VARIATIONS IN SECONDARY CARE UTILISATION AND GEOGRAPHIC ACCESS, 1996

INITIAL ANALYSIS

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TRENDS AND VARIATIONS IN HEALTH CARE UTILISATION IN NEW ZEALAND 1991-96

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CONTENTS

FIGURES

TABLES

1 Introduction

Many health systems aim to improve health status and eliminate disparities in health between population groups, and are paying much attention to socio-economic determinants of health. Access to care has also been shown to be an important contributor to health status (Davis 1991; Office of Technology Assessment 1992; Newhouse 1993). Frameworks that relate health service structures and processes to outcomes also frequently include access to health care as a determinant of health outcomes (Donabedian 1971; OECD 1987; Disability 1998; Drache and Sullivan 1999; Daniels, Kennedy et al. 2000).

New Zealand governments in recent years have required government agencies to promote 'better and fairer access to services', including geographic accessibility (Upton 1991; Creech 1999). New Zealand's current government expects better access to contribute to improving health outcomes and eliminating disparities (King 2000). The Government's New Zealand Health Strategy (NZHS) guides District Health Boards (DHBs), and one of its seven fundamental principles is 'timely and equitable access for all New Zealanders to a comprehensive range of health and disability services, regardless of ability to pay'[ii] (King 2000:vii). Further, the Government expects accessible services to contribute to reducing health status inequalities for target groups (Mâori; Pacific peoples; and, lower socio-economic groups). Yet links between access and health are poorly understood.

Most research on variations in access and how to improve access to care in New Zealand relates to primary care services. This paper reports on research that is a first stage in systematically understanding trends and variations in access to the health care system in New Zealand. Our initial focus is access to secondary care and proximity to health services, drawing together strands of research on utilisation and proximity to health services. This is a starting point to explaining health status variations across regions, and suggesting more efficient distributions of health resources.

This paper reports findings from a pilot study summarising variations in utilisation rates for publicly funded secondary health care services in New Zealand during 1996.[iii] Economic and geographic approaches are combined to focus on the relationship between distance and access using linked national datasets including the health service-related National Minimum Data Set (NMDS), Census data and a hospital location data set.[iv] We develop a conceptual framework for access in New Zealand's health system and demonstrate a method for explaining geographic variations in utilisation. The study tests the simple hypothesis that health care utilisation falls the further a patient lives from the service.

[ii] The recently established District Health Boards (DHBs) are decentralised local public agencies responsible for purchasing health services for geographically defined populations; they also provide secondary services.
[iii] Secondary care refers to services predominantly accessed through medical practitioner referrals and is provided by hospitals, excluding accident and emergency services (World Health Organisation 1978).
[iv] The Public Health Intelligence unit in the Ministry of Health provided the hospital location data set.

The analysis suggests a positive correlation between distance and utilisation beyond a 15km threshold. Below this threshold a weak negative correlation is observed. This correlation is statistically significant but explains little overall variation in discharge rates. The results suggest no general association between distance and utilisation. Key utilisation patterns include:

- DHBs with small populations have higher discharge rates compared with highly populated DHBs.
- Pâkeha are most likely to receive treatment, with the highest sub-population discharge
- Males and females have almost identical discharge rates (disregarding pregnancy-related discharges).
- Discharge rates rise for young adults (20-29 years) then fall away until the 50 years + age groups after which discharge rates continue to rise.

The structure of the paper is as follows. Section 2 reviews approaches to researching equity and access, highlighting significant findings. This section also introduces concepts of access in the literature. This includes two common concepts of access found and used in this study: potential access and realised access. Section 3 introduces our research approach, which is underpinned by a conceptual model of access to care in New Zealand developed for this project. Sections 4 and 5 review the data and methodology. Section 6 presents the study's descriptive and modelling results. Section 7 discusses the results of the study and their limitations, and gives pointers to future directions for our research agenda on access. A glossary of common terminology used in the paper, detailed logistic regression results and methodological background are appended to the paper.

2 Researching Equity and Access

In applying insights from the literature, we recognise that international and local research on equity of access varies. First, research uses different concepts of access and definitions of need and equity. Second, a number of services may be researched, and therefore researchers may find different patterns across services. Third, the organisation of health services, and their wider social context, differs across countries affecting a patient’s eligibility and passage through a health system. Fourth, it is likely that the large number of factors potentially explaining variations in access and utilisation will differ in importance for different concepts of access and services. Given the diversity in the literature on access it is important to take into account a study’s approach, concepts, and focus when interpreting its results and drawing insights about access.

McKinlay (1972) identified six main approaches to research the utilisation of services: economic, socio-demographic, geographic, social-psychological, socio-cultural, and organisational. Since McKinlay wrote in 1972, there has been significant methodological debate and empirical research relating to access and utilisation (see for example Gold and Stevens 1998, Phillips, Morrison et al. 1998, Parker and Campbell 1998, Rogers, Hassell et al. 1999, Dunn, Kingham et al. 2001, or Mohan 2001). United States journals such as *Health Affairs*, and *Health Services Research* have published results for large research projects, and further work is underway at agencies such as the Agency on Health Care Research and Quality. Much of this research focuses on access to care for particular groups, including women and children, those on low incomes and groups from various ethnic backgrounds. European journals such as *Social Science and Medicine* and its recent offshoot, *Health and Place*, also demonstrate a concern with differences in access and utilisation. Yet, Rogers, Hassell et al. (1999) argue that there has been very little development of the concept of access in the United Kingdom, as is the case for New Zealand.

A substantial international literature establishes frameworks for analysing access (Donabedian 1971; Andersen and Newman 1973; Aday and Andersen 1974; Penchansky and Thomas 1981; Hongvivatana 1984; Phillips, Morrison et al. 1998; Goddard and Smith 2001). Aday and Andersen (1974), key contributors to this literature, distinguish between ‘potential access’ and ‘realised access’. Potential access, here access, refers to the opportunity to enter the health system, that is, the availability of services. Realised access focuses on the relationship between service availability and the people who may avail themselves of services. Realised access is experienced at an individual level, but reflects a relationship between a number of factors including health policy, individual and population characteristics, and delivery systems. Health policy affects financing and organisation as in the Aday (1974) model; information as in the Goddard and Smith (2001) model, and regulation, for example, mandated benefits in the United States, or government requirements of DHBs and primary care providers in New Zealand (Aday and Andersen 1974; Goddard and Smith 2001).

Measurement of access remains difficult. In practice, much attention is paid to the utilisation of health care services, as a proxy measure of realised access. Realised access can be observed through both objective (utilisation) and subjective (satisfaction) measures (Aday and Andersen 1981). Using empirical measures of access researchers have identified factors affecting realised access and estimated the strength of links between these factors and realised access. Penchansky and Thomas' (1981) model describes five dimensions of access – availability, accessibility, accommodation, acceptability and affordability – as 'the degree of "fit" between the clients and the system'. Regression analysis suggested these dimensions and their related measures were generally valid. The measure of the five dimensions can be closely tied to spatial distributions and linked with demographic information (Ricketts, Savitz et al. 1994: 94). This makes them useful economic and geographic tools.

Other researchers, drawing on a range of concepts and approaches, have focused on particular dimensions of access, such as accessibility and affordability. Much United States research looks at links between insurance coverage and access to care, examining relationships between insurance coverage, access and health, by illness or procedure and by age, sex and ethnic group (Davis and Reynolds 1976; Office of Technology Assessment 1992). The Institute of Medicine's (1993) study showed that utilisation of some services varied significantly by insurance coverage, ethnic and income groups, for example, lower proportions of women never having had a clinical breast exam for certain ethnic groups; lower rates of referral-sensitive surgeries for people with lower incomes for some services (Milman 1993). In other services there were few differences in access, for example. similar rates of use across income groups for referral-sensitive surgeries such as hip/ joint replacement or pacemaker insertions, indicating realised access may differ across conditions.

Small area variations (SAV) studies are another sub-discipline, and explain some variation in hospital utilisation through variations in medical practice. SAV researchers in the United States have argued that observed geographic variations for similar populations are related to differences in physician practice styles (Wennberg and Gittelsohn 1982; Cangialose 1993). Wennberg and Gittelsohn (1973) reported that surgery rates for a number of procedures across small areas varied by a factor of three. A later study (Wennberg and Gittelsohn 1982), examining surgery rates in three states, identified a five-fold variation in tonsillectomy and hysterectomy rates. Roos, Wennberg et al. (1988) defines discretionary decisions as "decisions made with uncertainty" relating to clinical outcomes or the appropriate course of care. They classify hospitalisations according to an index of discretion. Roos, Wennberg et al. (1988) concludes that natural variation explains variation in surgery rates for low discretion conditions, such as hip fractures or major bowel surgery, but that patient and provider decisions are comparatively important dynamic in explaining variation in surgery rates for high discretion conditions, such as laparoscopic tubal interruption or dental extractions.

SAV conclusions are disputed, however (Folland and Stano 1989; Ryan and Mooney 1991). Folland and Stano (1989) attribute variation to standard socio-economic factors, and to both community and provider variables. They argue variations in utilisation may be misattributed to physician discretion if variations in patient demand are not separated from provider factors. Paul-Shaheen et al (1987) also note the inconsistencies of the SAV literature, with regression models explaining more variation once both community and provider variables are included.

Goddard and Smith recently summarised United Kingdom research on equity of access finding some evidence of inequity in relation to particular secondary care services, even after allowing for need and socio-economic status (Goddard and Smith 1998; Goddard and Smith 2001). They found minority ethnic groups have low rates of elective surgery for coronary heart disease; women have fewer investigations and surgical interventions for coronary heart disease; and those living further away from location of care experience lower utilisation for some services. They found there is no evidence of systematic inequities in aggregate GP consultations, but an uneven distribution of GPs. They also found lower utilisation of preventive care in more deprived areas.

United States, United Kingdom and Canadian medical geographic studies have shown spatial dimensions to be significant determinants of realised access (Hopkins, Pye et al. 1968; Weiss 1971; Girt 1973; Shannon and Dever 1974; Joseph and Phillips 1984: 4; Ricketts, Savitz et al. 1994). These studies consistently demonstrate that distance acts as a deterrent to utilisation, although this effect can vary by condition (Mayer 1983). The contemporary medical geography approach, outlined by Phillips (1981), emphasises the role of health care delivery system factors influencing the efficiency and effectiveness of health care services. This approach is particularly relevant in its focus on the location, planning and utilisation of health care facilities.

Spatial access can refer to either physical distance or travel time (Knox 1978; Senior, New et al. 1993; Senior, New et al. 1993; Hyndman, D'Arcy et al. 1999). This can complicate the measurement and analysis of spatial dimensions of access as there is debate over which is a more meaningful indicator (Bosnac, Hyg et al. 1976). However, researchers overseas have found simpler straight-line distance measures to be highly correlated with travel times (Phibbs and Luft 1995). Some United Kingdom researchers argue that presently geographical information systems (GIS) approaches have “only been used in a limited way in the [British] health arena”, and they have significant potential for the analysis of access (Lovett 1992; Parker and Campbell 1998).

Health service utilisation research in New Zealand has generally used a mix of economic, socio-demographic and geographic approaches, and relied on administrative (claims-based) data sets and surveys. The aim has generally been to describe differences in the utilisation of primary, secondary and pharmaceutical services and identify the key barriers to access. New Zealand research has focused mainly on primary care, with little research into explaining variations in access, particularly for secondary care, between districts or over time.

New Zealand studies report variations in access to care by geographic region and major diagnostic category, by ethnicity, deprivation, socio-demographic variables and area. These studies suggest a number of factors may influence access. More deprived areas have been repeatedly shown to have higher discharge rates (National Advisory Committee on Core Health and Disability Services 1992; Ministry of Health 1999; Salmond and Crampton 2000; Reid, Robson et al. 2000)). Peacock, Devlin et al. (1998) estimated expenditure concentration curves to estimate inequalities in access to services.

Research has compared particular population groups, especially Mâori and non-Mâori. A number of studies have found differences in realised access between Mâori and non-Mâori for particular services (Pomare, Keefe-Ormsby et al. 1995). Salmond and Crampton (2000) found that at almost all deprivation levels, Mâori under 25 and those over 65 have lower rates of hospitalisations than Pâkeha and other ethnic groups, but between the ages of 25 and 64, Mâori have higher rates of hospitalisations within many deprivation deciles. We have seen no research that aimed to explain these variations empirically, although potential explanations include differences in need, cost, location, transport, attitudes of doctors, and cultural factors (Barnett 2000).

Research on access to GP services in New Zealand likely explains some variation in secondary care service utilisation and satisfaction. Research shows uneven distributions of GPs, and consequent uneven utilisation of GP services and expenditures. There is some suggestion that some people in lower socio-economic groups use GP services more, but not at the rates predicted by rates of mortality and morbidity (Davis 1985; Davis 1986; Davis 1986; Davis 1987; Davis 1987; Malcolm and Clayton 1988; Malcolm 1993; Malcolm 1996; Malcolm 1998). Economic models have been developed to identify factors affecting realised access to primary care in New Zealand. Changes in price have been found to lead to changes in utilisation of GP care, but studies controlling for other factors have inconsistent findings (Tilyard and Dovey 1991; Durie 2001; Davis, Gribben et al. 1994; O'Dea, Szeto et al. 1995). In one seemingly contradictory study, no statistically significant price effect was found even when people indicated that the doctor's fee stops them going to the doctor when they think they should (Gribben 1992). The research suggests people may substitute from primary care services to free secondary care services or delay using services until health status has significantly deteriorated, however, the relationship remains unclear.

Significant predictors of primary care utilisation in New Zealand studies include perceived health status, time with current doctor (a negative association) and waiting times; and community services card (CSC) status (Gribben 1992; Gribben 1996).[v] Gribben (1996) examined realised access in a multinomial logit model using Household Health Survey data, and found chronicity[vi] and being male were highly associated with a probability of making no visits to GPs. Chronicity, CSC status and being more than 15 minutes from a doctor were associated with one or more visits to GPs. Although these were statistically significant results, there is concern that these studies have little explanatory power (Gribben 1996; Kokaua and O'Dea 1996).

Few studies have attempted to link primary and secondary care use to utilisation comprehensively. Dovey, Tilyard et al. (1992) focuses on the effect of employment status and household composition on health care utilisation in a general practice. They found that larger families dependent on government benefits spent less on primary care than equivalent families where an adult was in paid employment, but secondary care, and hence overall, expenditure was higher.

[v] CSCs are age- and income-tested subsidy cards for primary health care services and pharmaceuticals. CSCs are described on the Work and Income NZ website, http://www.winz.govt.nz/.
[vi] Chronicity refers to the degree of persistence (or acuteness) of a condition.

Other studies have examined the supply of hospital services and the demand for private insurance in New Zealand as an influence on utilisation. Johnston and Lynn (2000) examined the most recent two years of national (including private) hospital discharge data currently available, 1994 and 1995. They found some overlap between public and private hospital services. Typically, complex services are provided through the public sector, with exceptions such as female sterilisations. Barnett (1984) reviewed secondary care resource allocation and hospital service planning, projecting the impacts of contemporary reforms on equity and access. A later study (Barnett 2000) documented national patterns of local hospital closures and commented on the impacts of hospital restructuring over time. This paper noted a reduction in public hospitals and an increase in private hospitals, although the latter provided a different mix of services than in public hospitals. The 1992 Core Services Review report observed, and viewed as inequitable, regional variations in hospital utilisation as a result of uneven distributions of public and private hospitals (National Advisory Committee on Core Health and Disability Services 1992). But, the effects of hospital supply and restructuring on potential and realised access have not been analysed.

Another strand of New Zealand health services research has focused on modelling service proximity. The Ministry of Health has measured geographic accessibility by travel times to services (Performance Management Unit 1998). (Brabyn and Skelly 2001) demonstrates a method for estimating the geographical accessibility of public hospitals, suggesting that improvements in GIS technology and lower data costs open new opportunities for modelling accessibility in New Zealand. (Brabyn and Skelly 2001) note travelling over windy, gravel roads takes longer that travelling on sealed urban roads. They suggest straight line distances may not be a good proxy for spatial access in New Zealand as one in seven New Zealanders live in rural areas where unsealed roads are more prevalent. This study showed that the northern and southern parts of New Zealand have high average travel times to hospital services. Increasingly sophisticated GIS accessibility models are being developed in New Zealand, but these have not been applied to our problem with the links between geographic access and utilisation remaining unclear.

Health status affects the demand for health services. There is little evidence on the health status of New Zealand communities by location. One exception is a survey by Midland Health (Wheadon and Kokaua 1994; Wheadon and Kokaua 1994).[vii] This study highlighted a number of factors correlated with health status and utilisation, age, ethnicity, socio-economic status, travel and waiting times. A second, New Zealand Health Survey, was a population survey of around 8,800 people including socio-demographic factors, utilisation of a wide range of services and behavioural factors such as reasons for not accessing care. These surveys, however, did not report health status by location so the geographic distribution of health status is unclear.

Most New Zealand studies rely on measures of service use and mortality rather than self-reported health status measures. (Ministry of Health 2000) reported on determinants of health

[vii] Midland Health was one of four Regional Health Authorities (RHAs).

including deprivation, income, income distribution, education, occupation, labour force status, and housing using health status proxies including mortality and health service utilisation. Recently, the Rural Health Survey found 4.5% of postal questionnaire respondents reported having needed healthcare services but had poor access (more than 60 minutes drive time) (Rural Women New Zealand 2001). While response rates were low, the Survey's results suggested "inadequate access" (poor access when in poor health) varied across rural electorates.

International and local research identify several important issues in the research of access and factors that may influence utilisation. The research suggests a number of frameworks for researching access. New Zealand research has addressed a range of access, equity and utilisation issues but a gap remains in bringing these strands of research together to explain the importance of factors affecting utilisation, particularly for secondary care services.

3 Study approach

Analysis of factors influencing access to address the research gap must draw primarily on economic and geographic approaches, including econometric methods to determine factors that explain variations in realised access. This initial study uses NMDS hospital discharge data as a proxy for realised access, and controls for some important demand-side factors. The conceptual framework is introduced below, and our method is described in section 5.

Insert 1 Access to New Zealand publicly funded secondary care – a brief overview

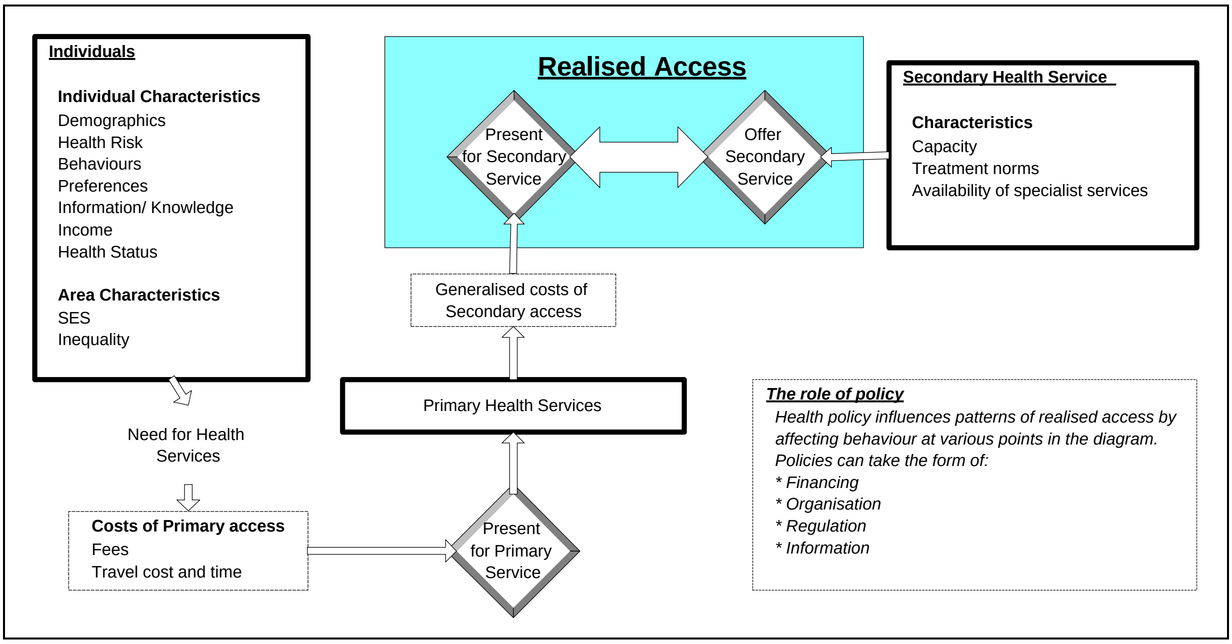
Access to secondary care services is mainly mediated through GP 'gatekeepers', with some hospitalisations due to Accident and Emergency visits and specialist referrals. Primary sector services generally have patient co-payments.

Once in the public secondary system patients face a zero co-payment at the point of use. Services are prioritised according to need and ability to benefit, given available public funding. They are often rationed by waiting lists so services are not immediately available to all who need them.

Private secondary care services may also be accessed on a user-pays basis. Charges are often paid in part of in full through private health insurance (72% of people admitted to a private hospital had health insurance, 1996/97 NZ Health Survey).

We have developed a model of access based on how patients move through the New Zealand health care system. Figure 1 illustrates key influences on realised access. This is an organising framework for our research. The shaded box in the top centre of the diagram represents realised access to secondary care – individuals present themselves for secondary care, and are offered care by a hospital. The surrounding boxes on the diagram indicate a range of demand (to the left of the diagram) and supply (to the right) factors reflected in realised access patterns.

Figure 1 Influences on realised access of secondary care



We relate utilisation to individual and population characteristics and system structures and processes. Supply and demand dimensions affecting 'the degree of "fit" between the clients and the system' (Penchansky and Thomas 1981). Supply reflects the capacity and costs involved in the production of health care, contributing to health outcomes. The demand for health care is a derived demand, stemming from individuals' desire for health (Grossman 1972) That is, health care is not ultimately a consumption good, but rather a step in 'producing' health. This approach highlights that a range of health care services may be used to secure health. It also emphasises the range of demand-side factors influencing a person's demand for health care, such as individual lifestyle behaviours, socio-economic status and health status, which researchers must account for.

The top left box lists individual and area (community) characteristics influencing an individual's perceived need for health care services. Whether that perceived need is translated into a demand for health care depends on the cost of access, financial and non-financial. Primary care mediates the demand for secondary services (Aday, Andersen et al. 1984; Shortell, Wickizer et al. 1984; Grant, Forrest et al. 1997), as primary care physicians may increase the demand for secondary services, by referring patients, or may decrease it, by offering substitute forms of care (Williams, Schwartz et al. 1983). Our framework, therefore, separates the decision to access primary health services and the decision to access secondary care. We also show the role of hospital-related supply factors in influencing access. For example, hospital capacity will affect the types of care offered and waiting times.

Reduced access influences individuals and the system in three measurable ways (Penchansky and Thomas 1981). First, utilisation of appropriate services will be lower, other things being equal. Second, people will be less satisfied with the system or services. Third, provider practice patterns may be affected, for example if their ability to deliver timely services is affected by resource or policy constraints. In relation to the first of these points, people with access problems may substitute towards more accessible but less appropriate health care services. That is, access problems may result in lower utilisation of appropriate services and higher utilisation of less appropriate services. Phelps and Mooney (1993) suggest substitution between various medical interventions as a possible explanation of regional variations in medical care use.

This approach combines economic and geographic techniques, within a New Zealand context, relating measurable individual, population and system factors to access. Studying patterns of utilisation in this manner can shed light on which dimensions of access may be important in explaining variations in access, such as socio-demography, geography or service organisation, and generating predictions which might highlight where inequities may exist

4 Data

The following section defines analytical expressions used in this paper and outlines our data sources.

4.1 Definitions

DRG (Diagnostic Related Group) codes categorise discharges based on the diagnosis made and procedures undertaken, for example asthma.[viii] MDCs (Major Diagnostic Categories) are an aggregated class consisting of several DRGs grouped on the basis of major organ systems, for example respiratory system. Discharge records include anonymised patient identifiers, based on the National Health Index (NHI). A discharge record may included multiple DRGs; we use the primary DRG for each discharge in this study.

Discharge rates and discharge incidence rates are two measures of hospital utilisation. We define **discharge rate (DR)** as the number of discharges, that is visits to hospital for in-patient treatment, per population group. The **discharge incidence rate (DIR)** is number of people who had at least one discharge per population group. If an individual has multiple discharges, the DIR will be lower than the DR. These two measures can highlight different barrier to access. Discharge incidence reflects whether someone gets in the hospital door. Discharge rate reflects whether, once in the system, people are able to equally access a range of services (reflected by multiple discharges).

DHB boundaries are defined in the New Zealand Public Health and Disability Act (2000), and are based on territorial authority and ward boundaries. Typically, they reflect Crown Health Enterprise boundaries and their associated hospital catchments. Cross-boundary flows are included in the dataset as discharges are recorded according to DHB of residence.

Census area units (CAUs) are unique geographic areas defined by Statistics New Zealand equivalent to a suburb. There were 1766 CAUs in New Zealand in 1996 each containing around 3-5000 people.

Straight-line distance (SLD) is used as a measure of hospital proximity.

4.2 Data Sources

In order to relate discharges, local population characteristics and hospital proximity we combine data from three sources.

Our first key dataset is the NMDS (National Minimum Data Set). NMDS records summary information for all public hospital discharges, and is held by NZHIS. This dataset includes age, gender and ethnicity data. We analysed discharge data for 1996, which are geo-coded according to 1991 CAU boundaries. Data were filtered for national coding consistency according to the Ministry of Health (2000)’s Hospital Throughput report. MDCs for Newborn

[viii] Coded using the Australian National Diagnosis Related Groups, version 3.1

and other neonates, Mental diseases and disorders, Alcohol/drug use and alcohol/drug induced organic mental conditions, and generic error DRGs[ix] were excluded due to concerns about coding consistency expressed by NZHIS.

Our second major dataset is 1996 Census data, supplied by Statistics NZ. The Census of Population and Dwellings is a 5-yearly population surveys that take a snapshot of population and dwelling characteristics. Information used from the Census includes socio-demographic, geographic distribution and economic factors.

Ethnicity data in these two datasets is not entirely reliable. NMDS ethnicity coding procedures may differ between hospitals and it is unclear how ethnicity is determined (Pomare, Keefe-Ormsby et al. 1995). Ethnicity data collected by different censuses is also problematic for inter-census comparisons, although this is not a significant issue for this initial analysis. Reported ethnicity statistics should be read in light of the above concerns.

Our third dataset is a hospital position dataset complied by the Public Health Intelligence, Public Health Directorate, Ministry of Health as part of a larger programme of research on geographic access to healthcare services.

5 Methods

In order to begin learning about the demand and supply factors that influence accessibility, we examine the correlates of “realised access” in the form of discharge rates. The two main challenges for our research are first, to derive sound estimates of key empirical relationships, using limited available data; and second, to ascertain the empirical significance and impact of a range of potentially confounding effects. In this paper we get initial indications first, by a descriptive analysis and second, by regression analysis.

Geo-coded NMDS and Census data were linked by 1996 CAUs. Patients in the hospital discharge dataset can be located to a 1991 CAU, therefore individuals who could be identified at CAU level were matched to 1996 CAUs. Differences between 1991 and 1996 CAU boundaries meant 16,391 records could not be matched as some individuals could not be identified at CAU level. Descriptive statistics on discharges are presented in section 6.

Discharge and census data were linked to hospital proximity data that uses SLDs (straight line distances). SLDs were calculated in this study as the straight-line distance from a CAU centroid to the hospital nearest a patient’s residence. The centroid position was weighted by where the population within a CAU lives (using underlying meshblock population data).[x] This calculation overestimates access as not all operations are available at the nearest hospital. SLDs were not calculated to the hospital treatment was received at as hospital identifier data is currently not routinely available from NZHIS. It might be argued, however, that access to a

[ix] DRGs 950, 952, 953, 954 and 956.

[x] Meshblock boundaries define 18,800 small geographic areas in New Zealand. These areas are equivalent to city blocks, containing between 50 and 100 dwellings, with an average size of about 65 dwellings. http://www.stats.govt.nz/.

secondary service is an important precursor to referral and as such acts as a proxy suitable, although not best, for the current analysis.

The first method in this preliminary analysis describes raw relationships without imposing any modelling structures on the data. We calculate simple descriptive statistics such as distributions by MDC, DHB and sub-population groups. These statistics are not adjusted for any population characteristics, such as gender, age, or ethnicity. We adjust for population composition using regression analysis, described below.

We use two regression analysis techniques to examine the relationship between utilisation and distance, controlling for important population composition characteristics. The second method of analysis is an ordinary least squares (OLS) regression of aggregated discharges on distance, people in close proximity (within 15km) to a hospital and all distances.[xi] The danger with a linear regression model is that it simply fits a straight line and can, therefore, predict discharge rates below zero or greater than 1. Negative rates are meaningless and rates greater than 1 are only applicable to discharge rates where it is possible to have multiple discharges by individuals.

The third method of analysis, multinomial logistic regression (MLR), addresses the issue of modelling rates. Logistic regression has the advantage of producing sensible results (rates between 0 and 1), but the disadvantage of only being able to analyse discharge incidence rates (DIR), as discharge rates can be greater than 1. In this stage we take into consideration the impacts of differences between population groups or places (for example, Auckland and Canterbury) on the relationship between utilisation and distance. We test whether any relationship found between discharge incidence and distance is due to the distribution of different population groups rather than distance.

We identify raw relationship patterns in the data with our first method. OLS regression is used to examine the strength of the relationship between distance and discharge rates or discharge incidence rates, controlling for a wide range of possible confounders. The third method, MLR demonstrates a better fitting model than OLS for estimating the relationship between distance and discharge incidence rates.

[xi] An error-adjusted OLS model was also used to account for different levels of data observation (individual level for discharges and CAU level for distance). This model is not reported in our initial analysis.

6 Analysis of variations in realised access

Common descriptive statistics and diagrams are presented below to highlight raw relationships in the linked aggregate discharge data.

Table 1 Descriptive statistics[xii]

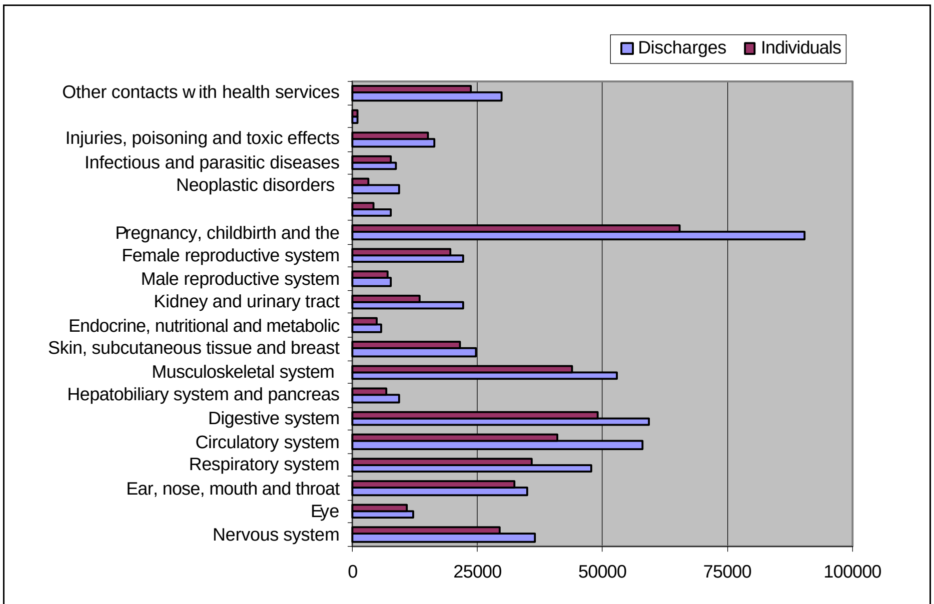
	NMDS, 1996 (matched records)[xiii]
Discharge records	539,443
Number of individuals	381,240
National discharge rate (DR)	15.4%
Discharge incidence rate (DIR)	10.4%

The DR is higher than the DIR indicating multiple admissions.

6.1 By MDC Group

Figure 2 displays the distribution of discharges and individuals by MDC treatment group.

Figure 2 Distribution of discharges across MDC groups

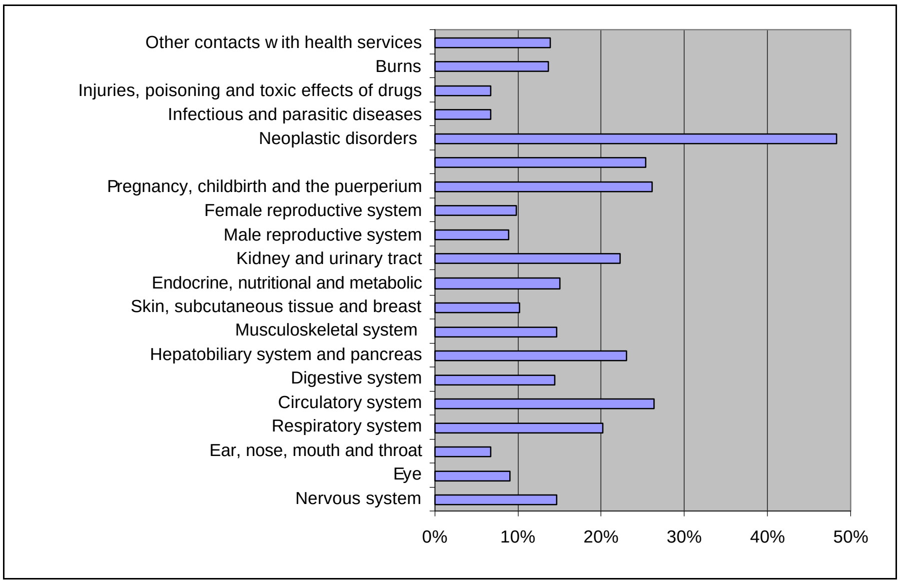


Over 55% of discharges are accounted for by 5 MDC categories. These MDC categories are (in descending order): Pregnancy, childbirth and the puerperium, Digestive system, Circulatory system, Musculoskeletal system and Respiratory system. The concentration is lower for individuals; 45% of people received at least one treatment within the top five MDCs, reflecting a high number of multiple discharges for the top five MDCs.

[xii] Definitions of these statistics are given in section 4.1.
[xiii] Due to mis-matching between 1991 and 1996 CAUs 16,391 records were excluded. Matched records are used for all further analysis.

Figure 3 shows the percentage of people who receive more than one treatment varies across MDC categories. Neoplastic disorders, Blood, Pregnancy, Kidney and hepatobillary system and pancreas treatment groups have 20% of individuals receiving more than one treatment within 1996. The Neoplastic disorders MDC is the highest with nearly 50% of individuals receiving more than one treatment. Across all MDC groups 72% of individuals only visit the hospital once for (any) in-patient treatment and only 1% of patients go more than 5 times during 1996.

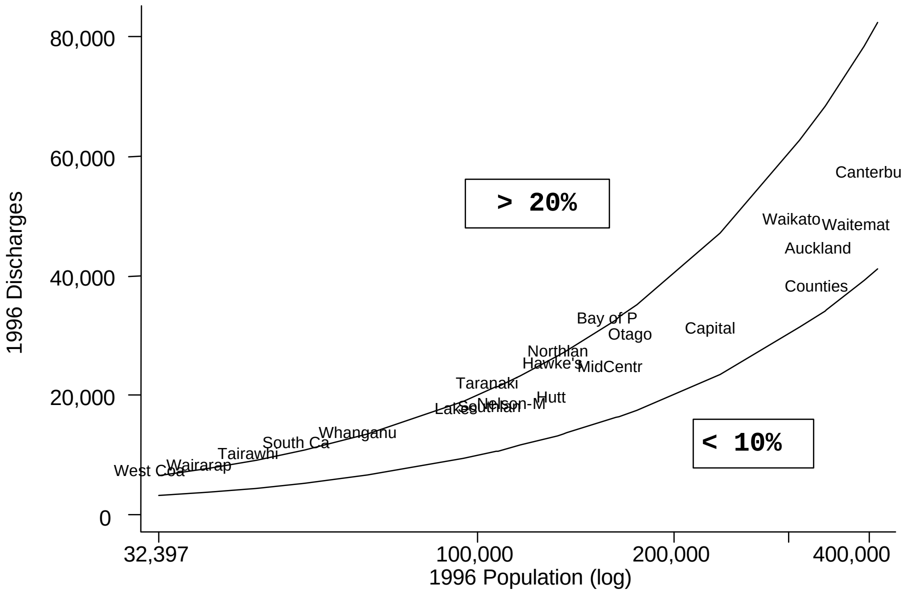
Figure 3 Proportion of individuals who receive more than one treatment by MDC



6.2 By DHB

DHBs are based on administrative boundaries, and DHB-based analytical results can readily inform policy. DHBs are used here to examine geographic variation in utilisation. Figure 4 plots the number of discharges against population within each DHB. Not surprisingly the larger the population within a DHB the greater the number of discharges recorded. The area between the two curves represents discharge rates of between 10 and 20%. The lower curve represents a discharge rate of 10% and the upper curve 20%. DHBs with small populations line up along the 20% discharge rate curve. As DHB population sizes increase, DHBs drift towards the 10% discharge rate curve. This indicates that DHBs with large populations have lower discharge rates than DHBs with small populations. The same pattern is observed when comparing discharge incidence rates across DHBs.

Figure 4 Discharges by DHB



6.3 *By Population Group*

Table 2 presents discharge rates across different population groups. Females have higher discharge rates than males, but once discharges related to pregnancy are removed the discharge rate for women drops to 12.4% (0.1% lower than males). Pâkeha have the highest proportion of discharges and incidence followed by Mâori and Pacific Peoples.

Table 2 Discharge rate and incidence rates across different population groups.

	Population	Discharges	Individuals	DR	DIR	Average No. of Discharges
Males	1777668	222223	154627	12.5%	8.7%	1.4
Female	1841073	317220	226613	17.2%	12.3%	1.4
Female	1841073	228226	163752	12.4%	8.9%	1.4
	2595021	390574	257866	15.1%	9.9%	1.5
	523482	76247	50071	14.1%	9.6%	1.5
Pacific	172962	22863	16325	13.2%	9.4%	1.4
Asian	160851	9872	7323	6.1%	4.6%	1.3
Not Known	167184	56278	44614	26.7%	33.7%	1.3
0-9 yrs	568131	69056	54026	12.2%	9.5%	1.3
10-19 yrs	527187	38679	30595	7.3%	5.8%	1.3
20-29 yrs	544968	86041	64568	15.8%	11.8%	1.3
30-39 yrs	578802	77470	58918	13.4%	10.2%	1.3
40-49 yrs	495996	43472	31882	8.8%	6.4%	1.4
50-59 yrs	345648	43943	29449	12.7%	8.5%	1.5
60-69 yrs	268158	59550	37189	22.2%	13.9%	1.6
70-79 yrs	195933	70110	43181	35.8%	22.0%	1.6
80 yrs +	93918	51122	31432	54.4%	33.5%	1.6
Total	3618741	539443	381240	15.4%	10.4%	1.4

Discharge and discharge incidence rates exhibit similar patterns across the population groups. Pâkeha have the highest discharge rates. Of the four ethnic groups reported the Asian ethnic group have the lowest discharge rates. Once pregnancy related discharges are removed, females have discharge rates very similar to males. A higher proportion of women visited the hospital for in-patient treatment than men in 1996, whereas men, on average, made more trips to the hospital than women for treatment.

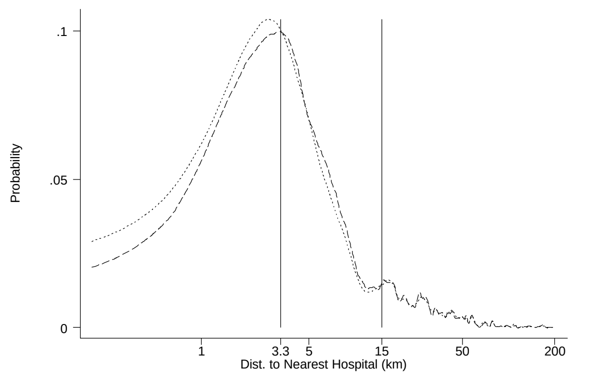
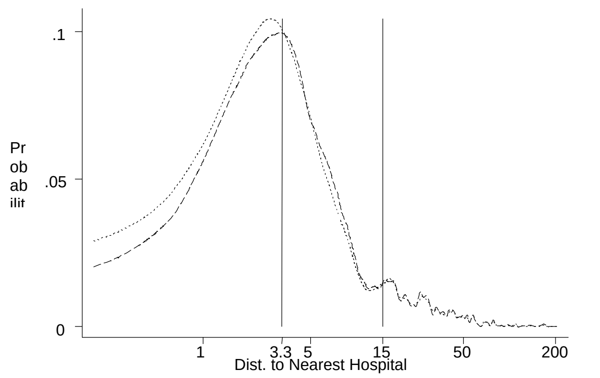
6.4 By Distance from Nearest Hospital

We hypothesise that utilisation decreases with distance. We have used CAU discharge/ incidence rates and SLDs to measure utilisation and proximity.

The distribution of discharges and population in relation to hospitals is shown in Figure 5. The vertical axis displays the probability of a person or discharge occurring at increasing distances from hospitals (.1 = 10%). The area under each curve sums to 100% of the respective group. Because hospitals are located in high population centres most of the population, and therefore discharges, occur close to hospitals. For example, 45% of discharges occur within 5kms of a hospital (dotted line), compared with 42% of the population (dashed line).

Discharges are proportionately larger than the population within 3.3 km of hospitals. This trend is reversed between 3.3 km and 15 km. The distributions remain close together, but become erratic after 15 km.

Figure 5 Probability distribution of Discharges and Population from Hospitals

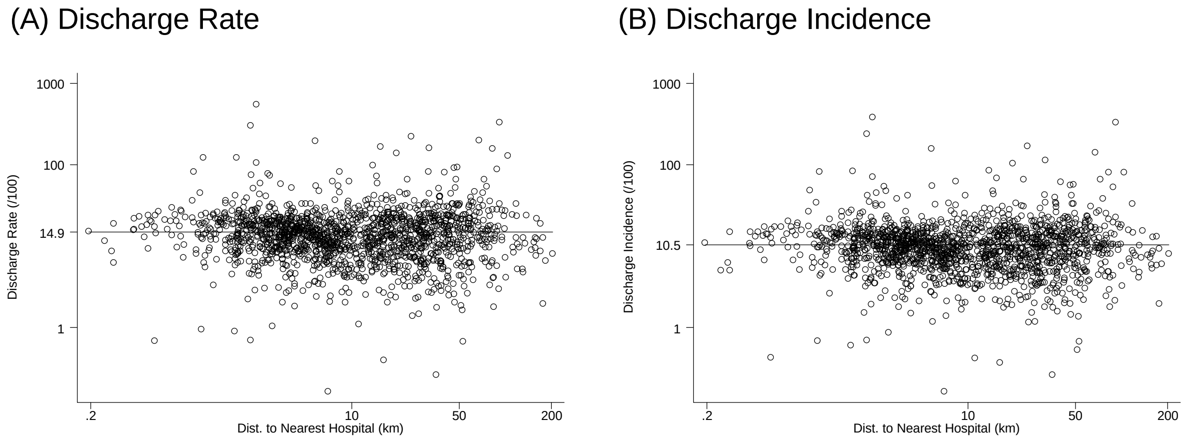
(A) Discharge	(B) Discharge Incidence
	

Note: The dotted line represents discharges and the dashed line population. A log scale is used.

Figure 5 suggests that there is a slight bunching of discharges and discharge incidences around hospitals compared with the population (0-3.3km). For distances greater than 15km it is unclear how the discharge rate behaves (69% of the population live within 15km of a hospital).

Figure 6 explores the relationship between discharge rate (A) / discharge incidence rate (B) and distance from nearest hospital at the CAU level.

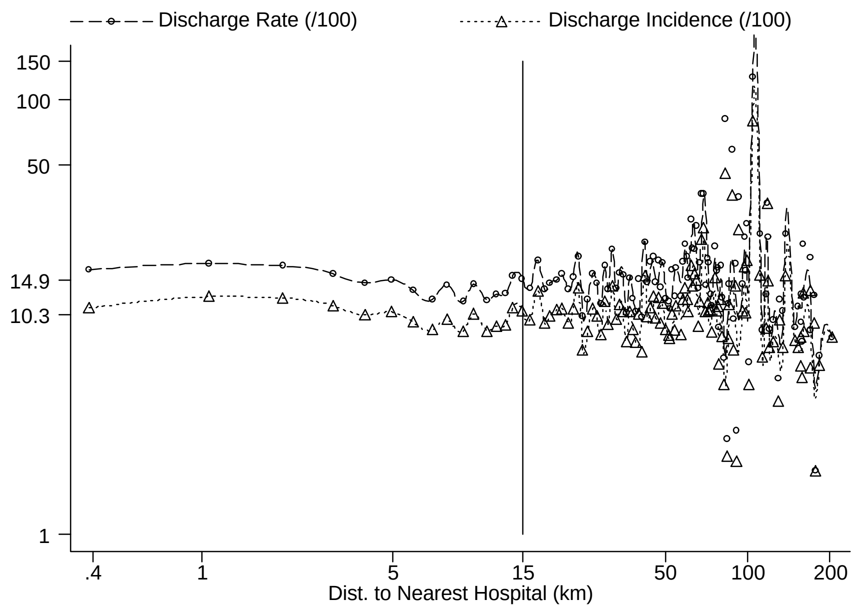
Figure 6 Discharge Rate and Incidence against distance from nearest hospital



Note: Both axes use logged variables.

Both discharge rate and incidence display flat relationships with distance from nearest hospital. The two distributions are very similar, but discharge rate is a greater magnitude (due to multiple discharges). The raw CAU discharge data used in Figure 6 do not show a clear picture between discharges and distance. Figure 7 presents a cleaner picture by aggregating discharges into 1km bands from nearest hospital.

Figure 7 Discharge rate and Incidence (1km bands) against distance



Note Both axes use logged variables.

The behaviour of the discharge rate (dashed line) and incidence rate (dotted line) in Figure 7 is very similar. As already shown in Figure 6, discharge rates are higher than discharge incidence rates. Both rates decrease to around 15km, suggesting a negative relationship between discharge rate and distance from nearest hospitals. There appears to be a slight increase from 15km, however, the relationship is not clear at greater distances.

6.5 Explaining the relationship between distance and utilisation

While simple descriptive analysis can suggest key patterns, it cannot explain whether these patterns are significant. Our second approach uses a linear regression to explain variations in utilisation. First, we use an OLS method to test the simple relationship between CAU discharge and incidence rates for distances less than 15km and for all distances. Table 3 contains the results from the OLS models. The relationship between discharge rate and incidence was tested for all CAUs (Model 1) and CAUs within 15km of a hospital (Model 2).

Table 3 AU discharge rate/incidence against distance from hospital (OLS)

	(A) Discharge Rate (/100)		(B) Discharge Incidence (/100)	
	Model 1	Model 2	Model 1	Model 2
All Distances (km)	.003 (.014)		-.005 (.009)	
Distance ≤15km		-.355 (.002)***		-.234 (.081)***
Constant	14.851	16.683	10.616	11.784
R^2	-.0006	.0088	-.0004	.0075
Observations	1607	959	1607	959

Note: Standard errors are in parentheses.

**** significant at 1%, ** significant at 5%, * significant at 10%*

Both discharge and incidence rates display similar results from the OLS modelling. For all CAUs the relationship between unit (km) changes in distance and discharge rate and discharge incidence rate is not significant, as suggested in Figure 6. A negative and significant relationship is found for CAUs less than 15km from nearest hospital, seen in Figure 7, but the model explains little of the variation in discharge rate and incidence (indicated by the small R^2 values).[xiv]

6.6 Impacts of population composition

Discharge incidence is not uniform across population groups (see Table 2) or places (see Figure 4). Below we analyse the impacts of population composition on the relationship between distance and utilisation using a second regression technique: logistic regression.[xv] We control for population differences using sex, age group and ethnicity dummy variables and allow for places to be different using DHB dummy variables. As noted above in section 5, we do not analyse discharge rates using a logit model. However, the analysis does not suggest a great difference between the behaviour of the two discharge measures and their relationship with distance.

[xiv] OLS models 1 and 2 assume that a unit (1km) increase in distance will have the same effect on discharge rates irrespective of whether the change in distance occurs at 10km or 100km. The effect of a percentage change in distance, rather than a unit change, was examined by transforming distance to nearest hospital (LHS variable) and discharge rate/ and incidence (RHS variable) using natural logs. Log distance assumes that a 1% increase in distance at 10km (.1km increase) has the same effect on discharge rates as a 1% increase in distance at 100km (1km increase). Transforming the variables gave a better fitting model, but did not change the underlying relationship, indicating the results are robust to the functional form used.

Table 4 reproduces the results from the (OLS) model 1 in Table 3B and reports the logit models which were run using all CAUs. The first logit model, model 1, includes only distance as an explanatory variable. Model 2 adds demographic dummy variables and model 3 includes area-based DHB dummy variables.[xvi] The relationship between discharge incidence and distance is slightly stronger (-0.01), but of a similar magnitude to the coefficient reported in Table 3B (-0.005). However, the relationship reported by the logit models 1 and 3 remains significant, compared with insignificant relationship reported by the OLS models in Table 3.

Table 4 Discharge Incidence and distance

Discharge Incidence Rate (/100)	OLS (DIR)	Logistic Regression (DIR)		
	Model 1	Model 1	Model 2	Model 3
All Distances (km)	-.005 (.009)	-.010 (.001)***	.002 (.002)	-.010 (.002)***
Demographics			√	√
DHBs				√
Constant	10.616			
Adj. R^2	-.0004	.000	.087	.091
Observations	1607	3655499	3655499	3655499

Note: Standard errors are in parentheses.
**** significant at 1%, ** significant at 5%, * significant at 10%*

As individual characteristics and distance are observed at different levels there is a possibility that the logit model may understate the amount of error associated with the distance coefficient.[xvii] When we control for demographics in model 2 the relationship becomes positive and weaker, with a coefficient of .002. However, distance redisplays a negative relationship (-.01) with discharge incidence when we control for demographics and DHBs in model 3.

Of the three types of variables on the right hand side of model 3, demographic characteristics explains more variation (.087) than distance and location (.004). When we control for population and place effects the negative relationship still holds with distance, however, it is not very strong. A 10km increase in distance from hospital results in a 0.1% decrease in discharge rate.

On average Pâkeha made more visits to a hospital in 1996 than Mâori, Pacific Island Peoples or Asians (see Table 2). The logit model 3 in Table 6 shows higher discharge incidence rates for Mâori and Pacific Island Peoples, 11.4% and 12.8% respectively, once we control for the impact of demographics and location.[xviii] The discharge incidence rate for Asians is still less than Pâkeha but the difference between the two groups reduces once we remove the demographic and location influences.

[xv] Logistic regression models the probability of an event (here, a discharge) occurring as a function of RHS variables (here distance and/ or population composition characteristics).
[xvi] Appendix 1 has summary statistics for the logistic regression and Appendix 2 has the logit model coefficients (reported as marginal effects of the RHS variables on the probability of a discharge incidence).
[xvii] This issue is discussed in Appendix 3.
[xviii] Marginal effect coefficients are calculated using the mean discharge incidence rate of 10.4%. These are reported in Appendix 2.

The logit model suggests that a patient's probability of visiting the hospital for treatment is determined by their sex, age, ethnic group, what part of the country they live in and how far they live from the hospital. For example, on average Mâori are .9% more likely to visit a hospital for treatment compared with Pâkeha whether they live in Northland or Canterbury. People living in Northland are 3.9% more likely to go to hospital compared with their counterparts living in the Canterbury DHB, irrespective of whether they are Mâori or of Pâkeha ethnicity. However these factors explain little overall variation in utilisation.

There is little change between discharge incidence rates for DHBs even when controlling for population characteristics. Most DHBs' discharge incidence rates change by about half a percent when controlling for population characteristics, however, the difference between incidence rates between Canterbury and the Bay of Plenty's decreases by 1%, whereas the difference between Canterbury's and Southland's incidence increases by 1% when controlling for population characteristics.

Figure 4 showed that discharge incidence rates do vary across DHBs, with the metropolitan DHBs reporting lower incidence rates than the rural DHBs, which have smaller populations. The logit model confirms this in maintaining the ranking of DHBs, but the difference between DHB discharge incidence rates becoming slightly less.

7 Discussion

This paper describes a conceptual framework for access in New Zealand's health system and demonstrates a method for explaining geographic variations in utilisation. The study uses the method to examine the relationship between secondary care utilisation and distance.

The first goal involved developing a conceptual model of access that is relevant to the New Zealand health system to guide research addressing identified research gaps. In section 2 we identified a number of ways of thinking about access and some of the significant issues surrounding the study of access presented in the literature. Researching access is complex as access involves a number of dimensions, can refer to a number of different situations and can be measured in a variety of ways. The conceptual framework outlined in section 2 guides our research and highlights dimensions of access that may be observed.

This section also identified gaps in contemporary research. New Zealand research has previously examined access to primary care focusing on particular services, population groups or dimensions of access, such as affordability. Little evidence exists which can explain variations in access to secondary care for different population groups, areas or across time. Geographic access is a key goal of the current government but there is little evidence about the factors affecting it. This initial analysis focused on one aspect of access to New Zealand's public health system, geographic access to secondary care services.

The second goal was methodological. Drawing on economic and geographic approaches we wanted to establish the importance of individual, population and system factors affecting access, while statistically controlling for a range of factors that may cloud the relationships. We demonstrated that it is feasible to link up national datasets to examine the relationships between secondary care utilisation, patient demographic profiles, proximity and population distribution. This approach can be used to examine a fuller range of access dimensions and to make comparisons across a range of services, population groups and time.

The third goal was to test the feasibility of this methodology using a simple hypothesis on the relationship between distance and access. We began by describing patterns of utilisation by MDC group, DHB, population group and distance. Simple descriptive patterns, however, are not sufficient to explain the significance of the patterns. A major advantage in our approach is that regression techniques can be used to investigate the significance of the patterns observed. This allows us to control for a wider range of possible confounders than has occurred to date, such as patient and location, using DHBs as proxies, to give sounder explanations of the roles of different factors affecting access. These explanations can contribute to understanding why access problems exist and may contribute to reducing access inequities.

First, the results suggest no general relationship between utilisation and distance. We found utilisation did decrease with distance below a 15km threshold. However, the relationship was weak with distance explaining very little variation in utilisation patterns. These results are unsurprising as during this initial stage of research the method used a simple, aggregate discharge dataset treating all conditions as having the same relationship with distance.[xix] While we have methodological concerns about the meaningfulness of this result, it raises questions about the burden of cost to people living in different locations. That is to say, people living in different places may incur unequal personal financial and non-financial costs when seeking secondary care, such as travel time or time off work.

Second, we found that DHBs with small populations, which are generally rural, had higher discharge rates than DHBs with large populations. One reason that may explain this observation is that they are more likely to admit a patient overnight due to the greater travel distance. Future work could examine outpatient and inpatient admission rates for rural and urban populations.

Third, ordinary least squares (OLS) regressions suggested that aggregate discharge rates and discharge incidence rates behave in a similar manner. Discharge rates, however, bunch around 0 and 1 so a simple straight line may not clearly capture the relationships. A second technique, logistic regression, was expected to better fit the data. The techniques gave similar estimates of the relationship between utilisation and distance, and as expected the logistic regression gave more sound estimates.

In this preliminary study we used a simple measure of proximity. Advances in GIS methodology and technical capabilities allow increasingly sophisticated use of data sources and appropriate measures of travel time and distance. The analysis can also be extended by using alternative geographic boundaries and provider locations. For example, incorporating a dataset on GP locations would allow the analysis to control for distance to a GP. Recently the Ministry of Health has developed spatial models with application to health services. The first model of a planned series by Brabyn and Skelly (2001) used New Zealand data to construct estimates of distance and time of travel to the nearest hospital. We understand provider location datasets for GPs and other practitioners are being developed.

Our conceptual framework suggests that utilisation will be affected by individual factors, such as health status and income, area characteristics such as socio-economic status and inequality, and system factors such as the location of primary health services and the availability of hospital services. The literature suggests health status, in particular, is an important factor influencing the use of health services. Including health status in the analysis is a primary goal for future work. However, the datasets used for this analysis do not contain a number of these factors so their impact on utilisation cannot be directly analysed. But as access is multi-dimensional and it is important to control for demand- and supply-side factors that confound the analysis of secondary care access. Data on these factors may be available from alternate utilisation datasets that include important information, such as health status, demographics and economic statistics. For example, the New Zealand Health Survey is a national sample and includes socio-demographic, economic information and, importantly, health status.

[xix] Analysis distinguishing between conditions is feasible using the approach outlined in this paper.

Our framework suggests one way to improve geographic accessibility to secondary services is to make a patient's passage through the health system easier by, for example, making services more readily available or accommodating. However, patients may make service use easier by choosing to live close to a hospital. This may explain the result observed in Figure 5, where a disproportionately large number of discharges occur within 3.3km of a hospital given the population. That is, people with high demands for secondary care may chose to live close to a hospital, reducing the spatial barrier to using a service. Our approach may be used to address the question of whether people with high demands do live closer to hospitals than people with low demands. Similarly, we might analyse the erratic relationship observed between distance and utilisation observed above 15km. This may relate to the structure of New Zealand cities, where 15km may represent an urban–rural boundary effect.

Variation in hospital service location can be used to address the question of whether modifying hospital location affects utilisation and health status. Such an analysis could, for example, take advantage of the variations in hospital proximity provided by hospital restructuring over time, and the introduction of mobile surgery units. Further, in our initial investigation hospital proximity is the primary supply constraint. More sophisticated analyses might take into account, for example, primary and secondary workforce availability, service availability at different hospitals, and hospital capacity (public and private).

Another limitation in this study is that by examining all discharges we impose the same relationship between distance and utilisation for different conditions. We plan to extend this work by analysing the relationship between distance and particular MDCs, or DRGs, which may reveal more distinct relationships. Similarly, the current study controls for particular characteristics such as ethnicity and location, but does not investigate the relationships between these factors and distance. Such analyses may produce information to inform access policies for Mâori health, rural populations and other priority areas. We may also analyse the impacts of the institutional organisation of services on geographic access by incorporating local variations in the range and types of health care that DHBs choose to purchase.

The project presented here is part of a planned programme of research. In the first stage we identified gaps in the New Zealand research, developed a conceptual framework of relevance to New Zealand and tested a methodology to explain geographic access to secondary healthcare. A second goal of the programme is to more consistently research access over time. Third, we want to focus on a wide range of services, for example primary care or pharmaceuticals, to understand the impact of different services on healthcare access. Fourth, by analysing the impacts of DHB reforms we can shed light on the influence of governance factors on access. Fifth, linking variations in access to variations in health outcomes, including further research into appropriateness of care, will allow us to estimate the contribution of healthcare access to the overall health and well-being of the New Zealand population.

Glossary of abbreviations

CAU	Census area unit
DHB	District Health Board
DR	Discharge rate
DIR	Discharge incidence rate
GIS	Geographic information systems
NMDS	National Minimum Data Set
NZHIS	New Zealand Health Information Service, Ministry of Health
SAV	Small area variations

Appendix 1 Logit Regression Variables

Table 5 Logit Regression Summary Statistics

Variable	Observations	Weight	Mean	Std. Dev	Min	Max
Discharge Incidence Rate	159398	3655499	0.104	0.306	0	1
Distance	159398	3655499	15.399	20.944	0.193	203.944
Male						
Female	159398	3655499	0.509	0.500	0	1
Māori	159398	3655499	0.144	0.351	0	1
PI	159398	3655499	0.048	0.213	0	1
Asian	159398	3655499	0.044	0.205	0	1
Other	159398	3655499	0.012	0.108	0	1
Not known	159398	3655499	0.042	0.201	0	1
0-9	159398	3655499	0.156	0.363	0	1
10-19	159398	3655499	0.145	0.352	0	1
20-29						
30-39	159398	3655499	0.160	0.366	0	1
40-49	159398	3655499	0.137	0.343	0	1
50-59	159398	3655499	0.096	0.294	0	1
60-69	159398	3655499	0.075	0.263	0	1
70-79	159398	3655499	0.055	0.228	0	1
80 +	159398	3655499	0.027	0.162	0	1
Northland	159398	3655499	0.038	0.191	0	1
Waitemata	159398	3655499	0.109	0.311	0	1
Auckland	159398	3655499	0.094	0.292	0	1
C. Manukau	159398	3655499	0.094	0.292	0	1
Waikato	159398	3655499	0.086	0.281	0	1
Bay of Plenty	159398	3655499	0.046	0.210	0	1
Lakes	159398	3655499	0.026	0.160	0	1
Tairawhiti	159398	3655499	0.013	0.112	0	1
Taranaki	159398	3655499	0.030	0.170	0	1
Whanganui	159398	3655499	0.019	0.136	0	1
MidCentral	159398	3655499	0.045	0.208	0	1
Hawke’s Bay	159398	3655499	0.038	0.190	0	1
Wairarapa	159398	3655499	0.011	0.102	0	1
Hutt	159398	3655499	0.037	0.188	0	1
Capital & Coast	159398	3655499	0.065	0.247	0	1
Nelson-Marlb.	159398	3655499	0.032	0.177	0	1
West Coast	159398	3655499	0.009	0.094	0	1
Canterbury						
S. Canterbury	159398	3655499	0.015	0.121	0	1
Otago	159398	3655499	0.049	0.215	0	1
Southland	159398	3655499	0.030	0.170	0	1
Unknown DHB	159398	3655499	0.002	0.041	0	1

Appendix 2 Marginal Effects from Logit Model

The coefficients reported from the logit model (2-4) are marginal effects calculated at the mean discharge incidence rate (10.4%) for all CAUs.

On average Pâkeha made more visits to a hospital in 1996 compared with the other identified groups of Mâori, Pacific Island Peoples and Asians (see Table 2). Logit model 3 in Table 6 produces a different picture with Mâori and Pacific Island Peoples reporting higher discharge incidence rates compared with Pâkeha of 0.9% and 2.3% respectively. The discharge incidence rate for Asians is still less than Pâkeha but the difference between the two groups reduces once demographic and place based differences are controlled for.

Table 6 Marginal Effects from Logit Model

Variables	**Model 1**	**Model 2**	**Model 3**
Distance (km)	-.010 (.001)***	.002 (.002)	-.010 (.002)***
Female		2.8 (.1)	2.8 (.1)***
Male			
		1.3 (.1)***	.9 (.1)***
Pacific Peoples		1.0 (.1)***	2.3 (.2)***
Asian		-4.3 (.2)***	-3.7 (.2)***
Other		68.6 (.2)***	69.4 (.2)***
Not known		-3.5 (.2)***	-3.4 (.2)***
0-9 yrs		-1.9 (.1)***	-1.9 (.1)***
10-19 yrs		-5.2 (.1)***	-5.3 (.1)***
20-29 yrs			
30-39 yrs		-1.3 (.1)***	-1.4 (.1)***
40-49 yrs		-4.5 (.1)***	-4.6 (.1)***
50-59 yrs		-2.7 (.1)***	-2.8 (.1)
60-69 yrs		1.5 (.1)***	1.3 (.1)***
70-79 yrs		7.6 (.1)***	7.2 (.1)***
80 yrs +		16.1 (.1)***	15.6 (.2)***
Waitemata			-.6 (.1)***
Auckland			-.1 (.2)
C. Manukau			-1.1 (.2)***
Waikato			1.3 (.1)***
Bay of Plenty			3.2 (.2)***
Lakes			3.0 (.2)***
Tairawhiti			5.3 (.3)***
Taranaki			4.0 (.2)***
Whanganui			4.0 (.2)***
MidCentral			1.1 (.2)***
Hawke's Bay			2.5 (.2)***
Wairarapa			4.2 (.3)***

Hutt			1.4 (.2)***
Capital & Coast			-.8 (.02)***
Nelson-Marlb.			1.3 (.2)***
West Coast			4.3 (.3)***
Canterbury			
S. Canterbury			5.5 (.2)***
Otago			2.6 (.2)***
Southland			2.6 (.2)***
Unknown DHB			2.7 (.7)***
R-squared (pseudo)	.000	.087	.091
No. of Obs	3655499	3655499	3655499

Note: Standard errors are 0.000, unless indicated in round brackets.

Male, 20-29 and Canterbury were used as the base comparison group as they were the largest sample size in their respective categories.

The above coefficients have been multiplied by 100, as discharge incidence rates are measured between 0 and 100 in the linear regression model in Table 3, but between 0 and 1 in the logit analysis in Table 6.

Appendix 3 Understating standard errors on distance

The relationship between distance to nearest hospital and discharge incidence is observed at the CAU level. The unit of observation within the logit model is a population group, therefore, some population groups will have the same distance measure (because they are in the same CAU). This will lead to the logit model understating the amount of error on the relationship between distance to nearest hospital and discharge incidence due to multiple observations of a Area's distance measure. Put another way, the logit model sees the distance relationship repeatedly making it look artificially strong.

A two-stage process is used to better estimate the error associated with the relationship between distance and discharge incidence. The first stage uses a regression model to estimate how much of the variation in the discharge incidence rate is due to differences between population groups and DHBs. For each population group the regression model produces an error term, this can be interpreted as the amount of variation not explained by the regression model (demographic and DHB differences).

The first stage regression model standardised discharge incidence rates across population groups and DHBs, therefore, we can treat the population groups within each AU as a single group and examine how much of the remaining unexplained variation in discharge incidence is explained by how far an AU is from the nearest hospital. This is achieved by creating a single unexplained term for each AU by taking the average error term, weighted by the size of each population group. The error term, or unexplained variation in discharge incidence rate, is regressed on distance of AU to nearest hospital. The (adjusted) standard errors produced for the distance coefficient provide a more realistic estimation of the error associated with the predicted relationship between discharge incidence rate and distance to nearest hospital.

Table 7 reports coefficients for the error-adjusted OLS regression model using the two-stage estimation process outlined above. The adjusted standard errors from the two-stage estimation procedure are included in the square brackets. Model 1, includes only distance as an explanatory variable. Model 2 adds demographic dummy variables and model 3 includes area-based DHB dummy variables.

Table 7 OLS Regression with adjusted standard errors

Variables	Model 1	Model 2	Model 3
Distance	-.010 (.004) [.03]	.002 (.004) [.006]	-.01 (.004)*** [.006]*
Demographics		√	√
DHBs			√
Constant	10.5	9.5	8.7
R-squared	.000	.089	.091
Observations	159398	159398	159398

Standard errors are in parentheses. Robust Standard errors are in square brackets

**** significant at 1%, ** significant at 5%, * significant at 10%*

The table shows that raw standard errors (in round brackets) are slightly higher compared with the logit model but comparable with those produced by the logit model. The adjusted standard errors are higher than the raw standard errors, confirming our suspicion that the logit model understates the standard errors. In particular the adjusted standard errors for model (1) are an order of magnitude 10 times the size of the raw standard errors. The increase in standard errors across the three models implies less confidence in a significant relationship existing between distance to nearest hospital and the discharge incidence rate.

Appendix 4 Estimating marginal effects in a logit model[xx]

Logit Models

The logit model is used for modelling a dependent variable that lies in the [0,1] range. In many applications, this is a variable that takes on only two values: 0 or 1. The logit model is:

$$\ln\left(\frac{p}{1-p}\right) = xb$$

$$\Rightarrow p = \frac{e^{Xb}}{1+e^{Xb}}$$

[β is k_x1; X is n_xk; x is 1_xk]

[xx] See the discussion in Greene, W. H. (1997). Econometric Analysis. London, Prentice Hall (International)..

Marginal effects

For continuous x, the marginal effect of x, m(x) is:

$$m(x,b) = \frac{\partial p}{\partial x} = b\ \frac{e^{Xb}}{1+e^{Xb}}\left(1-\frac{e^{Xb}}{1+e^{Xb}}\right) \\ = b\ p(1-p) \tag{1}$$

For discrete x, the marginal effect of x, d(x) is:

$$d(x,b) = p\big|_{x_i=1} - p\big|_{x_i=0} \\ = \frac{e^{Xb}}{1+e^{Xb}}\bigg|_{x_i=1} - \frac{e^{Xb}}{1+e^{Xb}}\bigg|_{x_i=0} \tag{2}$$

Estimating Marginal Effects

Estimates of $\hat{b}$ and σ_β^2 are readily available from econometric software packages. However, we are often primarily interested in estimates of m(x,β) or d(x,β).

Estimates of m(x,β) or d(x,β) are available by applying (1) and (2). There are two generally accepted methods for calculating these estimates.

Average marginal effect (preferred method)

An estimate of m(x,β) or d(x,β) is calculated for *each observation*. These estimates are then averaged across all observations.

Effect at mean X's

Mean values are calculated for the X variables, and these are then used in equation (1) or (2) to generate an estimate.

Because the functions are non-linear, the average value of the functions will not equal the value of the function evaluated at sample means, so a) and b) will generally give different results (although they are often not too different – See Green (1997) p.878)

Variances for marginal effects

We know that $\hat{b}$ is asymptotically distributed as N(β,Σ).

Both m(x,β) and d(x,β) are continuous in β, so we can apply the delta method.

Applying the delta method gives:

m(x,β) is asymptotically distributed as N(m(x, $\hat{b}$), $m_b(x,\beta)\ \Sigma\ m_\beta(x,\beta)'$)

d(x,β) is asymptotically distributed as N(d(x, $\hat{b}$), $d_\beta(x,\beta)\ \Sigma\ d_\beta(x,\beta)'$)

$$Var[m(x,b)] = \frac{e^{Xb}}{\left(1+e^{Xb}\right)^2}\left[I_k + \left(1-2\left(\frac{e^{Xb}}{1+e^{Xb}}\right)\right)bx\right]\sum\left[I_k + \left(1-2\left(\frac{e^{Xb}}{1+e^{Xb}}\right)\right)bx\right]' \tag{3}$$

$$Var[d(x,b)] = \frac{e^{X'b}}{\left(1+e^{X'b}\right)^2}\sum \quad (4)$$

Standard errors for m(x,β_j) and d(x,β_j) are calculated as the square root of the diagonal elements of equations (3) and (4).

Estimating Variances for marginal effects

As with the estimation of the marginal effects themselves, there are two methods for estimating the variance of the marginal effects:

Average marginal effect (preferred method)

An estimate of the variance-covariance matrix from equations (3) or (4) is calculated using the $k_x k$ matrix βx_i for *each observation*. These estimates are then averaged across all observations.

Effect at mean X's

Mean values are calculated for the X variables, and these are then used in equation (3) or (4) (as the $k_x k$ matrix $\beta \bar{x}$) to generate an estimate.

This estimate is then applied to equations (5) or (6).

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