Health service capacity modelling

PETER TRYE, NIGEL MURRAY, IAN WOLSTENCROFT, AND ALISTAIR STEWART

Peter Trye is a Fellow in Medical Management at the Royal Melbourne Hospital.
Nigel Murray is the General Manager, Building Programme and
Ian Wolstencroft is the Project Director, Inpatient and Ambulatory for the Health Services Delivery Plan at Auckland Healthcare.
Alistair Stewart is a Senior Research Fellow in the Biostatistics Unit of the Department of Community Health at Auckland University.

Abstract

This paper aims to describe a modelling tool that gives a framework for the estimation of future bed demand for hospital services. It also outlines some issues regarding the application of the model. A quantitative mathematical model was constructed that was based on two years of seasonally adjusted inpatient data. To calculate the number of beds required five years into the future, ten factors were applied to the number of bed-days used for each service. In the example given (Figure 1), 7,924 bed-days used in 1998-99 translated into a requirement for twenty-six beds in 2004. The value of this approach lies in the ability to describe and delineate each of the varying factors, and thus allowing clinicians, healthcare managers, the purchasers of health services and other stakeholders to be involved in a clear and explicit decision-making process.

Background

As part of its Health Services Delivery Plan (HSDP), Auckland Healthcare found itself faced with the task of replacing significant portions of an ageing infrastructure. Because of existing logistical problems, there had to be consideration of service transfer from one site to another, as well as the amalgamation and splitting of four hospital services across two sites. Other influences included a significant but disparate population growth across regions, changing disease patterns, changing policies on provider location and funding, as well as ongoing medical advances that affected bed usage.

This constellation of influences demanded that the planning process to determine the size of the facility should be approached from a rational and quantitative perspective. A description of the numerical model, its construction and its use within a decision-making process is outlined in this paper.

Model Construction

This model is based on a mathematical iterative linear equation that projects future demand for bed numbers, based on existing usage of beds as well as factors thought to influence their use in the future. It is applied through an Excel spreadsheet using hospital inpatient, outpatient and ambulatory data. The model was independently validated.

A simplified form of the equation is thus:

$$Y = \sum r_{1i} x_i + r_{2i}$$

Y: Projected demand in bed numbers.

X_i Existing bed utilization for the ith service.

r_{1i}, r_{2i} The terms r_{1i}, r_{2i} in the equation above represent the influence of the ten factors on the future bed utilisation.

It is not the purpose of this paper to give an in-depth theoretical mathematical analysis of modelling theory; rather it is the description of this model and its practical application within a decision-making framework that the authors wish to highlight.

Figure 1 shows a portion of the model as it applies to a single service. This figure allows closer study of the spreadsheet construction. The model automatically tabulates the interim and overall totals. These individual service models can be placed in parallel to allow quick and easy calculation of all services being studied.

Figure 1: Example of spreadsheet calculation for one hypothetical service

	Note that items 5 to 13 are factors described in table 1. Note that light grey shaded areas denote points of manual data entry.	Service A Patient Separations	Service A Bed-days
1	Patient separations/bed-days year to date - overnight x Full year effect Site A	1,031	7,583
	Patient separations/bed-days year to date - overnight x Full year effect Site B		
2	Patient separations/bed-days year to date - one day x Full year effect Site A	341	341
	Patient separations/bed-days year to date - one day x Full year effect Site B		
3	Total patient separations & bed-days (full year equivalent)	**1,372**	**7,924**
	Average length of stay (ALOS) = bed-days/total patient separations	**5.78**	
	Average length of stay (ALOS) = bed-days/inpatient separations	**7.35**	
4	Existing bed requirements at X% occupancy	85%	26
	Number of existing beds:		
	Site A		12
	Site A day-case beds		
	Site B		16
	Total		28
5	**Sub-regional equitable access**		
	Assess transfers OUT (%)	0.00%	
	Transferred numbers OUT	0	0
	Assess transfers IN (%)	0.00%	
	Transferred numbers IN	0	0
	NET transfer for sub-regional equitable access	0	0
	New inpatient and day-case bed-days	**1,372**	**7,924**
6	**Assess service and age specific population growth**		
	% Population increase	15.00%	
	Commensurate increase in patient numbers	206	1,189
	New inpatient and day-case bed-days	**1,578**	**9,113**
7	**% Of population with disease expected to double in prevalence over and above the population increase**		
	% Change	2.00%	
	Number change	27	158
	New inpatient and day-case bed-days	**1,605**	**9,271**

Figure 1: Example of spreadsheet calculation for one hypothetical service

Note that items 5 to 13 are factors described in table 1. Note that light grey shaded areas denote points of manual data entry.		Service A Patient Separations	 Bed-days
8	**Shift to private sector (contestability of secondary)**		
	% Change	0.00%	
	Change in numbers	0	0
	New inpatient and day-case bed-days	**1,605**	**9,271**
9	**Assess inter regional flows**		
	- IN (number of admits)	0	0
	- OUT (number of admits)	0	0
	Net shift	0	0
	New inpatient and day-case bed-days	**1,605**	**9,271**
10	**Intervention rates**		
A	**-Due to change in purchasing funding**	2.00%	
	Number increase for funding changes	27	158
B	**-Due to technology**	0.00%	
	Number increase for technology	0	0
	New inpatient and day-case bed-days	**1,633**	**9,430**
11	**Assess inter disciplinary transfer IN or (OUT)**		
	-IN (number of admits)	0	0
	-OUT (number of admits)	0	0
	Net transfer	0	0
	New inpatient and day-case bed-days	**1,633**	**9,430**
12	**Assess one day treatment transfers**		
	Starting point patient numbers	406	
	Increase in day-case procedures %	10.00%	
	New day-case numbers	446	446
	New inpatient numbers (by separate inpatient ALOS)	1,186	8,983
	New combined bed-days & patient totals	1,633	9,430
	Difference	0	0
	New inpatient and day-case bed-days	**1,633**	**9,430**
13	**Identify length of stay improvement for inpatients**		
	Improvement in average length of stay for inpatients	1.00	
	((Old inpatient ALOS)*New inpatient numbers)	7.57	8,983
	((New inpatient ALOS)*New inpatient numbers)	6.57	7,797
	Difference in bed-days		-1,186
	New inpatient and day-case bed-days	**1,633**	**8,243**
14	Final totals		
	Final inpatient numbers & bed-days	**1,186**	**7,797**
	Final day-case numbers & bed-days	**446**	**446**
	Final inpatient and day-case bed-days	**1,633**	**8,243**

Figure 1: Example of spreadsheet calculation for one hypothetical service

Note that items 5 to 13 are factors described in table 1. Note that light grey shaded areas denote points of manual data entry.		Service A Patient Separations	Bed-days
15	Allow occupancy		
	Rate	85.00%	
	Inpatients	**1,396**	**9,173**
	Rate for day patients	120.00%	
	Day-case	**372**	**372**
	Total	**1,768**	**9,545**
16	Beds to be provided		
	Site A (Overnight inpatient beds)		**25**
	Site B (Ambulatory beds)		**1**
17	Stipulated extra beds overnight		
18	Stipulated extra beds ambulatory		

The baseline bed utilisation for each service is based on the number of patients admitted during the sample time period and their length of stay. The sample period covers the calendar years 1998 and 1999.

The factors described in Table 1 are applied to the baseline bed utilisation for each service. The cumulative impact of each of these factors on the baseline bed utilisation, will give a projection for the number of beds that each service is likely to need at the end of the modelling period. By the end of 1999, there was agreement on the set of factors that affected bed demand, as well as the intensity of their effect. At that point, the model was used to project demand for the next five years.

Table 1: Factors used in the Capacity Model, their description and characteristics.

Factor	Explanation	Monte Carlo distribution classification
Sub-regional equitable access (SREA)	Population shifts due to changing intra Regional catchment boundaries.	Peaked distribution
Population growth	Taken from National statistics and age adjusted for each service.	Bell-shaped distribution
Disease prevalence	Percentage of population with disease that is expected to double in prevalence over and above the population increase.	Flat distribution
Contestability of secondary services	Shifts to and from the private sector.	Flat distribution
Inter-regional flows	Shifts between the regions, (likely to be tertiary or quaternary services).	Bell-shaped distribution
Funding	Intervention rates affected by funding or purchasing decisions.	Flat distribution
Technology	Intervention rates affected by the application of new technologies.	Flat distribution
Interdisciplinary transfers	The transfer of patients between the services.	Peaked distribution
One day treatment transfers	The increase of inpatient numbers that could be treated in an ambulatory (non inpatient) setting	Bell-shaped distribution
Length of stay	Changes in average length of stay.	Bell-shaped distribution

To allow for the natural variance of admission numbers, two techniques are used during the calculation. Firstly, the winter months (defined as being July, August and September) are analysed separately from the non-winter periods so that planning can take into account typical winter load patterns. Secondly, to avoid running at maximum capacity the calculated number of bed-days is divided by the target occupancy factor, which for most services is 0.85. Intensive therapy services are assumed to have a lower occupancy (0.75) because they have less ability to transfer patients to other wards, and so they must have the capacity to accommodate peak period traffic. (Calculations for the number of beds provided for "nationally provided services" were made separately as these services need to have enough beds to accommodate a cumulative occupancy of 100%).

After the calculation of the bed-day occupancy result, the actual number of beds to be provided is determined by dividing the result by the number of days for which the baseline admission number sample is taken. For example, winter months for two years: 2(2x31 + 30) = 184.

Finally, a Monte Carlo analysis is applied to the model. This analysis uses a frequency distribution for the values of each factor, defined in terms of their possible range of values and their type of distribution. The three classes of distribution used are described below:

1. Bell-shaped: in this case, we assume that the distribution of values follows a bell-shaped curve, and that the mean is central.
2. Flat: these variables are likely to have an even distribution between the two extreme values of the range. These variables are the most difficult to judge with respect to their probability distributions.
3. Peaked: these variables are judged to have the highest degree of certainty. The mean falls on the apex of the peak, with both slopes falling within a narrow range to the x-axis.

The matching of each factor to a distribution class is recorded in Table 1. Although the distribution type remains fairly constant across all services, the range will vary for each individual service.

After classifying the variables, a value for each factor is randomly generated from the distribution and these values are used to estimate total bed occupancy. With repeated use of this technique, a distribution for the expected total bed occupancy is generated. In this case, 10,000 iterations are made and for each of these, a final overall bed number was generated. The computer code for this is SAS code taken from The SAS/IML users guide for Personal Computers, Version 6 Edition.

Model components

Input data:

At Auckland Healthcare the baseline data upon which the model rests is routinely recorded and subject to audit and quality control. For each person admitted, personal details are collected along with information relevant to their hospital stay. This would include the type and destination of their admission, diagnoses and procedure codes along with other relevant facts. There is little controversy regarding the quality of this data. Certain variations from normal practice that would affect the number of bed-days, such as renovations to operating theatres are manually adjusted.

Regression is one statistical model that can be useful in making projection forecasts. In this case, it was not possible because the quality of data could only be guaranteed for thirty months. The length of this period was thought to be inadequate.

Factors:

The influencing factors are classified into the three categories of demand, supply and other external factors. The effect of these factors became the equation coefficients.

a) Demand factors:

Population growth and disease prevalence are demand factors within this model. The assessment of population growth is based on projections taken from Statistics New Zealand. By classifying the patient mix of each service into age and ethnic specific groups, it is possible to use matching age and ethnic population growth rates to calculate the expected growth of the service in question. Assessments for disease prevalence are made by each service, with internal and external review (Beaglehole 1997, Bell 1996, Brett 1998, Calder 1996, Cox 1994, Dockerty 1997, French 1996, Galgali 1998, Hoel 1992, Jackson 1995, Levi 1994, McCray 1997, McGowan 1998, Meyer 1993, Moss 1997, Murray 1997, Rosamund 1998, Simmonds 1996). In addition to the factor for prevalence, the use of a winter/non-winter baseline helps to account for conditions affected by seasonal climate change.

Although it is dealt with later as a supply side factor, length of stay could also be influenced by changes in disease prevalence. For instance, critical care medicine expected an increase in length of stay for their specialty. This is also noted by Meyer (1993).

Contestability of service provision with the private sector was included in the model because of the particular market characteristics operating in Auckland at the time. As well as significant new developments in the growth of capacity of private hospitals, the government of the time had signalled their acceptance of competition within the health sector.

Other demand factors that influence hospital usage include the public use of primary care facilities and primary care referral patterns. In the absence of clear primary care data, this could not be included in the model. However, it is assumed that in the absence of any major developments in managed care occurring over the next decade, then there would be no major change in primary care, or their referral patterns.

b) Supply side factors:

In this category, there are four factors within the model. These are: the effect of increasing intervention rates due to new technology, changing funding levels, length of stay and the siting of treatment for inpatients versus outpatients.

New treatments could increase the need for inpatient hospital bed space or decrease it, and consequently was difficult to judge. Because of this, 'new treatments' was classified as having a "flat" distribution within the Monte Carlo analysis. It is generally assumed that funding would remain constant or increase. Literature reviews were of some use here, but again each service had to justify the case for an increase in intervention rate (Aziz 1995, Caplan 1997, Chelluri 1995, French 1996, Gusto 1993, Hanson 1992, Lumsden 1992, Silberberg 1992, Zimmerman 1988). Estimates for funding revenues were made with the aid of the funding authority. In many cases, the length of stay was expected to decline in line with world standards (Harrison 1995, Harrison 1997, Goldacre 1995, MacIntyre 1997, Meyer 1993, Rushworth 1995).

As Auckland Healthcare is separating ambulatory and outpatient services from inpatient services, the transfer of ambulatory day-case work to another centre would extend the average length of stay for inpatients (Hensher 1999, Jones 1998, Ossoff 1994). Perceived changes in length of stay, are clearly demarcated from any length of stay change that arises out of the re-distribution of patients between the inpatient and the ambulatory facilities. The model automatically calculated the difference due to this change.

c) External factors:

Three other factors are included in the model. Sub-regional equitable access (SREA) is the name of the process that aligned populations to secondary and tertiary health care facilities. Here, the overall Auckland regional plan (HSDP) would provide the impetus for transferring certain secondary services to other regional hospitals. These changes were service specific and they aligned the catchment boundaries in order to place services closer to the client population (Health Funding Authority 1998).

Within New Zealand, Auckland Healthcare is responsible for particular national health programs as well as being the pre-eminent provider of complex medical and surgical services for the region. Because of national health policy, the number of patients being transferred to Auckland Healthcare will likely increase, though the expected changes would vary for different specialties (Health Funding Authority 1998). This is represented by the factor inter-regional flows (IRFs).

Finally, the last factor that is included in the model deals with other causes for the internal distribution of patients that in themselves are not related to the ambulatory inpatient split. Allowances are made for internal changes in service process, such as the transfer of paediatric cardiac care from the adult to the paediatric service.

Applying the model

Once the model structure was finalised, to implement it required substantial clinical input. The form of this input is reflected in the final settlement of the factors and the effect they had on bed utilisation. Endeavouring to obtain a consensus on the value of each factor was a significant challenge.

These assumptions were clarified in two stages. In the first stage, a literature search was undertaken to identify any firm data or global trends that could help to inform the decision process. Trends identified in the literature, and population projections from Statistics NZ were used to inform the process at that time. Changing length of stay, disease prevalence patterns and treatment trends were looked at closely.

Following this, the model and its assumptions were tabled for discussion before a clinical review panel. This panel comprised a combination of clinical leaders, management as well as independent epidemiological opinion. This process (albeit with different protagonists), was repeated at a later stage as the model was discussed with government agencies.

Before finalisation a Monte Carlo analysis was undertaken. This statistical procedure provided an important sensitivity analysis to the final work. Discussion of the actual numbers produced through this process is not important, but it is important to realize that in relation to total bed numbers this analysis gives the following outcomes. A calculated range of values that are distributed around the mean with usual standard deviation values, 95% confidence limits, as well as absolute upper and lower limits. Having this information helped to focus discussion during the negotiation process.

Discussion

The last two decades have seen substantial shifts in some of the benchmarks of hospital healthcare delivery, with increasing throughput, more admissions that are acute and a declining length of stay (Hensher 1999, Maarse 1997). There has also been a trend to downsize hospitals (in terms of bed number), although most of the work on this has dealt with the effect of declining psychiatric bed numbers (Bigelow 1991, Burkell, Lawrence 1991, Maarse 1997, Madden 1999, Ridick 1986, Shepherd 1998). There has been consideration given to the appropriate level of general bed provision in our hospitals, as well as some work looking into capacity planning for the psychiatric and general medical areas (Goplerud 1986, Jarman 1993, Johnson 1997, Pasley 1995, Snowdon 1993).

The work on capacity planning gives general guidelines, but there do not seem to be any models available in the literature that help planners to find their way through this difficult area. As hospital costs are the largest component of expenditure in health in the OECD, being able to make a case to funding bodies that justify the level of capacity being sought is of paramount importance (Hensher 1999). For planners the key question is how to create flexibility to manage uncertainty, ensure the capacity to cope with surges in demand without creating supplier induced demand (Hensher 1999). We believe that this model goes some way towards addressing these issues.

The main value in this approach is that it provided a framework and powerful modelling tool with which to shepherd the process of hospital bed capacity projection. It does this in two ways.

Firstly, by channelling a focussed discussion on the determinants of growth, it was possible to separate the various influences that affected or were thought to impact on existing and perceived future demand. This was important because some of these factors have a geometric growth pattern while others will influence demand in a linear manner. The ability to delineate the growth influences into groupings based on their mode of effect was useful in steering the debate along a rational course.

As an example, many services would base their expected growth rates solely on past patterns of patient use. Whilst reasonable from the services point of view, this type of claim was unmanageable from a company and funding perspective. The problem with this assumption is that most of the growth was assumed to reflect increasing disease prevalence. This was clearly not the case, and the model allowed us to look more closely at previous growth rates and delineate the driving factors behind them. Often this apparent increase in demand was not due solely to increasing disease prevalence in the community, but was influenced by other factors such as population growth, changing clinical treatments, or an extension to the clinical indications for treatment. Indeed, over the last decade much of the growth in expenditure has resulted from the change in clinical treatment patterns, rather than an underlying change in disease prevalence (Eddy 1993).

Separating out the different variables that affected past growth rates allowed a clearer interpretation of the demand that could be expected in the future. This helped reassure the funders that the phenomenon of supplier induced demand played a minimal part in our calculation of the bed numbers required.

This reassurance was important during the negotiation process with government agencies. Initially the view was expressed that our estimates were high, and that we had become captured and overly influenced by our own clinicians. This perception of provider capture would have significantly weakened our negotiating position if we had been unable to demonstrate a rigorous and robust framework within which we made our original estimates. This modelling process provided that mechanism.

The impact of managed care in New Zealand was difficult to define in terms of a single factor that could then be used in the model. The lack of a comprehensive primary care database, and at the time the absence of a clear policy intent to integrate funding across primary, secondary and tertiary care, led us to the conclusion that any forces for integration would not impact significantly on the planning process that we undertook. However, it was thought that the factors of contestability, disease prevalence and sub-regional equitable access (SREA) would reflect some of the effects of managed care.

The second major characteristic of the model was its ability to calculate immediately the final bed number outcome, (as well as other analytical end-points). This was useful when the negotiating parties could not agree on the appropriate value for the factor in question. In the example figure one it was shown that 7,924 bed-days used in 1998-99 translated into a requirement for twenty-six beds in 2004. If there were disagreement between stakeholders as to the appropriate value of one of the factors, insertion of the two values into the model would show how relevant the debate was. Often, this substitution would demonstrate a minor or negligible effect on the outcome for that service. For example, if the factor 'percentage of day-cases' was increased from ten to twenty percent, the model showed that there would be one extra bed required for the day-case facility, with no change to the inpatient requirement. The use of the model in this way was useful in bringing the negotiation process to resolution.

This model gives the ability of decision-makers to cut through many layers of discussion and focus on some of the major determinants of health service growth. It highlights areas that need further research; the most obvious of which is a proper community based "needs analysis". Because of the nature of its function, it continues to be useful past the planning stages and well into implementation. The explicit clarity of the assumptions provides a yardstick for those responsible and accountable for major capital project implementation. Although not a complete answer to capacity projection we believe it provides a very useful framework for rational and comprehensive capacity analysis within the health sector.

References

Aziz K 1995, 'Tumour markers: current status and future applications', *Scandinavian Journal of Clinical and Laboratory Investigation Supplement*, vol 221, pp 153-5.

Beaglehole R, Stewart A, Jackson R, Dobson A, McElduff P, D'Este K, Heller R, Jamrozik K, Hobbs M, Parsons R & Broadhurst R 1997, 'Declining rates of coronary heart disease in New Zealand and Australia, 1983-93', *American Journal of Epidemiology*, vol 145, no 8, pp 707-13.

Bell C, Swinburn B, Stewart A, Jackson R, Tukuitonga C & Tipene-Leach D 1996, 'Ethnic differences and recent trends in coronary heart disease incidence in New Zealand', *New Zealand Medical Journa*l, vol 109, no 1017, pp 66-8.

Bigelow DA, McFarland BH, Gareau MJ & Young DJ 1991, 'Implementation and effectiveness of a bed reduction project', *Community Mental Health Journal,* vol 27, no 2, pp 125-33.

Brett MS, 1998, 'Antimicrobial resistances among Shigella in New Zealand', *New Zealand Medical Journal*, vol 111, no 1068, pp 234-5.

Burkell J & Vingilis E, 1996, 'A critique of an evaluation of the impact of Hospital bed closures in Winnepeg, Canada: Lessons to be learnt from the Evaluation Research Methods', *Journal of Public Health Policy*, vol 17, no 4, pp 409-425.

Calder L & Priest P 1996, 'One year of tuberculosis in Auckland', *New Zealand Medical Journal*, vol 109, no 1021, pp 164-7.

Caplan LR 1997, 'New therapies for stroke', *Archives of Neurology,* vol 54, no10, pp 1222-4.

Chelluri L & Grenvik 1995, 'Intensive Care for critically ill elderly: Mortality, costs and quality of life', *Archives of Internal Medicine*, vol 155, no 10, pp 1013-22.

Cox B & Borman B 1994, 'Cervical cancer in New Zealand; national and regional trends', *New Zealand Medical Journal*, vol 107, no 984, pp 323-6.

Dockerty JD, Cox B & Cockburn MG 1996, 'Childhood leukaemias in New Zealand: time trends and ethnic differences', *British Journal of Cancer*, vol 73, no 9, pp 1141-7.

Dornbusch K, King A & Legakis N 1998, 'Incidence of antibiotic resistance in blood and urine isolates from hospitalised patients. Report from a European collaborative study. European Study Group on Antibiotic Resistance', *Scandinavian Journal Infectious Diseases*, vol 30, no 3, pp 281-8.

Eddy DM 1993, 'Clinical decision-making: from theory to practice. Three battles to watch in the 1990s', *Journal of American Medical Association*, vol 270, no 4, pp 520-6.

French J, Williams B, Hart H, Woo K, Wang L, Grant J, Ingram C, O'Brien P, Poole J, Sharpe N, Williams M & White H 1996, 'Management of acute myocardial infarction in Auckland', *New Zealand Medical Journal*, vol 109, no 1025, pp 248-51.

Galgali G, Beaglehole R, Scragg R & Tobias M 1998, 'Potential for prevention of premature death and disease in New Zealand', *New Zealand Medical Journal*, vol 111, no 1058, pp 7-10.

Goldacre MJ, Ferguson JA 1995, 'Inpatient workload in medical specialties: 1.Demographic profiles and time trends from linked statistics', *QJM: Monthly Journal of the Association of Physicians,* vol 88, no 9, pp 649-59.

Goplerud EN 1986, 'Assessing methods of predicting the need for Psychiatric Beds', *Hospital and Community Psychiatry*, vol 37, No 4, pp 391-395.

GUSTO Investigators 1993, 'An international randomised control trial comparing four thrombolytic strategies for acute myocardial infarction', *New England Journal of Medicine*, vol 329, pp 673-82.

Hanson DS & Brooks BJ 1992, 'Innovative therapies in haematology and oncology', *Medical Clinics of North America*, vol 76, no 5, pp 1169-84.

Harrison AJ 1997, 'Hospitals in England. Impact of the 1990 National Health Service reforms', *Medical Care,* vol 35, pp OS50-OS61.

Harrison ML, Graff LA & Roos NP 1995, 'Discharging patients earlier from Winnepeg Hospitals: Does it adversely affect quality of care?', *Canadian Medical Association Journal*, vol 153, no6, pp 745-51.

Hensher M, Edwards N & Stokes R 1999, 'International trends in the provision and utilisation of hospital care', *British Medical Journal*, vol 319, no 7213, pp 845-8.

Hensher M, Fulop N, Coast J & Jefferys E 1999, 'The hospital of the future. Better out than in? Alternatives to acute hospital care', *British Medical Journal,* vol 319, no 7217, pp 1127-30.

Health Funding Authority 1998. 'Through the Eyes of a Child. A national review of Paediatric Specialty services'.

Hoel DG, Davis DL & Miller AB 1992, 'Trends in cancer mortality in 15 industrialized countries, 1969-86', *J Natl Cancer Inst*, vol 84, no 5, pp 313-20.

Jackson R, Yee RL, Priest P, Shaw L & Beaglehole R 1995, 'Trends in coronary heart disease risk factors in Auckland 1982-94', *New Zealand Medical Journal*, vol 108, no 1011, pp 451-4.

Jarman B 1993, 'Is London overbedded?', *British Medical Journal*, vol 306, no 6883, pp 979-82.

Johnson AM 1997, 'Capacity planning for the future', *Journal Health Care Finance*, vol 24, no 1, pp 72-75.

Jones SB, Kuppersmith RB & Satava RM 1998, 'Otolaryngology in the information age: enabling technologies for the future of surgery', *Otolaryngologic Clinics of North America*, vol 31, no 2, pp 241-53.

Lawrence RE, Copas JB & Cooper PW 1991, 'Community care: does it reduce the need for psychiatric beds? A comparison of two different styles of service in three hospitals', *British Journal of Psychiatry*, vol 159, pp 334-40.

Levi F, Lucchini F & La Vecchia C 1994, 'Worldwide patterns of cancer mortality 1985-89', *European Journal of Cancer Prevention*, vol 3, no 2, pp 109-43.

Lumsden K & Anderson HJ 1992, 'Cancer at the crossroads', *Hospitals,* vol 66, no 23, pp 22-30.

MacIntyre CR, Brook CW, Chandraraj E et al 1997, 'Changes in bed resources and admission patterns in acute public hospitals in Victoria, 1987-1995', *Medical Journal of Australia*, vol 167, pp 186-89.

Maarse H, Mur-Veenman I & Spreeuwenberg C 1997, 'The reform of Hospital care in the Netherlands', *Medical Care*, vol 35, no 10, pp OS26-OS39 Suppl.

Madden CW 1999, 'Excess capacity: Markets, Regulation, and Values', *Health services research*, vol 33, no 6, pp 1651-68.

McCray E, Weinbaum CM, Braden CR & Onorato IM 1997, 'The epidemiology of tuberculosis in the United States', *Clinical Chest Medicine*, vol 18, no 1, pp 99-113.

McGowan J Jr & Tenover F 1998, 'Antimicrobial resistance in the intensive care unit: impact of new patterns', *International Journal of Clinical Practice Supplement*, vol 95, pp 14-22.

Meyer C 1993, 'Visions of Tomorrows ICU', *American Journal of Nursing*, vol 93, no 5, pp 26-31.

Moss AR, Alland D, Telzak E, Hewlett D Jr, Sharp V, Chiliade P, LaBombardi V, Kabus D, Hanna B, Palumbo L, Brudney K, Weltman A, Stoeckle K, Chirgwin K, Simberkoff M, Moghazeh S, Eisner W, Lutfey M & Kreiswirth B 1997, 'A city wide outbreak of a multiple drug resistant strain of Mycobacterium tuberculosis in New York', *International Journal of Tuberculous and Lung Disease,* vol 1, no 2, pp 115-21.

Murray CJ & Lopez AD 1997, 'Alternative projections of mortality and disability by cause 1990-2020: Global burden of disease study', *Lancet*, Vol 349, no 9064, pp 1498-504.

Ossoff RH & Reinisch L 1994, 'Computer assisted surgical techniques: a vision for the future of otolaryngology-head and neck surgery', *Journal of Otolaryngology*, vol 23, no 5, pp 354-9.

Pasley BH, Lagoe RJ & Marshall NO 1995, 'Excess acute care bed capacity and its causes: The experience of New York State', *Health Services Research*, vol 30, no 1, pp 115-31.

Redick RW, Witkin MJ, Atay JE & Manderscheid RW 1991, 'Availability and distribution of psych beds, United States and each state, 1986', *Mental Health Statistical Note*, vol 195, pp 1-14.

Rosamond WD, Chambless LE, Folsom AR, Cooper LS, Conwill DE, Clegg L, Wang CH & Heiss G 1998, 'Trends in the incidence of MI and in mortality due to coronary heart disease, 1987 to 1994', *New England Journal of Medicine*, vol 339, no 13, pp 861-867.

Rushworth RL & Rob MI 1995, 'Readmissions to hospital: the contribution of morbidity data to the evaluation of asthma management', *Australian Journal of Public Health*, vol 19, pp 363-67.

Shepherd G 1998, 'System failure? The problems of reductions in long-stay beds in the UK', *Epidemiologia E Psichiatria Sociale*, vol 7, no 2, pp 127-34.

Silberberg DH 1992, '2001 and beyond-What's ahead for Neurology?', *Annals of Neurology,* vol 32, no 6, pp 813-18.

Simmons D, 1996, 'Diabetes and its complications in New Zealand: an epidemiological perspective', *New Zealand Medical Journal*, vol 109, pp 245-47.

Snowdon J 1993, 'How many bed-days for an area's psychogeriatric patients?', *Australian & New Zealand Journal of Psychiatry*, vol 27, no 1, pp 42-8.

Zimmerman JE, Knaus WA, Judson JA et al 1988, 'Patient selection for intensive care: a comparison of New Zealand and United States hospitals', *Critical Care Medicine*, vol 16, pp 318-326.