# Modelling the Demand for Renal Replacement Therapies: Challenging Assumptions and Influencing Policy


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## Abstract

*Renal services comprise a growing and costly part of the health system. They provide life saving dialysis and transplant services for patients with kidney failure. Howewver, demand is increasing, costs are rising and there is an increasing shortage of the staff and facilities needed. The response is often to call for more resources The paper describes two case studies which used dynamic modelling to challenge assumptions about the implications of rising demand and to influence policies designed to repsond to it. The key impact of this work was to show that the future demand is as much determined by provider polices as they are by population and disease characteristics. Not all the problems are caused by rising demand and shortage of resources. In these two cases historical investment patterns and clinical practices are key drivers of current problems. Their future is not predetermined by external pressures but modifiable by internal policies.*


## Renal Services in New Zealand

Renal services comprise a relatively small but steadily growing and expensive area of the health sector, which has required increasing investment over the last decade. They provide support and treatment for people who are suffering from a failure of their kidneys, caused by a number of different factors, but especially obesity and type 2 diabetes.

If patients suffering kideny failure are not able to get a transplant – and New Zealand has very low transplant rates - then those requiring renal replacement therapy (RRT) have four major options, or modalities, for dialysis. These are: (i) haemodialysis in a hospital setting, fully staffed with trained renal nurses and renal physicians (in-centre haemodialysis), (ii) haemodialysis at home (home haemodialysis), (iii) haemodialysis in a unit not attached to the hospital that may or may not be staffed (supported self-care haemodialysis) or (iv) dialysis that utilises the membrane of peritoneum rather than a machine to cleanse the blood (peritoneal dialysis). Home haemodialysis and peritoneal dialysis are most suitable for patients with stable clinical conditions and enough mobility to support a degree of independence. In-centre dialysis is best suited for patients who are clinically unstable and/or have limited mobility. Dialysis in a supported self-care facility offers a ‘half-way house’ with a range of options from a facility that is not staffed, such as a community house, or a facility that is placed within a primary health care facility that can provide the clinical support as needed.

A key point to be made is that people who are suffering from kidney failure will die if they do not receive a transplant or dialysis. Deciding not to provide enough dialysis services to meet demand is therefore not an option that any health provider in New Zealand is prepared to do; rationing dialysis services is a debate that is yet to occur at a national level. Until it does, each DHB is faced with investing an increasing amount of scarce resources to provide for a rapidly increasing number of dialysis patients.

In New Zealand in the decade from 1995 to 2004, the number of renal dialysis patients (per million population) grew by an average of 7.2 percent per year. As at 31 December 2005 there were 3,093 (755 per million) receiving RRT in New Zealand.[1] Of these, 1,239 (302 per million) had a kidney transplant, and 1,770 (452 per million) received dialysis treatment. Within New Zealand, 436 patients (106 per million) commenced RRT in 2005. Among those receiving dialysis treatments in 2005, 34 percent were Maori and 19 percent were Pacific peoples[2].

The key drivers of the growth in dialysis patient numbers are the increasing incidence of chronic kidney disease (CKD) either presenting or being referred for dialysis, as a result of:

- improved survival rates in the general population, especially amonsgst those suffering from cardiovascular disease (CVD).
- the rise in type II diabetes,
- greater acceptance of, and demand for, dialysis services from Maori and Pacific peoples,
- greater acceptance of, and demand for, dialysis services from elderly patients, and
- greater expectation of dialysis services from the medically frail, to whom the service would not previously have been offered, or who would not have accepted an offer of dialysis.

This paper explores the use of dynamic modelling to challenge some key assumptions about this growth in demand and influence policy in two District Health Boards (DHBs) in the North Island of New Zealand.

**Projections of Renal Demand**

A number of District Health Boards (DHB’s) throughout the country are finding it difficult to cope with this increase which, because of an historical underestimation of demand, has taken many by surprise. As a result many renal services throughout the country are suffering from a shortage of staff and facilities that are operating at, and above, capacity. This situation has led some DHBs to try and get a better understanding of future demand so as to ensure planning is based on significantly improved data. Most of this work has involved linear progression models. For example, in 2006, a number of DHBs in the central North Island commissioned their local service agency to undertake some demand modelling. The results of this are shown below[3]:

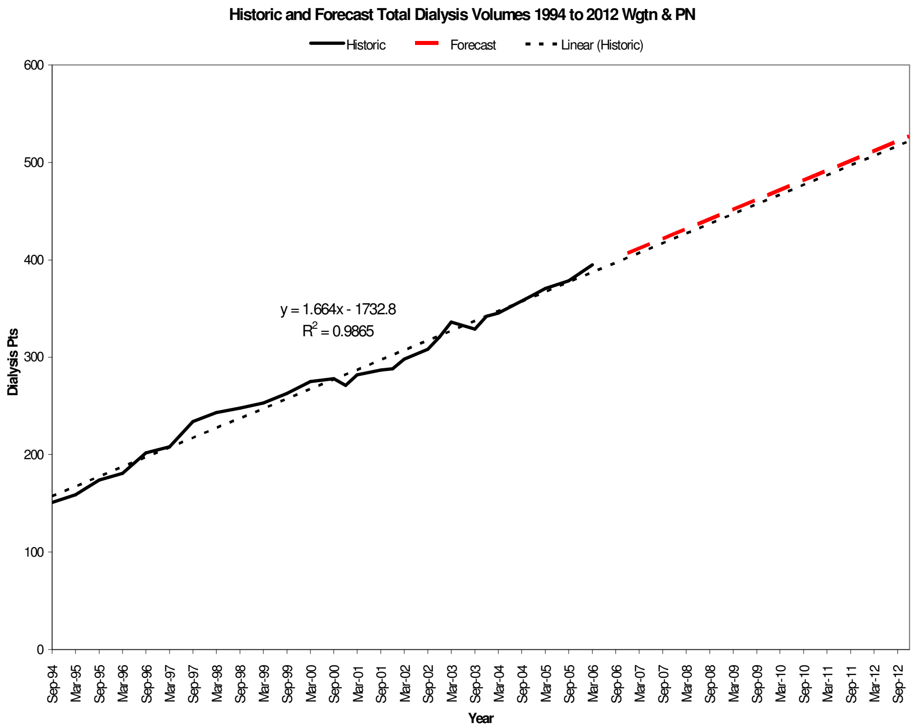


**Figure 1: Total Dialysis Volumes: 1994 to 2012**

This modelling showed, in line with the method used, a continual rise in demand. The subsequent report, based on this modelling recommended that due to the forecasted growth and the ageing population, a greater percentage of those requiring RRT would need in-centre treatments and, as a result, additional investments in hospital-based facilities needed to be made. This came as an unwelcome surprise to the DHBs who commissioned the report, as they had already made extensive investments in in-centre facilities, which, being the most expensive option for RRT was not an option that they wanted to be tied to. As many DHB's are facing tight financial budgets the thought of further investment in hospital facilities was a major concern and the report provided them with no other options to consider.

The report's emphasis on increasing in-centre dialysis was significant for a number of reasons. Firstly, research indicates that hospital haemodialysis patients have higher rates of hospitalisation, die earlier and experience more adverse events during haemodialysis[iv v]. In addition, many renal Physicians believe that the in-centre option is being used too widely[vi]. Although there is an element of selection bias i.e. those able and willing to have home haemodialysis are often younger and both physically and emotionally healthier, in-centre haemodialysis offer patients the worst quality of life and is also more costly. Differences in cost and patient benefit for supported self care and home dialysis are marginal. Both are significantly more beneficial and significantly cheaper than the in-centre option. The variation in the cost of providing supported self care facilities are largely due to the amount of staffing provided. Recent work done by Auckland DHB[1] puts the annual dialysis costs, including additional inpatient and outpatient costs, for each modality as[vii]:

| | |
|---|---|
| In-centre haemodialysis | $64,318 |
| Supported self-care haemodialysis | $48,172 |
| Home haemodialysis | $33,585 |
| Peritoneal dialysis | $36,614 |
| Transplant – initial operation | $109,000 |
| Transplant – per annum | $9,000 |

The growth projections, alongside recommendations that this also required further investment in hospital facilities was a great concern to health managers already grappling with increasing deficits and government pressure to tackle rising health costs. In late 2006 the authors were asked by one of the DHBs who commissioned the original demand modelling to use system dynamic modelling to map the dynamics of the demand for RRT, explore whether or not there were other service options and what the costs of those might be. This work is discussed in the next section.

## Understanding the Dynamics of Renal Demand – Case Study 1

The DHB had been facing a strong growth in demand for in-centre haemodialysis services, rising from 35 patients in 2004 to 55 in 2006 (compared to growth in home haemodialysis and peritoneal dialysis of only 4 patients each over the same period)

Like many other DHBs throughout the country it was also facing an increasing burden of chronic disease. Amongst these, end-stage renal failure (ESRF) is significant in that, while the numbers are relatively low the cost per patient is very high; ranging from between $30,000 to $70,000 per patient per year, depending on the modality choice. A significant proportion of this cost is generated by the inpatient and outpatient events experienced by ESRF patients, who are relatively high users of hospital services. In addition, ESRF patients tend to suffer from a number of co-morbidities[2]

## Co-Morbid Conditions of Dialysis Patients

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[1] This work utilised 2003/04 data from Counties Manukau DHB, a large District Health Board in South Auckland.

[2] The most recent ANZDATA report for the DHB, published in May 2006, showed that patients being provided with dialysis also had a number of other conditions

| | |
|---|---|
| Hypertension requiring treatment | 84% |
| Type II Diabetes | 39% |
| Coronary Artery Disease | 36% |
| Peripheral Vascular Disease | 20% |
| Chronic Lung Disease | 14% |
| Cerebro Vascular Disease | 12% |

**NOTE**: Many patients had more than one of these chronic conditions.

The concern therefore was not just that the numbers of patients requiring RRT was rising but also that ESRF patients are high users of other health services.

To help the DHB come to grips with these challenges we began by modelling expected demand based on current projections. Although the earlier demand model gave us the reference pattern for the central region of the North Island – linear growth of around 5% per year in the demand for renal therapies - we began by replicating the method used to produce a linear demand profile for the client. To do this we were able to use the ANZDATA database for the hospital[viii] with the following results:

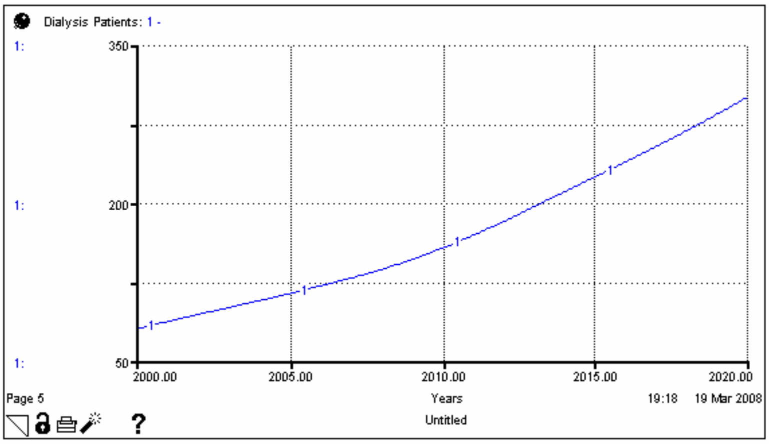


**Figure 2: Dialysis Patients – 2000 to 2020**

This provided the baseline growth pattern – scenario 1. It meant that the number of patients requiring dialysis would rise from the current 128 to more than 250 within 10 years. We extended this model to project the number of patients requiring in-centre dialysis current ratios were kept constant. the projections from that modelling showed that the number of patients requiring in-centre dialysis would grow from the current 60 to just under 120 within 10 years. Both of these baseline scenarios used conservative growth projections.

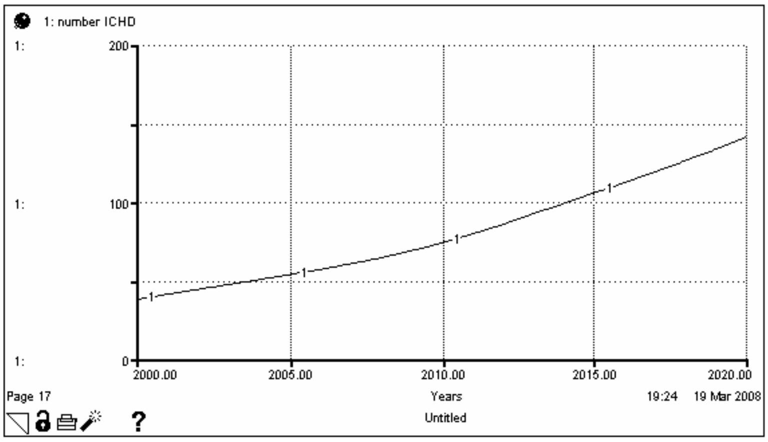


**Figure 3: Dialysis Patients Requiring In-Centre Dialysis – 2000 to 2020**

These two graphs highlighted the problem of concern. Numbers were going up and because of the ageing population so was the demand for in-centre dialysis. While we had little to dispute in terms of the basic progression – it was based on sound data – we were not so confident that the demand for in-centre dialysis would necessarily follow the same demand curve. We then began exploring other options and what would be required to put them in place.

The process included an extensive literature search and interviews with renal staff within the hospital. A dynamic hypothesis that argued against demographics being the only, or even prime driver of demand for in-centre dialysis was developed from this work.

**Dynamic hypothesis for the driver or demand for RRT – Case Study 1**

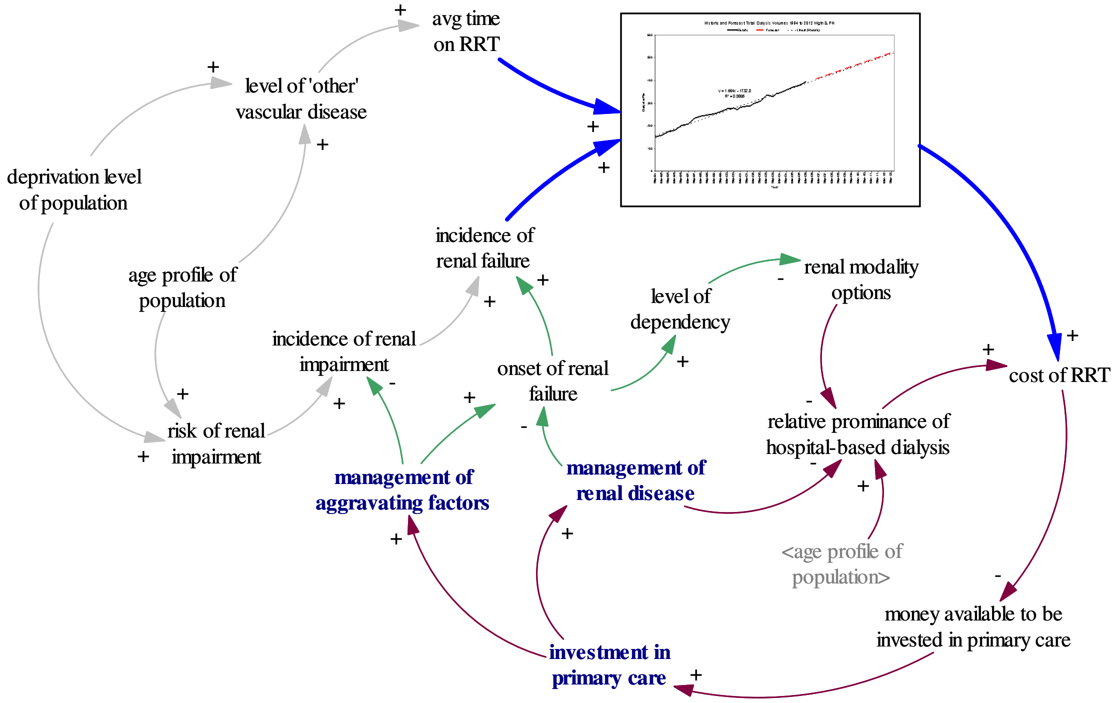


**Figure 4: Dynamic Hypothesis 1 – Drivers of Demand for RRT**

What this CLD highlighted was that while demographic and epidemiological factors were key drivers of renal disease and renal failure they were not the key drivers of the treatment modality chosen. More important however, was the way the disease itself was managed. We found was that just under 50% of patients were referred so late in the disease progression that they required immediate dialysis or dialysis in the near future. This meant that the training necessary for more independent therapies was not possible. In addition, it was difficult to get timely vascular access, which is necessary for home haemodialysis to be considered. As a result an increasing number of patients were being referred for in-centre treatment. Staff at the renal centre thought that if timely referrals were made, thereby enabling appropriate training and management of their renal disease, and vascular access was available in a consistent and timely manner, the percentage of patients starting in-centre haemodialysis could be reduced by about 45%. This was a high number and we not only wanted to test the viability of this but also what the consequences would be if the service could be re-designed to; firstly, overcome poor management of the renal disease prior to the need for dialysis and secondly, to improve availability of1 vascular access surgery.

Our next next step was to develop the CLD into a quantified dynamic model.

**Simulating Renal Demand – Case Study 1**

The following graphic shows the high-level sectors that we modeled. To quantify the model we used the hospital's databases as well as the national and hospital data in the ANZDATA renal database[ix].

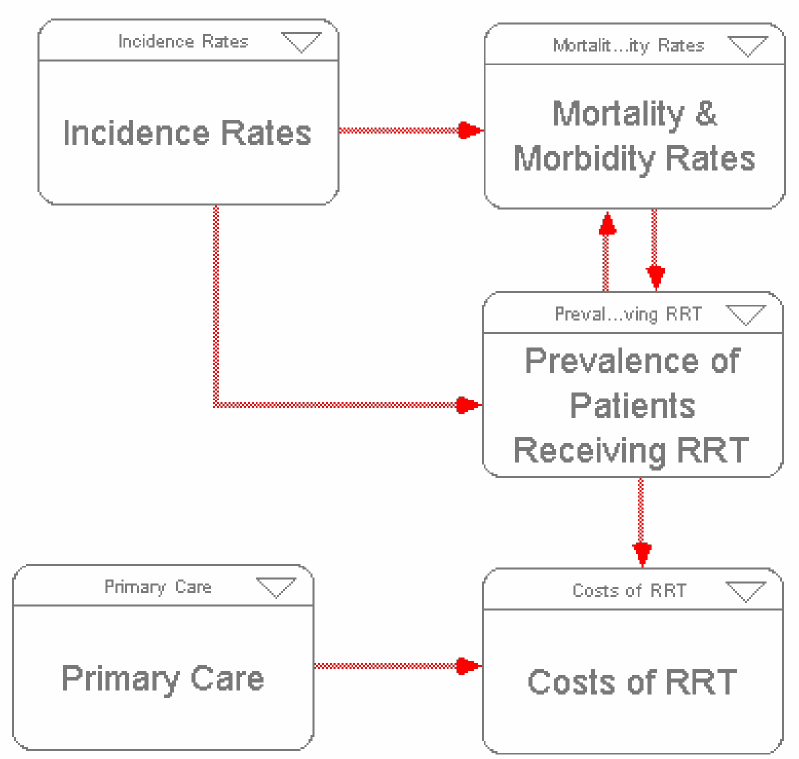


**Figure 5: Simulating Renal Demand – High Level Model**

The process of building this model occurred in an environment of tensions between clinical and management staff. It was important therefore that the model was seen to have both clinical and financial validity if the results of the model were to be accepted as a basis for future planning. To do this a number of steps were taken based on what is known about good collaborative modelling practices[x]:

- The detailed model, based on the concept model shown above, was developed in conjunction with the local renal team, hospital management and primary care providers. We took time to make sure key people were involved in developing the model structure as well as reviewing the numerical data that populated it.
- The model was populated with data taken from a number of sources including: the ANZDATA registry, DHB population data, data from a review of the literature[xi] and the 'informed judgments' of clinical and management staff involved. Because of the multiple data sources we ensured that any areas of uncertainty and/or debate were discussed with those involved in the modelling before being accepted as a model parameter.
- The model behaviour was mapped against historical data.

In addition, we tried to heed the advice of Homer (!997) in trying to bring together a good understanding of structure with strong empirical data[xii].

As a result the model had validity in the eyes of the managers and clinicians involved in developing it; they became spokespeople for its value. This was a powerful driver of change as the voice was now a combined clinical/managerial one. Once the model was completed a number of scenarios were developed based on our understanding of the issues being faced by the DHB and what we knew about best practice in renal care. The four scenarios were:

1. continuation of current practices and trends,
2. early referral
3. improved management of CKD.
4. Best practice combining the changes incorporated into scenarios 2 and 3,

What the scenarios showed was that, even under the conservative figures we incorporated in the assumptions, there could be significantly different outcomes in terms of overall renal demand and the numbers undertaking in-centre dialysis.

What the model showed was that early referral patterns had no effect on the numbers requiring RRT projected in the baseline scenario – scenario 1.. To impact these volumes the only option was to improve the management of CKD – scenarios 3 and 4. Early referral had an impact on the nature of the renal service and the nature of the demand it had to cope with but not overall demand volumes.

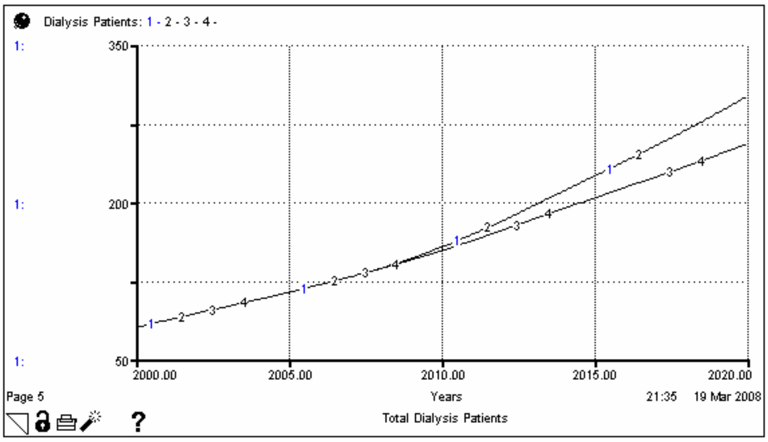


**Figure 6: Dialysis Patients – 2000 to 2020:**

However the picture was quite different when one looked at the impact upon the numbers flowing into in-centre haemodialysis (ICHD).

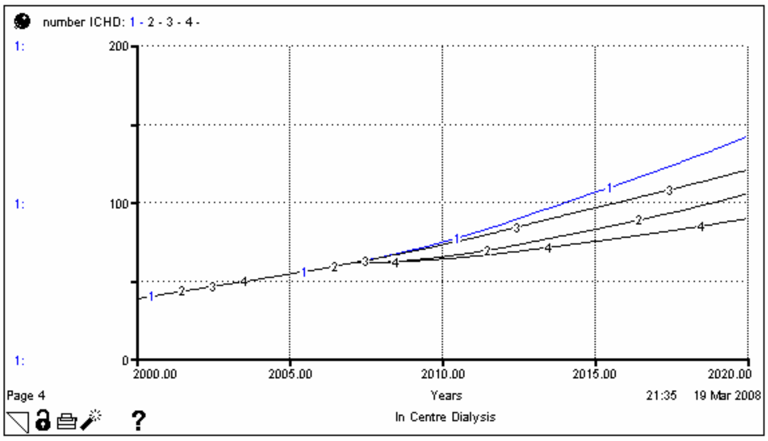


**Figure 7: In-Centre Patients Under Four Scenarios – 2000 to 2020:**

The demand for in-centre dialysis was significantly affected by improved referral patterns – scenario 2. Earlier referral enabled a much greater percentage of patients to take up other modality options and thus reducing the overall demand for in-centre dialysis. As further expansion of in-centre facilities had an enormous impact on capital expenditure (and overall facilities planning) this result was seen as offering the DHB a positive option for responding to the overall rise in demand.

When combined with improved management of CKD – scenario 4 - the number of patients requiring in-centre haemodialysis dropped even further. The earlier modelling gave the DHB one figure and one option; in-centre volumes would rise to around 120 within 10 years and as a result further investment in in-centre facilities needed to be made. Our work showed that the future was far less pre-determined. Depending on policy choices made by the DHB the number of patients requiring in-centre dialysis could be anywhere from a high of 120 to a low of 80. These figures would drive a considerably different investment pattern and drove home the message that the future was as much determined by their own choices as the nature of the population they were serving.

Using these scenarios a proposal was put to the DHB to invest in better links with primary care so as to improve patterns of referral to the renal service and to invest in supported self-care facilities to provide options other than in-centre dialysis. The report has been accepted and the renal initiative in primary care has been incorporated into the DHBs overall programme for chronic care management. A supported self-care unit has also been opened in a nearby house, converted to provide dialysis facilitiesand a dialysis chair has been established in a rest home to provide dialysis facilities for some elderly patients. No further expansion of in-centre facilities is now planned.

In addition, the overall recommendations of our report have become the basis for the development of a regional strategy which was completed and approved in late 2007.

## Case study 2

As a result of this work this work the lead author was asked, in late 2007, to undertake some modelling with a smaller DHB. As part of the process of assuming full responsibility for their renal service, which had, up until mid-2007 been managed by a larger, better resourced DHB, they employed their first renal physician in July 2007 and in February 2008 took over full responsibility for home haemodialysis training.

This was a much smaller service with 195 patients with ESRF. Of these 62 have transplants, 78 are undergoing some form of dialysis and 68 are enrolled in the pre-dialysis programme. Of these approximately 20 will require dialysis within the next 12 months.

The issue for this DHB was in many ways very similar to Case Study 1; increasing demand for RRT and increasing pressure of their in-centre facilities. They were also interested in exploring what other options were available to them.

As with the first DHB we developed a dynamic hypothesis with key clinicians and managers in the hospital and primary care. However, the conceptualisation in this case was slightly different;

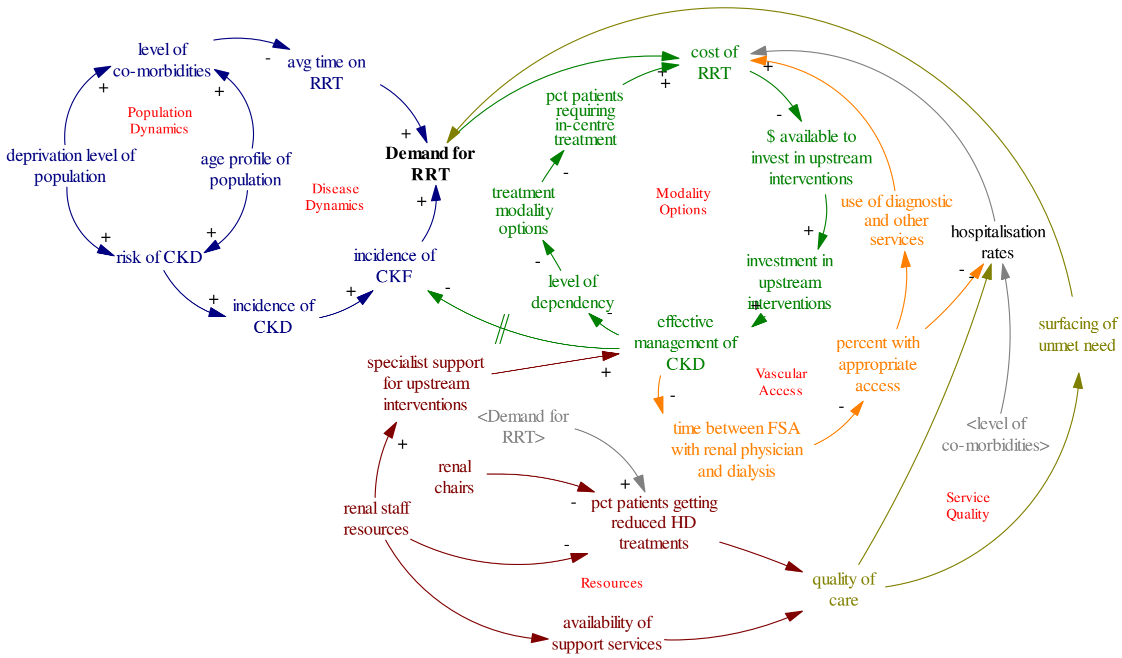


**Figure 8: Dynamic Hypothesis 2 – Drivers of Demand for RRT**

As with the first case the population and disease dynamics driving the demand for RRT were acknowledged. However this CLD put much more emphasis on the dynamics involved in driving modality options and vascular access. Prior to 2007, the service was supported by visiting renal physicians, all training was done outside the region and vascular access was, except in a small number of cases done in Wellington, approximately 250 kms away. The other significant issue here was that, due to service constraints there was the potential for service improvements to 'lift the lid' on suppressed demand.

The baseline modelling for this DHB provided the same story as with the first case; demand would continue to increase and, assuming no change in the ratio of patients requiring in-centre dialysis, pressure would continue to be put on their in-centre facilities.

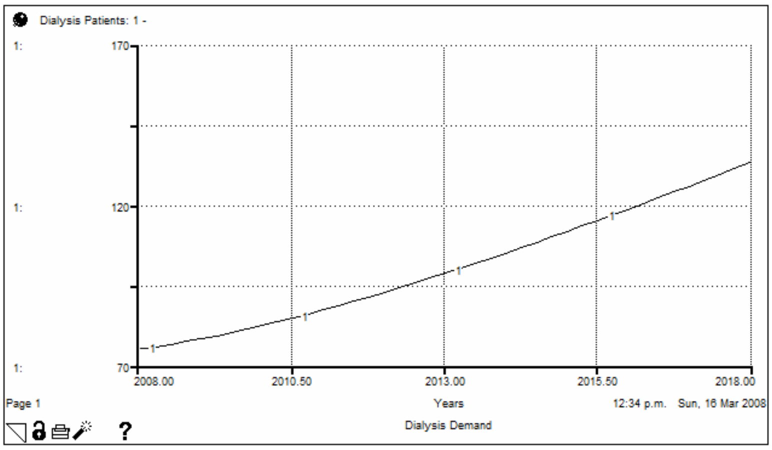


**Figure 9: Dialysis Patients 2008 - 2018**

Within this much smaller DHB's the model, based on extrapolations of current trends, indicated that dialysis volumes would increase from the current level of 75 to over 130 in the next 10 years. Furthermore, the numbers requiring in-centre services would rise from the current 38 to nearly 70 within 10 years. What this meant in terms of facilities was that the DHB would need to invest in a third renal unit – the current volumes were spread across two units with seven chairs (DU1) and four chairs (DU2)[xiii] respectively – within the next two years. As they have little space for further facilities on the hospital grounds this is of major significance.

To explore other options five major scenarios were developed. These were:

1. continuation of current practices and trends,
2. surfacing unmet need,
3. surfacing unmet need and increasing growth,
4. investment in supported self care and maintaining growth rates,

5. investment in supported self care and better management of CKD to reduce overall growth rates.

What the modelling showed here was that while a projection based on current trends showed a steady growth in demand the improvements required to shift more patients into dialysis options outside the hospital settings would increase demand in the short term above the baseline projections – scenario 2.

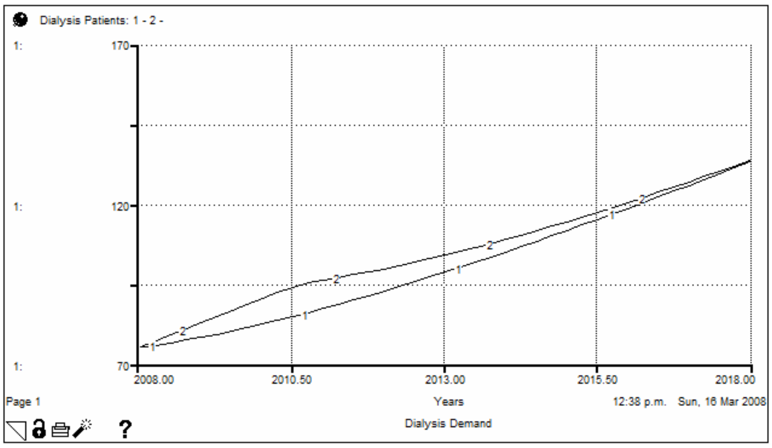


**Figure 10: Dialysis Patients 2008 – 2018 – Scenario 2**

With improved service provision, especially the arrival of a full-time renal physician, the numbers attending outpatient clinics would rise and lead to an increasing number of people requiring dialysis. This projection is already being born out with data on clinic visits:

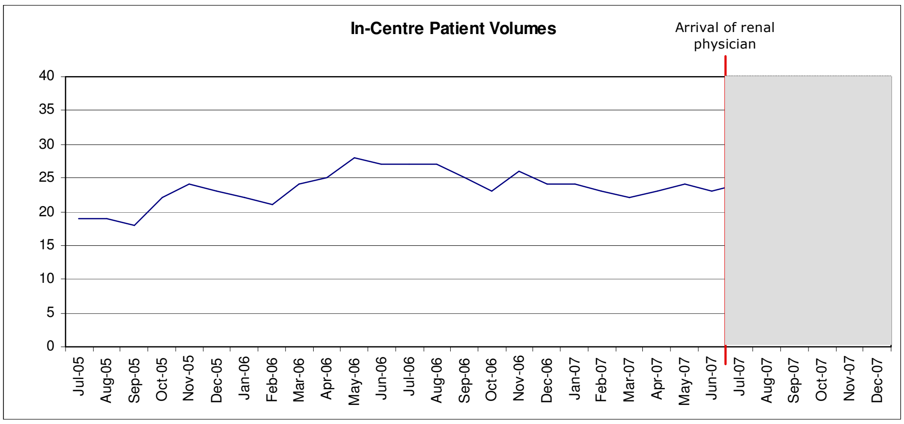


**Figure 11: Change in In-Centre volumes Since the Arrival of the Renal Physician**

In addition this is now translating into increased numbers of patients starting dialysis with the number of new patients starting dialysis in 2008 already ahead of projections based on the simple linear forecast. To make matters worse the DHB operates in an area with high levels of social deprivation and a high percentage of Maori. Standard growth rates are therefore likely to be conservative and the DHB recognises it needs to be prepared for higher than average growth rates over the next 10 years. A projection based on a 6% rather than a 5% growth rates provides an even more grim future;

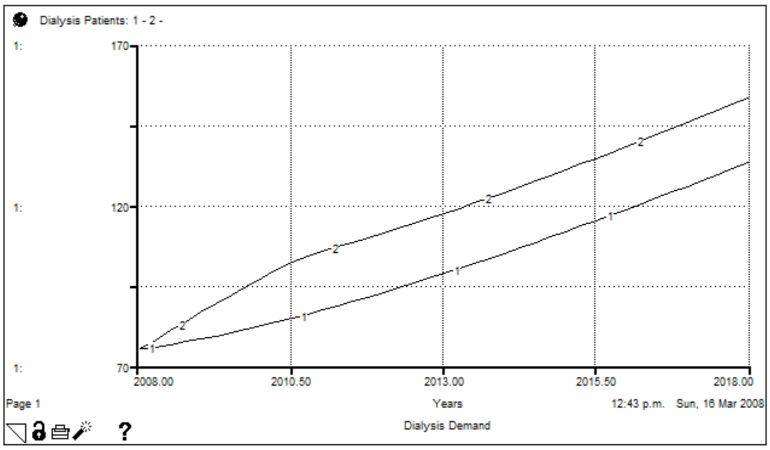


**Figure 12: Dialysis Patients 2008 – 2018 – Scenario 3**

Under this scenario the numbers requiring dialysis not only grow in the short term, due to improved service provision but continue to grow over the next 10 years at a rate above the national average. As a result dialysis numbers grow from current volumes of 75 to around 154 as opposed to the base case of 133.

The preferred scenario, scenario 5, which incorporates the key variables needed to move the service towards best practice guidelines, although projecting a much healthier future, predicts volumes above the baseline projections in the short term. Under this scenario future volumes would be around 113 in contrast to the baseline projections of 133.

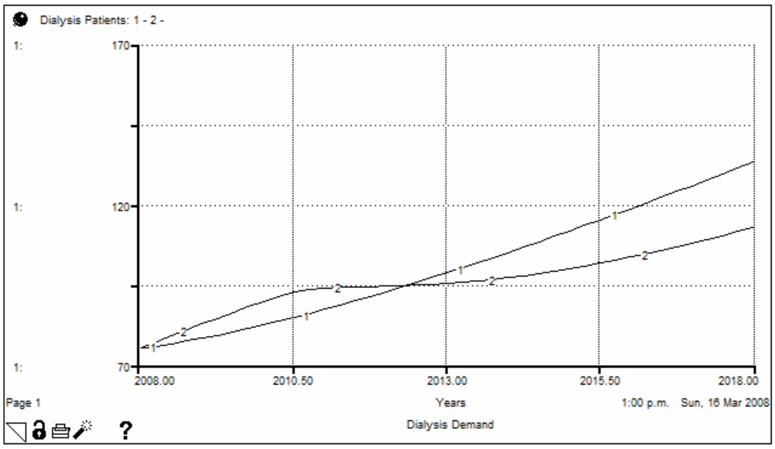


**Figure 13: Dialysis Patients 2008 – 2018 – Scenario 5**

Under this scenario in-centre volumes drop drastically with the opening of supported self care units:

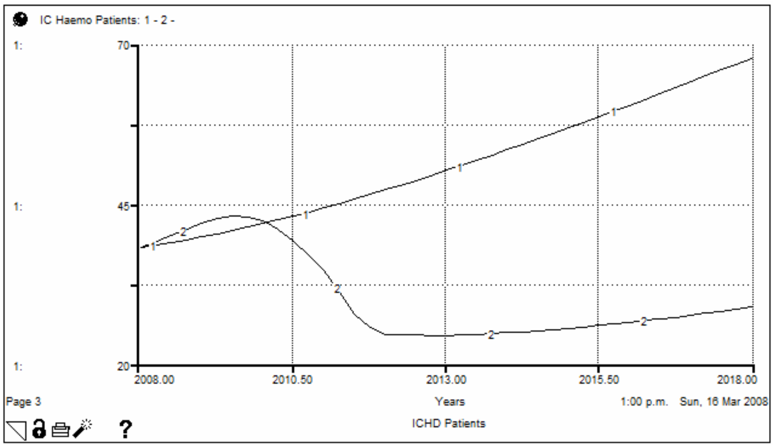


**Figure 14: In-Centre Patients 2008 – 2018 – Scenario 5**

The significant drop in volumes is driven by the opening of supported self care units and better management of CKD in primary care. Under this scenario the DHB is able to consider closing their second dialysis unit within two to three years rather than think about opening a third unit within the same time period.

As with the first case the key impact of this work was to show that the future demands were as much determined by their own polices as they were by population and disease characteristics. The way the service was designed has a major influence on the demands it has to respond to. In the second case, the years of under-provision meant that there was little, if anything, the DHB could do to overcome the 'worse before better, scenario. Making the improvements necessary to reduce overall demand and divert more patients away from the costly in-centre option would, in the short term increase demand.

## Summary SD Modelling as a Tool to Challenge Assumptions and Influence Policy

These two case studies show the power of System Dynamics to challenge the assumptions, driven by linear thing, that drive a lot of healthcare planning. All around the world health services are under stress. Demand is increasing, costs are rising and there is an increasing shortage of the staff and facilities needed to respond. The response is often to call for more resources; governments are being asked to increase funding, employers are being asked to increase salaries to attract more staff and staff are asking for more resources to meet their current challenges. In addition changing lifestyles are producing epidemics in conditions such as obesity and type 2 diabetes which are further increasing the volumes of people wanting a response from an already overloaded health service.

These two case studies highlight that despite external pressures much can be done by the providers themselves. Not all the problems are caused by rising demand and shortage of resources. At least some of the pressure is self induced. In these two cases historical investment patterns and clinical practices are key drivers of current problems. The future, at least in these two examples is not predetermined by external pressures but modifiable by internal policies.

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[1] RRT includes haemodialysis, peritoneal dialysis and transplantation.

[2] Australia and New Zealand Dialysis and Transplant Registry. ANZDATA Registry Annual Report 2006. Adelaide: ANZDATA Registry; 2006.

[3] Satterthwaite, Peter (August 2006) Renal Replacement Therapy Demand Model: Central Region (including Nelson Marlborough). Projected Patient Volumes 2007-2012.

[iv] Lynn K, Buttimore A. Future of home haemodialysis in Australia and New Zealand. Nephrology 2005;10:231-233.

[v] Metcalfe, W., I. Khan, H., et al. (2003). "End-stage renal disease in Scotland: Outcomes and standards of care." Kidney International **64**: 1808-1816.

[vi] Jassal, S., V.,, G. Krishna, et al. (2002). "Attitudes of British Isles nephrologists towards dialysis modlaity selection: a questionnaire study." Nephrology Dialysis Transplantation **17**: 474-477.

[vii] Ashton, T. and M. Marshall, R. (2007). "The organization and financing of dialysis and kidney transplantation services in New Zealand." International Journal of Health Care Finance Economics **7**: 233-252.

[viii] Australia and New Zealand Dialysis and Transplant Registry. ANZDATA Registry Annual Report 2005. Adelaide: ANZDATA Registry; 2005.

[ix] Australia and New Zealand Dialysis and Transplant Registry. ANZDATA Registry Annual Report 2006. Adelaide: ANZDATA Registry; 2006.

[x] For example: Vennix, J. A. M., H. A. Akkermans, et al. (1996). "Group model-building to facilitate organizational change: an exploratory study." System Dynamics Review **12**(1).

[xi] The literature review was also peer-reviewed by Dr. John Collins, Clinical Director, Department of Renal Medicine, Auckland District Health Board and Dr. Grant Pidgeon, Snr. Lecturer Renal Medicine, Wellington School of Medicine, Capital Coast District Health Board.

[xii] Homer, J. (1997). "Structure, Data and Compelling Conclusions: Notes from the Field." System Dynamics Review **13**: 293-309.

[xiii] DU1 refers to dialysis unit 1 and DU2 refers to dialysis unit 2.