P. Háva: *Analýza událostí veřejné politiky v ČR*, Part I., School of Social Sciences, Charles University, Prague.
7. Desai, K.R., Carol VanDeusen Lukas, and G.J. Young, 2000. Public Hospitals: Privatization And Uncompensated Care. *Health Affairs,* March/April 2000.
8. Košek, P., 1999. *Nabídka akutní lůžkové péče v ČR*. thesis, School of Social Sciences, Charles University, Prague.
9. Kotlas, P., 1998. Sítě aktérů jako aktivní faktor veřejné politiky. In Purkrábek, M. et al.: *Centrální rozhodování v ČR 1. díl*. School of Social Sciences, Charles University, Prague.
10. McKee, M., Healy, J., 2002. *Hospitals in a changing Europe*. Open University Press, Buckingham.
11. Preker, A.S., 1994. Meeting the Challenge: Policymaking and Management During Economic Transition. *The Journal of Health Administration Education*.
12. Vyskočilová, O., 2002. *Cesty odstátnění českých nemocnic*, Institute of Health Policy and Economics, Kostelec nad Černými lesy. (in Czech)

LIVING HIT: MAIN CHANGES OF THE HEALTH SYSTEM IN THE CZECH REPUBLIC (1998–2003)

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1. European Observatory on Health Care Systems

As declared on the website of the European Observatory on Health Care Systems http://www.euro.who.int/observatory, the Observatory *"supports and promotes evidence-based health policy-making through comprehensive and rigorous analysis of the dynamics of health care systems in Europe"*. The Observatory is a partnership between the following institutions and bodies: WHO Regional Office for Europe, governments of Finland, Greece, Norway, Spain and Sweden, European Investment Bank, Open Society Fund, the World Bank, the London School of Hygiene & Tropical Medicine, and the London School of Economics and Political Science.

2. HiT and Living HiT

HiT is an acronym for *Health Care Systems in Transition*; the goal of the HiT project is to describe national health care systems of mainly European countries. The aim is to make the description available for European policy makers and health care policy analysts. The profiles are published on the web site of the European Observatory (see below), and can be obtained in "paper copy" as well. There are country profiles of almost all European countries (except for Ireland, France, the Netherlands, and Ukraine) and some other countries (Canada, New Zealand, Israel, and so forth). The country profiles are in English, some of them in Russian or German. Many of them have been updated at least once. Living HiT is complementary to the HiT project, it is intended to cover all changes of the health care system and make them accessible without updating the whole original text. Only one Living HiT (Spain) is available on the website now.

3. Institute of Health Policy and Economics and the working team

The Institute of Health Policy and Economics (IZPE) is a research institute that has been founded in 2000 by the Ministry of Health of the Czech Republic. Many of my colleagues (M. Dlouhý, L. Durda, L. Dvořáček, P. Háva, P. Hanušová, H. Hnilicová, J. Kliner, L. Kružík, M. Schánělˇ, B. Staňková, A. Stožický, N. Tůmová-Křečková, V. Vorlíčková, and O. Vyskočilová)

participated in the team working on the HiT project. Information on the Institute and its other projects can be found on the website http://www.izpe.cz.

4. The Main Changes of the Health System in the Czech Republic in 1998–2003

Demography and health status
The Czech Republic has a population of 10.2 million (as of December 31st 2002). The number of inhabitants has been slightly decreasing since 1994, as the natural population growth has been negative. The total fertility rate has been declining; in 2001 it was only 1.16 (1.89 in 1990). The life expectancy has been increasing; male life expectancy was 67.63 in 1990 and 72.18 in 2001, while female life expectancy was 75.74 in 1990 and 78.71 in 2001. Similar to many other European countries the population is growing older. Some prediction models have shown that the number of Czech inhabitants in their eighties is going to multiple almost three times by 2050.

The main causes of death in the Czech Republic have been diseases of circulatory system (they cause about half cases of deaths) and neoplasm (they cause about 26% of all deaths). The infant mortality rate was as low as 4.1/1000 live births in 2002.

Political situation
There have been two regular elections in the period 1998–2003. The first of them was held in 1998 when ČSSD (Czech Social Democratic Party) won and assembled a minority government. The second election was held in 2002 and lead to the creation of a coalition government. There have been four ministers at the Ministry of Health during this period. Minister B. Fišer held the office for the longest period of those four ministers—28 months (he is responsible for increasing the wages of medical doctors).

Economic indicators and health care financing
The gross domestic product has increased during the period 1998–2002. GDP per capita in USD was 13,700 in 1999 and 15,600 in 2002 (it is an estimated value). The expenditures on health amounted to 7.4% of GDP in 2002 (EU average is 8.7%). Unemployment has become a very important economic indicator as it has increased recently. In 1995 the unemployment rate was only 2.93% and it reached 9.81% in 2002. The Czech economic situation is characterized by increasing national budget deficit and state debt in these years.

The health care system is based on compulsory health insurance. The biggest contributor to the public health insurance system is the state that pays insurance fees for people without wages, which means more than 50 % of population. The

biggest health insurance fund is General Health Insurance Fund (GHIF) that insures about 70% of all insured persons (of all inhabitants in fact). There are eight more insurance funds that can offer only slightly different services. GHIF shows a large misbalance between income and expenditures. Some believe that the misbalance has emerged due to redundant health care facilities in the spheres of secondary and tertiary care (i.e. hospital beds and some outpatient services). The redistribution system may play quite an important role in the problem. Redistribution is very simple and covers 60 percent of insurance contributions; this amount of money is redistributed as follows: one share for an insured person younger than 60 years and three shares for an older person. The plan is that all contributions should be redistributed.

The misbalance of the system leads to another question: is private funding of health care high enough? The expenditures on health have been increasing significantly — it was 134,928 million Czech Korunas (about USD 4.500 million) in 1999 and 168,520 million Czech Korunas (about USD 5.600 million) in 2002. The public sources funded 91.7% of health care expenditures in 2002; out-of-pocket payments covered 8.3% of expenditures on health. In the European Union, it is usual that public sources fund around 75% of expenditures. Out-of-pocket payment is a very sensitive theme in the Czech Republic and a change in this field does not seem to be expected while the Social Democrats are in power. But it seems that the discussion has been at least initiated (e.g. so called hospital services are in question).

Health care insurance and the sickness insurance have not been merged yet, even though their union has been discussed for several years.

Changes in the legal framework in health care

In the period 1998–2003, quite important changes in the legal area took place. The main changes were connected with the accession of the Czech Republic to the European Union. The legal system was harmonized with the EU law. The key change was the reform of public administration. It has covered many fields of public life and has influenced health care as well. Many hospitals that used to be founded by state (at the district level) have been transferred under the regional councils (they are regional executive bodies). Regional councils are the owners and founders of these hospitals now.

Since the changes of heads of the Ministry of Health occur very often we still miss some quite important laws. For example, new laws on health care facility and health care profession are still absent. The work of the changing ministry cannot cover the preparation of the conception of Health Care System in the Czech Republic; the last conception has been published in 1997. Since then some of the ministers have attempted to create a conception but it has never

been discussed broadly and therefore could not be approved by political representatives. The trouble is that it is understood that the conception should describe a reform strategy that would solve the financial issues in short-term horizon.

Health care delivery
The public health service has been afflicted by the public administration reform as well. A new Act on Health Protection was enacted in January 2002. The regional public health offices have been introduced as public health authorities and the regional institutes of public health provide necessary measures and analysis.

The primary health care in the Czech Republic consists of general practitioners for children and adults, gynaecologists and dentists. The private health care facilities are mainly private (around 90%). There was one general practitioner (GP) for about 1,650 inhabitants in 2002. The GPs are paid mainly on the payment per capita basis (the rest is still paid on the fee-for-service basis). Some regulation mechanisms (aimed especially at prescriptions) are applied.

The secondary and tertiary care comprises health care facilities of specialized outpatient physicians, hospitals as well as specialized bed facilities. It is planned to reduce the number of acute hospital beds and increase the number of beds for long term care. The DRG project should be introduced very soon.

5. Conclusions

The main changes of the health care system in the Czech Republic during the period 1998–2003 are connected with the public administration reform. The owners and founders of the former district hospitals have been changed due to the reform. The ownership of the hospitals has been transferred to regional councils (many hospitals were in debt). Many important laws are still missing.

The health care in the Czech Republic still has good results and it can be compared, in this sense, with any other in the world. But it cannot find a leader with explicit ideas and a vision of a systematic change. It has to face a period without conceptions — a proclamation about free and widely accessible health care has only been made recently and it may not be enough. The system has to cope with an enormous increase of expenditures on health in the time when the resources are very limited.

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PROCEEDINGS FROM PREVIOUS MEETINGS

Matson, E. (Ed.), Operational Research Applied to Health Services, Proceedings of the 23rd Annual Meeting of the EURO Working Group on Operational Research Applied to Health Services, Norwegian University of Science and Technology, Trondheim 1997.

de Angelis, V., Ricciardi, N., and G. Storchi, (Ed.), Monitoring, Evaluation, Planning Health Services, Proceedings of the 24th Annual Meeting of the EURO Working Group on Operational Research Applied to Health Services 1998, World Scientific, Singapore 1999.

Mikitis, E. (Ed.), Information, Management and Planning of Health Services, Proceedings of the 25th Annual Meeting of the EURO Working Group on Operational Research Applied to Health Services 1999, Health Statistics and Medical Technology Agency, Riga 2000.

Riley, J. (Ed.), Planning for the Future: Health Service Quality and Emergency Accessibility, Proceedings of the 26th Annual Meeting of the EURO Working Group on Operational Research Applied to Health Services 2000, Caledonian University Press, Glasgow 2001.

Rauner, M., Heidenberger, K. (Ed.), Quantitative Approaches in Health Care Management, Proceedings of the 27th Annual Meeting of the EURO Working Group on Operational Research Applied to Health Services 2001, Peter Lang, Frankuft am Main 2003.

de Oliveira, M. J. F. (Ed.), Accessibility and Quality of Health Services, Proceedings of the 28th Annual Meeting of the EURO Working Group on Operational Research Applied to Health Services 2002, Peter Lang, Frankuft am Main 2004.