Spatial information in the New Zealand economy

Realising productivity gains

Prepared for Land Information New Zealand; Department of Conservation; Ministry of Economic Development

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SKM

ecological associates

sustainability and behaviour change solutions

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Glossary

ANZLIC	Australia and New Zealand Land Information Council
ANZsi	Australia and New Zealand spatial infrastructure
BIM	Business information modelling
CAD	Computer aided design
CTF	Controlled traffic farming
EM	Elecro-magnetic
FTE	Full time equivalent
Fundamental data	Spatial data collected by governments in the course of undertaking government administration and fulfilling the government role. It has many characteristics of a public good.
Galileo	European GNSS constellation of satellites
GIS	Geographic information system
GLONASS	Russian GNSS constellation of satellites
GNSS	Global Navigational Satellite System
GPS	Global Positioning System generally referring to the US Navstar GNSS
LiDAR	Light Detection and Ranging (LiDAR) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses.
Mash up	Refers to recombining and modifying digital media files to create a derivative work.
OGC	Open Geospatial Consortium
Orthophoto	An orthophotograph is an aerial photograph geometrically corrected ("orthorectified") so that the scale is uniform. The photograph has the same lack of distortion as a map.
Principal-agent problem	The principal-agent problem describes the difficulties that arise under conditions of incomplete information when a principal hires an agent to undertake a task on its behalf. The problem arises because the parties do not have the same interests, objectives or rewards.
RTK	Real Time Kinematic (RTK) satellite navigation is a technique used in land survey and in hydrographic survey based on the use of carrier phase measurements of the GPS, GLONASS and/or Galileo signals where a single reference station provides real-time corrections.
RUC	Road user charges
SDI	Spatial Data Infrastructure
SQL	Structured Query Language (SQL) is a database computer language designed for the retrieval and management of data in relational database management systems.
VRT	Variable rate technology

Executive summary

In 2008, the use and re-use of spatial information is estimated to have added $1.2 billion in productivity-related benefits to the New Zealand economy. This value is the result of increasing adoption of modern spatial information technologies over the period 1995-2008, and is equivalent to slightly more than 0.6 per cent of GDP or GNP in 2008.

Other (non-productivity) benefits linked to the increasing use of spatial information are probably worth a multiple of this. Uncertainties around the likelihoods of future events and valuation methodologies limit the ability to express such benefits in dollar terms; however, non-productivity benefits are nevertheless important to policy and decision making.

Examples of the use of modern spatial information technology can be found in all sectors of New Zealand's economy. There is tremendous potential for further benefits to be realised, but the timing and likely degree of future impact is difficult to assess because the technology and applications continue to evolve rapidly, and because policies may also shift.

A range of barriers to the adoption of spatial information have constrained uptake and limited the ability to reap additional benefits in New Zealand. Past and current barriers notably include problems in accessing data, inconsistency in data standards, and a general lack of skills and knowledge relating to modern spatial information technology.

Had key barriers been removed it is estimated that New Zealand could have benefited from an additional $481 million in productivity-related benefits in 2008, generating at least $100 million in government revenue. This 'cost' of the presence of barriers will rise with each year that passes, as the nation's capacity to adopt is increasing continually and pent-up demand is growing.

A government intervention representing the best 'value-for-money' for New Zealand in the short term, which can be implemented at relatively low cost and which has the potential to generate benefits quickly is the release of basic spatial data held by government (i.e., enabling access at marginal cost, which would be zero in instances where it is made available over the Internet).

This would be a logical first step to develop New Zealand's spatial data infrastructure (SDI). A broader intervention securing an effective SDI would lead to the highest benefits overall to New Zealand. This report estimates the benefit-to-cost (BCR) ratio of such an intervention to be at least 5:1 where it is costed at $100 million and only one year of benefits is counted.

1 Modern spatial information in the NZ economy

1.1 Background to the report

This report was commissioned by Land Information New Zealand (LINZ), the New Zealand Department of Conservation, and the Ministry of Economic Development New Zealand in April 2009. The report was prepared by a team of consultants led by ACIL Tasman Pty Ltd and including consultants from Sinclair, Knight and Merz (SKM) in Wellington and Ecological Associates in Auckland. In line with the Request for Proposal (RFP) the report:

- describes how spatial information is used across sectors of New Zealand's economy
- describes and quantifies the value of spatial information in the economy
- estimates the gains available from removing barriers to spatial information making a greater contribution to productivity
- describes and estimates the value of greater use of spatial information to innovation and product markets.

The project was highlighted on the New Zealand Geospatial Office (NZGO) website, from which a questionnaire designed for this study could also be downloaded, and LINZ encouraged sector-wide feedback and participation through an emailed invitation to participate in the project.

The interest and enthusiasm from sector representatives in response to the emailed invitation led LINZ to commission an add-on Workshop which was held in Wellington on 10 June 2009, attended by representatives from the NZ spatial sector, and at which a number of key assumptions and assertions were tested against expert knowledge from the sector.

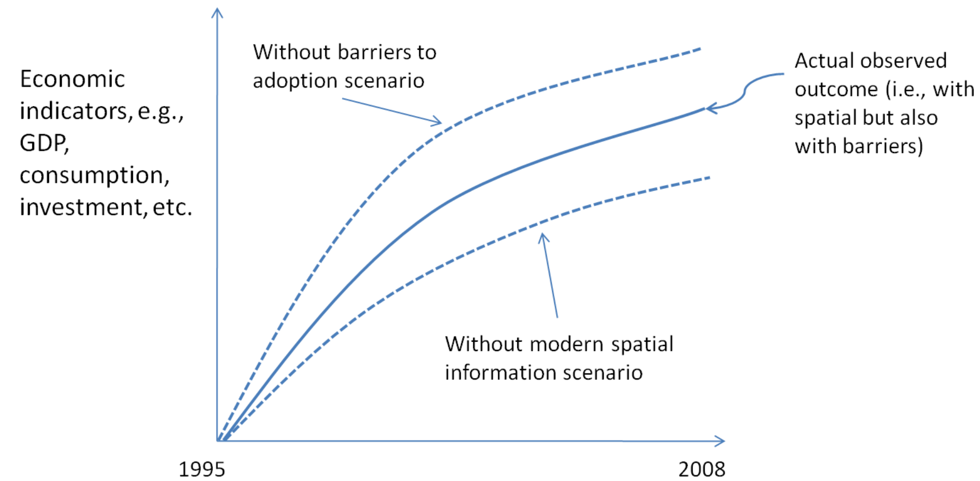
1.1.1 Basic approach

Due to the current absence of official statistical information on the use of modern spatial information technology in New Zealand, the economic impact assessment presented in this report is based on modelling 'with-and-without' scenarios using a computable general equilibrium (CGE) model (further details on the modelling approach are presented in Section 4).

The model provides the capability to analyse the flow-on impacts of changes in different sectors of the economy following the introduction of a new technology (or productivity 'shock') and to compare the impacts of these changes on economic aggregates such as GDP, consumption, employment and investment. This is illustrated in Figure 1, with the centre line showing the actual (observed) evolution of economic aggregates over time, and the two dashed lines representing two 'what if' scenarios:

- The lower dashed line gives an estimate of where NZ would have been in 2008 *without* modern spatial information technology
- The higher dashed line is an estimate of where NZ could have been in the *absence of barriers* to adoption (most importantly, free access to data)

Figure 1 **Economic indicators with and without spatial information**



Source: ACIL Tasman.

To assist with the development of the model, assumptions, and preparation of this report, the consultants carried out a series of face-to-face and telephone interviews. A number of additional organisations and individuals provided information through informal discussions or returning survey forms during the study.

Some interviewees requested that their responses be treated as confidential. As a result, some of the data which influenced the economic modelling does not feature explicitly in the report.

1.1.2 Other approaches to valuation

The Workshop highlighted that sector representatives see major value not only in the productivity gains that are modelled in this report, but also as in various social, environmental and other long term benefits from using modern spatial technology.

Most of the long term planning, health, biosecurity, ecological and other benefits that can be reaped from better use of spatial information are hard to value in dollar terms. Methodologies such as sophisticated willingness-to-pay (WTP) approaches are gaining recognition, but good contingent valuation studies are application specific and resource intensive, going well beyond the scope of work that could be covered here.

Contingent valuation surveys can provide good indicators of the value individuals place on defined services. However it would have been necessary to undertake contingent valuation surveys across all of the sectors surveyed. The cost of this was beyond the resources available for this report. Another problem with the application of techniques such as contingent valuation to the newer uses of spatial information is the low level of awareness of some of the newer applications in the general community. This makes it harder for responders to assign relative values to different services.

For these reasons it was decided that this report would draw on a productivity based approach to assessing the gains to the New Zealand economy from the use of spatial information. While this is a robust and verifiable approach to valuation it does not necessarily capture all of the value to the community.

Insofar as the productivity-related benefits developed in this report can be equated with 'use' values, and the range of other values with 'non-use' values, existing studies would suggest that the non-productivity related benefits are higher than the productivity benefits. However, precise estimation is difficult as the ratio of non-use to use value ranges from 1:1 to 100:1 in the extant literature (see, for example, Dziegielewska, 2007).

Any valuation of non-productivity related types of benefits is therefore likely to yield *a multiple* of the 'pure' productivity benefits reported here; however, issues relating to the choice of valuation technique as well as significant uncertainties around the nature of benefit capture prevent 'accurate' measurement of these additional benefits.

Emergency response times & lives saved

In the health area, it might be possible to develop relatively simplistic approaches based on the so-called value of a statistical life year (VOSLY). If it can be shown that a number of lives have been saved each year because of better/quicker ambulances, search and rescue, fire services, and so on, and if this could then be attributed to spatial information, one could easily obtain large dollar valuations.

To illustrate this, consider ambulance response times and the impact of modern spatial information. Paramedic response times influence short-term patient survival, particularly in cases of trauma and cardiac arrest (Mayer, 1979, Seow and Lim, 1993, Eplan, 2005, Shah et al., 2008). Knowledge of incident location is critical to rapid response; in rural areas with unsealed roads location used to be particularly difficult to identify (Svoboda, 2000).

St John attended nearly 275,000 emergency incidents and treated and transported over 340,000 patients during 2007-08 (St John NZ, 2008). Each year, around 1,000 New Zealanders have a cardiac arrest outside the hospital environment, of which currently around 8 per cent survive (i.e., 80 persons). Whilst St John would like to achieve higher survival rates, it is highly likely that a proportion of those currently saved benefit from modern spatial information technology because ambulances arrive more quickly at the scene than they used to 15 years ago.

Given the large number of incidents attended and patients treated, it would seem highly likely that modern spatial information technology enabling more rapid emergency response will have saved a significant number of lives over the period 1995-2008. As mentioned earlier, if 100 lives have been saved each year due to this then using a VOSLY method the benefit to New Zealand could be estimated at $1 billion or more each year.

Furthermore, additional lives will have been saved (and will probably be saved in future) by putting hospitals in the right place, and by building streets and cities in the right place (avoiding earthquake faultlines, coastal erosion, and so on). Associated benefits could in turn be worth a further sum of billions of dollars.

Planning and building "smarter" cities and transport systems that will not only cut down fuel costs, but could also avoid accidents (e.g., in-built sensors for urban vehicles), reduce emissions, enable changes in travel behaviour, make for a better living space, and so on, will add much more in terms of value. Similarly, where spatial information makes a contribution to maintaining national security and biosecurity, or social cohesion, this should in theory also be recognised.

One of the problems with 'adding up' all of these values is, however, that it takes more than spatial information or GIS to *realise* these benefits. Councils have to act on the spatially layered information; individuals have to alter travel behaviour, and so on. Hence the twin problems with such forward looking valuations are that:

- there is too much uncertainty around likely events and probabilities, and
- that the underlying valuation approaches are still somewhat controversial (WTP, VOSLY, etc).

This report therefore represents an attempt to develop a credible 'lower bound' estimate of economic impact, as measured by the change in productivity caused by the adoption of spatial information technologies.

1.2 What is spatial information and why is it valuable?

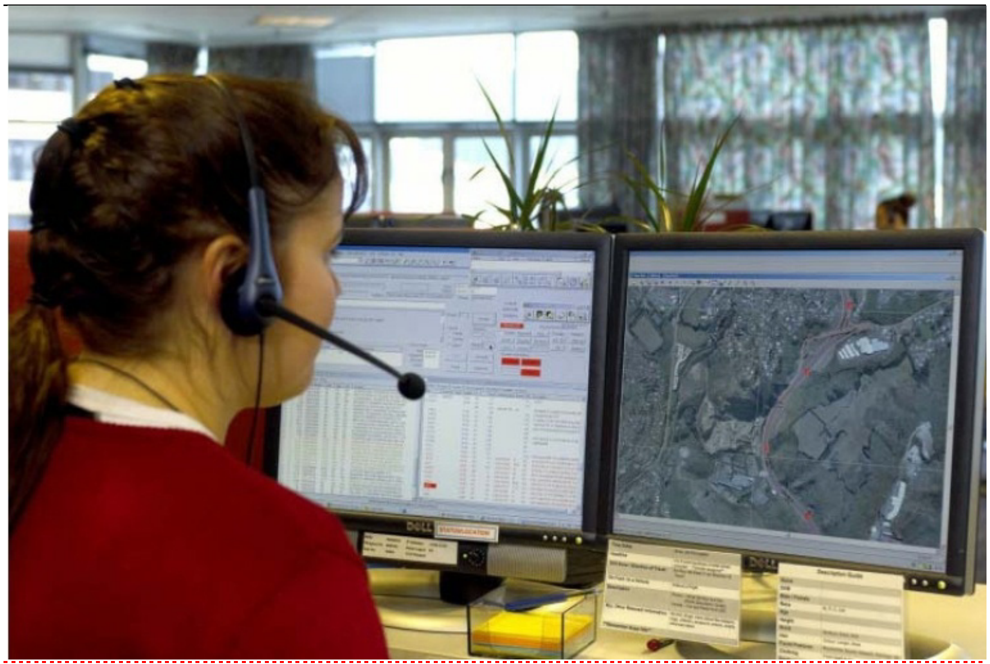
The *NZ Geospatial Strategy* defines geospatial information as:

> … information relating to the location and names of features beneath, on, or above the surface of the earth. (New Zealand Geospatial Office, 2007, p. 4)

As emphasized in the *Geospatial Strategy*, on some level or another all human activity depends on spatial information – on knowing where things are and understanding how they relate to one another. Having access to spatial information enables key service providers to answer 'Where?' questions in a range of critical situations, such as:

- Emergency response – Where is a distress call coming from (see Figure 2)? Where is a fire or severe weather front moving to?
- Health & biosecurity – Where is the source of an outbreak? Where has an incursion spread to?
- Defence – Where are troops in the combat zone? Where should we target monitoring effort and resources?

Figure 2 **NZ Police – modern spatial information technology in action**



Source: Jill Barclay, Technology Manager, GIS/ICT Service Centre, NZ Police

Spatial information is important to private businesses as well. Knowing where assets and inventories are located, how markets and demand profiles differ geographically, and so on, is critical to running an efficient business – it has been estimated that up to 80 per cent of information managed by business is somehow connected to a specific location (Geospatial Information &

Technology Association, 2008). Regulatory requirements and efficiencies in compliance are also pushing private sector uptake of various decision support and reporting systems that utilise spatial information.

As an example of the increasing use of spatial information, a recent survey of spatial data producers and managers in the US revealed the following list of 'unexpected' users (FGDC Cadastral Subcommittee, 2008):

- Citizen groups used aerial photographs to construct a 3D neighbourhood model to illustrate concerns about a proposed development.
- Forestry/logging companies reviewed assessment codes to identify forested land and to solicit property owners for services.
- A British company requested data to construct a virtual city to be incorporated in a computer game.
- Immigration officials analysed taxes and services in border areas to see how school districts are being impacted by different policies.
- Security agencies used building footprints and heights to plan protective services for a Presidential visit as well as for security exercises (plume overlays to estimate spread and impact of debris following terrorist strike).

The list of potential applications is large and can be expected to grow once the power of utilising spatial information becomes apparent to more users. These examples emerged from a small, informal survey in just a few US jurisdictions; unfortunately, more detailed statistical information on final user uptake and the nature of use remains sparse both in New Zealand as well as overseas.

Box 1 **Spatial prediction of NZ wildfire hazard**

The objective of this project was to develop new high-resolution, 25m grid data layers to describe the wild fire hazard across New Zealand, thus enhancing existing emergency response capability with the potential to save lives in future.

Weather data measured over time across the National Rural Fire Authority (NRFA) weather station network were used to calculate average fire hazard during the worst days in the fire season. Mathematical surfaces were fitted to these data to enable estimation of standard fire weather indices (FWI) across New Zealand. Results consisted of 7 new 25-m grid layers for fire weather indices (FWI) across New Zealand. From these initial FWI layers, additional derived layers of slope correction factor (SCF), fuel load (FL), rate of spread (ROS), and head fire intensity (HFI) were also calculated.

The results indicate considerable spatial variation in wildfire danger across New Zealand, and this is increasingly evident with the new 25-m grids that were developed. The values of fuel load, fuel types and slope correction factor have improved as a result of using higher resolution underlying spatial data layers.

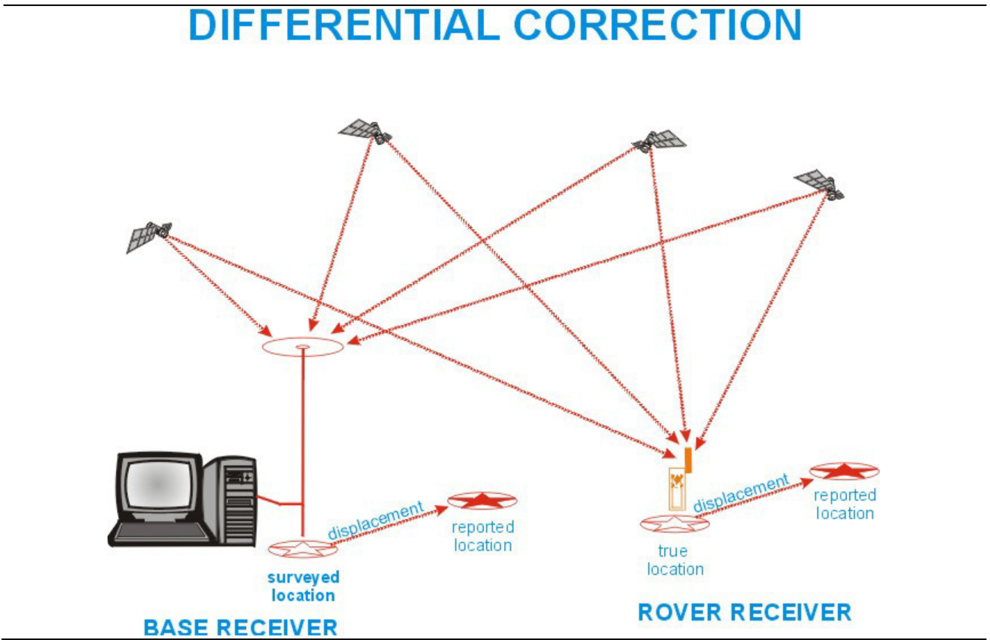
Source: Briggs *et al.* (2005), downloaded from NZ Fire Service website on 4 June 2009

1.2.1 Modern spatial information technology

Over the past 30 years or so, rapid advances in technology – in particular in data capture, computing and communications – have fundamentally changed the way in which spatial information can be captured, transmitted, displayed and utilized.

Until relatively recently, spatial information was mainly recorded and displayed on paper (maps, books, and so on). Navigation was based on the compass, landmarks, observation of the sun, the stars, time and plotting of positions on paper maps. The use of satellites as 'artificial stars' in conjunction with atomic clocks revolutionised navigation by allowing constant and highly accurate positioning on the ground and at sea. The advent of the digital age has heralded significant 'step changes' in technology which have already transformed many economic sectors and which are continuing to spin out new innovations and applications.

Figure 3 **GPS rover receivers receiving correction signals from a base receiver via satellites**



Source: www2.ocgi.okstate.edu/gpstools/overview1.htm

Today, spatial information can be captured, stored, transferred and analysed in digitised form – digital photography, mapping, and computer simulation and modelling are amongst the activities involved here. Where infrastructure such as the Internet, broadband and mobile telephony exist, it is at least in theory possible to access vast volumes of spatial information at short notice and low cost.[1]

The means by which images and spatial data are obtained have also evolved rapidly, and these range from the above-mentioned use of satellites (i.e., global navigation satellite systems or 'GNSS'[2]) to the use of unmanned aircraft and seafloor camera trawling. The cost of data capture is dropping whilst analytical capability and the efficiency of updating is vastly increased when compared to the previous processes involved in updating paper maps and archives.

Figure 4 **Surveying – capturing spatial information**

GNSS including GPS (see Box 2) in conjunction with software bundled as geographical information systems ('GIS'; see Box 2) enable a wide range of geospatial data to be layered onto digital maps in ways that were not possible 30 or even 20 years ago. Some of the newer applications were even unthinkable ten years ago – a reflection of the dynamism of this sector and continuous innovation.

[1] Later sections of this report discuss barriers to use or adoption.

[2] As of 2009, the United States NAVSTAR Global Positioning System (GPS) is the only fully operational GNSS. The Russian GLONASS is a GNSS in the process of being restored to full operation. China has indicated it will expand its regional Beidou navigation system into the global COMPASS navigation system by 2015. The European Union's Galileo positioning system is a GNSS in initial deployment phase, scheduled to be operational in 2013.

This confluence of factors – integrating geospatial referencing with modern decision support systems – is referred to as the rise of "modern" spatial information technology in this report.

Box 2 **What are 'GPS' and 'GIS'?**

The Geospatial Information & Technology Association (GITA) provides the following descriptions of GPS and GIS on its website:

> **"Global Positioning System," or GPS**, is a network of 24 satellites equipped with atomic clocks and equally accurate position measuring telemetry gear. The network was originally designed as a navigational aid for the US military, but the international civilian community has leveraged the USD10 billion [*Editor's note: $12 billion according to other sources*] investment in technology infrastructure into a market for hardware, software and services that continues to grow dramatically. Armed with inexpensive GPS receivers, for example, utility service crews can be quickly dispatched to the location of underground utilities in need of repair.

> **"Geographic Information System," or GIS**, is an acronym for a technology that offers a radically different way in which we produce and use the maps required to manage our communities and industries. Using computer programs, the technology links items displayed on a map with records in a database with the answers displayed on a map. The resulting combination, and the ability to manipulate the data in response to any number of "what if" scenarios, provides government agencies, utilities and a long list of private industries with a powerful and dynamic new tool that has opened doors in management effectiveness and organisational efficiency. A GIS creates intelligent super maps through which sophisticated planning and analysis can be performed at the touch of a button.

The history of GPS

When the Soviet Union launched Sputnik in 1957, it was recognized that this "artificial star" could be used as a navigational tool and researchers at MIT were able to determine the satellite's orbit by observing how the apparent frequency of its radio signal increased as it approached and decreased as it departed. The proof that a satellite's orbit could be precisely determined from the ground was the first step in establishing that positions on the ground could be determined by homing in on the signals broadcast by satellites.

In the years that followed, the U.S. Navy experimented with a series of satellite navigation systems. The *Transit* system in 1965 was developed to meet the navigational needs of submarines. By analysing the radio signals transmitted by the satellites a submarine could accurately determine its location in 10 or 15 minutes. In 1973, the U.S. Department of Defense was looking for a better method of satellite navigation. A brainstorming session at the Pentagon over the Labor Day weekend produced the concept of GPS on the basis of the department's experience with all its satellite predecessors. The first operational GPS satellite was launched in 1978, and the system reached full 24-satellite capability in 1993.

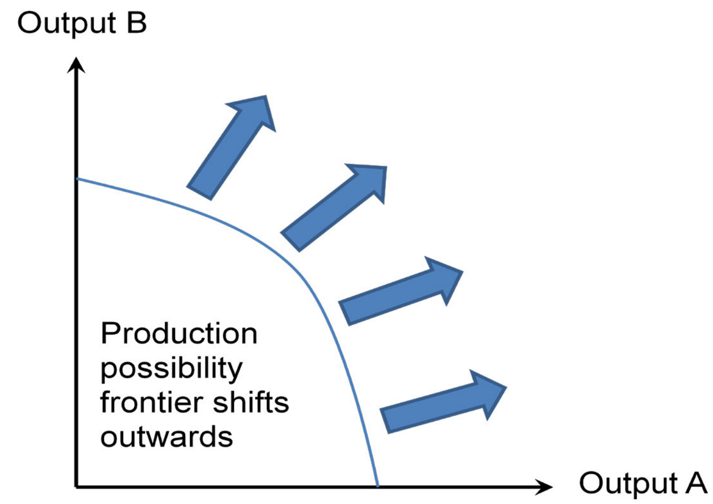
Sources: GITA website and http://www.beyonddiscovery.org/content/view.page.asp?I=464

1.3 Spatial information and the economy

1.3.1 Increasing productive capacity

The effect of introducing modern spatial information technology on the economy can be summarised as its ability to deliver more with the same resources; this idea is summarised in Figure 5 which shows an economy's so-called production possibility frontier shifting outward as a result of the introduction of modern spatial information technology. This report essentially aims to provide a better understanding of the likely extent and the factors affecting the rapidity of this shift in New Zealand.

Figure 5 **Spatial information & the NZ economy's productive capacity**



Source: ACIL Tasman.

There will always be winners and losers from shifts in technology – some tasks or jobs may for example become redundant – but the argument is that, overall, society can produce more and better outputs with the same inputs. This means that losers can be compensated while still leaving extra value for the economy as a whole. This 'extra value' may come in several forms:

- extra time available to existing staff, who can be thus be redeployed in other production or service areas, or to improve product or service delivery
- if there is strong competition among the adopters of the new technology and if many or all firms adopt the technology, better products and services *as well as* price reductions may flow to final consumers who thus benefit from what economists call 'consumer surplus' (an amount that they would have been willing to pay but are not asked to pay)
- where there is some degree of 'imperfect' competition so that firms can 'hold on' to the extra value in terms of reduced input costs or a premium charged on new products to final users, this may free up financial resources that can be reallocated to a number of areas:
  - some of these savings may be banked by firms as additional profits, paid out to shareholders as dividends, or reinvested in fixed capital, inventories or additional staff (or higher wages to retain existing staff).

A proportion of the 'extra' value to the economy is thus captured by final end users, and some of it is captured by the 'intermediaries' that deliver products and services (and this can include government, non-profit and commercial users). Economic growth in turn means the 'size of the pie' as a whole increases, which feeds back to these organisations as increased demand for their products. This 'size of market' effect is in addition to the effects discussed above.

Improved outcomes in areas such as health and the environment are important non-market benefits from the use of spatial information technology; these will also have longer term impacts on the economy which are harder to estimate and beyond the scope of the modelling for this report. These long term effects may however be critical to sustainable economic growth and should not be underestimated.

The range of possibilities means that the impacts of introducing spatial information can differ widely by application and across sectors, and accounting for these impacts can be difficult (see Section 1.3.7 and Box 3, which indicates a practical issue with attributing benefits from new technology when it consists of a range of complementary innovations including spatial ones).

Box 3 **Ambulances – an example of complementary technologies**

Ambulance New Zealand incorporates the membership of nine land ambulance services and a number of air ambulance operators throughout New Zealand. St John provides nearly 90 per cent of these services, with about 150 stations around New Zealand, 600 salaried ambulance officers and a further 2200 volunteers. Ambulance operations are currently coordinated out of eight communications centres.

Wellington Free Ambulance currently utilises a mobile data solution which includes Automatic Vehicle Location (AVL) – allowing its vehicles to be tracked via the Internet using a GPS receiver. Under the Ambulance Communications Project, AVL will be installed in all New Zealand ambulances, with the Tait supplied radio telephone network used as the secondary means of AVL data transfer.

The evolution of the communications technology which has incorporated the spatial element is a good example of synergies between different technology waves. Not all of the additional benefits from improved ambulance response times, for example, can be attributed to the spatial information component alone – although it is clear that without spatial information these benefits could not be realised at all.

Source: http://www.taitworld.com/main/index.cfm/1,796,550,44,html/Ambulance-New-Zealand-Inc

1.3.2 Information, data, knowledge and innovation

The terms information, data and knowledge are often used interchangeably. Data refers to information that has been organised so that it can be communicated, reproduced or interpreted (e.g., spatial information stored in digital format). Whilst this is knowledge, it is only of a 'rudimentary' type. As long as it remains unused, its value resides mainly in the *options* it creates for future analysis and 'value addition'.

Spatial data can aid deeper knowledge creation and enable inventive or innovative activity, thus ultimately contributing to the production of 'useful' knowledge. The 'core' spatial industry specialises in generating as well as utilising spatial data to create value added products and services.

Value addition does not always occur along a 'linear' path to market. Invention and innovation involve complex knowledge networks that are currently still very much the realm of economic research; however, the role and value of information in determining broad macroeconomic outcomes has been increasingly recognised as advanced industrialised economies are shifting to what has become known as the 'knowledge economy'. The role of R&D and human capital has been emphasised as influencing levels of long run economic growth (key papers by Grossman and Helpman, 1990, Romer, 1990).

Knowledge is sometimes seen as a kind of 'multipurpose' capital that can be transferred across sectors and applications; however, there is some controversy about this interpretation as there is a distinction between specific knowledge (which cannot be transferred) and other types of knowledge (which are hard to define and measure). The economic literature on knowledge capital, and it links with information, is extensive and increasingly concerned with empirical verification (e.g., Baetjer, 2000, Eckwert and Zilcha, 2001, Loof and Heshmati, 2002, Helmstadter, 2003, Haag et al., 2004, Asgeirsdottir et al., 2006, Carlaw et al., 2006, Veugelers et al., 2006, Laperche, 2007, Gibbs and Middleton, 2008)

In a related development, the Nobel Prize winning economist Joseph Stiglitz has referred to the rise of informational economics as a "change in paradigm" (see Stiglitz, 2000b, Stiglitz, 2002). This report echoes the sentiment in the context of spatial information, arguing that full appreciation of the value of spatial information involves a change in paradigm at various levels.

A number of reports in applied economics have scoped economic issues that are specific to spatial information, and given some indications of the value of spatial information and spatial data infrastructures or 'SDIs' (Weiss, 2002, Macauley, 2005, European Commission, 2006, ACIL Tasman, 2008, Almirall, 2008, Barlow, 2008, Park et al., 2008, McKenzie Podmore Limited, 2009, Mehrtens, 2009).

These all point to potentially high returns from spatial information (and investment in SDIs), whilst noting that there is uncertainty about how much money and other resources have already gone into, and are continuing to flow into the maintenance and upgrading of SDIs.

1.3.3 Market failure

Much of the large and ever-expanding body of theoretical literature in informational economics is concerned with the consequences of 'market failure' in the market for information, but the literature is wide and varied (some examples are Hirschleifer and Riley, 1979, Conrad, 1980, Gilboa and Lehrer, 1991, Lawrence, 1999, Eckwert and Zilcha, 2001, Chernew et al., 2008).

Box 4 explains key economic concepts which are often used when making the case for government intervention. In addition to these, governments take into account equity based arguments. With regard to spatial information, market failure based arguments for a role for government can be identified in the following areas – note that this list is not specific to New Zealand, and more locally relevant analysis is provided in Section 3 of this report:

1. Making data available: infrastructure investment, collection of data and the placing of data in the public domain are activities that have 'public good' as well as 'natural monopoly' justifications:
    - i once data are released into the public domain, anyone can use them
    - ii there are significant economies of scale in data collection and in the use of infrastructure
2. Providing middleware, basic standards, and regulatory frameworks: the government can play a role to help overcome information failure, that is, information *about* spatial information (many users do not know what they are getting, how to compare suppliers, what basic standards are, etc.). It can play a role in providing 'middleware' (e.g., a Registry) where the market fails to provide such middleware. It also has a responsibility to develop regulatory frameworks.
    - i there are few incentives for 'core' private spatial industry companies to direct potential users to sources of basic data or to other providers
    - ii similarly, successful private providers have little incentive to self-regulate and/or standardise; it is in their interest to minimise the potential for the loss of repeat customers
3. Training and education: governments are traditionally involved in training and education as private companies often under-invest in this area because they risk losing that investment when their staff members are poached by competitors ('free riders')
4. Assisting small business: this has an equity component but also an innovation system rationale; most of the spatial industry companies are small or 'micro' businesses with 5 to 20 employees (Park et al., 2008)

At the same time, there are 'demand side' arguments for governments' involvement with spatial information:

5. To assist with efficient provision of services: governments provide many services that benefit from use of spatial information
6. Policy making: governments recognise that having access to spatial data and modelling of spatial events over time can play a significant role in shaping policy (e.g., coastal erosion and land development); this also relates to governments' wider responsibilities to their constituents (social welfare, health, sustainability, etc.)

Box 4 **Market failure and natural monopoly arguments**

Public goods exist where provision for one person means the product is available to all people at no additional cost. Public goods are said to be non-rivalrous (that is, consumption by one person will not diminish consumption by others) and non-excludable (that is, it is difficult to exclude anyone from benefiting from the good). Common examples include flood-control dams, national defence and street lights. Given that exclusion would be physically impossible or economically infeasible, the private market is unlikely to provide these goods to a sufficient extent. The nature of public goods makes it difficult to assess the extent of demand for them. It is ultimately a matter of judgement whether demand is sufficient to warrant government provision.

Spillovers or externalities occur where an activity or transaction has positive (benefits) or negative (costs) economic welfare effects on others who are not direct parties to the transaction. Public goods and spillovers are similar analytically – spillovers have public good characteristics in that they are non-rivalrous and non-excludable.

Information failures occur where there is insufficient or inadequate information about such matters as price, quality and availability for firms, investors and consumers to make informed decisions... government may perceive a role to complement or verify market supplied information – for example, government licensing, registration and labelling regulations for chemicals and pharmaceuticals.

Natural monopoly occurs where it is more efficient for one firm to supply all of a market's needs than it would be for two or more firms to do so. It arises where there are significant economies of scale resulting from fixed costs which are large relative to the variable costs of supply. Monopolies may charge excessive prices, so regulation or government ownership is often adopted.

Source: Productivity Commission (Australia)

1.3.4 Government failure

While the term 'market' failure is employed almost routinely in debates about what governments should or should not do, concepts of 'government failure' are not discussed as frequently. Stiglitz (2000a) outlines four major reasons for the systemic failures of government to achieve its stated objectives in his textbook *Economics of the Public Sector*: limited information; limited control over private market responses; limited control over bureaucracy; and limitations imposed by political processes.

Stiglitz (2000a, p. 205) provides a number of explanations for this type of public sector inefficiency, including an absence of competition (a corollary to being the natural monopoly), the absence of incentive pay and various principal-agent problems such as the pursuit of bureaucratic objectives and high levels of risk aversion exhibited by government departments.

From discussions with various parties during this consultancy, it appears that while these are not the only factors, they certainly did play a part in restricting data sharing within/across NZ government agencies and also in restricting access to spatial data by non-government parties.

1.3.5 Elasticity of demand for information

The elasticity of demand measures the change in the quantity demanded which occurs following a change in the price of the product or service being traded. This is an important consideration for spatial information policy, as many local councils and other government data custodians continue to charge for spatial information.

There is evidence that charging a price, however low, can have a strong deterrence effect, in particular when potential buyers are unsure of what they are buying or how it will assist them (uncertainty of product is a peculiar feature inherent in the market for traded information; see Stiglitz, 2000b).

Secondly, where a price is charged for information, there is evidence that demand is elastic, i.e., responds relatively strongly to changes in the price charged (and 'cuts out' as price exceeds a threshold level). NIWA's latest Annual Report contains some evidence of the impact of reducing price:

> This year, we opened up web-based access to our archived data free of charge. The response was excellent with the number of registered users of the National Climate Database rising from 130 to over 4000. (NIWA, 2008)

In other words, a drop in price to zero saw 'demand' multiply more than 30-fold. This may not reflect the 'true' price elasticity because of the large backlog of demand that may have been met in the first year. Noting similarly sharp increases in demand following the introduction of free access policies, Newbery *et al.* summarise some of the evidence on public sector information and similar sectors, and conclude that the range of plausible elasticities is 0.5 to 2.5 but that in most instances the price elasticity is likely to be between 1.0 and 2.0 (Newbery et al., 2008).

1.3.6 Technology adoption and diffusion

As indicated in the last section, the economic impact of spatial information will ultimately reflect the level of adoption as well as the degree to which benefits are reaped by individual adopters. Making data available and reducing price are clear levers by which adoption and diffusion can be accelerated.

More broadly speaking, the classic textbook reference by Rogers (1964) identified a five-step decision process involved in technology adoption and diffusion:

1. Knowledge – potential adopter becomes aware of an innovation but has no particular opinion of it (this could be via advertising or through word-of-mouth)
2. Persuasion – the potential adopter seeks further information to help from an attitude toward the innovation
3. Decision – the potential adopter engages in activities that lead to a choice to adopt or reject the innovation (the process is internal to the person and can be difficult to measure empirically; however considerations of price and perceived usefulness/necessity will play into this decision)
4. Implementation – the innovation is adopted and put into use (e.g., user installs spatial data software or uses car navigation aids)
5. Confirmation – person evaluates the results of an innovation-decision already made which may affect decisions such as whether to continue using the innovation or return to previous status quo (e.g., remove software or return car navigation aid)

With regard to modern spatial information technology, the majority of potential users in New Zealand (if one includes households and individuals) are still unaware of various spatial information technologies; however, a number of organisations and individuals have moved through all five stages described by Rogers, and for these adopters the evidence and feedback received during the preparation of this report suggests that they are unlikely to return to the previous status quo.

Rogers (1964) also estimated the categories of adopters as being innovators (2.5 per cent), early adopters (13.5 per cent), early majority (34 per cent), late majority (34 per cent) and laggards (16 per cent). These reference figures are adopted for the current report, as they were based on and have been broadly corroborated by many case studies including those in the original contribution by Rogers.

Rogers does not indicate a typical 'speed' of adoption or rate of diffusion over time, although the received wisdom now states that adoption typically follows an S-curve path with a 'tipping point' occurring at some stage where rapid uptake in the broader population occurs.

The Bass model, named after Frank Bass whose 1969 paper concerned take up of consumer durables (Bass, 1969), still forms the main mathematical approach to predicting the rate of adoption over time. It follows Rogers' model by differentiating between innovators and imitators, but importantly for the purposes of this report, it differentiates between two coefficients:

- the coefficient of innovation, external influence or advertising effect, and
- the coefficient of imitation, internal influence or word-of-mouth effect

The critical finding which has been widely validated is that the latter coefficient is much more important in determining the rate of uptake over time (by a factor of twenty or more).

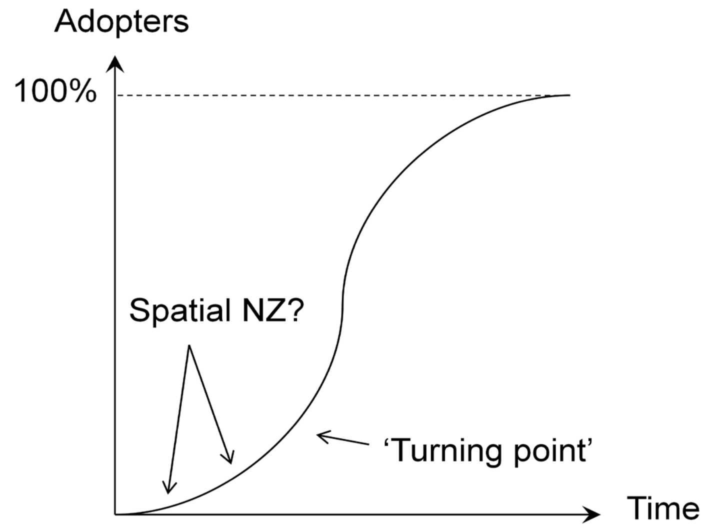
This has important policy implications for the spatial information sector. It means that people are far less likely to adopt if they read or hear about a product; rather, they need hands-on experience or 'demonstration' of the benefits. The private sector is traditionally very efficient at doing this, and in the case of car navigation aids we are witnessing the 'take-off' phenomenon now – where rapid adoption occurs as a result of the demonstration effects.

The issue with assuming a simplistic S-shape uptake curve is, however, that the spatial technology market as a whole is dynamic over time and that there are in fact many different types of spatially enabled products and services. While we may already be past the turning point for car navigation aids, enterprise GIS is much further down the curve.

Figure 7 illustrates this simplistically by depicting three curves instead of one – one for basic GPS/GNSS applications, which have almost universal adoption in some sectors, and two for continually evolving GIS applications, some of which are widely adopted in a few sectors, but the full potential of which has not yet been exploited. Unlike most types of innovations which have been studied to date, and for which adoption, market penetration or diffusion models have been estimated (e.g., radio, colour TV, home PCs, mobile telephones or microwaves),[3] modern spatial information technology therefore represents a shift with less clear 'single product' characteristics).

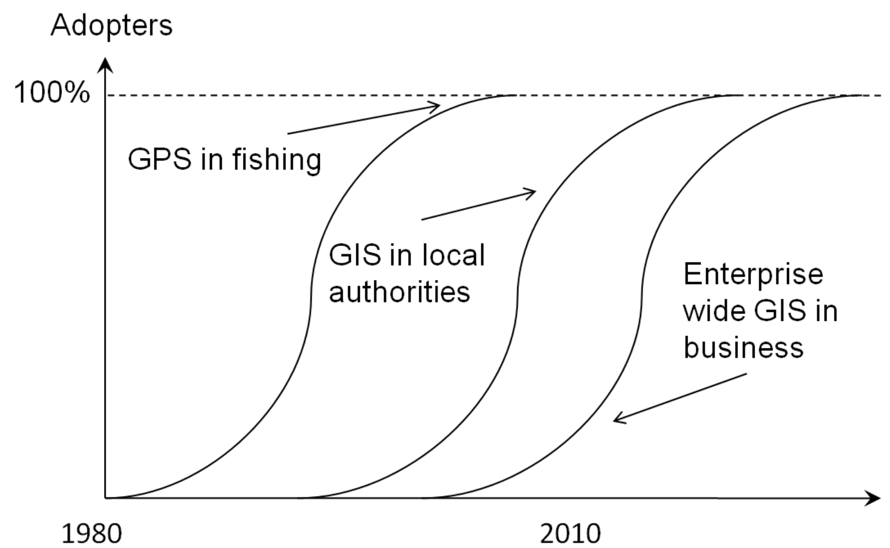
[3] See, for example, the list of examples on http://andorraweb.com/bass/

Figure 6 **S-shaped diffusion or technology uptake curve**



Source: ACIL Tasman

Figure 7 **Series of S-shaped adoption curves over time**



Source: ACIL Tasman

1.3.7 Productivity accounting

Productivity accounting is a branch of economics that attempts to attribute measured productivity gains to its sources. It is briefly discussed here so that the reader will have a better understanding of the productivity shocks that are employed to model the impact of spatial information in this report.

Traditionally, productivity accounting decomposes productivity gains into gains from two major inputs, namely capital and labour, and a residual called multifactor productivity (MFP).

MFP is often seen as a proxy measure of productivity growth due to technology shifts; however, in the case of spatial information the utilisation or absorption of this information can improve the quality of capital or labour itself. This type of impact is called *embodied* technological change and is particularly hard to measure. For example, if key employees are able to make consistently better decisions then the quality of labour has essentially improved – dealing with spatial information consequently has knowledge effects which become embodied in the labour stock.

Detailed investigation of these complexities with regard to spatial technology is beyond the scope of this report, and as already indicated these issues have been touched upon here to assist the reader in understanding some of the discussion that follows. The first, very important, point in relation to which the above terminology becomes important is the history of productivity change in New Zealand, which really sets the spatial information technology shift into its proper context.

1.3.8 Productivity growth in New Zealand

An examination of trends in productivity yields a better appreciation of the *constraints to growth* inherent in any nation's economy. Long term productivity growth averages released by Statistics NZ (2009b) show, for example, that MFP grew at an average annual rate of 1.1 per cent over the period 1978-2008. Labour productivity grew by 1.2 per cent annually and capital productivity *fell* by 0.5 per cent each year, on average, over the same period.

Over the last 30 years, total productivity has therefore grown at a rate of around two per cent per annum (OECD data suggest that over the period 1985-2006 this could be 2.4 per cent per annum). If modern spatial information technology had not been introduced this growth would likely have been lower; but the question is, to what degree?

The figures above suggest a broad 'envelope' of plausible scenarios for the impact of spatial information on productivity growth and thus its potential economic impact – that is, some tenths of percentage points of difference in productivity growth.

These figures may appear surprisingly small – after all, the last 30 years witnessed massive improvements in computer processing power, rising agricultural yields and much other technological progress. What this really shows is that whilst technology shifts may improve productivity in specific tasks by a factor of hundreds or thousands, output as a whole simply cannot grow by a similar magnitude over a corresponding timeframe.

1.3.9 What about the ICT sector?

Since a significant proportion of the core spatial technology sector sits in the ICT sector as currently defined, it is relevant to ask whether there are any robust findings regarding the impact of ICT on productivity at the macroeconomic level. A recent study that examined the long term productivity impacts of ICT in the New Zealand context found that these were "somewhat elusive" (Engelbrecht and Xayavong, 2007).

The paper did uncover evidence of a labour productivity and MFP differential in favour of more ICT intensive industries; however this was explained largely by structural effects (e.g., the move of more highly skilled workers into the sector at the cost of other sectors; deregulation, etc.) and not by a pure productivity effect. Similarly, an Australian Productivity Commission report into the role of ICT stated that:

> Whilst it is now generally agreed that the use of ICT has a positive influence on productivity growth — at least in industries that use ICT intensively — the observed differences across countries in the extent of ICT uptake and related productivity effects have continued to be a puzzle. (Productivity Commission, 2004)

A number of studies have established that ICT and workplace reorganization can have positive and significant effects on productivity at the firm level, while at the same time increasing the demand for skilled labour (Brynjolfsson, 2000, Black, 2001); however, as already indicated, these findings have not been readily corroborated at the macroeconomic level; that is, they do not scale up easily to the whole economy because of the structural effects already alluded to, and because various types of spillovers and complementarities that remain hard to measure.

A recent UNCTAD-led study of ICT use in developing countries, taking Thailand as a case in point, for example notes that:

> ICT use becomes increasingly relevant to productivity when combined with soft skills such as good management and superior marketing abilities. Unfortunately, such soft skills and soft technology inputs cannot be quantified directly and therefore their effect is hard to assess. Empirical research usually corrects for this unknown effect by accounting for different economic results in foreign-owned firms, in exporting companies, in establishments belonging to multi-unit corporations or simply in more experienced firms. Therefore, policy implications derived from such research do not directly recommend that the intensity of ICT use be scaled up (for example by increasing the number of computers per employee). Rather they recommend investigating how the combined use of ICT and superior managerial capabilities can account for variations in ICT gains between firms with different characteristics. (UNCTAD, 2008)

The Australian Productivity Commission conducted its own research (Productivity Commission, 2004) and reviewed the previous literature on the topic, concluding that the current evidence suggests that ICT may have contributed "around two or three tenths of a percentage point" to the acceleration in annual growth in output (aside from any MFP effects) and possibly a further one to two tenths of a percentage point to MFP growth. Put together, this provides a plausible range of one to five tenths of a percentage point in total productivity growth acceleration due to ICT (the latest available OECD statistics suggest the contribution could be at the upper end of this range at around 4.5 tenths of a percentage point).

These figures, in turn, provide the logical reference against which the impact of spatial information might be estimated. It is tempting to assume that spatial information can only be a subset of the ICT impact, but this would be a mistake, because spatial information is different – as explained in the next section – and because a good share of spatial information technology has been developed in sectors that are not currently classified as belonging to the ICT sector.

The experience with attempting to pin down the productivity gains from ICT also serves as a cautionary tale for those who may attempt a similar exercise for spatial information in the future. Much more detailed evidence needs to be collected for a sufficiently large sample of organisations (with an appropriate comparison group) before the 'true' productivity effects will likely be discovered.

1.3.10 Economic footprint versus economic impact

The economic footprint of the spatial information sector should, in theory, include costs that any organisation incurs in the capture, procurement, processing, understanding, and utilisation of spatial information. In theory this activity could be grouped, but such a grouping does not exist within the current system of national accounts. Components of the sector are found within many Australian and New Zealand Standard Industrial Classification (ANZSIC) sectors and subsectors.

Economic impact is a wider concept, which is pursued in this report as the economy-wide impact of the productivity improvements that result from the adoption of modern spatial information technology.

During the preparation of this report, it became clear that many private sector organisations employ in-house GIS specialists. At this stage it is difficult to know whether there are more dedicated spatial data related workers within or outside the 'core' spatial industry (organisations that specialise in the capture and processing of spatial information, develop spatial software, and so on).

An assessment of the economic footprint of the sector may be possible with a national survey or industry census; use of a 'satellite' account approach – along the lines, say, of the tourism satellite account – could be more challenging. Methodologies for appropriate statistical capture of the sector are still in development.

This type of measurement problem is to be expected with emerging technologies. Fortunately, some data have been collected which can inform assessment of broad, forward looking policy issues.

1.3.11 Extent of sector based on current information

In 2007, the NZGO commissioned the Geospatial Research Centre (GRC) to undertake capability mapping of the New Zealand geospatial sector. Responses were received from 38 organisations: six Crown Research Institutes, six Universities, 23 companies, the Animal Health Board, New Zealand Defence Force (NZDF) and the New Zealand Fire Service (NZFS). Extrapolating from the responses received, the report estimates sector costs and revenues to be broadly matched at around $100 million (Park et al., 2008).

Two years have elapsed since the survey but it still stands as the only 'order of magnitude' estimate of the economic footprint of the 'core' spatial sector in New Zealand (no exhaustive 'Census' has been carried out in New Zealand); given reported growth rates of up to 35 per cent in the sector, as well as the fact that the methodology for 'scaling up' from the 38 surveyed companies to the sector as a whole is not clear, the 'true' footprint could now be closer to, or even in excess of $200 million.

In addition to the 'core' sector, there will be intra-organisational or 'in-house' costs (e.g., GIS Managers employed by commercial entities and within government; a proportion of Chief Information Officers' salaries might for example be attributed to GIS as well). The aggregate level of these costs is unknown but would include some fundamental data capture and processing as well as database maintenance and management costs.

One of New Zealand's major private sector providers of spatial technology is Eagle Technology which has around 40 GIS staff and stated that around 400 organizations in NZ use GIS supplied by Eagle technology. Those organizations range from NZDF to small consulting companies. Also, around 80 per cent of larger Territorial Local Authorities (TLAs are estimated to use ESRI's ArcGIS (one of the platforms distributed by Eagle) and this is in line with other estimates of ESRI market share. It is by no means clear that these 400 or so organisations represent a *complete* list of adopters in New Zealand – however, if one can extrapolate from 80 per cent coverage of TLAs to wider use, then the national list of users is likely to be 500 organisations or more.

Depending on which measure of market share is chosen, and how sections of larger organisations or enterprises are counted, it may well be that a plausible estimate of the number of government and enterprise units that have adopted modern spatial information technology is closer to 1,000.

As indicated earlier, the partial and informal survey undertaken for this study showed that organisations relied heavily on consultants but employed between one and six staff who were dedicated to the use and maintenance of the spatial information technology. McLeod (2009) estimates 330 GIS staff in 85 local authorities. Of these, twelve were larger Councils with GIS staff of 15 each according to the estimate, and the remainder had, on average, two GIS staff (McLeod, 2009).

If a FTE staffing ratio of one to two per adopting organisation is accepted, 500 to 1,000 adopting organisations would imply 500 to 2,000 FTEs in this activity amongst the NZ user community. This in turn could translate into expenditures of up to $200 million per year, which is similar to the estimated turnover of the core sector itself. This broadly fits with the estimate by one key expert interviewed for this report who stated that there are around 1,500 trained GIS professionals in New Zealand.[4]

The interviews carried out for this report do suggest that much effort – perhaps more so than in other countries – is outsourced to the specialist providers that are part of the 'core' spatial sector. It is still possible that the combined 'in-house' costs are larger than the turnover of the 'core' spatial sector; on balance our view is that it is entirely conceivable that annual costs to the New Zealand economy could now be in the region of $400 million.

4 Eagle Technology interview.

2 Sector-by-sector analysis

For the purposes of this report ten case studies were carried out to deliver relatively broad coverage of the major sectors in the NZ economy. The sector by sector analysis also draws on previous reports and findings and combines the insights gleaned from a number of interviews, conversations and written responses to the survey posted on the LINZ website.

2.1 Government services (incl. local government)

Local and central government entities were early adopters of modern spatial information technology. The combined sector accounts for around 15 per cent of value added generated in the New Zealand economy. According to industry observers and the Advisory Group that commented during the preparation of this report, the mid- to late 1990s was the time when many government agencies investigated improved collection and dissemination of spatial information, and many moved to adopt GIS. One of the early, world leading efforts in New Zealand was the introduction of Landonline, further discussed in Section 2.1.1.

Adoption of spatial information technology typically brought efficiencies in the provision of services whilst simultaneously improving the quality of services delivered to the public. In other cases, government initiatives involved outlays for completely new activities. This report cannot cover all of the examples of use of spatial information in government; a sample of projects or applications is discussed, including in some detail:

- Land Information New Zealand – Landonline (Section 2.1.1)
- New Zealand Transport Agency – RAMM, InfoConnect (Section 2.1.1)
- Ministry of Fisheries
  - NABIS (Section 2.1.3)
  - VMS (Section 0)
- NIWA seabed and habitat mapping (Section 2.1.5)
- Animal Health Board – VectorNet & DMIS (Section 0)
- Ministry for the Environment – Land Use and Carbon Analysis System LUCAS (Section 0)
- Local Government applications (Section 2.1.8)

Some of the others which can only be mentioned in passing here but which are known to utilise spatial information heavily include:

- Police, Fire, Ambulance (see Box 1, Box 3 and Figure 2)
- Crown Minerals (short discussion in Section 2.12.2)

- Ministry of Defence and New Zealand Defence Force
  - Joint Geospatial Support Facility projects, e.g., KiwImage (see Box 5)
  - Navy Hydrographic Survey Vessel activity
  - Radiola differential GPS tracker system replacing manual theodolite as a means of tracking aircraft during flight inspection
- GNS Science – earth systems research and advice
- New Zealand Post Office – despatch and tracking
- Other Ministry for the Environment
  - Land cover mapping
  - Forest condition & biodiversity mapping
  - State of the Environment reports
  - Waitaki Catchment Recreation and Tourism Activities (GIS report)
- Other NIWA
  - NZ Freshwater Fish Database
  - National Climate Database
  - River Environment Classification
- Ministry of Agriculture & Forestry
  - Mapping of national vineyard for the wine industry
  - Forestry in emissions trading (GIS enabled)
  - Biosecurity projects / functions (e.g., GIS for beekeepers)
- Ministry of Research, Science and Technology projects
  - Marine Invaders Spatial Prediction model (MISPM) with Ministry of Agriculture and Forestry
  - Evaluation of National Measurement Standards

Box 5 **KiwImage – NZDF and government collaboration**

The New Zealand Defence Force (NZDF) signed a contract with Sinclair Knight Mertz Pty Ltd (SKM) as part of the KiwImage project in April 2008. This is an 'All of Government' initiative to purchase satellite imagery of New Zealand for use by NZ Government Departments and Local Government. The KiwImage project aims to complete capture images of all of New Zealand and its offshore islands at 60cm resolution in the next 2-4 years. At this level of resolution individual trees and bushes, walking tracks and road markings should all be discernible.

Most of the initial work on the project was performed by the NZ Fire Service and in 2007 NZDF was asked to host the purchase, storage and distribution of the imagery database. The imagery will be used to update topographical maps and databases for Government departments, Local Government and Emergency Services ... The Defence Force's Joint Geospatial Support Facility in Devonport, Auckland was given the task of implementing the project. SKM has been awarded the contract to provide the imagery which is gained from Global Image in the United States.

2.1.1 Land Information New Zealand (LINZ) – Landonline

One of New Zealand's world leading efforts in the area of government use of spatial information, which was repeatedly referred to by various experts as well as in the Workshop and in the general literature, was the creation of Landonline – New Zealand's automated survey and titles system (see Box 6 for an introduction and background to the system).

LINZ itself was established in 1996 and Walsh (2006, p. 3) states that government took the decision to develop Landonline in 1997. An early case study indicated that it was expected that implementation would take six years (Jackson, 2000), but as mentioned in Box 6 the process was in fact completed in around five years. It is probably safe to assume that benefits from the use of Landonline have been flowing from around 2002. One hundred per cent e-lodgement was achieved in 2009.

Landonline forced LINZ to shift from being a traditional paper based organisation to a digital, location independent organisation. Landonline also meant that for the first time LINZ had a backup of its archive of records (30 million records covering 130 years of activity), thus enabling recovery in the event of a disaster.

The early business case assumed that investing in Landonline would generate internal savings of $13 million per annum and savings to external users of $26 million, which it was thought would be predominantly achieved through efficiencies as well as through lower fees (Jackson, 2000). The current manager of the team which processes survey and title transactions at LINZ, and who interacts closely with customers, estimated that the move to Landonline reduced the number of people required from five hundred in twelve offices to one hundred and fifty in two offices.

The implied productivity impact of the move to Landonline has consequently been very significant – at a minimum, the estimates imply that the NZ public service would otherwise have had to employ three hundred and fifty employees to conduct these specific tasks. The productivity gain can be approximated using an estimate of earnings. Using a conservative figure of $100,000 per staff member (incl. on-costs) the productivity gain to the public sector from Landonline would be around $35 million per year – around 2.5 times as high as suggested under the original business case. Landonline would likely have seen 'payback' within four years of operation (given that the total cost of implementing the system has been estimated at around $120 million).

In addition there would have been significant savings from reduced office space, reduced need to supervise or manage staff, and so on. The old paper system needed an additional one linear km of storage each year, so six years of Landonline will have resulted in a significant savings on storage as well.

Phrased in terms of the terminology used in this report, a $35 million productivity benefit from Landonline in 2008 is equivalent to a total productivity shock to Central Government of around 0.11 per cent, based on appropriations for total output expenses of around $30.6 billion reported in the 2008 budget. If local government expenditures are also included then the implied productivity shock is slightly lower at 0.09 per cent.

Box 6 **Introduction to Landonline (LINZ)**

Landonline provides land professionals with secure access to New Zealand's only authoritative titles register and digital cadastre maintained by LINZ. The functionally smart system enables registered users to conduct secure electronic title and survey transactions in real time, automating and speeding up traditional (and sometimes prolonged and complex) manual processes. Landonline is not designed for public access or use. Its survey and title lodgement and registration functions can only be accessed by authenticated, registered users to ensure the integrity of the titles register and digital cadastre is maintained at all times.

Development of the system

Landonline was designed in close collaboration with all stakeholders including surveyors, lawyers, conveyancers and local authorities. This ensured their needs were incorporated into development and provided opportunities for users to review and improve their workflows and service to their clients. In a process spanning five years, LINZ converted over seven million physical records into digital records that are now held in Landonline. These include titles, title instruments, plans, parcels and geodetic survey marks dating back over 150 years.

As the core national land information repository, Landonline has also enabled LINZ to streamline its own business functions, resulting in faster processing of both manual and electronic survey and title lodgements and registration. Today, all lodgements are processed straight into Landonline. Only documents or records which are too fragile or large to convert to digital records, or which are too infrequently accessed are unavailable in Landonline.

Source: http://www.Landonline.govt.nz/about-Landonline/introduction.asp

2.1.2 New Zealand Transport Agency (NZTA)

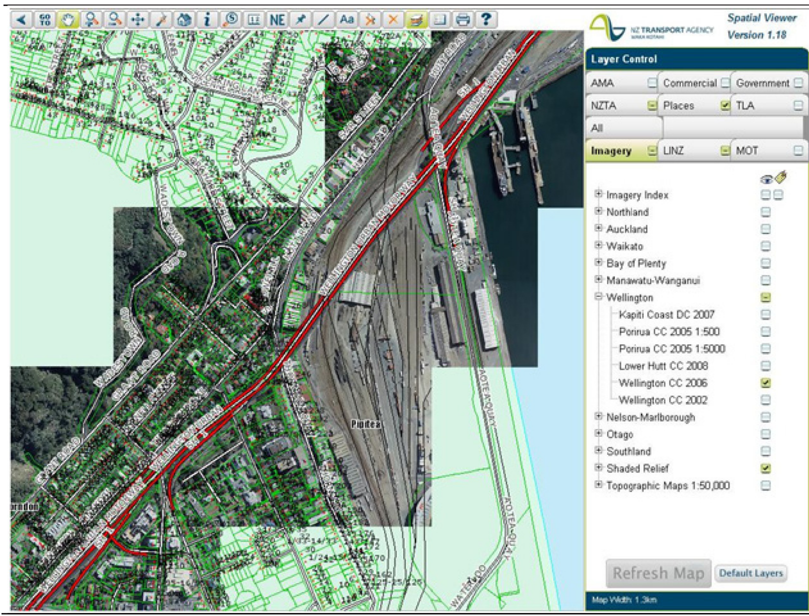
New Zealand's roads are managed by the NZ Transport Agency (NZTA), a Crown entity established on 1 August 2008 which brings together the functions of Land Transport New Zealand and Transit New Zealand to provide an integrated approach to transport planning, funding and delivery. Efficient road assessment and maintenance management (RAMM)[5] is

5 This is also the proprietary term for the core product by CJN Technologies who have been leaders in NZ road asset management software for 25 years.

important to achieving NZTA's objectives, and spatially enabled RAMM software is the asset and planning tool for state highways.[6]

To put the importance of NZTA in context, it should be noted that the transport system plays a central role in the performance of the economy. Road transport is particularly important to regional New Zealand and the export industries which drive these local economies. Seventy per cent of all freight in New Zealand goes by road, and about 84 per cent of people go to work by car, truck, or motorbike. Reflecting this importance and the size of the challenge of maintaining an efficient and effective transport system, NZTA is responsible for Crown revenue of $2.8 billion and allocation of $2.0 billion, with an operating budget of around $240 million per year (NZTA, 2009).

Figure 8 **NZTA Spatial Viewer and some of its layers over Wellington area**



Source: SKM case study

Between 2004 and 2006, Transit NZ (one of NZTA's predecessors) put in place a strategy to articulate and implement a vision for the use of geospatial information. As a result of this a Spatial Viewer (SV) application was developed to integrate all available data. This is now fully operational and utilises more than 200 GIS layers and other associated non-spatial data – staff can query the data and access other data sources.

The Spatial Viewer has improved data representation and created significant potential to undertake more advanced spatial analysis in future. Access to data has improved, including to staff in the field, and the technology can assist

6 Manu King noted that RAMM should not be represented as an enterprise-wide system for NZTA.

senior managers in their decision making. Implementation of the project has increased staff awareness about available data and it is likely that new initiatives will emerge from this advance in the use and availability of spatial data within NZTA.

High Speed Pavement Condition surveys

High Speed Pavement Condition surveys and SCRIM (skid resistance) surveys are undertaken annually on the entire State Highway network using the SCRIM+ survey vehicle operated by WDM Ltd.

Data collected as part of the survey includes:

- Skid resistance (SCRIM) in both wheelpaths
- Texture (mean profile depth) measured in both wheelpaths and mid lane
- Roughness
- Rutting
- Geometry (gradient, crossfall and curvature)
- GPS road centreline coordinates
- Network Video

Results of this survey provide NZTA with road condition information and NZTA also utilises the outputs for highway performance monitoring, treatment site selection, trend analysis and deterioration modelling. The road network centreline coordinates captured by the GPS also provides key network spatial data that is used in the NZTA Spatial Viewer.

Linking GIS Video Viewer to Spatial View Stage 3 (2009)

Video data are collected during road condition surveys and stored in a dedicated database. Video data are useful to a wide group of users including those involved in highway maintenance, transport planners' capital project teams, consultants and contractors. They are also useful for answering public enquiries and help improve customer service. The video viewer saves both staff time and resources by allowing an initial assessment at the desktop in the office, with a site visit only if required.

The new functionality of the SV was proposed because the existing video network was difficult to navigate. Users of the SV requested the additional functionality and benefits of the system are seen in the spatial context (visual), the video image context map view and in the form of improved navigation. Furthermore, likely long term benefits were seen not only in terms of direct usage of the viewer, but also in terms of follow-on benefits such as a safer working environment, and the reduction in the carbon footprint which would come from more efficient roading.

Figure 9 **NZTA integrated GIS with video viewer**

Source: SKM case study

The video link has been used by approximately 218 internal and 150 external users (total of 368) and this is expected to increase to 500 within the first year of implementation. The internal productivity improvement value was estimated around $436,280/year for the internal users (1,700 productive hours) and $353,588/year for the external users (1,170 productive hours). Based on these estimated conservative figures the total productivity improvement within a year for 500 users for 11 month/year would be $984,097. With 500 users, each user would need to save 20 minutes per week to result in a saving of over $1 million, which "seems reasonable".[7] This type of productivity benefit alone would be equivalent to 0.4 per cent of NZTA's annual operating budget.

Asset design and planning

Most "asset design", i.e. construction design, is still based on field surveys;[8] however LiDAR, road scanning information and GPS are also used in some projects. Where it is used, it can be of high value in avoiding the need to survey locations as part of the asset design process. Digital elevation models developed using LiDAR data can also enable additional assessment work for environmental approvals (water, air quality, noise modelling). Integration of data enables location of data in the fraction of the time using existing (or recently existing) methods even though the data are often held electronically. As mentioned before, NZTA is not as yet reaping these benefits on a routine basis, but rather on a selective project-by-project basis.

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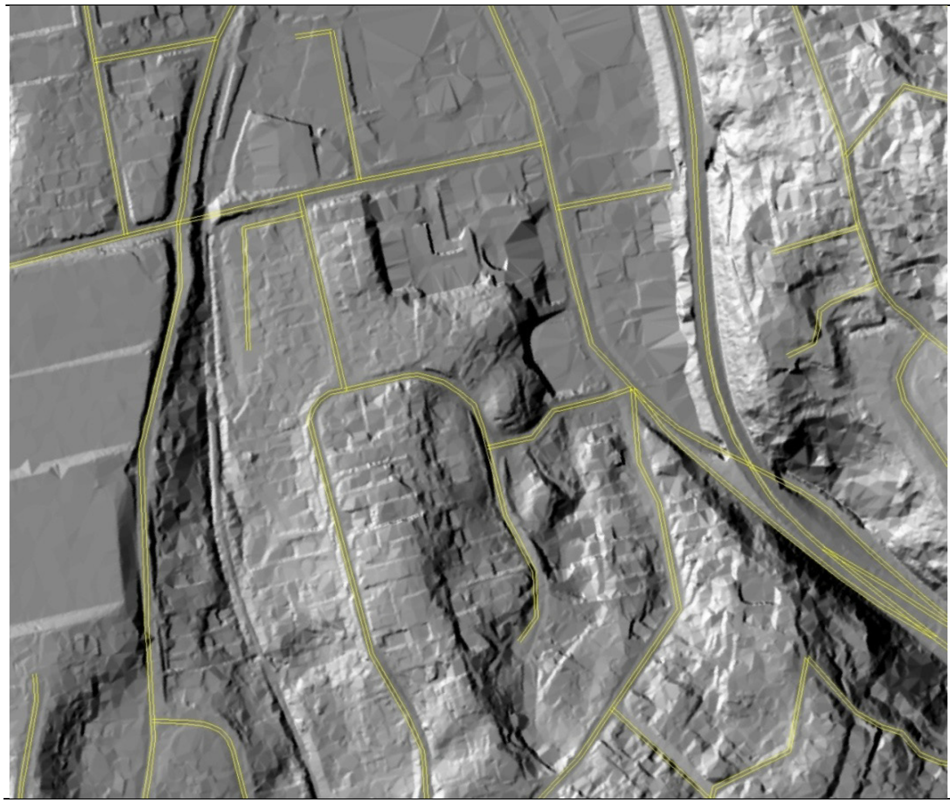
7 Manu King, *pers. comm.*

8 ibid.

Figure 10 **LiDAR in the context of road planning and design**



Source: SKM case study

Summary of benefit to NZTA

The above discussion indicates that NZTA and its predecessors have benefitted from adopting and integrating various modern spatial information technologies (and data), and this will flow through to the NZ road system and ultimately benefit road users.

An important benefit is the availability of road condition survey data matched to location data which means NZTA staff can make some initial assessments from their desktop with attendant savings, compared with the previous situation under which there would have been more intensive use of surveyors to develop projects.

For the improvement on the spatial viewer alone in 2009, the extent of the saving was estimated at up to 0.4 per cent of NZTA turnover. GIS systems may have had a larger initial impact in percentage terms when they were first introduced. Combined with other benefits reaped at least since around 2004, NZTA is highly likely to be seeing significant net productivity benefits to the organisation, however defined.

NZTA contractors benefit from road construction efficiencies as well (further discussed in Section 2.5), and insofar as some of these benefits are passed on to NZTA in terms of better or more "road per dollar" this will allow NZTA to improve and extend its services, and once again ultimately benefit the road user and tax payer.

InfoConnect – user benefits

The InfoConnect initiative was launched by Transit New Zealand which is now part of NZTA. InfoConnect's aim is to ensure that road users have access to timely and accurate road condition information. InfoConnect can be used by interested parties (e.g., software developers) to access verified Highway Info data, which includes state highway road and traffic information, webcam coverage in Auckland, Wellington and Christchurch, planned road works, unplanned road closures and delays, maps, and holiday traffic information.

There is no charge for access to the InfoConnect APIs (application programming interfaces), as one of the aims of InfoConnect is to allow for innovative uses of the data that would not necessarily be possible if access was limited.

Some examples of projects that are already delivering benefits to the public include:

- HowsTheTraffic.co.nz – Parkside Media used the Auckland Traffic API to provide a visual dashboard of traffic in the Auckland area for the readers of their Car and SUV website
- AA Roadwatch – the AA have integrated TREIS traffic alerts into a dedicated visual map of traffic events around the country
- MultiCam – Stanton Software used InfoConnect to develop iPhone Apps for web cams in Auckland, Wellington and Christchurch. These are currently for sale in Apple's iTunes App Store
- NZ Traffic – independent software developers GivUsADeal used the Traffic Web Cams API to build an iPhone App that will let users view all traffic webcams on their iPhone
- Auckland Traffic – Gravitini have developed an iPhone App that lets users see the congestion status of Auckland's motorways, and then touch one of the web cam icons to get an image of the location

As emphasised in this report, benefits from using spatial technology go beyond 'pure' productivity benefits – in NZTA's case, wider benefits will include improved road conditions (comfort) and travel time savings (public users who benefit from InfoConnect projects) as well as potentially extending to the saving of lives where a better transport system reduces accidents and fatalities.

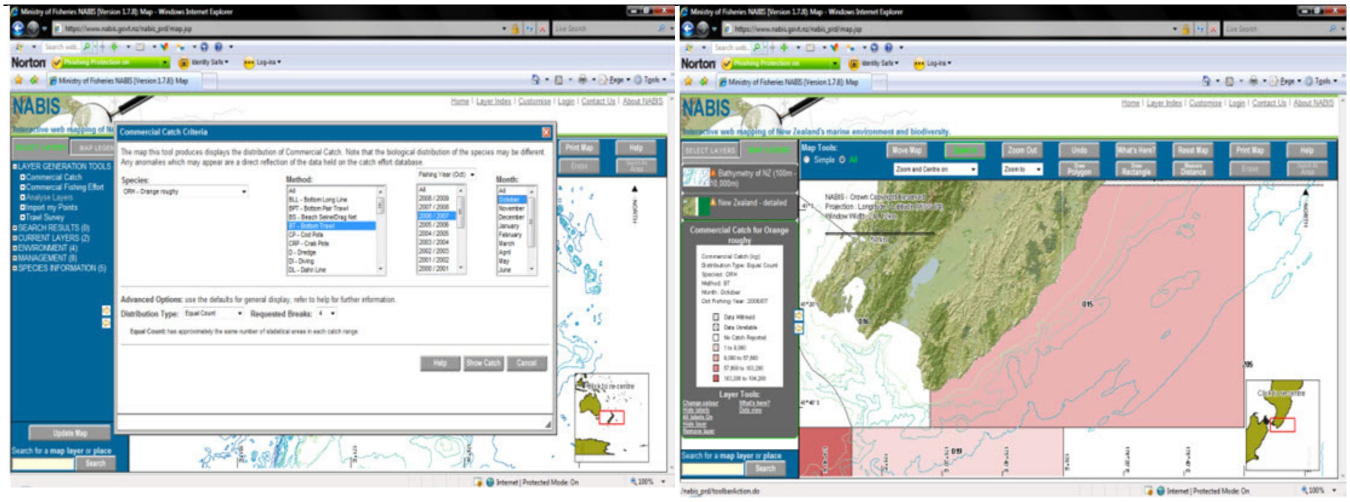
2.1.3 National Aquatic Biodiversity Information System (NABIS)

In 2001, the Ministry of Fisheries (MFish) developed a geospatial data reporting management tool, NABIS (National Aquatic Biodiversity Information System) which allows users to create a base map of an area of interest, with GIS layers depicting information including biological distributions for finfish and invertebrates, fishery management areas, and commercial catch information. Commercial fishers can also use the system to plot the locations of their fishing tracks on the water by importing recorded latitude and longitude information. Three full time equivalent staff focus on managing and developing NABIS within MFish.

In May 2008, 2,000 NABIS users were surveyed to inform the development of the second generation NABIS system. The survey found that the system is used by a mixture of students, scientists, analysts and researchers. Forty survey respondents assessed that NABIS improves their productivity by an average of 9 per cent, equivalent in total to an estimated 3.6 full time positions. Across the 2000 NABIS survey respondents this would be equivalent to 180 FTE. The total number of NABIS users is unknown but it is highly likely that the value of these gains already outweighs the estimated cost of developing the second generation NABIS system of around $1,500,000.

A map generated to show commercial catch of orange roughy by bottom trawl in October 2007 in quota management area 15 is outlined in Figure 11.

Figure 11 **NABIS – example of orange roughy catch in quota management area 15**



Selecting fish stock, fishing method, and time — *GIS layer created in NABIS*

Source: Ecological Associates case study

2.1.4 MFish – Vessel Monitoring Systems (VMS)

GPS is also used by MFish as part of the Vessel Monitoring System (VMS) to monitor fishing activities in the New Zealand fishing zone.VMS was introduced in NZ in 1994 and New Zealand currently operates a VMS involving up to 200 fishing vessels.

VMS systems use electronic transmitters called Automatic Location Communicators (ALC) that are placed on fishing vessels to transmit information via satellite about the vessel's position to authorities. This information is useful in near real time for ascertaining whether a vessel is fishing in closure zones where fishing is either temporarily or permanently prohibited. The transmitted information can also be monitored to assist with verifying catch effort activity reported by commercial operators. A number of ALC devices have been vetted by MFish as compliant with Ministry of Fisheries Type Approval Standards, in part due to their resistance to tampering.[9]

VMS is seen by MFish to be a cost effective means to monitor the activity of fishing vessels and assists with targeting compliance efforts in commercial fisheries for greatest effectiveness.[10]

2.1.5 NIWA – seabed and habitat mapping

Advances in GPS technology have enabled the mapping of habitat, seabed, catch information, and fish stocks. These advances have helped transform spatial data into meaningful information that can be used to catch fish as well as manage stocks over time.

Computer programs that connect into a vessel's GPS, sounder and seafloor discrimination devices are, for example, being used to create databases of the seabed's topography in the area that a boat fishes. By creating 3D maps of the seafloor instantly, fishers are pinpointing hills on the sea floor on which to set and tow trawls. Programmes are also being used to mark the location and movement of long-lines, nets and pots in 3D in order to avoid foul ground where fishing gear becomes caught on the seafloor. This technology is outlined in Figure 12.

Recent progress with spatial technology has also enabled the mapping of marine species and their habitats at a smaller spatial scale. The National

[9] http://www.high-seas.org/docs/hstf_vms_final1.pdf

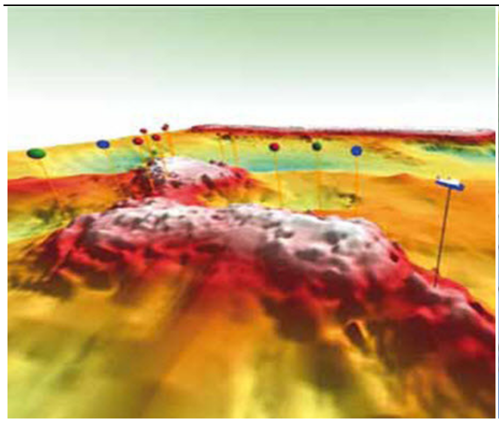
[10] Review of Sustainability Measures and other management controls for 2007/08 (1 October) fishing year Volume 1: Final Advice Papers and Summary of Recommendations 24 May 2007

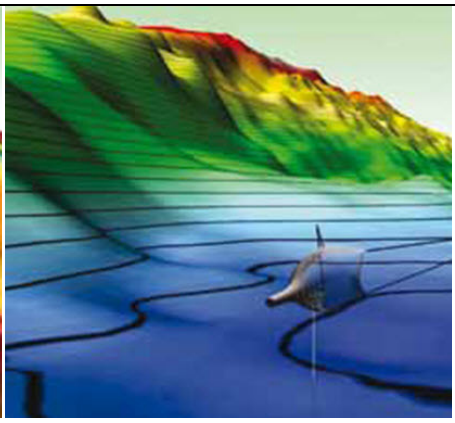
Institute of Water and Atmospheric Research (NIWA's) 'Marine Recreation' research programme in the inner Hauraki Gulf sought to better understand the inter-relationships between the recreational snapper fishery, snapper populations, and the underlying seafloor habitats, including the invertebrate animals living there. Habitat mapping used as part of this research programme involved a number of key steps:

- A geographic information system (GIS) used data to produce broad scale habitat maps of seafloor features such as plateaus, holes, ridges, slopes, and channels
- An underwater video (DUV) towed along transects was used to create finer scale seafloor habitat types to determine what the different physical features from the remote mapping actually were
- Estimates of snapper catch, and snapper abundance observed along the DUV was then related back to the different habitat types in which different abundances of snapper were observed. An assessment was also made of how the type of prey items snapper were targeting related back to the different kinds of seafloor habitats

These various datasets can be used to create new maps that enable the rapid assessment of habitat features, and then predict the relative values of those places for fish and fishers, and likely threats to those values.[11]

Figure 12 **Seabed topography**





Topography of sea bed	*Location and direction of net*

Source: Ecological Associates case study

[11] Mark Morrison, Ude Shankar, Darren Parsons, Glen Carbines, and Bruce Hartill *Snapper's-eye view of the inner Hauraki Gulf* Water & Atmosphere 16(2) 2008

2.1.6 The Animal Health Board (AHB) – containing bovine TB

Bovine TB is an infectious disease caused by the bacterium *Mycobacterium bovis*. In New Zealand, contact with wild animals (known as TB vectors) is the major source of TB infection in dairy cattle. The most common TB vector is the Australian brush tail possum. A high prevalence of bovine TB in dairy cattle could result in negative consumer perceptions and market reactions and significant production losses for New Zealand farmers[12]. Potential export trade bans on the dairy, beef and deer industries as a result of bovine TB have been estimated at a cost of $1.3 billion over 5 years[13]. In 1998, the Animal Health Board (AHB) was appointed under the National Pest Management Strategy to protect NZ dairy, beef and deer exports and reduce the cost of Bovine TB to farmers. Their current objective is to achieve the international standard for TB freedom where 99.8% of domestic cattle and deer herds are free of bovine TB for three years[14].

Disease and vector control of bovine TB has moved from a paper based system in the 1990's to a system that widely adopts modern spatial information and technology. While disease and vector control planning has always been spatially based, systems are now underpinned by digitised geospatial information. This includes the VectorNet and Disease Management Information Systems used by the AHB.

Prior to the formation of AHB, bovine TB control was undertaken by pest destruction boards which were amalgamated into regional councils. Possum control by government is also currently managed on public conservation land by the Department of Conservation[15] (DOC).

Spending on control of Bovine TB in 2007 was $81.92 million; $44.86 million from the private sector and $36.92 million from local and central government. This private sector spending includes at least $16.97 million paid by dairy farmers as levies (Animal Health Board, 2008).

Vector control: spatially based methodology and tools

Vector control involves creating buffer zones of low-density TB vector populations between TB-infected vectors and cattle herds. In order to create

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12 http://TBfree.ahb.org.nz/Default.aspx?tabid=118

13 http://www.landcareresearch.co.nz/research/programme.asp?Proj_Collab_ID=7

14 This figure has been set by the Office Internationale Epizooties (World Organisation for Animal Health).

15 DOC controls possums on 1 million ha of public conservation lands where its priorities are highest, while the AHB has controlled possums on 4.5 million ha, of which c. 13% has been estimated as being on public conservation lands.

buffers, surveying the extent of TB-infected wildlife populations and their habitat close to and near buffers zones has been used to determine the level of pest control needed.

In the 1990s, vector control planning was a paper based exercise involving manually tracing over aerial photographs to highlight possible possum habitats in bush/pasture margins. Sites for control were typically traced on to paper and the areas and perimeters were calculated using a mapping wheel. The distribution and abundance of possums in these areas would be monitored by observing the rate at which possums were caught in trap lines that were randomly placed[16] in these control areas.

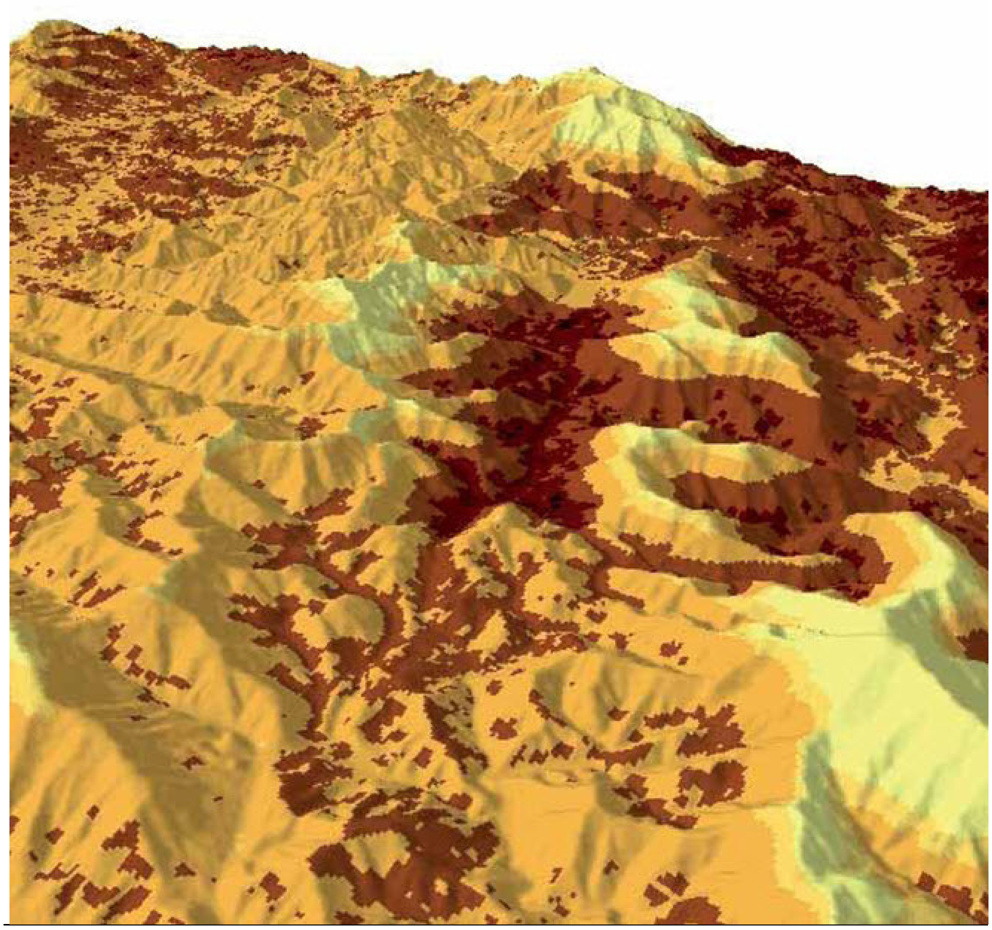
As well as aerial photos, the addition of satellite images of land cover are now being used as a base for identifying and representing (digitising) possum habitat as a GIS layer. Data from monitoring in the Marlborough high country since 2005 has been used to predict high possum densities, where numbers are likely to host TB. This GIS layer has been overlaid with digital environmental data (including altitude,[17] vegetation class, slope and aspect) to create a model to predict possum densities. This includes predictions in areas that have not been directly surveyed. This type of digital mapping is outlined in Figure 13 below.

This process of mapping possum habitat allows a lower-cost partial control approach where only area of high possum habitat and abundance are selectively targeted. In addition, the ability of the model to predict possum density reduces costs associated with possum monitoring.

[16] determined by using grid overlays or random number generation

[17] Possums are likely to live at lower altitudes

Figure 13 **Digital mapping for possum control**



Note: The darker the colour, the higher the predicted possum abundance.

Source: Ecological Associates case study

The impact of the use of GIS based habitat mapping in the Marlborough high country has been to reduce the area requiring possum control by up to 40%, reducing the costs of vector control from $15 per hectare of total area to about $7-8 per hectare.[18] The application of this mapping technology is still in the early adoption stage but is now being widely applied by AHB as discussed later in this report.

A barrier identified relating to the wider use of habitat mapping involves the inaccuracies of some of the digital environmental data used to create GIS layers. Some of these inaccuracies relate to a lack of real time information. For example, vegetation and forest data uploaded into the Land Cover Database Version 2 (LCDB2) may not show recent changes to vegetation types resulting from land use changes, or may result in the incorrect interpretation of

18 Landcare Research Manaaki Whenua Interview

vegetation type when images show vegetation in shadow at certain times of the day.

Methods of Vector Control

Improvements in TB vector control methods have resulted in reduced costs through greater precision in targeting and application. These methods, including the aerial application of bait, and the selection and laying of ground-based trap lines and bait, have increasingly made use of modern spatial information and technology.

In addition to the use of GIS information to determine the most favoured locations for vector control, the use of GPS has allowed greater precision in the site specific application of bait or trap lines.

Hand-held GPS units have been utilised by possum control contractors since the mid 1990's as a means to more quickly and accurately locate, set and check trap lines or bait locations. Prior to this, contractors would be given an initial starting point on the edge of the bush (e.g. track entrance, fence post or some other identifiable position), a direction and a distance to the trap line which had to be located through the use of paper maps and compass bearings.

Hand held GPS is now widely adopted across the industry for possum vector control and monitoring. This has allowed contractors to reduce the time taken to locate trap lines, and reduce the time taken to record location information of traps or baits laid[19] or catch results. This has resulted in an estimated 11% time savings per monitoring contract[20], as well as providing benefits in reducing data entry errors and increasing transparency in the accuracy of reported catch and monitoring results.

GPS guided aerial poison drops by DOC and AHB since the 1990's have also allowed the application of baits at increasingly lower rates. Aerial drops can be sown in narrow strips or clusters of favoured possum habitat rather than being spread more widely at lower densities. Differential GPS systems on aircraft have also increased the precision of application by generating flight paths with calibrated swath widths. Flight data recorded by differential GPS has been used as a check against flight plans to ensure efficient and effective drops. This precision shortens the amount of time an aircraft is in the air, and saves on fuel consumption.

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[19] Recording trap or bait sites and catch results on GPS units replaces the manual recording of 14 digits on a recording sheet to be transcribed on a summary sheet.

[20] Possum Control and Monitoring Contractor Interview

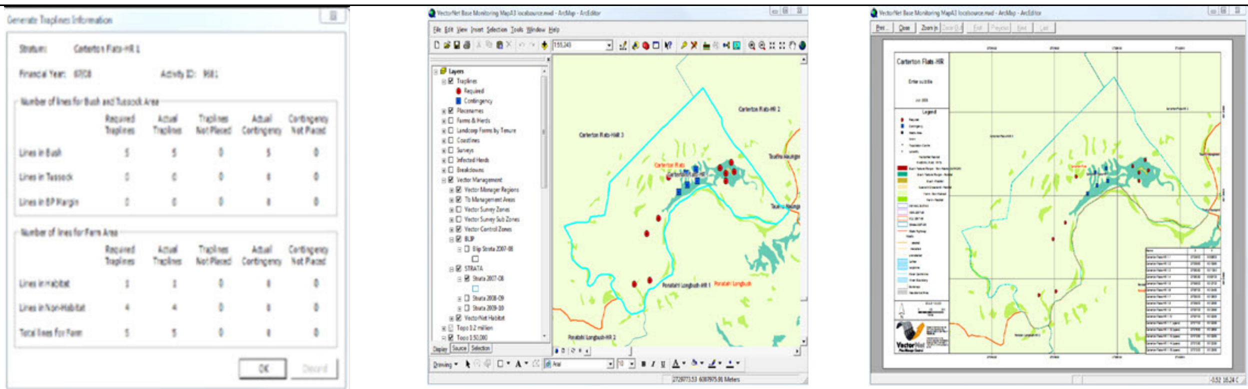
From an average rate of application of 1080 poison of 6.3kg per hectare in 1995[21], application rates had decreased to around 2kg per hectare by 1998 by refining the use of GPS[22]. Application rates have been reduced by a further 60% through the use of the latest digital mapping databases as part of the recent monitoring in the Marlborough high country since 2005. This most recent drop in application rates will equal further cost savings when applied across AHB coordinated operations.

VectorNet

The advances in vector control methods and habitat mapping outlined above are being integrated into the AHB's bovine TB control operations. This is most recently occurring through the use of the VectorNet information system that was completed in early 2008. VectorNet uses a map-based interface to access, query, and report on all aspects of AHB's vector control processes. VectorNet contains a number of geodatabases that staff use for contract management, strategic planning, and reporting purposes.

With regards to vector control, VectorNet has a central spatial database that is updated with GIS environmental data (including altitude, vegetation class, slope and aspect). Similar to the mapping research outlined earlier in this report, these data are used to calculate areas of possum habitat, to automatically determine the number of traps required in an area to meet the population monitoring requirements, and where they are to be placed in the field. This process is outlined in figures 2, 3, and 4 below.

Figure 14 **Generate Trap line - VectorNet**



Generate Trap line *View Results* *Create Map*

Source: Ecological Associates case study

[21] Warburton. B, Cullen. R 1995: Cost-effectiveness of Different Possum Control Methods SCIENCE FOR CONSERVATION: 4. Department of Conservation, Wellington

[22] Gillren, D 1999: GIS and Possum Control on Mount Karioi. Presented at SIRC 99 - The 11th Annual Colloquium of the Spatial Research Centre University of Otago, Dunedin

Vector control and monitoring contractors have the capability to use GPS-enabled handheld devices to locate trap lines or bait stations generated by VectorNet, update the database with vector control or monitoring results from the field, then upload information through a Web browser to VectorNet. Data are then validated and added to the reporting geodatabase.

VectorNet has refined the process so that contractor effort is being targeted to habitats and locations where possums are likely to exist. Cost savings are also realised due to ability to predict possum habitat and abundance, which reduces the need to monitor possum abundance and TB incidence in the field to the same extent as before. Preselecting trap lines and numbers will further reduce time taken to locate trap lines and specific trap locations, as these locations are downloaded from VectorNet to handheld devices used in the field. Savings will be achieved in terms of reduced labour time to locate, lay and retrieve traps.

There is an estimated $550,000 annual efficiency gain on the overall vector programme budget from better information provided by VectorNet. AHB has recognised that not all these savings are due to the spatial information or technology per se, but from the coordinative efficiencies provided by VectorNet.

In addition, there is an estimated $1,800,000 annual management cost savings related to the new spatially based VectorNet programme. The number of vector control and monitoring contract arrangements have been reduced from 11 to 6 (reducing the number of contractors from 107 to 45), and staff levels have been increased from 45 to 92 within existing budget levels.

The expected NPV [net present value] for VectorNet is $1.9 million with a payback of 3.3 years.

These savings are balanced against estimated annual costs relating to spatial information and technology including $70,000 on licences for spatial data, and the necessity to use up to 9 full time equivalent (FTE) employees at a cost of approximately $630,000 per year to maintain data accuracy.

AHB estimate that additional costs of approximately $5 million would be incurred annually in the absence of the spatially enabled VectorNet system[23]. This cost would include the inability to halt vector control as quickly as currently occurs due to data reporting mechanisms on the proof of control being less effective.

[23] Animal Health Board Interview

Disease control – the Disease Management Information System (DMIS)

Bovine TB disease control has traditionally been spatially based, involving controls on the movement of cattle from areas containing infected herds, documentation of herd's bovine TB status, and documentation of the history of cattle being moved from any herd or property[24].

A number of bovine TB testing zones have been defined to control the movement of cattle and the spread of disease. These zones are the:

- Movement Control Area (MCA): Areas where more than 1% of herds are infected. Pre movement tests[25] are required plus annual testing of all cattle stock over 3 months. Requires boundaries of the zones to be gazetted and reviewed annually to ensure that at least 1% of herds in each area are infected.
- Special Testing Area (STA): No pre movement tests are required but variable age and frequency testing is dependent on geography and TB risk.
- Surveillance (S): Areas that are TB "free". Triennial testing required over 24 months.

These testing zones historically tended to be hand drawn on physical maps and had text descriptions of physical boundaries. However, with advances in the use of modern spatial information and technology, the process of defining and reviewing boundaries of testing areas and testing the animals within them has been refined.

The Disease Management Information System (DMIS) was created by AHB in 2005, which uses GIS to record the geographic location of herds on each farm as well as each herd's type, test history, TB testing zone, and TB test results by age, sex, and date. DMIS is used to notify farmers when their herd requires testing and records and calculates the number of infected herds in each zone. DMIS has also refined the process for defining and reviewing MCA zone boundaries using an Arc View based GIS package that utilises standard land cover, parcel, and topographical layers.

Boundary changes are used to make sure that MCA zones are kept as small as possible because of the movement restrictions that apply to them[26]. Arc View is used within DMIS as part of an annual process to review all boundaries by

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24 National Bovine Tuberculosis Pest Management Strategy National Operational Plan: 1 July 2005 – 30 June 2013

25 TB tests required up to 60 days prior to movement of cattle off farms.

26 For example, because the MCA is defined by having greater than 1% infected herd prevalence, as the overall number of infected farms in the MCA decreases (and the overall % decreases), a non infected farm near the boundary may cease to be in the MCA where a boundary shift inward will still allow the overall rate of infected herds to remain at over 1%.

making an assessment based on the herd prevalence and disease incidence in each area, plus the likelihood of any herd becoming infected in the 12 months following a boundary shift. Figures 5 and 6 show how Arc View GIS has been used to present and recommend MCA boundary changes.

VectorNet is also increasingly being used by AHB to coordinate disease control including the administration, movement and control of animals between declared Movement Control Areas.

Cost avoidance

These spatially based GIS tools are being used to assess and define boundary changes to bovine TB testing zones that have varying levels of control within them. This process avoids the cost to the dairy industry of having the restrictions and costs that are applied to farms with infected cattle being applied herd or industry wide.

Costs and restrictions applied to farms with infected cattle include:

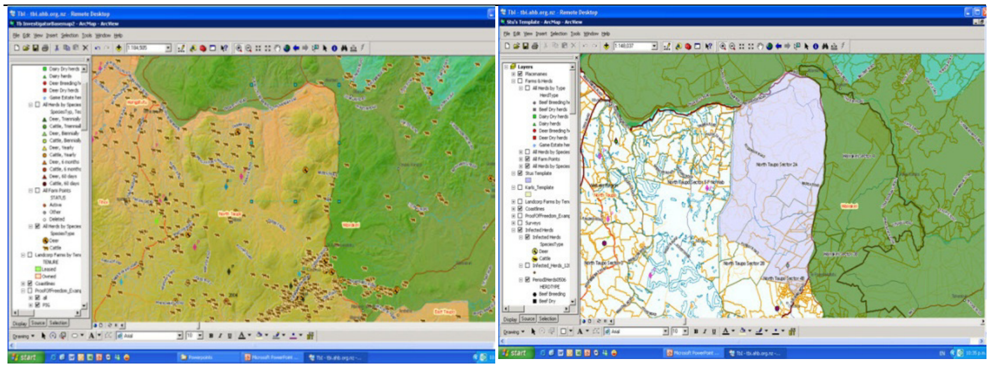
- Inability to sell calves off farms
- Inability to milk cows that are reactors
- Inability to graze off herds over winter to other multi-herd grazing units
- Compliance and reporting costs to AHB, including the requirement that two consecutive clear whole herd tests are received, with a minimum of six months between tests and no further evidence of disease. Tests cost $2.30 for a skin test per animal or $35 for a blood test per animal.
- Loss of stock that need to be slaughtered, with 65% of the market value of animals being compensated to farmers. This compensation is paid for by industry levies. There is a population of 5,261,000 dairy cattle in New Zealand in 2007 with a market value ranging from $475 to $1,425 per animal[27].

Rather than an industry-wide shut down, more precise zoning of the disease incidences (e.g. into MCA, STA and surveillance zones) has allowed trade to continue and costs to be avoided compared to what would otherwise have been the case if there was an industry wide shutdown.

Furthermore, farms with non infected herds have avoided the costs and restrictions applied to farms with infected cattle through the definition of the bovine TB testing zones and the management of animals within them.

[27] PGG Wrightsons Ltd: Maximum Valuation Limits for Dairy TB Reactors. Dairy valuations from 1st May 2009. Approved PGG Wrightsons Ltd

Figure 15 **Movement control areas managed in GIS**



Change to MCA in 2007 *MCA Change drawn and presented as recommendation*

Source: Ecological Associates case study

2.1.7 Land Use and Carbon Analysis System – LUCAS

LUCAS is being implemented to meet New Zealand's reporting requirements under the Kyoto Protocol. The data and information required to determine New Zealand's carbon stock changes will be stored in the LUCAS database. LUCAS is a cross-government programme led by the Ministry for the Environment (MfE) in partnership with the Ministry of Agriculture and Forestry (MAF).

The LUCAS team now consists of 20 staff. The project relies heavily on spatial data and modern spatial information technology, which it began to use "seriously" around five years ago:

> For the large and long-term LUCAS project the use of modern spatial information is absolutely critical. The project could not be completed without access to the technology (including the data). (Peter Stephens, Designer, LUCAS)

The satellite imagery for LUCAS is purchased under an all-of-government purchase agreement so that other government departments and local government can use these data. Apart from enabling NZ compliance with Kyoto, these and other data can be used for:

- verifying land that can be planted under the Permanent Forest Sinks Initiative and the Forest Emissions Trading Scheme (ETS)
- national land cover mapping.
- forest condition and biodiversity
  - This programme will undertake New Zealand's first national forest inventory since the 1940s. Additional data are collected at the same time as field party members collect forest and soil carbon data. This can in turn be used for:
    - … biodiversity assessments of indigenous forest and shrublands
    - … sampling frameworks for regional and local vegetation monitoring

LUCAS is an important example of spatial information enabling and being used in new applications rather than creating productivity improvements for existing processes. LUCAS will enable accounting and reporting of afforestation, reforestation and deforestation under Article 3.3 of the Kyoto Protocol during the first commitment period (CP1) from 2008-2012. Whilst the project has required a significant investment cost in terms of data acquisition and staff numbers required to implement the project, at the very minimum it should achieve avoidance of penalties that could be issued in the future in case of non-compliance with Kyoto requirements.

To better understand the size of the task which would have had to be undertaken in the absence of modern spatial information technology, it should be noted that LUCAS will calculate the amount of carbon stored in forests and soils and how these carbon stocks change with land use. This involves reporting for five terrestrial carbon 'pools':

- Above-ground biomass
- Below-ground biomass
- Dead wood
- Litter
- Soil organic matter

It is obvious that if this had to have been achieved by 'traditional' means (paper maps, etc.) it would have been a monumental, if not impossible, task. The respondent for this case study stated that the benefit-cost ratio for LUCAS has been estimated at 25:1; whilst the methodology for arriving at this figure is unknown it may well turn out to be an underestimate. Systems such as LUCAS will be critical in enabling and enforcing the shift to a low (or lower) carbon economy. This has ramifications for the entire economy.

2.1.8 Local Government

Many NZ local government entities began to seriously consider the use of modern spatial information technology in the mid- to late 1990s, although adoption has often been incremental. Implementation and upgrading of systems continues as the nature of use is expanding from basic applications to organisation-wide use. Important areas in which spatial information systems have made a significant impact are:

- asset mapping and management enabled by such mapping (e.g., footpath repairs and road maintenance)
- improvement in service delivery across a range of services such as rubbish collections, cleaning, and so on
- setting of rates and taxes (e.g., based on size of parcel or land values)

- management of local emergency response (and planning for emergency events)
- road works and traffic management
- schools admission and transport
- improved land use zoning and spatially based policy decisions affecting issues such as designated activity centres, green wedges and pedestrian routes
- other planning involving layered data, e.g., future needs assessment linking location of schools to suburb demographic changes; heat mapping and housing stock analyses; urban growth boundaries and future transport infrastructure requirements; etc.

In addition, citizen access to local spatial information is an increasingly important role for local governments worldwide. This enables, for example, better fault reporting (e.g., online) and responding more quickly to complaints.

The Auckland Local Government Geographic information (ALGGi) initiative is noteworthy. The group's strategy of joint data capture or purchase, sharing of ideas and skill sets along with continual networking could be extended to other jurisdictions; however, as emphasised by Barlow (2008):

> we are not in a position (human resource-wise) to take it to a higher level (p. 5)

This suggests that capacity and skills constraints are impacting on the ability to exploit full value from the use of spatial information at the local and regional levels.

2.2 Private services

This aggregated sector includes financial services, residential, recreational and other services and business services not elsewhere classified. It is the largest sector of the NZ economy by value added, with a share of around 28 per cent. It includes technical and professional services such as surveying, engineering, marketing, business consulting, etc. Some fall within the 'core' spatial industry, others use spatial technologies to provide their services more efficiently or to provide new and improved services. Businesses increasingly use spatial information to assist with strategic decisions. One of the interviewees commented that:

> In every case organizations have made a business decision to invest in GIS technology. The return on investment comes through improved productivity, better (and faster) decisions, regulatory conformance and cost savings. It is essential to appreciate this prevalence of GIS usage in NZ – GIS is only ever implemented to meet business (i.e. economic) needs and the fuel that powers GIS use (spatial information) therefore underpins a huge range of organizations. (Interview with Eagle Technology)

The business sector includes a number of GIS specialists, to whom spatial information is obviously critical. Examples of specific GIS/spatial consultants and service providers include the aforementioned Eagle Technology, Explorer Graphic Limited (EGL), Terralink International, Xcelerate and Geographic Business Solutions (GBS). Eagle are the exclusive distributors of ESRI GIS technology in New Zealand, the dominant software platform in local and central government. Xcelerate and GBS are new businesses offering innovative solutions across software platforms.

In addition to these, many of the NZ engineering consultants have in-house spatial capability, often making use of spatial data provided by their clients (e.g., LiDAR data for the Auckland Region provided by Watercare for the preparation of cross-sections and detailed designs of pipelines and other assets). They may also collect data for their clients in order to undertake design activities (e.g. GPS based survey data for asset management/design). Examples of consultants in this space include SKM New Zealand (350 in New Zealand), Beca, Opus International Consultants (1,800 in New Zealand), MWH New Zealand, and GHD New Zealand.

2.2.1 Surveying & mapping services

Spatial technologies have had a major impact on surveying and mapping (ACIL Tasman, 2008). GPS units have been of major value in surveying where the site is such that one can't physically see some of the objects (e.g. in a forest). Traditionally, surveyors would have had to traverse the site to fix locations. With GPS a direct line of sight is not needed.

Interviews carried out during the preparation of our previous study (ACIL Tasman, 2008) indicated that, as a result of modern spatial info-technology, there have been 25-100% productivity improvements in surveying over the last five years. Tools to improve the productivity of surveyors in the field also assist with creating a high precision cadastre. Remote sensing and airborne mapping systems are also able to significantly accelerate surveying efforts. Depending upon the level of detail required for the job at hand, aerial survey can be a much more efficient option (see next section).

2.2.2 Consulting services by the Geospatial Research Centre

The Geospatial Research Centre (GRC), although allied with the University of Canterbury as an R&D hub, was in fact set up in 2006 as a commercial entity (a private limited company). The GRC has provided some very innovative, cost-effective solutions for data collection including by the use of robotic aircraft. The longer term status of the GRC is currently somewhat uncertain as the economic downturn has impacted on the commercial side of the GRC's operations; however, the long term R&D function of the GRC is not seen as being under threat.[28]

Based in Christchurch, the GRC provides (and its successor will continue to provide) research and consultancy services in the fields of positioning and orientation, with particular expertise in sensor integration, image analysis, data visualisation and electronics. The GRC did see high demand of its specialised services from the private sector – in the last two years, the GRC secured over $1.1 million in contracts from commercial organisations in New Zealand, the US and UK including the Defence Technology Agency, NZ Post, Race Technology, Rakon, Sonardyne, Tait and Trimble. As a result, staff numbers grew rapidly from 5 at its founding in 2006 to around 20 now.

2.2.3 SKM/geology team use of GIS

The SKM/geology team use GIS systems to display previous boreholes, test pits, hand auger holes and cone penetration test (CPT) holes on a map of the area. The data are collected by:

1. Searching existing archives when undertaking desk studies for sites. GNS Science / Wairakei Research Centre have a similar database and can supply location maps with any relevant borehole logs; archives can supply geotechnical reports for recent developments.
2. Drilling or excavating holes for projects. Map coordinates and rough levels are taken using GPS.

Having access to the database makes searching for known exploratory holes easy – the site being studied can be visualized on the map and any surrounding hole logs identified. The time saving is estimated at 20 per cent:

> If the database wasn't there we would probably have to go through a spreadsheet and identify any nearby logs by the address only, with the possibility of not identifying all info available. There are currently around 370 logs on the database in the Wellington area. The database also has potential cost savings for SKM clients. If there are previous holes in close proximity to a site, less holes could be required. (SKM case study material)

2.2.4 Users of Landonline, NZTopoOnline and other LINZ products

As pointed out in the discussion of Landonline (Section 2.1.1), the system was expected to generate significant benefits to private service providers including surveyors, lawyers and conveyancers. Efficiencies to these types of users were

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28 Steven Mills, *pers. comm.* 31 July 2009 indicating the likely formation of an academic research centre: "it probably won't be the GRC (Ltd) providing that capability in the near term, but rather the academic centre (which doesn't have a formal name yet)".

originally estimated at $26 million per annum (Jackson, 2000); however these estimates could be serious underestimates – as shown in Section 2.1.1 the extent of internal efficiencies from Landonline was probably underestimated by a factor of 2-3. If the external users' efficiencies differed by a similar order of magnitude then the benefits to private users from Landonline alone could exceed $50 million. It is however difficult to assess the true level of benefit in the absence of more detailed statistical information on the nature of use and the benefits being derived.

Some additional data supplied by LINZ can be analysed; these data relate to the use of NZTopoOnline, the Internet version of the New Zealand Topographic Database, which has been receiving 500,000 to 600,000 website hits per month since mid-2003 (Land Information New Zealand, 2008a). The number of 'unique visitors' to the site is typically between 4,000 and 5,000 per month (including some large organisations with multiple users, but which are only recognised as a single unique visitor). Accessing the website is free of charge. Private sector users identified by a user survey included:

- GIS Professional
- Senior GIS Analyst, Engineering consultancy
- Architecture – Architect
- Resource Information Officer, Forestry sector
- IS Manager, Forestry Company
- Environmental consultant
- Environmental planners
- Programme Manager Logistics industry
- GPS map maker
- Event planning

Around one third of users had session times in excess of half an hour, and 20 per cent of users used the site at least weekly (Land Information New Zealand, 2008b). These figures suggest that there is a sizeable proportion of users who make relatively intensive use of the NZTopo site, and who are potentially deriving significant benefits from use. It certainly appears likely that there are at least several thousand 'events' each month which could be associated with significant user benefits. Judging by the time savings reported with use of digital maps and modern spatial information technologies in general, it is highly likely that this in turn implies thousands of hours of work avoided each month as a result of the use of NZTopoOnline. The annual benefit of this to providers in the private services sector could easily run into several million dollars.

A saving from the use of Landonline, NZTopo and other databases and products provided by LINZ of $50 million per year would thus appear conservative. ANZSIC Divisions M & N (Professional, Scientific, Technical, Administrative and Support Services) reported expenses were around $27.5 billion in 2007. This translates into a productivity shock of around 0.18 per cent for the sector as a whole in terms of the terminology used for this report.

2.3 Manufacturing

Manufacturing accounts for around 14 per cent of value added in the NZ economy. The benefits in manufacturing are perhaps not as obvious as one might suspect; however, asset management and supply-chain control (logistics) benefits that flow from the use of spatial information technology in other sectors also have the potential to be realised in manufacturing. For firms that operate plants at a number of locations the potential benefits could be significant. Similar to the discussion on the retail sector, there are potential benefits from better planning informed by GIS systems. However, little evidence of these benefits was identified in the specific context of New Zealand during the preparation of this report.

2.4 Trade services (including retail)

Trade services generate about 14.7 per cent of *value added* in the NZ economy.[29] The retail sector alone employs around 325,000 people in New Zealand, which accounts for about 20 per cent of the national workforce. In 2008, total sales for this sector amounted to around $66 billion. The industry includes 49,000 outlets, of which about 7,500 are run by 150 networks or chains (New Zealand Retailers Association, 2008).

Retailers combine spatial information with demographic and expenditure data in order to answer the core questions such as "who are my current and potential customers and where are they?" (ESRI, 2004) This informs commercial and retail strategy in a range of areas, which are discussed below, including:

- Boundaries and catchments
- Store location, size and design
- Product placement
- Targeted marketing
- Improved customer information

[29] An indication of the proportion of GDP – however, due to issues with allocating taxes such as GST to specific sectors, for which there is no single approach, the value added share may differ somewhat from a sector's true contribution to GDP.

In addition, the large retail chains benefit from the logistical applications for improving transport and delivery efficiencies similar to those discussed in Section 2.10 of this report.

The use of spatial information and technology is still the preserve of the larger organisations. The following is a list of some of the retail chains in New Zealand which have already benefitted from spatial information technology:[30]

- Beaurepaires
- Bunnings
- Farmers
- Foodstuffs
- Harvey Norman
- Kmart
- Liquorland
- McDonalds
- Mitre 10
- Noel Leeming Group
- Palmers
- Paper Plus
- Progressive Enterprises
- Shell New Zealand
- Sky Networks
- Smiths City
- Sony
- The Warehouse
- Warehouse Stationery
- Westfield

It is noteworthy, that few NZ retailers have their own in-house spatial data analysts. Of those that do, fewer still will have been trained in the detailed analysis of spatial data. Some of the larger, complex operations with diverse store networks or evolving product lines are likely to have only 1 or 2 (FTE) staff members specifically trained in spatial information analysis.

Almost all organisations therefore rely to some extent on external assistance to collect and analyse data for a number of reasons. Firstly, the advancement of software tools (see below) requires significant ongoing skill development. Secondly, data need to be identified collected, cleaned and formatted from a

[30] This list is based on published client lists of several spatial information consulting firms.

potentially very large number of sources most of which will require licences or intellectual property negotiations. In addition, while some data can be handled by in-house staff on a day to day basis, there are times of significant data upload (e.g. post census) requiring considerable resources.

These changing skills and data handing requirements account for a rapid growth in consulting services which often provide a single point of contact for data collection and analysis. Currently there are around 30 organisations that offer a range of specialist advice in market development (segmentation and profiling), financial analysis, store location and direct marketing.

Use of consultants is currently too expensive for the majority of small retailers. Looking to the future, however, it is believed that competition within the sector, improvements in software applications, as well as increased awareness of the benefits of adopting spatial technology, will lead to increased uptake across the sector.

The following sections discuss some of the practical examples of where spatial information is being utilised in the NZ retail sector.

2.4.1 Boundaries and catchments

Perhaps the most widespread spatial application is the mapping of customer catchments. Sometimes termed location intelligence, this can be used either at regional or district level, for a commercial centre, a collection of outlets such as a mall or for an individual store. At its broadest level, demographic information is collected at Census Area Unit level (including numbers of households, income and gender) and is used to model the likely demand and purchasing characteristics in a particular location.

From a regional and local development perspective, this has helped Councils develop policies on town centre growth and business zoning. For example, refined applications of location intelligence have assisted in 'gravity modelling'. This is where demographic factors are combined with data on complementary services, ATM availability, car parking and information on other competing retailers to determine the likely pull, or gravity, that a new retail centre may have.[31]

Similarly, commercial retail networks have developed growth (or reduction) strategies, opening or closing stores where demand is forecast to change or where new sites will increase their market share. This type of catchment modelling has also helped to identify boundaries for operation *within* retail

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31 Interview Critchlow Ltd

networks, setting legal areas for franchises, avoiding cannibalisation as well as identifying the likely impact of competitor operation.[32]

Mapinfo was the first to develop desktop GIS software that has since evolved into a range of applications offering varying components in location intelligence. The Mapinfo Users Group of New Zealand (MUGNZ) provides support, links and a forum for advancing the quality and access to data available for analysis[33].

2.4.2 Store location, size and design

Location intelligence models can be greatly enhanced with additional data on consumer habits, observations in a target area, traffic modelling, pedestrian counts, as well as expenditure forecasting.[34] Analysis of this information can lead to highly defined market segmentation and customer profiling which can then be spatially modelled to derive the optimal store location, even identifying a position on the best side of a particular street. Where location accuracy is modelled to this extent, some retailers will map lease holding data to identify when a particular site becomes available. This can give network or store owners the confidence to make development decisions they may not otherwise have made. In addition, banks are increasingly recognising the value of these data when considering loan applications.

Once the site is selected, the size of the store and its design and layout are the next considerations. Demographic data can once again be used to consider the optimal floor area for a given population and computer aided design linked with topographical maps can assist with orientation and layout while minimising resource and building consent costs.

2.4.3 Product placement

Retailers that have a diverse product range across their network identify particular items or brands that sell better in some catchments than in others. Consumer trends and customer profiling coupled with spatial mapping enables businesses to forecast demand for new items in different areas and therefore identify the stores where they should be placed.

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32 Radar products combine census data information with lifestyle surveys and property valuation information to assist with franchise and sales territory plans, neighbourhood and street profiles and prospect mailouts. http://www.mosaicnz.co.nz/pmp.htm

33 http://www.mugnz.com

34 Interview Critchlow Ltd

Taking account of seasonal variations across the country can also influence stocking decisions for some goods in places where the advance of colder or warmer temperatures will affect purchasing decisions.

2.4.4 Targeted marketing

Mail box advertising is a well developed practice in New Zealand. Conservative estimates suggest that around 10,000 paid distributors, centrally coordinated by 2 main distributing agencies,[35] deliver around 1.5 billion promotional mailings a year nationwide.

Even in its most basic form, targeted marketing employs spatial information. New spatial information technology allows more detailed customer profiling, so that only certain streets may be targeted.

Given that direct marketing can account for up to 80 per cent of overall marketing budget, these spatially based refinements in strategy can make a significant contribution to the retailer's bottom line.[36]

In terms of savings, spatially enabled targeted mailouts may lead to financial savings of up to 10 per cent of the overall marketing budget.[37] This approach also reduces the cost of paper and printing and will therefore significantly reduce environmental impact over time.

A specific tool used in NZ targeted marketing is *Mosaic*. This enables advanced spatial analysis of market segmentation at both household and neighbourhood levels. It uses over 350 variables (including census, housing valuation, shopping habits and data from Land Information New Zealand) to develop 11 core groups classifying a total of 42 household types (see Table 1).

[35] PMP Marketing & Reach Media

[36] Interview Critchlow Ltd

[37] Confidential interview

Table 1 **Core groups of NZ household types used in spatially enabled targeted marketing (Mosaic)**

Symbols of Success	Three categories describing the most affluent New Zealand households. High spending families and high achievers in the most desirable suburbs.	5.1 per cent
Suburban Comfort	Three categories describing wealthy areas of educated professional families in established and new suburbs.	8 per cent
Urban Intelligence	Three categories covering educated and high-earning young singles and sharers in the inner suburbs.	4.8 per cent
Singles & Starters	Five categories of students and younger workers living in high density, lower cost suburbs.	8.6 per cent
Family Growth	Five categories of young families mostly with school-age children, living primarily in cities.	12.6 per cent
Provincial Pride	Three categories of true kiwis in provincial towns. Many older couples and empty nesters.	8.3 per cent
Working Fringe	Five categories of mixed families with stretched budgets in outer suburbs. Settled, mature households in New Zealand's blue-collar and multicultural centres.	17.8 per cent
Community Challenge	Four categories covering low income, low spending households in smaller homes and older people nearing retirement.	9.1 per cent
Grey Power	Two categories for comfortable retirees enjoying the end of a long life.	3.1 per cent
Cultural Ties	Four categories describing the areas of highest cultural diversity. From families with school-age children in state housing to entire rural communities.	8.5 per cent
Rural Ties	Five categories of rural landowners and workers in New Zealand's farming heartlands. From hobby farms to rural economic powerhouses.	13.5 per cent

Data source: adapted from http://www.mosaicnz.co.nz

2.4.5 Improving customer information

A relatively recent development in New Zealand is the use of improved information for customers on store locations and stock availability. Offered through websites, smart store locators enable customer to identify the nearest store that stocks a specific item thereby creating certainty in their trip and increased confidence in the company brand. Those organisations that have developed this service will tend to offer maps of the location as well as information on opening hours. In addition, those websites that offer direct mail delivery of their merchandise will note the customers address in geo-code format enabling efficient route mapping for delivery. Efficient routing leads to estimated savings of 20-30 per cent again reducing environmental impacts.[38]

In future there is potential for tagging individual stores to enable location via GPS on a mobile phone. This would not only improve customer experience but could also serve to improve stock control.

2.5 Construction

Construction is fundamentally spatial in nature – roads and buildings, dams and tunnels all require and transform spaces. According to official statistics there were 53,594 enterprises with 131,980 employees in the construction sector in 2008 (Statistics New Zealand, 2008a). The vast majority (97.3 per

38 Confidential interview

cent) of these enterprises are in the building construction and construction services sectors, and these are typically small firms or sole traders with less than two employees on average (Statistics New Zealand, 2008a). The remaining 1,466 enterprises or 2.7 per cent of all construction enterprises are heavy & civil engineering companies; these are typically larger and on average employ around 20 staff based on the official statistics. This small number of companies accounts for around one-quarter of the sector's employment.

In terms of the productivity impacts reported in this study, based on a number of interviews and feedback received, the adoption of modern spatial information technologies is largely restricted to the bigger companies such as the ones dominating the heavy & civil engineering construction subsector. Small companies and sole traders probably have little the need for 'enterprise-wide' GIS; they may benefit from hand-held devices which are spatially enabled, but the extent of use of this in the New Zealand construction sector is currently unknown.

Modern spatial information technology does have a proven ability to accelerate large capital projects, generating efficiencies both on the ground as well as in the planning stages. Examples of where the use of spatial information has benefited New Zealand construction companies include:

- LiDAR data used in developing digital terrain models for design. Digital terrain models enable highly accurate modelling of design and cut/fill requirements without the need to undertake detailed physical survey
- GPS systems for graders used in road construction; in road projects machinery which is GPS enabled also allows tracking of construction equipment and materials transport via GPS and GIS in a similar way to the intelligent transport methods discussed in other sections of this report
- In excavation work GPS is being used to control the positioning of machinery to accurately excavate material. Geo-positioning software is also used in building height determination
- Robotic total stations with integrated GNSS/GPS are used by construction companies in surveying sites (as well as by consultants in the business services sector).
- Design and project management software tools that increasingly approach CAD/GIS/BIM interoperability
- Companies operating in the construction sector are also beginning to benefit from use of enterprise-wide business GIS (Section 2.1.2 gives an example of a spatial viewer)

2.5.1 GPS controlled excavation, rework minimisation and other on-site benefits

Reykjavik University in Iceland investigated the benefits of using GPS machine guidance in construction equipment which has been widely adopted in NZ (Aðalsteinsson, 2008). The aim of this project was to compare the performance of an excavator using a GPS guidance system with an excavator in the same line of work but was done the traditional way (and with surveying). The task involved the digging of trenches in two different ways.

The project concluded that GPS machine guidance is improving the performance of belt excavators by minimizing unnecessary excavation. As a result considerable time and fuel is saved (22%). When unnecessary excavation is minimal, filling requirements are reduced and so the purchase of sand was also 59% less. GPS machine guidance ensures less deviation in height with accuracy ±4cm. Construction equipment with GPS machine guidance were better utilized and the machines are self-contained and can work independent of the surveyor, who is not always available. Driving of trucks diminished, as less material is driven from the site and less fill is needed for excavations. The equipment was seen as extremely user friendly according to the operator of the excavator, who was using it for the first time. Overall the GPS usage resulted in a 55% saving in time.

As expected the use of GPS to control machinery has led to a reduction in the amount of rework required to landscape excavated areas. In some cases this can yield a reduction in rework of 70%. Another benefit is the flexibility that GPS positioning allows. For example if a problem is encountered in one area of a job-site the equipment can be moved to deal with it and then relocated accurately to start work again without a costly re-survey.

Supervision of construction work is also reduced as there is no need to continually check progress against pegs. With GPS data being collected progress can be recorded and viewed within GIS system semi-live. This can translate to a reduction in supervision by 75% or more.

2.5.2 Environmental data collection

Linear infrastructure projects including roading, pipework and electricity transmission require accurate surface terrain models. This has historically been done using aerial photogrammetry which requires very time consuming analysis. Preliminary design mapping (1" = 200'), digital terrain modelling, orthophoto rectification, and preliminary earthwork calculations are all preliminary design activities for which LIDAR can be used.

Three case studies by the National Consortium for Remote Sensing in Transportation in America have found that using LiDAR to collect data on corridor terrain can reduce the cost of collecting data by 92% and the time required by 60%.

When applied to a $1 billion capital works project this would equate to a cost saving of $15-20 million – equivalent to a 0.15 to 0.2 per cent productivity shock in terms of the terminology used for the economic modelling in this report.

2.5.3 Construction fleet management

Installing GPS systems on trucks supplying materials and moving around construction sites has several benefits. It provides visibility and control for dispatchers to the construction trucking fleet. Mapping software in vehicles can assist efficient delivery of products to unfamiliar locations. GPS mapping programs have the ability to identify optimum routes. Concrete trucks can be fitted with bowl rotation sensors to provide real time field data to the central office. More examples of this type of benefits are covered by the discussion in Section 2.10 of this report, which deals more generally with transport and logistics related benefits.

2.5.4 Fulton Hogan case study

Fulton Hogan (FH) is a large trans-Tasman infrastructure construction, road works and aggregate supplier. In 2007 the company reported an annual operating profit of $92.93 million, from revenue of $1.61 billion and employed over 4,800 people. Fulton Hogan is beginning to see value in GIS/spatial information but is probably still at initial stage along the GIS learning curve – in particular with regard to the enterprise-wide benefits that can potentially be reaped from the technology.

At present, advanced spatial technology is only used on specific FH projects or in specific applications. Some FH vehicles are GPS enabled and much data are in fact captured (but not necessarily utilised). GPS units are currently being used by some FH crews who report a 50% productivity increase but there are only a small number of crews using them.

Other applications of GIS at FH include:

- Feilding Open Space Mgt – GPS to assist in reporting
- Waikanae sweeper, sweeper activity plotted on Google Earth map for client
- Navman technology on around 100 vehicles but not well used
- Crews use aerial photos for location of assets
- Mobile devices, estimate 70% uptake in roading asset mgt area (Works, Transfield. Auckland Motorway alliance is leading uptake
- FH consultants use LiDAR – no physical surveyor required

- use free imagery/info
- GPS enabled equipment enables shifting machinery around worksite when problems are encountered with no need for re-survey worksite when returning to half completed work.
- Improved scheduling and routing of crews and ensuring that the right people are directed to the right jobs.
  - Fulton Hogan are working towards using existing data of vehicle/crew location to optimise scheduling of jobs (right crew for each job, who is in the vicinity when 'emergency' jobs arise) and track performance. The estimate is that this will save 30 per cent on traditional methods of scheduling and managing maintenance activities (based on experience in the UK). This is largely about using existing data in new ways rather than collecting new data. Existing data includes information about the location of crews (GPS enabled vehicles), information about the location of assets (GPS, imagery) and data with a spatial component such as quarry records (when vehicles are weighed out there is a data point for vehicles at a location – the weighbridge – at a point in time).

Figure 16 **Roads contractor using handheld RAMM device**

Source: SKM case study

FH use GPS enabled equipment for all major projects but not as yet in maintenance. This avoids pegging out sites and is used for generating as-built drawings. This completely changes the management of the site as staff are able to assess progress using GPS data rather tracking against pegged out worksite. GPS use on a typical job would save four engineers due to pegless construction. FH is a fast follower in this space and estimates its uptake to be 100 per cent.

Barriers to GIS uptake and future plans for Fulton Hogan

Data can be expensive and understanding the cost/benefits for particular jobs remains important. Ideally the company would avoid maintaining systems for clients and instead link into clients' data – but this presents challenges regarding formats/standards. The large number of clients means that data linkage is challenging due to the lack of consistency in software and various formats.

As mentioned earlier, FH has not as yet moved into regular use of GIS and spatial technology for maintenance work; it was mentioned that the degree of accuracy required becomes very important in the maintenance field. Variations in GPS accuracy make periodic work over time more challenging. Discrete projects continue to be more amenable to GIS integration.

The cost of GIS will also continue to be relevant. Contractors are cost focussed and want to know the benefits of paying for the technology. FH have outlined the following strategy to incorporate GIS more fully:

- working with leaders in the use of GIS/GPS within the company
- workshops on strategy led by FH region that need GIS/GPS capability for a contract.

In conclusion, FH is using modern spatial information technology with some tangible benefits but its uptake is not as yet widespread through the company. Given that FH collects a vast amount of location based data (in excel, SQL, Oracle programs) which is currently used in a limited way there appears to be clear potential for using a GIS as a portal to access these data. The future of GIS at FH will depend on education, demonstrating cost/time savings and the adoption of standardised data formats and accuracy controls.

2.6 Agriculture

Precision agriculture is seen as the future of agriculture, which will involve increasingly heavy use of spatial information. Self steer technology using GPS has been used by some farmers for up to a decade now; the next move is to more complex variable rate technology (VRT) which has significant potential to reduce costs to farming operations – estimates vary from 10 to 20 per cent of costs – improve environmental outcomes, and make farming a more sustainable industry. This makes farming more sustainable not only because the productive capacity of land is maintained for longer periods (e.g., through less rapid soil degradation), but also because modern spatial information technologies have the capacity to make farming less onerous on farm workers (e.g., tractor drivers – in fact the next step in some broad acre applications is *driverless* GPS controlled tractors).

2.6.1 Ravensdown – fertiliser application

Ravensdown is a large cooperative of NZ farmers, formed in 1978 by a group of farmers who wanted to gain better control of their fertiliser supplies (Ravensdown, 2008). Ravensdown reported a turnover of $672 million in 2008, with nearly 1.5 million tonnes of fertiliser sold in that year. The company began using GIS to record and present soil testing data, but involvement in modern spatial information technology grew out of the desire to be more involved in the fertiliser ground spreading market,[39] which is a fertiliser placement service provided to farmers (accurate spreading of fertiliser by truck). Usually this operates as a joint venture with the drivers involved.

Ravensdown estimate that they have around 60 trucks servicing this market out of a total of around 300 nationwide. It was estimated that 75 per cent of all the trucks nationwide would be using GPS. Other NZ players in this space are TracMap and Precision Tracking. TracMap was established for this particular application/software and has 12 permanent staff.

The company sees its strengths in its adherence to Spreadmark (the quality assurance scheme for the placement of fertiliser on farm land in New Zealand) and its quality equipment which enables it to cover larger areas (wider spread). It was mentioned that the "other half" of the NZ fertiliser market does not offer the types of services and functionality that Ravensdown offers.

GPS enabled Ravensdown to carry out more effective spreading using a proprietary system on its trucks (largely 'out of the box' software on trucks) – this controls the spinners and enables data capture and uses a highly accurate differential signal. Data transfer occurs via the mobile network.

The area in which Ravensdown had to invest more significantly in terms of spatial technology was the 'back end' processing of the information from the trucks. This was automated using arc software which creates centre lines and polygons, as well as a pdf file for customers that is available via an external map viewer using aerial imagery from TerraLink (see Figure 17).

The system was originally developed by Eagle Technology, but more recently GBS redesigned the system using ".net" and other open source web based applications.

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[39] Interview Mark McAtamney, Chief Information Officer, Ravensdown.

Figure 17 **Fertiliser application map customer viewer**

Source: SKM case study

The efficiency gain from using modern spatial information technology in the delivery of fertiliser application services was estimated at 30 per cent – in terms of time and fuel saved and the wider spread, which is only achievable with any degree of confidence with real time GPS track/guidance. Less fertiliser is used due to the reduction or complete elimination of overlap. There is also an ability to drive at night during peak season which is of value to farmers.

Ravensdown continues to invest in its GIS resources, with two staff on hardware in vehicles, and 20 per cent of one FTE in the head office; the company continues to contract out detailed design matters and reported that the capability of consultants is continually improving. Current data includes aerial (TerraLink), cadastral and fertiliser application history, but Ravensdown would like to see a national farms database (extension of Agribase).

As steps for the future, Ravensdown can see benefits from a digital elevation model as it could be used to plan application based on slope and aspect to water and sunshine (but would also require more detailed data on climate, rainfall and temperature). A key aim in fertiliser application is to avoid rivers so that runoff into sensitive waterways can be minimised. Ravensdown emphasised the value of data sharing.

Ravensdown would value having access to other information such as pasture growth recorded by farmers using Pasture Coach, farm production, planned fertiliser applications, irrigation, and so on. The data are already held by farmers, and Ravensdown could provide storage and integration via an external viewer. The Chief Information Officer of Ravensdown suggested that a national list of what data are available would be useful (and how to get the data).

More generally, the company reported that farmers struggled to understand the value of spatial data initially but are now increasingly demanding it. Corporate farmers in particular were seen as increasingly using it for tracking of fertiliser use and to compare nutrient budgets with actual outcomes, i.e., they are seen as working on getting down to the field level which essentially means trying to get to grips with variable rate approaches and technology.

Ravensdown mentioned that imagery is still seen as being expensive, however they are happy to work with government and commercial providers at reasonable cost. For Ravensdown, key considerations are that it needs to be current and orthocorrected (i.e., correlate to differential GPS on trucks).

2.6.2 Wine – precision horticulture

The wine industry is a major export revenue earner when compared with the rest of the New Zealand horticulture industry. Major horticultural exports in 2006 included fresh kiwifruit which represented 30%[40] of total horticultural exports, followed by wine (22%[41]), fresh apples (14%[42]), processed/frozen vegetables (12%[43]) and fresh vegetables (9%[44]).

The industry has changed significantly over the past nine years. The vine producing area and total wine production have increased dramatically, which is illustrated in

[40] $699.4 million.

[41] $510.2 million.

[42] $330.2 million.

[43] $291.4million.

[44] $204.9 million.

Table 2. This reversed a trend of moderate growth in wine production between 1990 and 2000. This growth was due to decreasing average yields per hectare that were related to the changes being made in the grape varieties grown, and a large vine area that was yet to come into production[45].

Table 2 **Summary statistics of New Zealand grape wine industry**

	2000	2008	% change
Number of wineries	358	585	63.4
Producing area (hectares)	10,197	29,310	187.4
Average yield (tonnes per hectare)	7.8	14.4	84.6
Wine production (million litres)	60.2	205.2	240.9
Wine exports (million litres)	19.2	88.6	361.5
Wine exports ($million)	168.6	797.8	373.2
Domestic sales of NZ wine (million litres)	41.3	46.5	12.6

Source: New Zealand Winegrowers Statistical Annual 2008

The wine industry continues to grow rapidly with export volumes expected to increase by over 30% between 2008 and 2009[46]. Past and future expected growth has led to the conversion of land previously used for agriculture and other types of horticulture.

Important factors in making this and other land productive for viticulture involves choices around the placement and alignment of vine rows, the grape varieties grown, and the application of inputs (e.g. water, fertiliser). Many of these decisions can be assisted by the application of spatial technology and information which is increasingly used in "precision agriculture". Precision agriculture involves varying and targeting management to suit the characteristics and needs of specific areas of the land, identified through spatial and temporal analysis.

Precision agriculture has demonstrated the successful application of modern spatial information and technology in New Zealand and overseas. There are aspects distinctive to viticulture that have been recognised as making the industry amenable to the approaches developed in precision agriculture[47].

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[45] http://www.maf.govt.nz/mafnet/rural-nz/profitability-and-economics/producer-boards/review-of-wine-legislation/winedisc-02.htm.

[46] Ministry of Agriculture and Forestry 2008: NZ primary sector forecasts encouraging (media release) http://www.maf.govt.nz/mafnet/press/2008/080805-sonzaf.htm.

[47] *Lloyd Smith & Peter Whigham 1999:* Spatial Aspects of Vineyard Management and Wine Grape Production. Presented at SIRC 99 – The 11th Annual Colloquium of the Spatial Information Research Centre University of Otago, Dunedin, New Zealand December 13-15th 1999.

Aspects of 'precision agriculture' that have been applied in the New Zealand wine industry since 2000 include:

- Controlled traffic farming (CTF) or 'guidance'
- Variable rate technology (VRT).
- Advances in imagery and mapping which includes:
  - soil condition mapping
  - crop stress and yield mapping.

The degree to which these techniques have been employed in the wine industry will be discussed in the following sections. Case study analysis did not indicate a higher industry-level adoption of precision horticulture techniques in other major horticultural exports (e.g. kiwifruit, apples, and vegetables).

2.6.3 Controlled traffic farming or "guidance"

Controlled traffic farming (CTF) refers to the use of positioning technology for equipment guidance in horticulture.

This technology has been adopted in surveying as part of vineyard development. Challenges exist in ensuring vine rows are installed in straight lines over rolling hill country. Harvesting machines operate most efficiently and safely on long straight rows that run straight up hills, as this prevents the machines tilting to the side on an incline[48]. GPS has been used to guide tractors in surveying and mapping vine rows since 2002. Real Time Kinematic (RTK) signal correction has been used to provide guidance data to within 25mm accuracy.

Using RTK required early adopters to build base stations on known, surveyed points on vineyards, and the use of mobile receivers on tractors within a ten kilometre range of the base stations[49] to survey and map vineyard rows. This required set up costs of approximately $120,000 for a 1000 hectare vineyard, but reduced survey times by a factor of 10[50].

This capital requirement has meant that GPS guidance using RTK has not been widely adopted in vineyard surveying, but it has been used for surveying approximately 3000ha, or 10% of the total New Zealand production area. One firm providing the required GPS equipment, Trimble Navigation Ltd, reported that its prices relating to this guidance technology have decreased by 55%

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[48] http://brucecasswinelab.com/?q=about/articles/labor.

[49] The base station transmits corrections via radio to the mobile receivers in the field. A typical radio link required for RTK is in the UHF, VHF, or spread spectrum radio band. http://www.trimble.com/ag_gps.shtml

[50] Vineyard Estate Owner Interview.

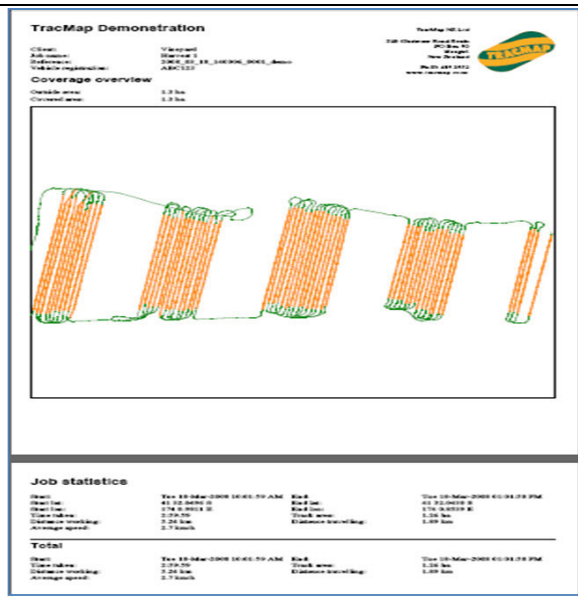
between 2004 and 2006[51]. These cost reductions may reduce the barrier of uptake of technology by vineyards in the future. However the requirement for purpose built base stations on vineyards for RTK signal correction may ultimately serve to limit the uptake to larger vineyards.

Vineyard production

Controlled traffic farming has also been adopted as part of vineyard production; specifically in planning the routes taken by vineyard machinery for spraying and harvesting. GPS guidance units are used to develop on-screen maps that indicate the optimum route to follow along vine rows (e.g. the best turning circles for harvesters or sprayers to take). These optimum routes can then be used repeatedly in each growing season. Units also show which rows have been covered and those that have not in real time, and can record the location of partially completed rows that can easily be returned to later. An example of a GPS unit and the map produced is shown in Figure 18.

Figure 18 **Controlled traffic farming – GPS in a vineyard**

GPS Unit



Route map

Source: http://www.tracmap.co.nz/viticulture--horticulture/, Tracmap demonstration map : http://office.tracmap.co.nz

An important commercial benefit is the reduction in overlaps, for example spraying the same row twice. Benefits due to reduced overlap of spraying have been estimated to be in the order of 11% savings on spraying costs[52] . Another

[51] Roz Buick 2006: RTK base station networks driving adoption of GPS +/- 1 inch automated steering among crop growers. Agricultural Division, Westminster, Colorado, USA.

[52] GPS Equipment Supplier Interview.

benefit is that spraying and harvesting can be undertaken during periods of poor visibility that are affected by weather or the time of day.

Vineyard monitoring

GPS guidance units have also resulted in significant benefits as a result of increased monitoring capacity. This includes monitoring of vineyard production as well as monitoring of wine quality. Time savings have been realised due to the ability to monitor the efficiency of production, including monitoring harvester and sprayer route, movement, speed, fuel consumption, and engine temperature. Results have been used to improve driver efficiency for example, by identifying and eliminating hazards or bad work practices. Recent evidence suggests time savings of between 1% and 10% are attributable to monitoring via GPS units[53].

GPS units have also been used to monitor wine quality. The reduction of overlaps discussed above ensures that environmental performance is increased by minimising the use of chemical sprays and thus reducing the risk of residues. GPS units also provide data on where in a vineyard certain grape varieties have been harvested from. This allows winemakers to define sub-blocks within a vineyard on the basis of the characteristics of the grapes within them, and to harvest and blend batches of grapes from different blocks. This enhances the traceability of the product, through a record system that can identify sources of components of a wine blend back to their locations within the vineyard. This ability to trace a product from the ‘paddock to the plate’/’soil to the glass’ is becoming seen as increasingly important[54].

Just as important to wine quality is the need to ensure that the yield of grapes grown per hectare is not too high. This is in light of recent reviews by UK wine critics that high yields of sauvignon blanc grapes in Marlborough were taking their toll on wine quality[55]. Wine makers often limit the yield of vineyards by setting a maximum tonnage of grapes that can be grown per hectare. When grapes are purchased from contracted vineyards for wine making, GPS units are used to record the routes used by harvesters. This is to demonstrate that rows have not been missed out in order to not exceed maximum grape tonnage per hectare requirements[56].

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[53] Vineyard Estate Owner Interview.

[54] *Lloyd Smith & Peter Whigham 1999:* Spatial Aspects of Vineyard Management and Wine Grape Production. Presented at SIRC 99 – The 11th Annual Colloquium of the Spatial Information Research Centre University of Otago, Dunedin, New Zealand December 13-15th 1999.

[55] http://www.stuff.co.nz/marlborough-express/news/2462522/UK-wine-critics-opinion-decried

[56] A maximum of 15 tonne/ha for Grape Growers interviewed.

GPS units typically involve hardware costs of approximately $3,000 to $4,000[57], and costs of approximately $160 per month[58] relating to the use of differential GPS (DGPS) to provide a correction signal to within a 1 metre accuracy. GPS units are known to be used for controlled traffic farming on approximately 1,400 hectares of vineyards, or 4.8% of the total New Zealand production area. While some equipment suppliers interviewed considered that the ongoing cost of accessing DGPS was a barrier to the uptake of this technology, feedback from the larger scale wine makers suggested that this ongoing cost was not significant in the context of their overall operating expenditure. Smaller vineyards adopting GPS units that require DGPS is considered more likely than the adoption of GPS technology that uses RTK signal correction. This is because rather than requiring a base station on the vineyard itself for RTK signal correction, DGPS can be sourced from other existing base stations, worldwide networks of DGPS radio beacons or satellite differential service providers.

2.6.4 Variable rate technology

Variable rate technology (VRT) offers another productivity tool in addition to Controlled Traffic Farming CTF. VRT uses detailed spatial information to enable the matching of inputs (e.g. water, fertiliser) with crop and soil requirements as they vary within a field. VRT allows a grape grower to apply the appropriate type of management to blocks of land that contain similar characteristics. For example, he or she could vary canopy management, pruning, bud removal, bunch thinning, leaf trimming, the application of sprays for disease and pest control, and irrigation to suit different soil types within a vineyard or to suit areas producing different yields of grapes.

Research is still being undertaken in order to better understand observed yield variations within vineyards. For example, research was instigated in 2006 to observe yield variations within vineyards, and to understand the correlation between yield and canopy vigour (foliage). Until this type of research is completed and is more widespread, the degree to which spatial information can make an impact in applying VRT is limited.

A specific example where variable rate technology is being applied in the industry relates to frost control. GPS enabled sensors have been located at various points around a number of vineyards to monitor environmental data including air temperature, humidity and soil moisture content to accurately warn of approaching frost fronts or frost conditions. A senor used to measure air temperature is illustrated in Figure 19.

[57] Equipment Supplier and Wine Grower Interviews.

[58] Equipment Supplier Interview.

Figure 19 **Sensor used to measure air temperature**

Source: http://www.indigosystems.net.nz/

When temperature or soil moisture reaches certain thresholds, GPS enabled sensors are used to remotely activate water frost protection systems in different parts of the vineyards. These systems involve the use of solenoids that pump and spray water via sprinkler irrigation systems. Sensors cost approximately $2000 each[59] and realised savings from their use include fuel cost savings of between 30 and 40% [60] from selectively running irrigation systems and labour cost savings of 3.3%[61]. Adoption of this type of VRT is still low, with early adopters recognising that more widespread adoption requires the dissemination of information about the potential benefits and the greater collection of yield data.

2.6.5 Mapping and imagery

With the limited collection of information on yield variations within vineyards, the mapping of this information has also been restricted. Yield mapping could show spatial variations in crop yield (e.g. tonnes per hectare), that is not being illustrated by the practice of measuring average yields. Current emphasis has been on relating yield for the whole industry to meteorological data (e.g. temperature and weather events) occurring at critical times during the season rather than on relating yield to spatial variations within a vineyard[62].

[59] With one grape grower interviewed indicating that 30 sensors were located over 1000 hectares of vineyard.

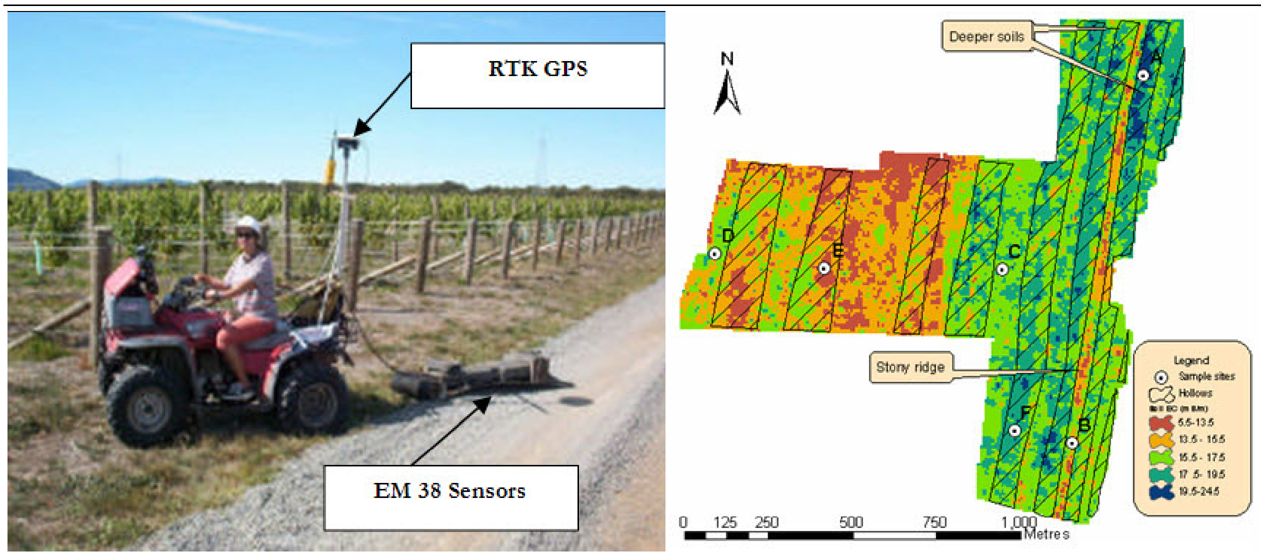
[60] Realised cost savings of $120,000 for a total of 1400 ha of vineyards.

[61] For a 400ha vineyard.

[62] Low temperatures occurring during late spring affects flowering, and in turn the fruit set in the following season. Using a stepwise, multiple regression technique a model has been developed to predict yield from temperature data in December and January. This provides a preliminary estimate of yield 12 months before harvest date, with a risk analysis using historical flowering temperatures. The yield estimate is updated following flowering in the current season (approximately four months pre-harvest) http://www.agroecologia.cl/pdf/02.pdf.

Examples where mapping has occurred using modern spatial technology and information includes the use of Electro-Magnetic Induction (EMI) surveys to define soil zones. EMI surveys use EMI units to pulse an electromagnetic field through the ground and measure a returning signal against a background field. Different ground conditions (and soils) distort the returning signal in different ways, which can be measured and recorded. EMI surveying in Marlborough has involved the use of Geonics EM38 sensors to measure EMI across vineyards. This information has been mapped with the use of GPS units using RTK, mounted upon all terrain four-wheel motorbikes. The outputs of this surveying are maps of the micro-topography and soil characteristics of vineyards in Marlborough. The data has been interpreted using ArcView GIS. This process is illustrated in Figure 20.

Figure 20 **Electro-Magnetic Induction (EMI) surveys to define soil zones**



RTK GPS and EM 38 *EM Survey Map*

Source: Slide show presentation posted on the world wide web: "Remote Sensing in the Vineyard" Mike Tuohy, NZ Centre for Precision Agriculture, Institute of Natural Resources, Massey University, Palmerston North, NZ

The outputs from this research included integrated land suitability maps of vineyards, which could then be used to determine the most suitable wine grape varieties for locations within the vineyard[63]. The provision of EM Survey services are currently being offered by commercial companies, but it is estimated that less than 2% of vineyards have been surveyed[64].

[63] http://www.nzcpa.com/content.php?content.6.

[64] Equipment Supplier Interview.

Conclusion

The wine industry in New Zealand is an industry that is still in the process of adopting modern spatial information and technology. Viticulturalists are increasingly using digitised geospatial information as land is converted from other uses, and as productivity gains from grape growing become increasingly important. The systems have built upon technological advances from precision agriculture. This includes the use of GPS technology to guide vineyard development and to optimise spraying and harvesting processes. GIS is also beginning to be used to map environmental characteristics of vineyards and GPS is also beginning to be used to match inputs with crop and soil requirements as they vary within a field.

Cost savings have been realised from the use of modern spatial information and technology. Overall, some individual wine growers stated that they saw their overall productivity rise by 20% as a result of the introduction and refinement of modern spatial technology and information[65]. Barriers to the adoption of modern spatial information and technology have been related to the initial hardware and signal costs involved; however these costs are decreasing over time. Adoption by smaller vineyards as the benefits realised by initial adopters become obvious is a future trend for the industry.

2.7 Food

The food sector is responsible for around five per cent of value added in the New Zealand economy. It notably includes meat and dairy products but also beverages, sugar, oils & fats and other food products. The benefits of adopting spatial technologies to this sector were explored in the context of a case study of Fonterra, one of the major food companies in New Zealand, as discussed below.

2.7.1 Fonterra dairy products

Fonterra is the world's leading exporter of dairy products and responsible for more than a third of international dairy trade. In New Zealand it is co-operatively owned by 11,000 New Zealand dairy farmers. The company's annual turnover is $19.5 billion with a sales volume of 2.6 million tonnes and 15,900 employees. The company benefits from modern spatial information systems in several ways:

- On the logistics side in the transport division Fonterra uses an in-house scheduling/tracking system utilising GPS (this is run out of Hamilton) that uses a road network created in MapInfo known as Genesis

[65] Combined use of CTF and VRT. Vineyard Estate Owner Interview.

- Fonterra's Strategy Team also uses MapInfo and Google Maps to inform their supply and transport strategies – the Strategy Group use data owned by the Transport/Logistics group (read-only format)

Spatial information is also important for the strategy team in communicating to area managers and the Fonterra Board. Ward and boundary information is important for Shareholders Council elections and their administration. The legislation for Fonterra also covers exclusion of farms and Fonterra uses MapInfo to ensure that the legislation is being complied with (the Clean Streams Accord, etc.). The strategic analysis requires spatial tools - a task that takes 2 minutes using spatial tools would take 2 weeks without electronic data and the ability to interact with that data in a spatial format.

Benefits in terms of accelerating individual tasks in strategy and planning are clearly important but their financial impact on the company is difficult to assess. It is however also noteworthy that Fonterra staff reportedly enjoy using MapInfo which could in turn enhance productivity or assist with staff retention in the longer term.

In terms of more readily measurable productivity benefits from spatial technologies, the transport/logistics benefits were highlighted. Fonterra collects from up to 10,500 farms each day, transporting milk to 26 production facilities – clearly a monumental task and one in which spatial information is already known to have the ability to make significant productivity impacts (as discussed in Section 2.10, which deals more specifically with various transport benefits). This was confirmed in discussion with Fonterra, as outlined below.

When Fonterra first formed in 2001 they used had an early spatial capability – a point to point system with a road overlay for scheduling known as the Computer Aided Milk Scheduling (CASH) system. This was not centralised and data was transferred through radio or small devices that were used by the drivers' team leaders for manual input.

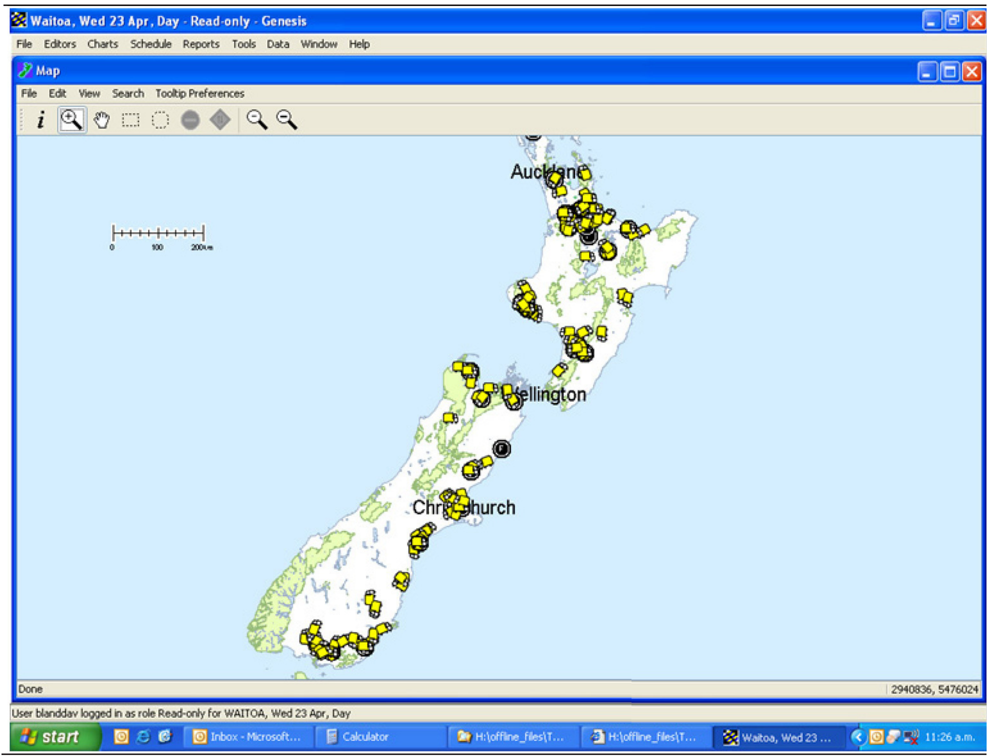
The modern spatially enabled system used by Fonterra for the last two years involves live scheduling, dispatching and tracking of vehicles/loads. The run sheet is delivered electronically to an in-cab system. Units in trucks log location every 7.5 minutes (the limit set by communications technology, not spatial technology), and identify when trucks are at farm. Tags identify the farm and a flow metre logs the pickup quantity. A significant investment was required to get this up and running – for example, change in vat piping, purchase of in-cab units, software, and so on. Five staff at Fonterra were involved in the development of Genesis, and the success of the project also relied on significant user input.

The system is dynamic in the sense that vehicles can be rerouted almost instantly, taking into account a range of factors to identify the optimal route.

Given the ability to track driver location in real time it allows, for examples, directions to be given to drivers during night-time pick up when visibility may be low. The system also takes account of various constraints such as the ability to turn out of driveways (using Google Earth to identify tanker turn restrictions), bridge weight limits, and scheduled pick-up time.

For Fonterra, all of this has led to an ability to reduce or redeploy schedule and dispatch staff,[66] as well as enabling a reduction in vehicles on the road. These changes have influenced the productivity shock modelling for the current report – efficiencies of 20 to 50 per cent were achieved in specific areas. Spread across the company as a whole, the productivity gains from spatially enabled transport logistics at Fonterra could be in the region of 0.25 per cent labour productivity, with additional savings from multi-factor productivity.

Figure 21 **Location of all Fonterra trucks at a point in time**



Source: SKM case study

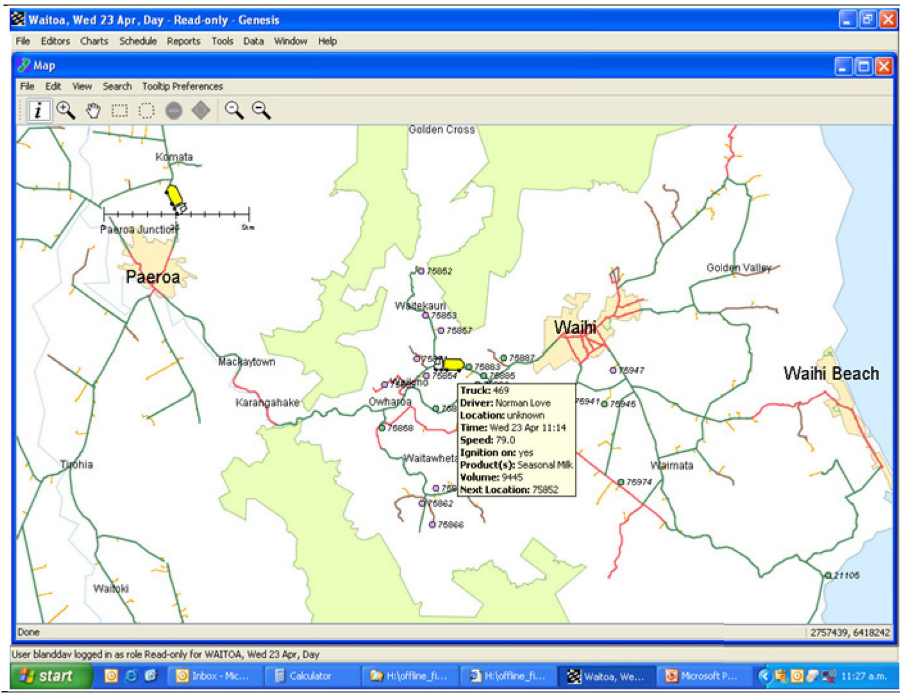
Development of the spatial platform for this application also means there is now spatial data for Fonterra suppliers in spatial format/context, and it is used by other parts of the business (strategy, property, production planning) – whilst these parts of the organisation were not instrumental in creating the

[66] Numbers provided but confidential. These savings have occurred in part as a result of centralising scheduling/dispatch operations. It is not possible to do this without spatial data and GIS technology to integrate data effectively.

system/capability they are now increasingly starting to consider how they can build on the platform for their own purposes, e.g., forecasting milk production based on climate and grass growth. This is a typical example of a case where initial innovation is now providing demonstration effects that will see incremental adoption and growth of acceptance of spatial information through the organisation.

A number of other aspects of the Fonterra experience are relevant for this report. Fonterra reported to be engaged in ongoing development and that consultants from the 'core' spatial industry were providing excellent service, including developing solutions for dealing with low quality cadastral data. Whilst there was significant customisation of the product, the basic equipment (in cab GPS/dispatching, GIS integration) is off the shelf.

Figure 22 **Location of vehicles and single vehicle detail**



Source: SKM case study

Forward looking issues

Fonterra is examining the possibility of using better altitude data. At present the approach is to start at the top of the hill and work down to avoid hauling milk up hill. Fonterra has elevation data for each supplier but currently has to assume straight line elevation change between suppliers. A high quality digital elevation model would also be useful for understanding logistics implications of bringing on new suppliers or identifying areas that could be developed.

An issue with merging public (cadastral) and Fonterra (highly accurate) data was noted but the company has generally managed to find work-arounds.

Barriers have been technical – the business case was easy to establish (perhaps since there have been several iterations of computer based tracking prior to GPS enabled Genesis). Finally, it was noted that better mobile data transmission rates would be helpful.

2.8 Fishing

New Zealand's fisheries are managed spatially to ensure the sustainable utilisation of fish stocks. Commercial fishing is governed by the Quota Management System (QMS), introduced in 1986, under which individual transferable quotas (ITQs) can now be bought or sold for 96 fish species. The ITQ provides the rights to catch a proportion of the Total Allowable Commercial Catch (TACC) in a defined geographic area that is set annually for each fish species.

Productivity has improved vastly in recent decades, with a reversal in the 1960's and 1970's trend of a greater amount of inputs being employed to harvest a smaller amount of fishing output (Sharp, 1997). The number of registered commercial fishing vessels in New Zealand fell from over 5,000 in the late 1970s to 1,863 in 2007-08; however landings of wet fish increased more than fourfold from around 100,000 tonnes to 441,000 tonnes in 2007 (NZ Ministry of Fisheries, 2008).[67] Much of the increase in output has been absorbed by overseas demand, with exports in 2007-08 reaching 283,680 tonnes; in the last ten years, the assessed value of the catch has increased by 45 per cent to reach nearly $4 billion in 2008 (Statistics New Zealand, 2009a).

The implied twelve-fold increase in output per registered vessel and the rise in the total value of the catch are the result of a variety of technological and management changes, for example, the replacement over time of small boats with larger vessels equipped with modern tackle and powerful sonar (the number of boats in the category of 12 meters and over has risen from 581 in 1995 to 849 in 2008); however, more recent productivity gains also relate importantly to the use of modern spatial information technology, as discussed in the following sections.

[67] In addition, New Zealand's commercial aquaculture harvest has increased more than ten-fold from less than 10,000 tonnes in the early 1980s to 107,521 tonnes in 2007 (Statistics New Zealand, 2002, Aquaculture NZ, 2008)

2.8.1 Commercial fishing

The introduction of GPS devices in the late 1980s coupled with plotters allowed fishers to significantly increase the catch per unit effort (CPUE) by tracking the locations and times where catches are highest, reducing search costs and saving fuel. Prior to the advent of GPS with 24 hour coverage large offshore trawlers would fish in pairs – one boat to fix a position on a sea mount and one boat to trawl from it. With the advent of 24 hour coverage, GPS plotters recording tracks over time have meant that single vessels can be directed to the most productive fishing locations. This has reduced input costs including crew, fuel and gear, due to the reduced time vessels spend looking for and keeping a fix on the best fishing locations.

As an example, Sanford Ltd use beacons that supply the exact GPS position to its vessels' navigation computers. This has been shown to save the vessels both time and fuel by allowing them to travel directly to where the buoys (and lines) are located. While total fish produced by Sanford Ltd increased by 64 per cent from 51,272 to 84,121 tonnes between 2004 and 2008, diesel consumed per kg of product decreased by 20 per cent from 0.40l/kg to 0.32l/kg (Sanford Ltd, 2008).

Individual NZ fishers interviewed for this report stated that they saw their productivity rise by 20 per cent *or more* as a result of the introduction and refinement of modern spatial technology and information. Estimated realised savings from the use of GPS tracking includes reductions in fuel use of approximately 10 per cent and time savings on the water in locating fishing grounds of approximately 14 per cent per trip.[68]

Commercial fishers are also using GPS to record and report catches in real time on the water to inform fisheries management decisions and to sell fish on the market at the optimum time.[69] Prior to the use of GPS, daily catch information from offshore trawlers would be coded and sent to shore by single side-band radio. The reliability of the signal meant that the information would not always be received. Catch information is now reported via satellite from factory trawlers to their fishing companies marketing teams on shore on a daily basis. This use of GPS technology[70] allows the pre-sale of fish if the optimum price can be achieved before the fish is landed. This practice has been widely adopted as part of offshore fishing operations, and discussions with

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68 Commercial Factory Fish Trawler Skipper Interview.

69 While government requirements for the collection of catch information for management purposes are still largely recorded on paper, the Ministry of Fisheries is currently investigating the development of an electronic based reporting system.

70 For example, Sealord's "Sat-C" system and Sanford Ltd's "Marel" hardware and software tracking system.

commercial fishers suggest this technology provides an additional time savings of 4 per cent per trip.[71]

Discussions with commercial fishers also indicate that the use of seabed mapping software with real time access has reduced gear losses by 50 per cent per trip, [72] and reduced time spent fixing gear (nets) while at sea by 50 per cent per trip.[73]

Commercial fishing companies are increasingly using information to plot and map their own catch effort data over time (e.g. time, species targeted/caught, vessel, methods). These data are also being aggregated and mapped at an industry level for the purposes of informing and lobbying government decisions around TACC setting.

No scientific papers on the impact of spatial information technology on New Zealand commercial fishing could be identified during the preparation of this report; however, with regard to Australia's Northern Prawn Fishery, which may serve as a comparison, a peer reviewed published paper concluded that the impact of full adoption of the technology was an increase in the combined fishing power of the fleet of 12 per cent (Robins et al., 1998).

2.8.2 Rock lobster stock monitoring – the ERNIE system

Fisheries stock monitoring for rock lobster has traditionally involved the use of trained technicians in two-person teams on board fishing vessels. These technicians manually record information about rock lobster length, sex, maturity, and injury, as well as weather and sea conditions, water depth, and method of capture. This information is reported to the annual rock lobster stock assessment process which informs fisheries management decisions around the TACC. The real cost per observer technician to the industry is estimated at being $600-$1,200 per observer day (Gibbs and Middleton, 2008).

The NZ Rock Lobster Industry Council has developed ERNIE (Electronic Recording of Nature, Investigation of Environment), a purpose built, waterproof, handheld computer, using software technology which enables direct downloads of monitoring results to the existing industry research data base. The computer records the information outlined above using digital callipers as well as recording the GPS location of catch, and is illustrated in figure 4 below.

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[71] Commercial Factory Trawler Skipper Interview.

[72] Out of an annual expenditure on gear of $250,000. Commercial Factory Trawler Skipper Interview

[73] Used to spend 24 hours of a 7 day fishing trip fixing or recovering gear. Commercial Factory Trawler Skipper Interview.

Figure 23 **ERNIE in action**

Observer using digital callipers *ERNIE device*

Source: Sykes (2002); photographs by T. Burkhart

The ERNIE system enables more data to be collected in the time available on board fishing vessels, and allows the direct download of electronic data into the research data base to provide a more cost effective and timely analysis for inclusion in stock assessments (Sykes, 2002). Since being developed in 2000, observer catch sampling undertaken in one of the rock lobster fishery management areas provides a case study of the cost savings that have been realised. Costs from undertaking 28 sampling days with one technician using ERNIE were 28 per cent lower than undertaking 28 sampling days with two technicians manually recording data (one measures, one records on paper) – the total GST exclusive cost fell from $57,800 to $41,406.

2.8.3 Maori fishing grounds

There are currently 8 Mataitai Reserves (customary food gathering areas) where commercial fishing is not permitted. Whilst GPS was not used to develop the boundaries for these reserves it has been used subsequently to record the location of dive surveys and thus to map stock abundance over time which affects future authorisations of fish take and will feed into future mataitai applications. This is one of the many areas in which the use of modern spatial information technologies is non-commercial in nature and difficult to quantify in terms of the economic modelling for this report.

2.9 Forestry

Commercial forestry in New Zealand is mainly restricted to the planting and harvesting of exotic species which have been planted in the country since the early 1900's. In total, commercial forest covers over 1.8 million hectares or 6% of New Zealand's total land area[74]. The main forestry species include, Radiata pine 89%, Douglas fir 6%, Eucalyptus 2%, and 3% covering variety of species

[74] New Zealand Forest Industry Facts & Figures 2008/2009 – MAF p.3.

(including Black walnut and Corsican pine) grown selectively for special uses. Some individual native trees are also individually identified for harvesting, requiring special permits.

New Zealand's forests are very fast growing (a cycle for Radiata pine is between 25-30 years). As a result the trees are intensively tended to maximise quality, ensuring that two thirds of the forests are managed to produce knot free timber. Statistics New Zealand identifies a wide range of uses across all industry sectors for products ranging from logs and poles, sawn timber, pulps, particle and fibre board, papers and news print.

The year to March 2007 reported a total area of 35,600 hectares planted in exotic species including 2,600 of previously unplanted area). An area of 41,000 hectares was felled with a harvest of 18,300,000 cubic metres[75]. The yield per hectare was reported at 444 (m^3/ha) for 2007, a drop of 3.5% from 2006[76]

The total value of forest production for 2008 was $5.1bn of which $3.5bn arose from exports to over 40 countries. The sector accounts for some 1.1% of value added in the NZ economy.

Taken together, the New Zealand forest industry employs around 25,000 people who work to supply 1.1% of total world forest products and 8.8% of forest projects in the Asia Pacific region [77].

Forecasts for 2010 suggest an additional production of 10 million cubic metres (a 55% increase per hectare) based largely on the maturing of current resources. It is estimated that this increased production would require a $5 billion investment in processing facilities[78].

2.9.1 NZ Forestry ownership and management

Around 90% of plantation forests are independently owned or managed on behalf of the owners by Timber Industry Management Organisations (TIMO) with about 50% of the total managed by small independents. About 6% is owned by the Crown. Forestry management is an increasingly variable and complex market. Some foresters will manage their own land and forests while others will only own the forest and lease the land. Others will manage forest and or land on behalf of owners. As a result, harvest time can see various changes in leasing arrangements with large forest areas changing hands between owners along with new investors arriving on the scene.

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[75] Forestry Plantings by Region, Year to 31st March 2007 – Statistics NZ.

[76] New Zealand Forest Industry Facts & Figures 2008/2009 – MAF p.3.

[77] New Zealand Forest Industry Facts & Figures 2008/2009 – MAF p.17.

[78] http://www.maf.govt.nz/mafnet/rural-nz/overview/nzoverview015.htm.

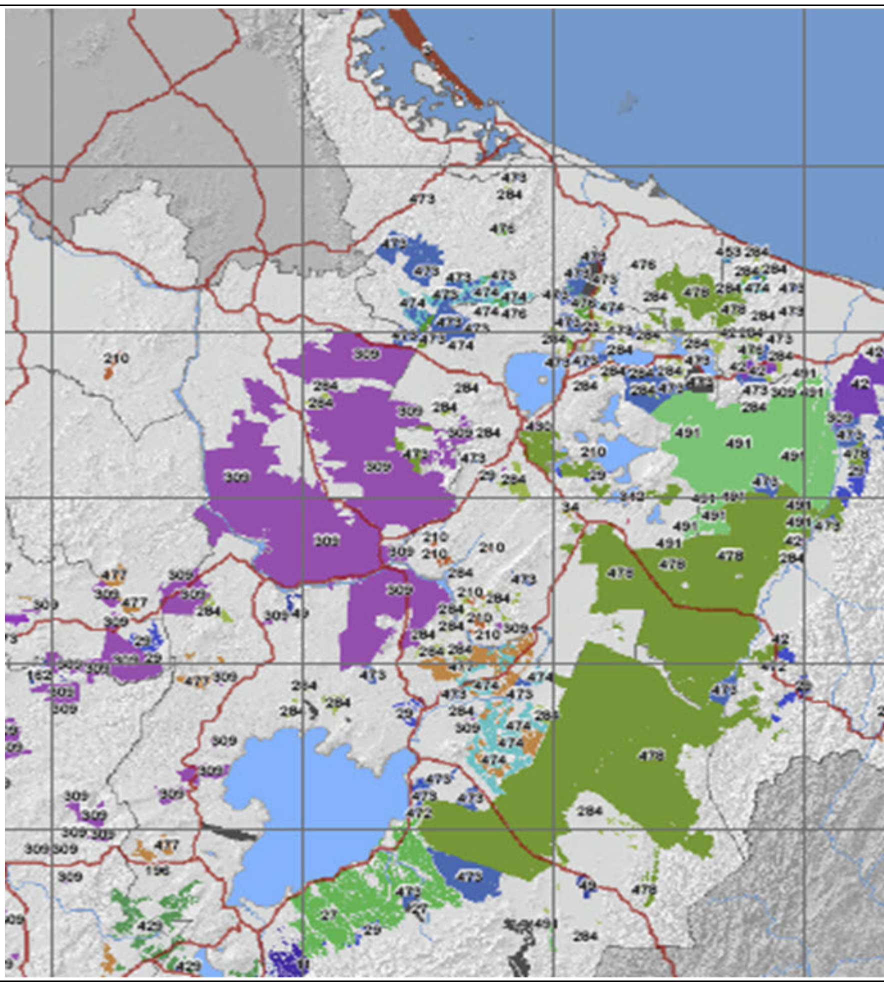
An additional complication is the fact that much of the management occurs in land parcels spread across vast areas where some of one owner's forest may be completely surrounded by another's. The larger owner/managers are shown in the table below:

Table 3 **Major forestry owners / managers**

Forest owner/manager	Percent of total
Hancock Natural Resource Group	16.4%
Kaingaroa Timberlands	9.6%
Matariki Forests	7.4%
Ernslaw One	4.6%

Data source: New Zealand Forest Industry Facts & Figures 2008/2009 – MAF p.5.

Figure 24 **Example of forest ownership in the central North Island**[79]



Source: Adapted from Exotic Forest Ownership/Management West Central North Island Wood Supply Region – MAF, 2008 – Indicating management of 50ha and over

[79] Adapted from Exotic Forest Ownership/Management West Central North Island Wood Supply Region – MAF, 2008 – Indicating management of 50ha and over.

In all around 40% of forests are owned/managed by about 17 larger organisations with around 1million ha forested by some 45,000 smaller forest farms[80]. Working across these are a number of industry specialists (e.g. PF Olsen) that provide advice and in some cases total forest management.

2.9.2 Spatial information and technology in the forestry industry

Spatial information and technology is an essential and integral part of the New Zealand Forestry industry which could be considered to be one of the earliest adopters. At its most basic, Global Positioning Systems (GPS) have enabled precise location of boundaries between forests, where no other identifying features exists.

The technology has also enabled the location of stands, topographic features, people, trucks and machinery within those forests allowing for better communications and more efficient management. Some of the wide ranging applications are summarised below.

Figure 25 **Modern GPS designed for use "under canopy"**

Source: Waiariki Institute of Technology: http://www.forestryschool.ac.nz/courses-short%2Fglobalpos.asp

From a central government perspective, MAF is able to identify the land area under commercial forest to chart the growth of the industry and develop wood availability forecasts.[81] In addition, clear boundaries enable legal containment of operations as well as protection of native species and improvements in biodiversity control.

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80 Interview Scion.

81 http://www.maf.govt.nz/statistics/forestry/other-forestry-releases/ownership-map/.

Within this role, and from about 2000, MAF protects native forests and produces special licences for harvesting. An individual Rimu tree (*Dacrydium cupressinum*) can be worth upwards of $30,000 so it can be important to accurately map their location within a well defined boundary.[82]

Apart from the core location and cross-boundary control function, modern spatial technology and information has enabled further benefits that were previously difficult to achieve. These include the identification and mapping of key features including topography, waterways, wetlands and hazards. Areas of environmental or heritage significance are also plotted ensuring reduced environmental impact and compliance with resource and protection requirements. These requirements vary from region to region and therefore accurate logs of activity are essential to maintain records and reduce operational costs.

Knowledge of key features is essential for effective planting and harvesting plans including accurate estimations of contracted works, managing water courses and run off and also assisting with the development of efficient access routes and networks (in some larger forests these could require up to 15,000 truck trips per month).

Adding to this core location function, spatial technology and information provides a means of directly enhancing productivity by identifying and mapping factors which affect growth including water courses, soil type and climate. Add to this other variables such as rate of weed growth, species invasion and areas of high wind and fire risk and foresters are able to collect sufficient data to not only protect their forests but also accurately apply fertilizer and pesticide through targeted aerial spraying[83]. (Previously foresters relied on the knowledge of local pilots). With this information it is possible to more accurately estimate growth rates for different stands, assisting with forecasts of future yields and their value.

A fundamental forest activity is the inventory stock-take. This occurs at varying levels depending on the land area, the distance between forests and the maturity of the trees. In a 30 year cycle it is expected that an intensive stock-take is carried out about 5-6 times with the most intensive of these just before harvesting. Interim monitoring can vary with some foresters undertaking a weekly fly over of their stock. Without spatial technology enabling clear delineation of boundaries previous stocktaking required high levels of resources and was considered to be comparatively rudimentary[84].

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82 Interview MAF Crown Forestry.

83 Interview Scion.

84 Interview Future Forest Research.

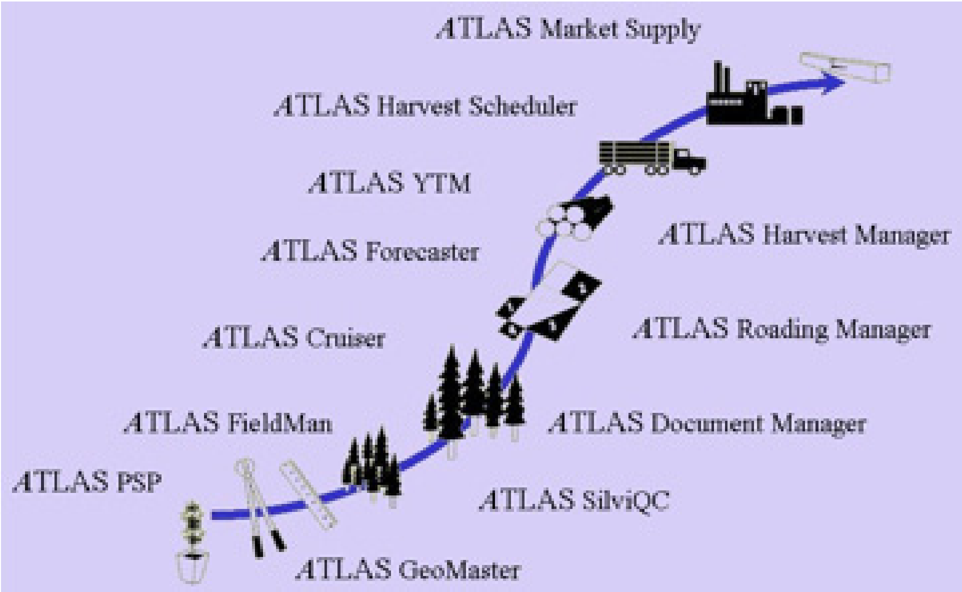
2.9.3 Forestry R&D

Foresters were early adopters and advancers of spatial technology and information from the late 1980's and early 1990's, and since that time the potential for forestry applications has increasingly been recognised. Forest research institutes have focused much of their energy on developing spatially grounded applications that maximise productivity and management efficiency in order that benefits can be realised across the industry.

With mapping at the core of the industry, some of the attention has centred on developing software that can plot a wide range of variables (as described above) in order to identify the most productive areas and the management plans that will enable greatest yields and return. Atlas Technology continually develops a wide range of tools for managers to map and track the forestry value chain as can be seen below.

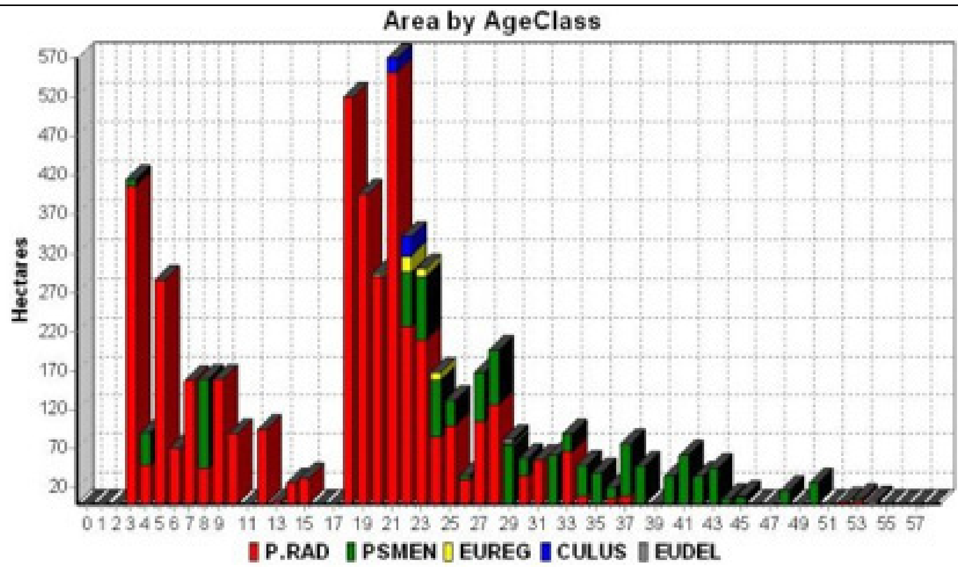
These tools serve to reduce risk and increase confidence in management decisions.

Figure 26 **Atlas tools and applications with significant spatial information components**



Source: Reproduced from http://www.atlastech.co.nz/atlas+suite.aspx.

Figure 27 **Screenshot of Atlas Geomaster enabling identification of land area by the age of different tree species**



Source: Reproduced from http://www.atlastech.co.nz/geomaster.aspx?PageContentID=777.

2.9.4 Spatial information – benefits and costs in forestry

Traditionally, forestry was a long-term supply driven industry centred around an ability to sell trees as they matured. However as different buyers require different quality wood for their end products it was often difficult to match demand with supply. This resulted in foresters either supplying wood of variable quality or buying in logs from other producers to match their customers' needs. This in turn resulted in extra costs associated with either the over provision of high quality wood to low quality users or increased transport costs when logs where purchased from other foresters[85].

Up until 2006 Carter Hold Harvey Forests held the majority share (330,000ha) of forest land in central Northland harvesting some 5 million tonnes a year[86]. In 2005 Project Canopy was developed by their IT services subsidiary, Oxygen, to improve efficiencies by linking GIS with their financial management systems. This gave a single overview of operations from planting to harvesting and shipping based on a range of variables including distance, sales price and contract agreements[87]. It is estimated that the use of GIS coordinated with

85 Herald 19th April 2005.

86 This forest area is now largely owned by Hancock Forest Management New Zealand.

87 Oxygen Business Solutions: Case Study, Project Canopy 2005.

other technologies resulted in estimated savings from improved land use efficiency in the order of 10%[88].

While this figure is hard to confirm, current forest managers consider that is may be an accurate estimate for a large commercial operator[89]. In addition, spatial information is considered to increase savings by significantly reducing the number of staff required (in some cases from 30-3 FTEs). Further management savings could include reducing time for planning operations, recording work progress and calculating payments which together could amount to a 15% reduction in management costs.

In terms of estimated costs, the larger foresters could incur the following:

Table 4 **Estimated annual costs of spatial capability to NZ foresters**

Spatial Staff 3-4 FTE	$300,000 to $400,000
Licensing	$70,000 to $120,000
Consultant/ contractors	$50,000 to $150,000
Aerial photography	$50,000 to $150,000

Data source: Ecological Associates estimates based on industry interviews

On this basis it is reasonable to assume that an average cost per hectare for spatial information and technology for large forest owner/managers could be in the order of around $3/ha. However this is likely to be greater for smaller foresters.

Barriers

Although spatial data and technology are widespread in the forestry industry it is considered that it is not utilised at its full potential even in the largest operators[90]. The main barriers to effective uptake are identified as the licensing costs as well as access to quality information. It is estimated that a further 10-15 per cent of costs could be saved if the base data was easier to source. In addition, and particularly in the research sector, intellectual property (IP) arrangements and associated costs restrict the efficient development of applications. It is estimated that up to 25 per cent of research time can be spent sourcing relevant data and determining or negotiating IP rights. Further, the cumulative costs of intellectual property can make some potential tools and advancements too costly to realise. However there is some sense that, due to a lack of skills, some software tools have increased beyond forest managers'

88 Herald 19th APRIL 2005.

89 Interviews Future Forest Research, Scion, PF Olsen, Survey Hancock Forest Management.

90 Interview Scion.

ability to use them. As a result contracted services may be required which can in turn be a costly barrier.

These barriers are compounded particularly for smaller foresters as they will often be less aware of the data that are available and will have fewer funds to hire or contract skilled data analysts.

It is considered that improvements in IP tracking and access to standardised data (preferably on-line) could enable access to information that could increase productivity across the industry. For example, it is estimated that the 45,000 smaller forest farms (covering one million hectares) could potentially increase the productivity or value of their land by up to 25% with low cost access to quality data and tools.

2.10 Transport

The collection and movement of goods is a resource intensive exercise with capital outlay comprising vehicle maintenance, fuel, personnel to co-ordinate movements and vehicle drivers. An efficient transport system depends not only on modern vehicles and trained drivers, etc., but also on well maintained infrastructure such as roads and ports. The benefits from spatial technologies to the transport system as a whole are therefore broadly two-fold:

- direct operational savings and
- investment and planning benefits.

The latter is particularly relevant to government investment in roads and transport in general, and has the potential to assist in containing infrastructure budgets. Those effects are discussed in further detail in Section 2.1.1 under 'Government Services'; this section focuses on the private sector benefits.

Transport activity has always had a heavy spatial component (taking people and goods from point A to point B in the most efficient manner). Modern spatial information technologies have had a very significant impact on the sector. Many companies have been utilising GIS software to track vehicles, their loads and to assign routes 'on the go' to reduce the number of vehicles required and kilometres travelled. A number of companies from outside the core transport sector (e.g., retail chains operating their own fleets, major utilities and telecoms) have also benefited significantly from modern spatially enabled fleet management systems.

According to Statistics NZ there were 14,900 enterprises with 88,270 employees in the transport, postal and warehousing sector in 2008. This is up from 13,511 enterprises employing 86,340 people in 2000. A major proportion (over 40 per cent) of these are taxi drivers, coach drivers or heavy truck or tanker drivers, which numbered an estimated 37,218 in 2006 according to the latest available statistics, which is up from 30,732 people in 1996 (Department of Labour 2009). Total revenue of the transport, postal and warehousing sector stood at around $18.5 billion in 2007, with surplus before income tax at around $1.7 billion in recent years. In terms of value added, the sector accounted for about 4.7 per cent of the New Zealand economy.

Market penetration or rate of adoption of leading edge applications of GIS/GPS to dispatch and scheduling is estimated at 25 per cent – and the sector is moving rapidly from early adopters to early majority. Many modern trucks are routinely equipped with GPS technology. The 'middle of the pack' service providers in the sector are still using semi-spatial schedule and dispatch systems (not involving real time tracking), whilst the 'old school' approach is broadly paper based with significant utilisation of tried and tested communication systems such as radio or mobile telephony (local transport company).

2.10.1 Medium sized freight and haulage companies

The benefits from spatially enabled fleet management technology extend beyond the large players such as Fonterra. For example, JD Hickman Ltd operates a fleet of 65 trucks. Founded 18 years ago as a refrigerated transport service it now provides haulage and storage services nationwide, with depots in Auckland, Hamilton, Palmerston North and Taranaki. One of the benefits this company reported from introducing a GPS tracking system for their fleet relates to minimising road user charges (RUC). RUC are charged both on weight and distance travelled and appropriate valid licences must be purchased regularly and displayed on vehicles. To the operator there is a risk of over-buying (unnecessary expenditure) as well as under-buying licences (which could attract fines). Similar to the Fonterra experience, the tracking system also inherently aids with dispatch and managing the growing fleet.

The system chosen by JD Hickman Ltd is able to track on-road and off-road kilometres automatically, and feeds that information back to the business in real time. The online user interface also includes a RUC lodgement form, giving businesses a direct link to LTNZ and no paperwork to complete. The RUC feature is important for JD Hickman. Also being able to review the fleets' movements managers are able to determine where delays are occurring and change routes to accommodate these problems. The service provider reports when drivers are speeding, or idling too long (which can get expensive).

Another example of a smaller scale operation is Frews Contracting which specialises in services covering cartage, earthworks, demolition, salvage, recycling, landscaping and trade supplies, and container services (providing container transport and delivery to and from the Lyttleton Port to locations around Christchurch and Canterbury). They employ around 45 staff, and run a fleet of around 30 trucks, plus a range of diggers, excavators, loaders and crushers. Frews Contracting upgraded their communications and dispatch platforms to a modern spatially enabled integrated system recently. The new system has a wide range of features, including real-time vehicle location, job dispatch, time-clock keeping, vehicle idling and maintenance reports, route planning and managing RUC rebate claims (Xlerate – the same system used by JD Hickman).

2.10.2 Couriers

Couriers represent another set of clients who have benefited significantly from modern geospatially enabled dispatch and tracking systems. Couriers operate within a very competitive marketplace with major international players such as DHL and well established NZ companies such as Freightways Ltd. Urgent Couriers Limited (UCL) is one of the largest specialised on-demand courier services in New Zealand; the company contracted core spatial sector consultants to deliver a dispatch mapping system that would give them a competitive edge. UCL wanted a spatial website to enable their despatch operators to view and query the locations of couriers, pick-up and drop-off locations on a detailed map. UCL wanted a website up and running quickly with minimal startup costs. UCL had existing despatch software which stores the location of known clients as a physical address. GBS decided to develop a solution using Free Open Source products (MapServer, PostGreSQL and Apache). These were used to display the base map, store spatial information, and serve the website respectively. Dynamic spatial information (job locations and Courier locations) are then displayed on the map in real-time.

GBS took the addresses from UCL and geocoded them for display on a web map. The GPS coordinates (from mobile devices) for couriers are retrieved at a specified interval into a SQL Server database and these are displayed on the map. This allows the dispatchers to see current jobs and active couriers on a detailed map of Auckland.

In addition to basic map navigational tools (zoom, pan etc), extra tools were provided to enable despatch operators to locate despatch regions, suburbs, couriers and addresses quickly. These were provided on the web interface along with layer controls to rapidly toggle the visibility of couriers and current job locations.

To manage client location changes and the addition of new clients, a module was provided that allows the operators to easily find and update or add the locations for clients and common places. GBS also developed a tracking system whereby authorised staff members can track/replay the routes of specified couriers within specified time windows from a history of GPS locations for each courier.

2.10.3 Waste Management

Just as with any other type of fleet needing management, fleets of rubbish trucks have also benefited from new spatially enabled tracking and scheduling systems. Two of the NZ companies involved in rubbish collection (including garden rubbish) that were mentioned in telephone interviews were Greenfingers and Transpacific. Savings in transport costs in the region of 10-15 per cent were considered routine.[91] Having the on-screen visibility of the fleet, and collection points, enhances the ability to change routes to meet schedules and improve customer services.

Waste Management is another company that has built a thriving business based on rubbish and recycle collections. It operates waste and recyclable collections and management services all over New Zealand. Waste Management's branch in New Plymouth, with a fleet of 25 trucks, oversees the collection of residential and commercial waste and recyclables from Urenui in the north to Waitotara in the south. In October 2006, Waste Management secured the contract for the residential collections for the three District Councils in Taranaki – that's over 35,000 households each week. Prior to taking up the contract with Waste Management, one of the councils had concerns on how their complaint process would be handled, in particular missed collections, as under the new contract, the level of service to be provided differed significantly to the previous collection contract. In order to ensure that customers were to receive the high level of service the Council wanted, Waste Management agreed that they needed a system that could tell the difference between a missed collection and a late bin.

Waste Management is now utilising a GPS based fleet productivity tool. Waste Management are able to track the location of their vehicles, and the system is able to link into sensors installed in each truck, giving locations and times for certain events like using the lifting arm on trucks. As the user-interface is online, the service provider has been able to give the Council's call centre direct access to the movements and activity records for each truck; when a complaint comes in, they can look it up immediately and come up with a solution straight away.

This is a good example of the types of benefits that translate into better customer service but which cannot be modelled easily as productivity shocks within the framework of this report.

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91 Steve Critchlow, *pers. comm.*

2.11 Communication and Utilities

Gas and electric utilities, as well as major communication companies, use modern spatial information technology to model networks, issue work orders for maintenance, dispatch service crews, organise marketing to prospective customers and plan service expansions.

Utilities management in New Zealand presents challenges due to the geographic spread of population, mountainous terrain and natural hazards. Services such as electricity, natural gas, telecommunications, stormwater/sewer, industrial gases and LPG must be distributed efficiently to reduce company overheads.

According to Statistics NZ there were 996 enterprises with 12,690 employees in the electricity, gas, water and waste services sector in 2008. Surplus before Income Tax for the Electricity, Gas, Water and Waste Services sector has been running at levels of around $1.9 billion in recent years.

2.11.1 Watercare

Watercare Services Limited is New Zealand's largest company in the water and wastewater industry. The company supplies bulk water to the Auckland region, an area of approximately 340 square kilometres through a regional water network. The water is supplied to six water retailers which in turn supply the water to customers in the Auckland region. The company supplies an average of 347,000 cubic metres of water daily. The water is drawn from 12 sources comprising 10 dams, the Waikato River and an aquifer at Onehunga.

The company uses GIS, which functions as an integrator of asset information including non-spatial data. All users have access to a spatial 'portal' to Watercare information on their desktop. Asset maintenance crews have GIS on handheld computers which is synchronised with network periodically. Job-sheets as well as location information is available in the field and there is an ability to log jobs. Information held includes photos of assets (e.g. valves within manholes/sumps). Remote GIS (on handheld) is available but the trend is to create custom applications based on ArcPAD or similar.

There are two broad types of benefits from GIS seen by Watercare – in the office and in the field. In the office the benefit is that it avoids having to access data on assets via several systems (e.g. avoided training, time for searching). In the field, crews save significant time in searching for assets and it also avoids having to survey all assets. Surveyors are now only used where there are potential legal issues such as right of way for a utilities corridor. Watercare maintains a team of 6 GIS Staff.

2.11.2 Transpower

In its role as System Operator, Transpower manages the real-time operation of New Zealand's electricity system. The System Operator also manages the wholesale electricity market. Transpower does not own the electricity but provides a co-ordination service to the electricity industry whereby it schedules the production of electricity from all power stations monitors the entire network and ensures the security of the New Zealand electricity system.

Transpower's spatial information is not integrated at the moment but Transpower are in final stages of a business case for enterprise-wide GIS similar in approach to Watercare. Current application of spatial information and technology is focused on project specific applications such as LiDAR for asset design and vegetation mapping and cadastral data for stakeholder management.

A Transpower subsidiary currently provides GIS services (develops maps, etc.), but again on a task specific basis rather than in an integrated fashion. It was also noted that much of the data sits with contractors – they do the maintenance and identify forward programme, as there is not necessarily an immediate need to hold the data with Transpower.

Transpower stated that accurate LiDAR data are invaluable for the design of assets.

2.12 Minerals / Mining

Exploration, minerals discovery and mining are highly spatial activities. As a result, almost all of the organisations or stakeholders in this sector have highly developed spatial data capture and analysis capabilities. Spatial data and advanced spatial modelling applications are routinely employed in the sector; however, measurable benefits to private industry that could be tied directly to specific uses of modern spatial information technology as defined in this report could not be identified during the preparation of this report.

Whilst use of, for example, 3-D seismic, led to significant resource discovery and additional resource extraction in Australia, similar increases in output were not apparent for New Zealand. Most of the impact is thus likely to occur in the future, although the extent to which additional extraction will be allowed to proceed at least partially depends on government policy.

2.12.1 Glass Earth Gold – NZ gold exploration company

Glass Earth Gold is an example of an innovative, science driven company in this sector in New Zealand. In a recent exploration update, the company claims to be closer to gold production with encouraging results from placer gold evaluation:

> Glass Earth's placer mine evaluation studies are significantly advanced following encouraging results from 122 shallow RC drill holes in the Central Otago region in tandem with active exploration campaigns of drilling, ground-based resistivity surveys, mapping, and analysis in the Hauraki (funded and operated by Newmont); Mamaku-Muirs; and Otago Regions ... Resistivity surveying on the Muirs/Massey Reefs followed encouraging drilling results in 2008, assisting in delineating a potentially new high level vein system adjacent to the known reefs. Infill resistivity will precede further drilling in 2009 as funding becomes available. (GlassEarthGold News Release 19 March 2009)

This would indicate that modern spatial information technology will ultimately play a role in additional production of gold; however, as the news release indicates, this is still some time away.

2.12.2 Crown Minerals

Crown Minerals manages the New Zealand Government's oil, gas, mineral and coal resources, known as the Crown Mineral Estate. The organisation maintains large datasets containing spatial information; this is necessary not least because the allocation of exploration rights has a fundamental spatial component. Making spatial data available has played a role in attracting overseas investment to New Zealand. However the impact of Crown Minerals falls under the heading of government services in terms of the sector aggregation used for this report.

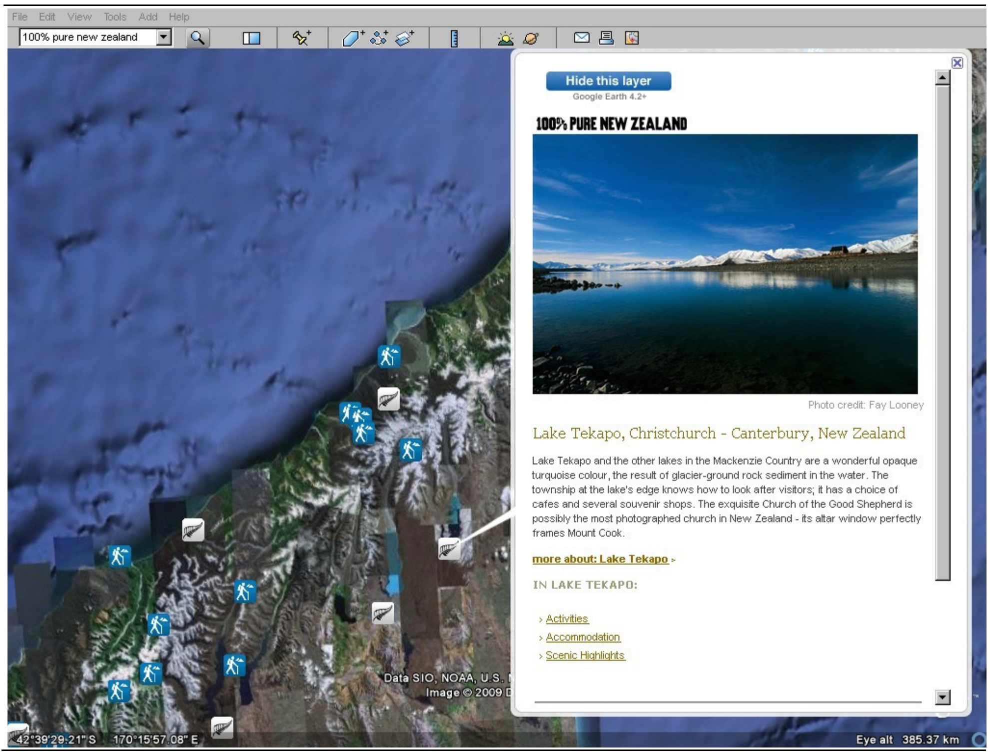
2.13 Tourism

Tourism is important to the NZ economy. According to the latest available tourism satellite account, tourism directly contributes an estimated $7.9 billion to GDP, equivalent to 5.1per cent of GDP. The indirect value added of industries supporting tourism generated an additional $6.2 billion in 2007 (Statistics New Zealand, 2008b). These estimates are based on the Tourism Satellite Account which draws information from statistics reported for other ANZSIC sectors. As the sectors in the economic modelling are based on ANZSIC, including a separate shock for tourism is not possible in this report. However, impacts on tourism are reviewed below, using as a basis the draft by Forne (2009).

A first example is the "100% Pure New Zealand" overlay for the Google Earth visualization tool provided by Tourism New Zealand. The layer allows users to pan and zoom to destinations and click details of what they will find (see example below). Tourism New Zealand has a website[92] that provides historic and predicted tourist flows. Service providers in the tourist industry can use a browser to construct custom maps which show tourist flows by country of origin, transport mode, and season. Users of the Tourism New Zealand site can also download the underlying data and use a free downloadable tool for more sophisticated analysis, like scenario planning. Private and government organisations are developing sophisticated visualisations of tourist flows for analysis. These visualizations help them to:

- plan tracks and other facilities in specific locations, like national parks
- understand stopping behaviour – developing intelligence into how people travel and where and why they stop. Using stopping models, maps can be developed that reflect the average tourist's probability of stopping at particular places – which has obvious commercial value. GIS assists in this process by allowing multiple flow representations on a single map.
- model the biosecurity impacts of tourism flows – tourism presents a significant biosecurity risk (Forer, 2008)
- make detailed analyses of flows to plan facilities and investment.

Figure 28 **100% New Zealand Google Earth Overlay**



Source: Tourism New Zealand web site

[92]See http://tourism.maphost.co.nz/ which is one of the sites under the general home site of http://www.tourismresearch.govt.nz

2.14 Inferences for economic modelling (sector-by-sector)

The sector-by-sector case studies, literature reviews, expert opinion (including feedback received at the Workshop) informed the assumptions made for the economic modelling, details of which are further discussed in Section 4. As noted in the introduction to this report, authoritative national statistics on use/uptake of modern spatial information technology do not exist.

Findings have been couched broadly within Rogers' framework (see Section 1.3.6 of this report) – in other words, where there was a strong view that the sector is still at the 'innovator' stage, as a default we would have assumed that only 2.5 per cent of potential adopters had taken up the technology to date. These assumptions have been modified and enriched to take account of findings such as "only the large players have taken it up", or where more specific information could be gleaned from the case studies, etc.

Whilst there are a number of reasons respondents to our informal survey found it difficult to make accurate estimates of productivity impacts, figures of "10 per cent or more" were frequently cited in discussions. Figures are adjusted as explained in the sector-by-sector discussion below.

Furthermore, in the absence of information, the most conservative assumptions were employed, for example, in the minerals/mining sector the productivity shock was set at zero because little evidence for *realised* benefits could be identified. To some degree this depends on what is defined as 'modern' spatial technology. It can certainly be argued that the use of spatial technology has led to better prospects in the minerals/mining sector (and played a role in attracting additional investment) but this is a type of intangible that could not be modelled within the CGE framework.

2.14.1 Private services

Feedback received indicates that spatial information technology is used by innovators in the sector, and almost exclusively by larger enterprises. In this report, it was indicatively estimated that 500 to 1,000 organisations may be using modern spatial information technology in New Zealand.

If around 500 private service sector enterprises were using the technology this would be equivalent to 2.3 per cent of enterprises with more than 10 employees in the private services sector. This fits broadly with 'innovator' status and is accepted as the basis for the productivity shock used in this report. As discussed in the case studies, many applications see productivity increases of 10 per cent or more. The lower end estimate of 10 per cent total productivity shock for the enterprises which have adopted is used.

Finally, given that this is likely to be a very price responsive sector, it was assumed that removal of barriers could have led to a doubling of uptake and utilisation over the period 1995 to 2008. The resulting assumptions are:

- total productivity shock of 0.23 per cent for the sector in 2008
- An additional 0.23 per cent could have been obtained by removal of barriers.

2.14.2 Government services

Productivity gains are difficult to estimate in this sector; however, having reviewed a range of case studies it would appear reasonable to assume productivity increases in the range of 5-10 per cent (mid-point of 7.5 per cent used for this report). At the local government level it is critical to service provision and it is quite pervasive - hence almost complete adoption has been assumed but the nature of spatial product is also seen to be changing.

At the central government level, it is used in major service areas but still seen to be in the early adoption stage (12.5 per cent) and 2008/09 output appropriations sectors that were considered to be affected include Biosecurity, Climate Change, Emergency Management, Environment, Fisheries, Local Government and a share of Transport.

In total, a representative share of 6.9 per cent of all government operating expenditures was considered to be affected, and a 7.5 per cent productivity improvement was applied against this. Furthermore, this report comments on significant potential for increased data sharing across government, and a doubling of the impact was seen as reasonable – either through more and better use of data or through additional adoption in areas where benefits could have been reaped but were not.

- Total productivity shock of 0.52 per cent for the sector in 2008 and
- an additional 0.52 per cent could have been obtained by removal of barriers.

2.14.3 Trade services (including retail)

Large retailers have adopted GIS and an estimated 7,500 out of 49,000 stores would have been affected (the major retail chains), which is equivalent to around 15.3 per cent and broadly corresponds to Rogers' early adopters stage (12.5 per cent). A number of savings were identified in the case studies.

2.14.4 Manufacturing and Food

In these two sectors, there was a shortage of evidence, although the case study of Fonterra provided some insights. Use of modern spatial information technology as defined in this report is seen to be restricted to innovators at this stage (i.e., assumed 2.5 per cent adoption for the modelling). This is probably an underestimate at least for the food sector, where Fonterra accounts for a significant share of output. A productivity improvement of 10% (reference case) is used

- The sector wide productivity shock in each of these sectors has been set at 0.25 per cent productivity shock in the absence of better information.
- It has also been assumed that in the absence of barriers, the productivity shock could have been 50 per cent greater (additional 0.125 per cent).

2.14.5 Agriculture

Early adopter stage (12.5 per cent) was seen as likely. Using Fonterra fertiliser maps supplied to farmers (10,000 maps out of an estimated 80,000 productive farms in New Zealand) would exactly correspond to 12.5 per cent. Whilst only a subset of these farms are practising precision agriculture or variable rate approaches, they would have benefited from the spatially enabled systems that Fonterra uses when applying the fertiliser. Input cost savings of greater than 10 per cent are likely to have been achieved by precision agriculture and VRT adopters in agricultural industries. This report assumes a representative figure of 10 per cent total productivity for all early adopters (12.5 per cent), but also that a further 50 per cent could have taken up modern spatial technology:

- Total productivity shock of 1.25 per cent for the sector in 2008 and
- an additional 0.63 per cent could have been obtained by removal of barriers

2.14.6 Transport services

Owners and managers of major road transport fleets rapidly adopted the technology with reported productivity gains of 10 per cent or more, although the extent of adoption is unclear. Few organisations with less than 20 employees are likely to have adopted the technology, as the small number of assets in these fleets means that effective oversight and management can typically be achieved by traditional methods. Those with 20 or more employees will likely have had a strong incentive to adopt, although statistics on adoption are not available.

For this report, to stay on the conservative side it was assumed that road transport enterprises with over 50 employees had adopted modern spatial information technology (in reality, some smaller enterprises will likely have adopted, and not all of the bigger ones). As a broad estimate, half of the road transport sector based on employee numbers is likely to have benefited from modern spatial information technology.

Road transport in turn accounts for 42 per cent of the total transport services ANZSIC sector based on number taxi drivers, coach drivers or heavy truck or tanker drivers. Air transport is at the early innovation stage with negligible benefits. Sea and rail transport benefits were not scoped in any detail for this study and are only small subsectors. The following assumptions are made for the modelling:

- Total productivity shock of 2.1 per cent for the sector in 2008 and
- an additional 1.05 per cent could have been obtained by removal of barriers.

2.14.7 Construction

As reported in the case study section, benefits are currently mainly found in large projects, and the technology is used by innovators, suggesting 2.5 per cent as the adoption level (Fulton Hogan stated that "few crews are using it"). Construction productivity gains of 20-50 per cent and more have however been reported. For the small subset of adopters we assume a 30 per cent productivity shock; and with removal of barriers this could have been 50 per cent higher. This yields the following estimates:

- Total productivity shock of 0.75 per cent for the sector in 2008 and
- an additional 0.38 per cent could have been obtained by removal of barriers

2.14.8 Utilities

The utilities sector consists of a relatively small number of large enterprises. Most of these have adopted ('late majority'). This report assumes 75 per cent of the large organisations, covering 66% of employees in the sector, have adopted. In-field efficiencies of up to 50% were reported in survey, 30% in maintenance; overall 15% is thought to be conservative as there are also significant efficiencies in network rollout and planning.

The productivity benefits are difficult to measure and are changing as utilities are increasingly exploiting enterprise-wide productivity benefits; as a conservative proxy for the total productivity shock, the share of wages in sector expenditures (6.3 per cent of sector expenditures) has been used. With the removal of barriers it would be expected that the sector would have achieved full adoption by now (i.e., a 33 per cent increase moving from 75 per cent adoption to 100 per cent). This yields the following estimates:

- Total productivity shock of 0.63 per cent for the sector in 2008, and
- an additional 0.16 per cent could have been obtained by removal of barriers.

2.14.9 Communication

The communication sector is dominated by a few large players (estimate 87% of sector), and the sector has seen full adoption. Benefits are similar to those reported for the utilities sector (see discussion in the previous section), and a similar approach to estimating the productivity shock has been used – with the exception that there could not have been any additional benefit from removal of barriers as the sector is already at full adoption levels. This yields the following estimates:

- Total productivity shock of 0.82 per cent for the sector in 2008, but
- no additional productivity benefit from removal of barriers.

2.14.10 Forestry

Large commercial plantations have adopted the technology. They manage 40 per cent of forests but account for only 20 per cent of ANZSIC employment in the sector. Since the productivity shock is a total productivity shock with aspects both in labour productivity and other productivity, for the weighting of the productivity improvement for the sector as a whole a 30 per cent sector share has been used (mid-way between 20 per cent and 40 per cent). The identified benefits from improved land use, labour and management savings, etc., were in the region of 10-25 per cent. The mid-point of 17.5 per cent was adopted. If barriers to access had been lifted (notably yielding cost reductions) it is estimated that the remainder of the sector could also have been at the early adoption stage (i.e., 12.5 per cent of the 'remaining' 70 per cent of the sector would likely have adopted). This yields the following estimates:

- Total productivity shock of 5.25 per cent for the sector in 2008, and
- an additional 0.46 per cent could have been obtained by removal of barriers.

2.14.11 Minerals/Mining

Whilst there was early and full adoption of complex spatial technology applications in this sector, concrete examples of realized benefits in terms of productivity (i.e., more output per unit of input, or reduced costs for the same output) could not be identified; as discussed earlier, the report assumed no verifiable productivity shock for the sector. As emphasised earlier, the prospects of making additional resource discoveries or discovering resources earlier than would otherwise have occurred is still a high probability.

- No productivity shock included for the purposes of this report.

2.14.12 Fishing

Modern spatial information technology is critical and pervasive in deep sea trawling in particular, which accounts for around 17 per cent of the NZ fleet. The productivity benefits in deep sea trawling are estimated at a minimum of 20 per cent (time saved, fuel, loss of tackle, etc.). The sector has already fully adopted these applications and consequently no additional adoption could have occurred with the removal of barriers:

- Total productivity shock of 3.44 per cent for the sector in 2008, but
- no additional benefit from removal of barriers.

3 Barriers and opportunities

Section 1 of this report introduced spatial information and highlighted a number of economic issues (including 'market failure' and the role for government), whilst Section 2 identified applications of modern spatial information technology with a range of case studies and vignettes from the different sectors of the NZ economy. From this, it is clear that the use of modern spatial information technology has:

- has resulted in substantial benefits to New Zealand society
- is being used more often and in new areas
- is contributing to economic growth and competitiveness.

The work also showed a number of barriers that have held back, and are continuing to hold back, the use of spatial information in New Zealand.

This section identifies some of the main barriers and outlines significant opportunities for reducing them by making a spatial data infrastructure. The reduction strategy essentially 'glues' together existing bits and pieces of critical spatial data and the infrastructure for using it, as well as fostering the use of spatial data 'culturally' by clarifying roles, responsibilities, processes, entitlements and relationships.

Early and cost-effective interventions by government are likely to be:

- solving the technical issues about exposing spatial data to the web in a few agencies and then replicating the solutions more widely including through the use of open source software
- requiring government departments and local authorities to make their spatial data available at marginal cost (which would be zero in case of web based delivery)[93]
- providing technical elements of an SDI that other parties will not make available which could include spatial standards, metadata, and catalogue and registry functions

Section 4 of this report estimates the cost of the barriers at around $0.5 billion in 2008, including a loss of government revenue of at least $100 million. The early, cost effective interventions can be expected to go some way towards realising these potential benefits.

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93 Noting that many TLAs suffer from capacity constraints that would make it difficult to comply with this requirement in the short term it is clear that any such intervention would have to be sequenced and funded appropriately.

3.1 Nature of the barriers

This section draws on concepts of market failure and government failure to identify barriers to spatial information adding more to productivity in the New Zealand economy. It also draws on the limited existing literature and on the anecdotal evidence gathered in preparing this report.

3.1.1 Market failure

Key economic concepts which are often used when making the case for government intervention include the notion of a 'public good' in the economic sense (i.e., having the property of being nonrival and nonexcludable), various types of unpriced spillovers which may be associated with public goods (i.e., positive externalities), information failures, transaction costs and natural monopoly arguments.

These concepts were explained in Section 1.3.3 of this report, where it was also pointed out that the body of literature on market failures and informational economics is extremely wide and varied.

A discussion paper by the Australian Spatial Information Industry Joint Steering Committee (2002) applied these generic economic principles to spatial information and identified the key roles of government in the spatial information sector as follows:

- Developing policy and frameworks
- Promulgating and mandating use of standards and assessing compliance
- Specifying and developing products and services to meet public interest needs
- Providing infrastructure, fundamental data and basic services
- Competitive purchasing and quality control of particular services, such as data collection, infrastructure provision and access
- Ensuring equity of discovery and access to information
- Delivering broad societal outcomes, such as inter-generational equity, effective use of public resources and protecting rights of consumers.

The report identified the key tests for involvement of the public sector as:

- a public interest need is to be met, and
- a public agency is sole provider, or
- the private sector is unable to provide a particular product or service, or
- based on national competition policy measures, use of a public sector provider is the most cost efficient use of resources.

Key observations

It is important to note that:

- spatial data are not a public good in the economic sense of the term until they are placed in the public domain (the data are in fact to some degree 'excludable' and are not a public good by virtue of their mere existence)
- market failure does not automatically imply that government *should* interfere; costs and benefits from intervening must still be assessed
  - the government also has to carefully balance private sector interests with the wider public interest, and ideally act to help deliver the wider results sought while not crowding out private initiative
- similarly, a natural monopoly situation does not mean that government *must* perform this function; private companies can sometimes provide some of the key spatial data services, and invest in the infrastructure necessary to provide value added servies, that might traditionally have been seen as the remit of government
  - real time GPS (or GPS augmentation) for example is delivered private sector providers in NZ (e.g., Fugro); as a consequence, the role of government in entering these markets must be reviewed very carefully
- finally, dynamics can be important and if government enters or supports a sector that is moving rapidly it should also consider its 'exit' strategy – along with the preceding comment this means that the *appropriate role of government is fluid and shifts over time.* Assessing the government's role requires close attention to the way the technologies are developing and how market participants are behaving.

3.1.2 Government and regulatory failure

The concept of government failure was introduced in Section 1.3.4 of this report, which noted that limited information, limited control over private market responses, limited control over bureaucracy, and limitations imposed by political processes are all seen as key causes of government failure in the economic sense of the term. Regulatory failure is a type of government failure, albeit with its own complexities which cannot be discussed in detail in this report.

In the context of spatial information in New Zealand, it was commented several times during the preparation of this report that the government holds large amounts of spatial data but in many cases these data are either not being shared effectively across departments (i.e., held in 'silos') and sometimes not released at all, and that there is a lack of knowledge as to what data are available where, and how one can access them. This situation indicates aspects of government and regulatory failure in the economist's sense of these terms are occurring. This has led to suboptimal data sharing within government as well as lower data use and re-use by non-government entities.

Stiglitz (2000a, p. 205) provides a number of explanations for this type of public sector inefficiency, including an absence of competition (a corollary to being the natural monopoly), the absence of incentive pay and various principal-agent problems such as the pursuit of bureaucratic objectives and high levels of risk aversion exhibited by public servants. A range of explanations for the failure to share spatial data in New Zealand based around this concept of government failure can be offered.

Many agencies buy or generate spatial data to help them perform their own functions. They have strong incentives to do so efficiently, but the incentives operate vertically within the organisation. Agencies have few incentives to make spatial data available to potential users who are not seen as central to the organisations' core business.

Current policy settings require government departments to make data available at the cost of dissemination. The cost of disseminating data though is a function of how an agency organises its business. If data and systems are organised around meeting internal needs, the cost and practical difficulty of getting the data out to other users will potentially be high. Local authorities are permitted to set their own policies on pricing access to data and many attempt to recover costs by selling it rather than distributing at marginal cost.

Pricing policies for access to data are particularly important. The analysis on price elasticities at Section 1.3.5 indicates that prices (even relatively low prices) can be significant determinant of greater use of spatial data. Where pricing for public data is too high, the use of spatial data by others will be less than optimal resulting in a loss of economic welfare for the economy generally.

Incentives also operate on people working within agencies to restrict access to data. Individual and managers may be unwilling to release data because they feel its quality is not high enough or over concerns about legal liability for the accuracy and quality of data. Some data held by public agencies may be held in formats that suit the organisations' internal use of the data, but are not suited to wider use without significant reformatting. Such reworking involves multiple private actors in work which adds little value to the organisation while it would deliver broader economic benefits.

A comment from the workshop illustrates the perception that formats indeed are an issue:

> "Most (all?) New Zealand framework datasets largely ignore open standards, they have adopted a proprietary information model based on many different vendor solutions".

License arrangements may also restrict access by unnecessarily restricting reuse, imposing conditions about that are hard to apply when the data are used in web applications, or taking time to complete.

People in agencies who are responsible for data do not have incentives to create metadata that describe the data they hold because they already understand the data and how it is structured. But without good metadata, it is difficult for others to discover the data and figure out how to use it most effectively.

The problems of data access have been the subject of considerable attention; there is potentially a way around these problems that may not involve significant additional costs for government organisations. This involves agreement on open standards and protocols which if adopted across government agencies could provide a framework for access to basic data. Such a framework has been developed by the Open Geospatial Consortium which is discussed in Section 3.2 below.

3.1.2 Identified barriers – literature and anecdotal evidence

The Geospatial Research Centre's capability mapping report (Park et al., 2008) identified the following list of priority issues for the NZ geospatial sector:

1. Lack of geospatial understanding
2. Problems accessing NZ data
3. Staffing issues
4. Difficulties starting / developing a business in NZ and then moving offshore
5. Access to funding
6. IT issues
7. Limited awareness / use of (internationally aligned) standards, metadata and protocols
8. Government issues

A number of these are 'generic' issues, i.e., not specific to the spatial sector alone in New Zealand (notably Points 3 to 5 on the list above). Extending the capability mapping carried out by the GRC during a recent consultancy, The Hon. Gary Nairn (2008, p. 4) identified key constraints as being the lack of understanding of the importance and benefits of geospatial information (Point 1 on the GRC list above), inconsistency in data standards (Point 7), and problems accessing data (Point 2).

As noted in Section 3.1.2, one of the clearest barriers identified in the interviews and workshop for this report was the limited access to spatial data held by central and local government and other public agencies. A website (http//officialinfo.wordpress.com) maintained by two individuals in the geospatial industry records a number of attempts to obtain spatial data from central and local government agencies. It reveals that pricing, formats and licensing are key issues for more seamless access to public data.

Work for this report also shows how barriers can be perceived by users in the retail sector (see Box 7).

Box 7 **Barriers in the retail sector**

There is limited knowledge across the retail sector of the benefits of spatial information and that there is some hesitancy amongst executives and senior managers which hampers further investment. This is compounded in many cases by the costs of investing in spatial applications both in terms of cumulative licences for data and also consultancy fees. Overall, this tends to make access to detailed analysis the preserve of larger organisations who make strategic decisions across regions and who will also benefit significantly in terms of resource efficiencies.

Smaller organisations may undertake some in-house analysis however this could take up a significant proportion of their resources, and many do not have the skills required to format and analyse the data for specific purposes. For those that do use spatial information either directly or indirectly, data quality and lack of standardisation is an issue.

Overall this suggests opportunities for government enabling access to publicly produced data via the internet, rather than current limited and costly distribution through intermediaries. Further, continued development of software and the potential increase in desktop analysis packages would enable smaller organisations to adopt the technology leading to significant increases in the use of spatial information.

Source: Ecological Associates, based on feedback from interviews.

There would appear to be important economic benefits to the retail sector. Adoption of open standards through a coordinated approach by the national and local governments would appear to be one option worth exploring to reduce these barriers and realise longer term and wider economic benefits for industries such as the retail sector.

3.2 Spatial data without barriers: an efficient and effective SDI

Another way of thinking about barriers is to compare the status quo with the ideal state; a highly functional spatial data infrastructure or SDI. While there is no single agreed-upon definition of SDI it is essentially a framework of spatial data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way. A successful SDI, almost by definition, addresses the barriers discussed earlier:

> The fundamental argument for investing in spatial data infrastructure (SDI) rests in its ability to address market failures, coupled with significant returns to scale and scope. Moving towards an effective SDI is like moving from 'desktop' GIS to 'enterprise-wide' GIS, that is, there are significant benefits to be had from effective sharing and re-use of data which is why A Spatial Data Infrastructure (SDI) facilitates and coordinates the exchange and sharing of spatial data between stakeholders in the spatial data community. (Rajabifard et al., 2006)

This paper does not attempt to prescribe the platonic form of an SDI; indeed SDIs around the world might be considered a work in progress. Modern SDIs are typically built from a combination of open standards, open access to distributed data maintained at source, top down action by government and bottom-up development by users.

The reference architecture for SDIs promoted by the Open Geospatial Consortium (OGC) is a sufficient description for the purposes of this paper. The OGC is a consortium of over 386 companies, public organisations and universities participating in a consensus process to develop publicly available interface standards:

> OpenGIS Standards support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. The standards empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications (http://www.opengeospatial.org/ogc, accessed 31 July 2009)

The standards and principles established by the OGC are worthy of consideration by government in addressing the barriers discussed in this report. A summary is provided in Box 8.

Box 8 Spatial Data Infrastructure: the OGC reference architecture

The main OGC interface specifications are:

- WMS: Web Map Service
- WFS: Web Feature Service
- WCS: Web Coverage Service
- WMC: Web Map Context
- W3DS: Web 3D Service
- CS-W: Catalogue Service for Web

The OGC has defined GML (Geography Markup Language) as the format for interchanging geographic datasets. Also ISO standards play a role. Important ISO standards is the geospatial domain are:

- ISO19110: Standard for registration of feature type definitions
- ISO19115: Metadata standard for geographic datasets
- ISO19119: Metadata standard for services van de services
- ISO19139: XML encoding of ISO19115 metadata standard

Publish-find-bind paradigm

The OGC reference architecture has the following roles:

- Provider
- Broker
- User

The publish-find-bind paradigm describes the interaction between the different roles. A data provider publishes its geographic dataset as a service (e.g. WMS or WFS). The service and the geographic dataset are being described by metadata (using ISO19115 and ISO19119 standards). The metadata is being harvested into a catalogue (broker). A user queries the catalogue for a specific geographic dataset through the catalogue service (CS-W) by specifying keywords and search area. Then the user retrieves the geographic dataset through a service and is able to use the data in its own business process.

Technology

The technical elements of an SDI can be built from proprietary components or components developed by the open source community.

Web Map Service (WMS)

The WMS is a service that returns a georeferenced map (layer). In this context a map is considered as a two-dimensional visualisation (according to a predefined style) of features and can be in common formats like jpeg. The service does not return the actual features. By default a WMS serves one or more styles per layer. By defining a style on the client side and sending this style as part of the WMS request to the server, a map with a user-defined style is obtained. In this way thematic maps can be made. The styles used for rendering the map have to be specified in a Style Layer Descriptor (SLD) document. SLD is an XML encoding for the definition of the styles of geographic features.

Web Map Context (WMC)

It is possible to combine layers from different WMS's on the client into one single map view. Requirement is that the layers are requested with the same bounding box and output size and are within the same coordinate system. The OGC developed the WMC specification to store the definition of these map views in a XML document. Using these WMC documents is it possible to retrieve map views on another client and at a later time.

Web 3D Service (W3DS)

The Web 3D Service is a service for displaying three-dimensional data. The service returns 3D geographic elements from a specified area in VRML format which are rendered on the client. Because rendering takes place on the client, real time navigation through the 3D image is possible.

Web Feature Service (WFS)

The WFS is the service for selecting, inserting, updating and deleting features and enables geographic and attribute filtering of the features. The OGC filter encoding specification has te be used for the filter definition. It describes the XML to be used to define spatial and attribute filters. The selected geo-features are returned in GML format.

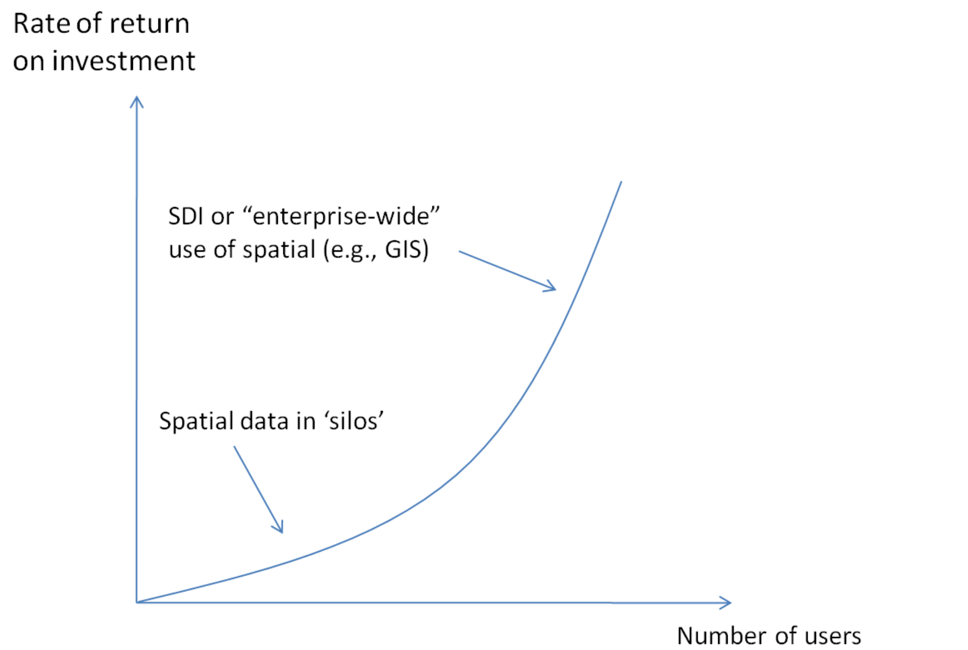
Catalogue Service for Web (CS-W)

A Catalogue service offers functionality to store (harvest) and query metadata of services and geographic datasets in a catalogue.

Source Adapted from http://www.atlis.nl/eng/ogc.html

Making an SDI can be considered as a national level analogue of adopting an enterprise-wide spatial system in an organisation, and productivity gains of the same order can be expected.

Figure 29 **The rate of return on investment (SDI or 'enterprise-wide' versus 'silos')**



Source: ACIL Tasman

Due to the size of investment initially required, the 'public good' aspects of SDIs, and the nature of some of the benefits (e.g., biosecurity, etc.) some elements of this type of infrastructure will have to be funded by government. Individual companies, especially the smaller players, won't create all the networks and capabilities for an SDI on which their competitors may 'free ride'.

As high-income economies become more and more knowledge driven, the infrastructure underpinning knowledge creation, maintenance and use also become increasingly fundamental to the functioning of the economy. SDIs are an important sub-set of these knowledge infrastructures. These emerging infrastructures go beyond infrastructure in the traditional sense of roads and buildings to include investments that increase the capability and options to create, share and use knowledge:

Whatever definition is accepted, it is clear that SDIs will include elements that are related not only purely to technology (cables, computers, software, data storage, etc.) but also to the relationships, norms and rules of exchange accepted by those involved in knowledge creation and its maintenance and use. This architecture of technology and protocols will be necessary to realise the ultimate outcome of a vibrant and innovation driven market for spatial information. A country may have supercomputers and high bandwidth internet, but if there is no process or capacity for sharing data, knowledge growth will be stymied as data still sit within 'silos'. If countries do not address this problem the market will be constrained, potential new industries will be lost to other countries and international competitiveness will suffer.

3.3 Government role in making an efficient and effective SDI

To create an SDI, a set of initiatives should ideally be launched as a package, possibly a sequential package within an overall policy objective articulated in terms of developing and SDI for the nation. This essentially requires a 'step-change' in approach, backed up with ongoing effort by government and other players to implement the changes necessary over a longer time frame. Broadly, policy implementation might be conceived of as:

- specific discrete initiatives and interventions by Government, supported by
- a policy framework that will foster a culture of support for an effective SDI in governments and industry.

Specific initiatives or interventions are proposed below to address the market failure and government and regulatory failure problems discussed earlier. These include routinely making publicity funded spatial data available through the internet so that they can be readily re-used (this addresses the government failure issues) and implementing elements of an SDI that address the spillover and public good nature of the data that would not otherwise occur if left to the market (so addressing the market failure issue).

This section also makes some suggestions/proposals about the instruments to use. Some are designed to achieve a demonstration effect in terms of Rogers' diffusion theory. The idea being that if solutions (especially to the government failure problems) can be devised and made highly visible, they can be replicated across many agencies.

Such demonstrations should also provide information about the costs some of the proposed interventions which could plausibly come later. This cost information (which this study does not address) would be needed to support harder interventions like regulating to make laggard agencies participate in an SDI.

3.3.1 Routinely exposing its own spatial data for reuse

The analysis of barriers earlier in this section indicates that considerable value can be realised simply by exposing spatial data to the wider community of users via the internet. This value is additional to that created by systems such a those discussed in section 2 of this report, which largely serve defined sets of data to meet the needs of a specific set of users.

By exposing data directly via the internet, it is available to anyone to use, recombine and add value in ways that cannot be predicted by policy makers or even industry analysts at the present time. Critically, in a cost constrained environment, exposing existing data could leverage benefits ahead of more costly interventions like purchasing new data, or making other parts of the technical infrastructure for an SDI.

Two examples illustrate how government data from multiple sources can be recombined:

- GeoCommons (see www.geocommons.com) delivers basic analytical and mapping services through a web browser.
- Koordinates.com (see http://koordinates.com) provides downloads of map layers in a range of formats.

Both these services contain many layers of spatial data from publicly funded sources in the case of Koordinates largely from New Zealand.

More commonly applications can consume publicly funded data (usually behind the scenes) to provide much more specific functions like locating an address on a map or layering different sets of information over a particular property.

For data to be accessible and reusable a number of the barriers identified earlier in this section need to be addressed, specially pricing, licensing, metadata, as well as providing data in forms which maximise its use and re-use.

Pricing

The work on price elasticities earlier in this paper indicates that prices (even relatively low prices) can be a significant barrier to information re-use. The main policy settings on pricing access government held information date mainly from 1997, before access to data via the internet was cheap and ubiquitous as it is in 2009 and before the nature and value of information as a good was fully appreciated.

The settings for government departments refer to 'cost of dissemination' but as noted earlier, this cost is likely to reflect the way agencies organise their business rather than true marginal costs if dissemination was a priority.

If the institutional barriers are addressed, it is likely that the marginal cost of routinely exposing spatial data via the web could approach zero.

There would still be some costs (say bandwidth) and some agencies would lose their current revenue from sales of data. The loss of revenue to particular agencies would need to be addressed, but there is plenty of scope to solve that problem because gains (including tax revenues to the government) from making data free would be expected to significantly outweigh the income lost.

Licensing

Work by several government agencies including New Zealand State Services Commission (2008) and the Victorian Parliamentary economic Development and Infrastructure Committee (2009) suggests that much simpler and more permissive licensing arrangements can be used for government held information without creating additional risks to government.

The work referred to suggests that perhaps 85% of public sector information could be available under the most permissive form of creative commons license which essentially requires only attribution of the source data to its originator. Ideally users would agree to such a license as part of the process for accessing data via the web.

Metadata

To be accessible and usable, spatial data must be accompanied by metadata that describe how the data are structured, what they describe and how they can be accessed.

The metadata need to be usable by computers and human users. Ideally there would be a mix of highly structured and standards compliant metadata as well as tagging that facilitates discovery through search engines and the emerging semantic web.

Providing data in forms that maximise reuse

To maximise the benefits of publicly funded data agencies would make the fullest possible sets of spatial data available in relatively raw form. If agencies attempt to operate too far down the value chain or exclude access just because data is no longer of use to the agency, they will crowd out private initiative and innovation.

This involves something of a paradigm shift from thinking spatial data and systems as products aimed at specific uses and users and towards thinking of it as raw material for innovation.

Data though must be exposed in a form that can be readily consumed by those who will add value to it, especially by the people who design and provide web applications with a geospatial component. The forms which are ideal for consumption over the web are not necessarily the forms agencies adopt for their internal use or for the products, services they offer to core users.

Technical format issues are beyond the scope of this report, but the almost universal feedback received in preparing it was that technical issues are relatively trivial and barriers around formats are essentially institutional in origin.

The New Zealand Transport Authority's cooperative work with web developers on its InfoConnect website described in Section 2.1.2 is an excellent example of effective work on data format issues. The work may be having demonstration effects too and a recent report said about the website that it:

> ...provides third parties and the developer community with the tools to create applications using NZTA's data. The organisation realised it could leverage experts in the field to make its data accessible, instead of trying to do it all in-house ……. [the website's features can] scale from one developer, working out of his or her spare room, to big corporations wanting to use information from NZTA. 140 developers have signed up …… applications rolled out to date include programs from the AA, MetService and a few phone applications, which are available on the iTunes App store … (NZ Computer News 2 December 2008).

This example from NZTA also illustrates a trend taken up again in Section 3.4 (where the costs of barriers are estimated). The trend is that even without any concerted action across the whole of government agencies will quite likely get better at exposing their spatial data over time. Another example is provided by the Ministry for the Environment making its Land Cover Database (LCDB) freely available under a creative commons licence on the Koordinates website.

This trend does not provide an argument for a 'do nothing' approach. The estimates made in section 3.4 suggest that the greatest productivity gains can be made by concerted action across government as soon as possible.

3.3.2 Making the technical elements of an SDI that other players will not make

Again it is beyond the scope of this study to make specific recommendations about technical issues. Analysis of market failure does suggests some components of an SDI where government could initially focus attention.

Standards

Reasonably comprehensive and mature standards relevant to describing, structuring, and transacting spatial data already exist, largely provided through a mixture of cooperation between market participants, voluntary and government action. The two main collections of spatial standards are promulgated by the international standards organisation (ISO) and the Open Geospatial Consortium (OGC). ANZLIC also works on standards at the Australia/ New Zealand level.

Mehrtens (2009) has identified a role for government in standards on public policy grounds. Activity in this area could focus on metadata standards (because metadata is clearly a barrier), and could also focus on data models for some of the subject areas which are most critical to emergency services or to the economy like addresses and roads.

Standard data models are needed so that users of have a shared an accurate understanding of how datasets are organised and how the data they relate to objects of qualities in the real world. There will be a role for government in coordinating and providing support for standards so that development in international standards are understood and work by government, industry, the science community and academia is ordered effectively.

Other technical elements of an SDI

The OGC reference model for an SDI described briefly in Box 8 in section 3.2 contains components which may need to be provided by governments and are so provided in SDI implementations in other jurisdictions. They include some of the catalogue components, metadata registries, and in some implementation cases, a portal component that provides more comprehensive access to data than markets would provide.

Comprehensive access via a portal is though a not a starting point or even an essential early building blocks of an SDI.

3.1.3 Choice of instrument

One kind of intervention is clearly indicated: making practical implementations in agencies that break down the technical barriers to exposing spatial data to the web. The solutions should be documented, costed and support for applying them elsewhere should be provided. Potentially candidates for this sort of work include applying metadata standards, data models, and designing the stacks of software which sit between spatial databases and the web are

Free and open source software offers particular advantages in this context as it is by definition replicable without payment and the improvements and adaptations made to it are in the public domain, and as indicated in Box 8, open source options for all the technical components of an SDI are available.

Free and open source software and proprietary software however have very different characteristics in terms of up front and ongoing costs, risk, and how support can be obtained. Agencies may also see a need to use proprietary software for mission critical applications or for ‘heavy lifting” tasks where highly capable proprietary software excels.

Mixtures of proprietary and open source solutions are though increasingly used in implementations of SDIs and the government should thoroughly explore how open source solutions can be employed because of the potential advantages in cost and replicability.

Solutions to the more abstract institutional barriers can be the subject of demonstration effects too. Issues like privacy, copyright, licensing, and possible liability issues around data quality are likely to be common to many kinds of spatial data.

If they can be solved once, the solutions are probably highly portable. The New Zealand State Services Commission's work on Creative Commons licensing (State Services Commission 2008) is an example of this process in action.

A harder set of interventions is also indicated and could plausibly be sequenced and designed in detail after some of the demonstration effects are evident. The sequencing issue is a critical one because the barriers being addressed are institutional. The literature on government and regulatory failure suggests that if mandatory requirements aimed at making data available were imposed *before* the means to comply with them are demonstrated individuals and agencies would find ways to work around the requirements and make them ineffectual.

These harder interventions which could follow after demonstration effects have been established could plausibly include some include mixture of

- incentives on chief executives and senior management to make spatial data from their agencies available
- directing government departments to make specified spatial data available in specified formats with the most liberal possible licensing, and at zero cost
- mandating spatial standards for public agencies
- legislating for Local Authorities to make specified spatial data available in the same way
- devising policies so that research with spatial outputs funded through the public good science system is publicly available and where appropriate free.

These interventions need to be supported by much better information about the spatial sector, as noted elsewhere in this report there is very little reliable information about what is going on in the sector. Like any significant policy initiative the effect of the interventions needs to be monitored too.

3.3.3 Dynamic policy settings

The spatial sector is particularly dynamic. The technology is changing rapidly as are the activities of actors in markets. This means that the logical role for government is and will continue to change rapidly too.

The changes are particular important in relation to the big ticket items like acquiring and processing large sets of data. Government agencies appear to be highly responsive at the margins if there is a clear policy imperative for instance in getting the LUCAS data needed for international obligations on climate change.

There does not appear to be any established process in place to monitor what markets are doing and set cross government priorities to fill any gaps where government acquisition of data is indicated or exit from acquiring data where it is no longer required.

One suggestion for data acquisition that emerged several times during this study was the digital elevation data needed to construct a digital elevation model. The discussion of GPS augmentation in section 2 suggests another possible role for government in supporting a consistent approach and the need for it to be very finely calibrated.

3.3.4 Maintaining and developing the culture to support an SDI

An effective SDI won't be created simply by making a series of specific interventions. Many of the human and cultural components of an SDI lie outside the government or the direct effect of any interventions it makes.

There needs to be an overarching and shared policy goal under which the other participants in the spatial sector, industry, academia, and spatial professional can organise themselves and how they interact with government.

McLaren (2006) suggests that:

> Although there is no single model for a successful NSDI [National Spatial Data Infrastructure], all are different and reflect the varying cultural, institutional and political contexts, the following critical success factors provide guidance on how to avoid potential cul-de-sacs:
>
> - Introduce a shared governance model amongst the stakeholders that will provide strong leadership, involvement and support. Without this, there will be a high risk that the objectives of the NSDI strategy will remain unfulfilled.
> - Encourage effective partnerships among the public, private, voluntary and academic sectors. Be inclusive, wherever possible, and encourage shared services.
> - Cooperate with the stakeholders governing and implementing the regional SDI strategies within the country and gain from their lessons learned.

- Sustain a strong communication strategy to ensure all stakeholder communities understand what is happening, why it is happening and how they can support the initiative.
- Create a robust business case that identifies a wide range of economic, social and environmental benefits, rather than just supporting a few stakeholder communities, and an associated performance measurement framework to monitor the benefits realisation.
- Design a NSDI that directly supports political initiatives and obtain joint funding wherever possible.
- Introduce a capacity building programme to ensure that sufficient and appropriate human resource capacity is available to create and exploit the NSDI.
- Clarify the proposed scope of the NSDI over time and obtain funding and resources to support the implementation plan.
- Provide clarity and transparency of the underlying business models to the stakeholders and simplify the licensing of geo-spatial information wherever possible.
- Intervene to change the underlying principles of the NSDI. Evolution does not always generate the desired outcomes in the NSDI arena. (McLaren, 2006)

Inherent in this prescription is the need for some certainty about what the government will do and when, and also what it won't do. This need for a clear path is essentially what was suggested by The Hon. Gary Nairn that:

> ...strong leadership to be taken at the Ministerial level as is occurring right around the world. It is recommended that the Minister establish an Action Agenda for Spatial Information. (2008, p. 3)

If such a clear path was established the government could facilitate, foster and encourage the co-creation of an SDI along with the other parties.

Particularly relevant here are the government agencies that deal with training and education, small business support, economic development and research funding and even immigration.

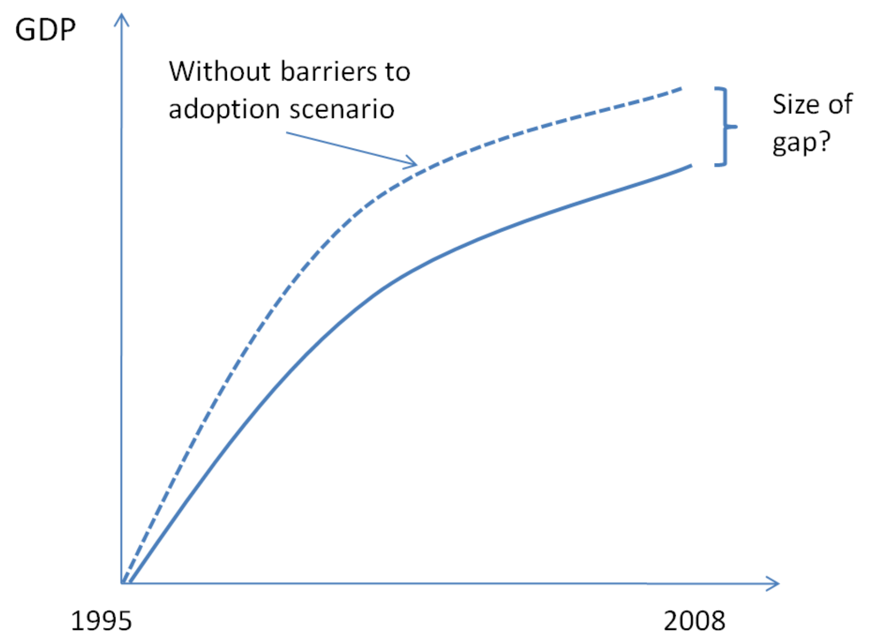
These agencies cannot be expected to develop their own detailed analyses of spatial information issues; they are however very important because they control some of the levers that affect some of the barriers identified in this report such as staff and skills shortage.

3.4 The 'cost' of the barriers and the gain from removing them

New Zealand has experienced considerable benefits from spatial information but the barriers discussed in this section represent 'missed opportunities' too. This section sets out to estimate the costs of those barriers and the productivity gains available from removing them.

In terms of the economic modelling carried out for this report, the 'lost opportunity' consists of the gap between the two curves shown in Figure 30 – where the economy could have been in the absence of the barriers.

Figure 30 **The 'cost' of the barriers – Illustration 1**



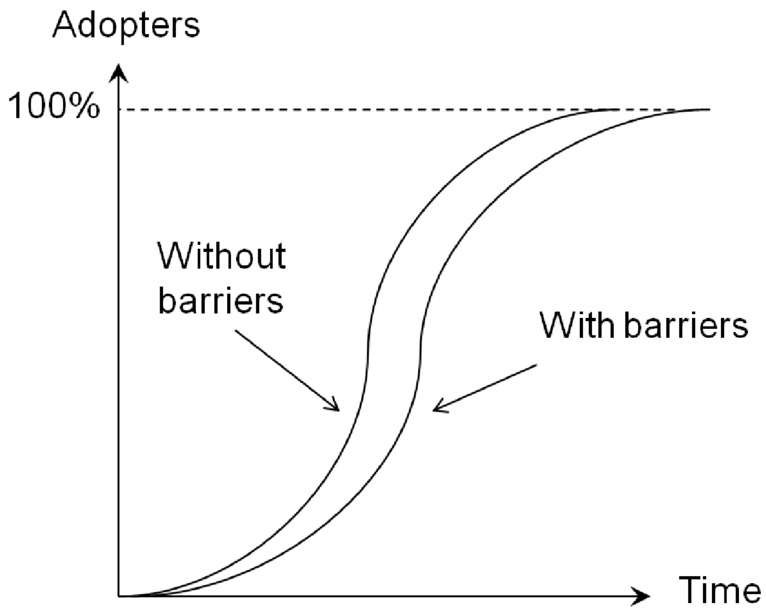
Source: ACIL Tasman

Another way of stating this that, in the absence of the barriers in New Zealand, adoption and market penetration of spatial information could have been more widespread.

This is reflected in Figure 31, which places the "real", i.e., observed, adoption curve (with barriers) next to a notional adoption curve depicting the situation without barriers. At any point in time, i.e., along the x-axis, uptake would have been higher in the absence of barriers. Alternatively it is possible to examine a point along the y-axis to derive how much earlier a given level of adoption might have been achieved.

To enable the economic modelling discussed in Section 4 it was essential to gauge the likely extent of these differences. Sector-by-sector discussion was included in Section 0 of this report. The general equilibrium modelling described in Section 4 of this report was then employed to estimate the implied dollar cost of having had the barriers in place.

Figure 31 **The 'cost' of the barriers – Illustration 2**



Source: ACIL Tasman

The impacts discussed in Section 0 were greatest where the barriers are a major impediment to uptake and least (even zero) where a sector already has a high level of uptake.

3.4.1 The "tipping" point for adoption

In general, one can say that 10 to 25 per cent of potential adopters need to have taken up a technology before the tipping point and thus the 'steep' part of the adoption curve is reached – when the 'coefficient of imitation' really kicks in (see discussion in Section 1.3.6) – that is, before critical mass in terms of demonstrating the benefits to the average user has been reached. The discussion in Section 2 of this report indicated that probably somewhere between 500 and 1,000 organisations have taken up GIS in New Zealand.

The latest available NZ Statistics figures indicate that there are over 22,000 enterprises with more than 10 employees in New Zealand – indicating that the current level of take-up is still less than 5 per cent of enterprises (and if smaller organisations were taken into account this would put NZ firmly in Rogers' 'innovator' stage and therefore at the relatively flat, initial section of the S-curve).

This means that it is more likely that New Zealand is still some distance from the steep "tipping" point on the curve. The fact that New Zealand is some way off the tipping point does in fact suggest that there may still be significant scope for government to contribute to accelerating uptake – that is to say, to bring forward the time until the tipping point is reached. Investment in a modern SDI is exactly the means by which this 'brining forward' could be achieved.

An important corollary to this is that any benefits thus generated should only be counted for as many years as the 'time to take-off' can be estimated to have been brought forward. So even if a $100 million investment in SDI removes all barriers, additional benefits attributable to the intervention cannot be counted indefinitely into the future – as the lower curve on Figure 31 shows, New Zealand would have got there eventually.

3.4.1 How far does New Zealand lag behind comparable countries?

In order to better understand where New Zealand might have been in the absence of barriers to adoption, a comparison of the NZ experience with spatial information related developments overseas is informative:

- In the US, a 1994 presidential 'Executive Order' launched the US spatial data infrastructure (SDI) initiatives; in Europe, ideas for a European SDI were put forward from 1995 onwards under the 'GI 2000' umbrella. Formalised national approaches from overseas now include the National Spatial Data Infrastructure (NSDI) initiative in the United States, the Canadian Geospatial Data Infrastructure (CGDI) and the Australian Spatial Data Infrastructure (ASDI)
  - While New Zealand has the broad Geospatial Strategy which was formulated in 2007, it does not as yet have a formal policy on SDI (Cottrell, 2009). In New Zealand a "federated" model has been preferred to SDI (Cottrell, 2009);
- In Australia, for example, the Spatial Industry Business Association (SIBA) formulated the Spatial Information Industry Action Agenda *Positioning for Growth* in 2001 to support the emerging spatial information industry. NZSIBA was only launched in 2009.
- Understanding the sector – early spatial industry 'Census' type initiatives happened in Queensland in 2002 and Victoria in 2005 (fivenines consulting, 2005) and earlier abroad. The closest NZ equivalent is the GRC capability mapping report for 2007 (Park et al., 2008)

New Zealand's relative position in terms of the way spatial information is used is much more difficult to assess. Given that there are many areas of application, there will be some in which New Zealand is way ahead (e.g., Landonline) and some in which it is significantly behind, notably because of the market's relatively small size and the limited pool of skilled staff. It is therefore hard to know whether New Zealand 'punches above its weight' or not. However there are some notable omissions where one would have perhaps expected more action by now:

- GIS/GPS in schools: some notable, privately led efforts are underway in New Zealand (e.g., Intergraph's programs); however, for comparison, GIS in schools has been happening since 1996 in Australia and ESRI's schools program has been implemented in over 500 schools. More importantly, in addition to private sector effort, there have been concerted government efforts such as Queensland Education's grants programme and other initiatives (McInerney, 2005, 2006). We are not aware of similar government programs in New Zealand
- GIS in public health and epidemiology: sentinel papers here can be traced to the mid-1990s (e.g., Hjalmars et al., 1996, Nicholson and Mather, 1996) but in New Zealand, peer-reviewed published literature has only begun to emerge in the last five years (e.g., Hales et al., 2003, Brabyn and Barnett, 2004, Hoque et al., 2004, Scoggins, 2004, Brabyn, 2005, Brabyn and Beere, 2006)
  - … This does not necessarily imply that NZ did not benefit from use of the technology as most NZ grants/projects via FRST, for example, were aimed at reports for stakeholders or were internal to the department concerned[94]

- It is also possible to engage in some preliminary analysis of industry development by comparing the (admittedly limited) data from New Zealand to those collected abroad. A ready example is that of Victoria where the aforementioned census of the core spatial industry – excluding players in the government sector – indicated that around 223 spatial industry businesses generated revenues estimated at $470 million and employed some 5,570 staff.
  - Victoria's population in 2005, when the survey was undertaken, was 5.0 million, whilst New Zealand's was 4.2 million in 2007 when the NZ capability mapping occurred which estimated a turnover of around $100 million.
    - … Even ignoring the fact that the NZ estimate includes government players, this shows means turnover per head of population was around four times higher in Victoria than in New Zealand ($94 versus $24)

Feedback received from a number of experts during the preparation of this report indicates that in a range of areas New Zealand is perceived to have fallen behind after a strong start in the late 1990s. Responses included

[94] Pip Forer, *pers.comm.* 15 June 2009

comments in specific areas such as "at least two years behind" and "progress on a well thought through data strategy back at least 3-4 years".

The discussion on the price elasticity of demand suggests that a reduction in price alone could have had a significant impact on uptake over time. There is general agreement in the literature that demand is likely to be elastic (elasticity > 1). An effective 100 per cent reduction in price would be expected to raise the quantity of spatial information demanded by more than 100 per cent (this refers to a move along the demand curve, not a shift in the demand curve). How this would have fed through to final use of spatial products in the general community is however open to conjecture. It might be argued that the capability to employ spatial data is still not in place for the average citizen.

As technology is improving rapidly and more and more households and smaller companies routinely employ ICT, the extent of the lost opportunity also increases – not opening up access in 2003 is an entirely different proposition to not opening up access in 2009, because the demand curve for spatial information has itself shifted outwards. This means that pent-up (unrealised) demand is highly likely to be increasing as time passes. At the same time, increasing incomes will have an exogenous (independent) demand shifting effect.

3.4.4 Dollar estimates

Using the technique described, the cost of the barriers is estimated at around $0.5 billion in 2008. The implied loss of government revenue is at least $100 million.[95] For the reasons outlined above these figures (annual costs due to barriers) are likely to rise with each year that passes until the barriers are dismantled. The estimates presented in this report can therefore give an indication of the likely *future benefits* of making a concerted effort along the lines discussed in Section 3 above, most notably investing in making data accessible and reducing access charges.

The New Zealand economy as a whole can likely gain $0.5 billion or more in additional annual productivity benefits with an effective SDI in place. Even if the government took a 'self interested' view and excluded all the wider benefits

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[95] This result is not 'self-evident' from the results of the economic modelling shown in Section 4 of this report, where the economic gains are split into 'productivity' benefits as well as government tax and tariff revenue (the latter increase by $54 million between the two scenarios shown); however, given that real GDP is estimated to grow by around $0.5 billion with the removal of barriers, based on the historic shares of private and government consumption in total expenditure, the government share of the gain would likely exceed $100 million. If transfer payments administered by government were included (e.g., pensions) this figure could be even higher.

from its consideration, additional government revenue from higher productivity alone would highly likely exceed $100 million per year.

To put the size of the investment and possible returns into context, if a $100 million investment in SDI brings the time to 'take off' forward by one year only, the broad benefit-to-cost ratio for the New Zealand economy as a whole and in terms of productivity only would be 5:1 (for the New Zealand government 1:1); in the event that it brings 'take off' forward by ten years, it could be 50:1 for the New Zealand economy as a whole (and 10:1 for the government). It must be stressed, once again, that this refers to pure productivity benefits and does not include all the other non-productivity benefits which are also very important drivers of investment in the sector.

Exact SDI costings were not scoped in this report, but the likely impact is likely to be somewhere in between these two extremes (i.e., higher than 5:1 but lower than 50:1 for the New Zealand economy), especially if the SDI intervention can be implemented at a cost of less than $100 million.

3.5 Future directions for the sector

In this report, the shift from single use to multiple use of spatial data has been noted under a number of different guises. Shifting from desktop to enterprise-wide use of GIS, enabling more effective 'sharing', moving towards an all-of-government approach, even the move from the so-called aggregator model to the distributed model essentially entails the same thing – spatial data are re-used, value is added in new ways, and learning becomes cumulative rather than once off. These shifts are occurring at several levels as new technologies are developed and existing ones are being harnessed better.

> The most important trend occurring today is the melding of GIS and the web. We are seeing the work of GIS professionals able to be leveraged using web technologies so that the reach of their work is increased. The ultimate expression of that is the reach into the consumer GIS world where analysis results can be published out to consumer products such as Google Earth and Virtual Earth. (Interview, Eagle Technology)

Such changes should ultimately have an impact on the uptake of spatial information by individuals, as people increasingly see spatial technologies being employed in their homes, cars, and so on. Such shifts will in turn result in a greater understanding and acceptance of spatial information technologies in the workplace, thus removing a major barrier to enterprise-wide GIS implementation.

> Enterprise GIS has become more modular recently and this modularity will continue. This will allow more incremental implementations of GIS – adding capability to an existing system will be much lower risk than has been the case in the past.

> It is very likely that further ICT advances will allow GIS users to take advantage of higher resolution content, geo-referenced video and more frequent collects of data.
>
> A key feature of Web 2.0 is the notion of web applications being able to post information back onto the server. It is likely that this will result in more consumer-driven corrections of government data sets as citizens 'red line' errors back to the producer.
>
> The convergence of mobile phones and GIS offers significant national benefit. One example is the offering of traffic congestion information. (Interview, Eagle Technology)

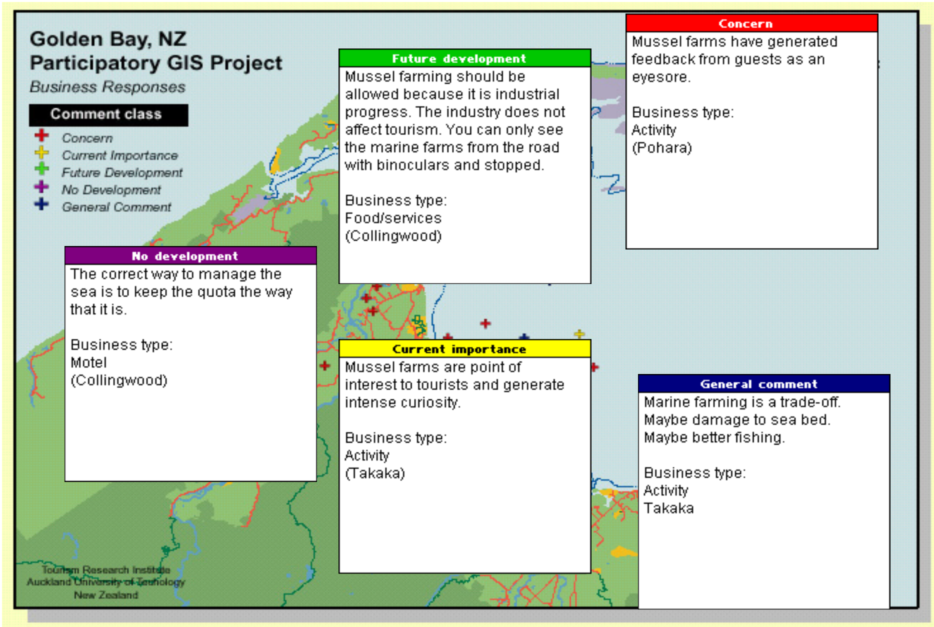
Another interesting direction for the future is linked to e-governance and issues of devolution or decentralisation. Spatial information technology can enable communities to understand their environments better, and assist in communicating and coordinating 'grassroots' action. In planning tourism for the Golden Bay region, for example, GIS provided a tool in resolving the conflict between industry interests and the community's interest in preserving the relatively undeveloped beaches. The community collected and visualised their information and this gave the local residents a stake in decision-making and planning.

There is a vision of a future where anyone can 'mash up' maps in an easy operating environment, say, a tool that is the equivalent of word processing software that is now part of standard software uploaded on every PC. At present, it looks like that is a few years away from becoming a reality; however, in the longer term it is entirely conceivable that various technologies integrate spatial information:

- GPS/GNSS mobile telephony applications that go beyond simple mapping (e.g., tracking epidemics; direct marketing and so on)
- computer games and consoles
- more advanced navigation systems (potential accident avoidance is in-built)
- integration with credit card chips or other handheld devices
- small business management systems (integrating time, spatial, and price dimensions for stocks & inventories, scanning sources in real time to permit coordinated reordering that maximizes efficiencies, etc.)
- night vision and other types of equipment to assist the visually impaired
- car sharing schemes or other travel planning assistance

more advanced planning and development processes integrating information on existing quality and rate of decay of assets and roads as well as public housing stocks, etc., to ensure projects are timely and objectives are met efficiently, and so on.

Figure 32 **Golden Bay Participatory GIS Project**



With an effective distributed system underpinned by SDI there is almost unimaginable potential for spatial information to become 'mainstream' – from enterprise systems to government, consumers and in social networking applications:

- government applications in emergency management, security, biosecurity, social services, policy and planning, service delivery, transport management, etc.
- management of climate change and water resources along with natural resource management generally
- business systems including facilities management, logistics, planning, marketing, retail management, consumer services, etc.
- social networking including consumer communications, product research, consumer feedback, social inclusion.

Predicting where spatial information technologies will go is impossible, precisely because of some of the option characteristics inherent in spatial data and the new technologies that are developing and blurring the boundaries between existing technologies. Processes will be influenced by the way in which technologies are converging. Some idea of the value already being recognized is in the options that companies are taking out in the acquisitions of spatial companies recently. Examples include:

- Pitney Bowes acquisition of MapInfo
- Nokia's $9 billion acquisition of Navtech

- Gamin's acquisition of Tom Tom
- Quascos acquisition of Century 21 in Australia.

It is also understood that Microsoft is acquiring businesses with spatial capacity. These investments indicate that it is a sector with a future.

The role and future of spatial information is also intricately and importantly linked with New Zealand's wider innovation system. The speed with which modern spatial information technology applications are developed and spatial information permeates the NZ economy is at least partially a reflection and measure of the capability of the innovation system; at the same time, this capability is affected by modern spatial information technology.

As noted during interviews carried out for this study, New Zealand is certainly perceived as a place where innovative activity is encouraged, and the 'core' spatial information innovators in the private sector are particularly creative, knowledge intensive technology transformers. Spatial information, in short, has the potential to play an important role in the NZ economy in future.[96]

[96] The possibility of foreign takeovers/acquisitions of NZ spatial innovators, such as occurred in the case of Navman Wireless in 2003, must also be noted.

4 Macroeconomic modelling

For this report, ACIL Tasman's CGE model, *Tasman Global*, was used to estimate the impacts that spatial information induced productivity enhancements have had on the New Zealand economy to date. Further, an estimate was made of the potential benefits that could have arisen if identified opportunities had been pursued by businesses and the government and a higher rate of spatial technology adoption achieved as a consequence.

Tasman Global is a large scale, dynamic, computable general equilibrium model of the world economy that has been developed in-house by ACIL Tasman. *Tasman Global* is a powerful tool for undertaking economic analysis at the regional, state, national and global levels.

General equilibrium models such as Tasman Global mimic the workings of the economy through a system of interdependent behavioural and accounting equations which are linked to an input-output database. These models provide a representation of the whole economy, set in a national and international trading context, using a 'bottom-up approach' – starting with individual markets, producers and consumers and building up the system via demands and production from each component. When an economic shock or disturbance such as an increase in a sector's rate of growth is applied to the model, each of the markets adjusts to a new equilibrium according to the set of behavioural parameters[97] which are underpinned by economic theory.

In addition to recognising the linkages between industries in an economy, general equilibrium models also recognise economic constraints. For example, increased demand for labour may increase real wages if there is full employment.

A key advantage of general equilibrium models is that they capture both the direct and indirect impacts of economic changes while taking account of economic constraints. For example, Tasman Global captures the expansion in economic activity driven by an investment, and at the same time accounts for the constraints faced by an economy in terms of availability of labour, capital and other inputs. Another key advantage of general equilibrium models is that they capture a wide range of economic impacts across a wide range of industries in a single consistent framework that enables rigorous assessment of a range of policy scenarios.

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[97] An example of a behavioural parameter is the *price elasticity of demand* – the responsiveness of demand for a commodity to a change in the price of that commodity. Each of these markets, for example the market for a commodity or a factor such as labour or land or the market for capital goods, is then linked through trade and investment flows.

More detail of the *Tasman Global* model is provided in Appendix A.

4.1 Database aggregation

The database which underpins the model contains a wealth of sectoral detail. The foundation of this information is the input-output tables that underpin the database. Industries and commodities in the model can be aggregated or disaggregated as required for a specific project. For this project the model has been aggregated to:

- three economies, namely New Zealand, Australia and the rest of the World
- 32 industries/commodities as presented in Table 5.

The aggregation was chosen to provide the maximum detail possible for the applications of modern spatial information technologies as well as identifying the key industries in the New Zealand economy.

Table 5 **Industry/Commodity aggregation used in *Tasman Global* modelling**

	Industry/Commodity		Industry/Commodity
1	Crops	17	Other mining
2	Bovine cattle, sheep and goats, horses	18	Nonferrous metals
3	Other animals	19	Nonmetallic minerals (including cement, plaster, lime, gravel)
4	Raw milk	20	Chemicals, rubber, plastics
5	Wool	21	Wood and paper products; publishing and printing (excluding furniture)
6	Forestry	22	Clothing and textiles (including leather products)
7	Fishing	23	Other manufacturing
8	Meat products	24	Water
9	Dairy products	25	Construction
10	Other processed food	26	Trade services (includes all retail and wholesale trade, hotels and restaurants)
11	Coal	27	Transport
12	Oil	28	Communications services
13	Gas	29	Other business services (including financial, insurance, real estate services)
14	Electricity	30	Recreational and other services
15	Petroleum & coal products	31	Government services (including public administration and defence)
16	Iron & steel	32	Dwellings

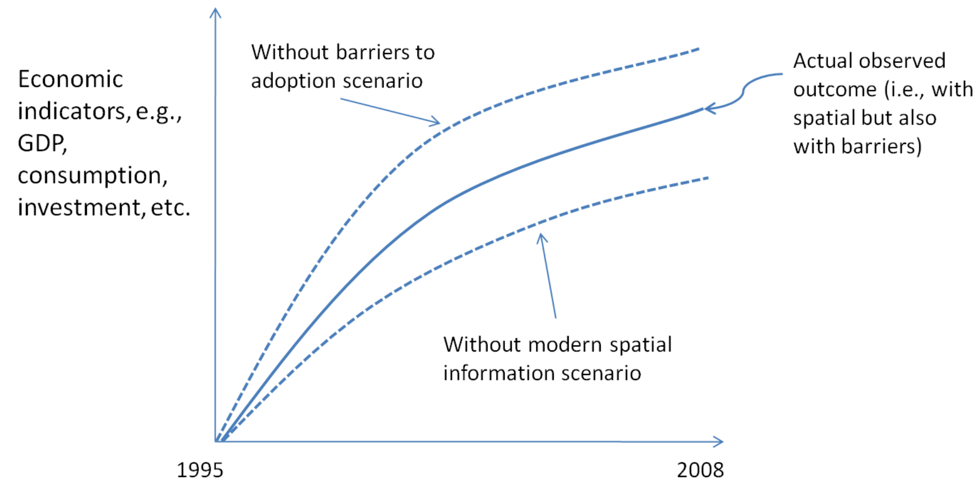
Data source: ACIL Tasman aggregation

4.2 Tasman Global modelling

4.2.1 Scenario description

In CGE analysis the outcomes of the policy simulation modelled are reported as deviations from the business as usual reference case (see Figure 33). To eliminate the impact of price movements in the results, economic variables such as the change in Gross Domestic Product are reported as deviations from their real rather than nominal values.

Figure 33 **Scenario description**



Source: ACIL Tasman Chart

For this study the business-as-usual reference case is the situation where the New Zealand economy grew as per historical records (the Base Case). This reference case is then compared to the alternative policy scenarios:

- Without spatial information scenario. In this scenario, the quantifiable productivity benefits identified from the case studies (see Table 6) have been removed. The difference between this scenario and the base case with spatial information scenario provides an estimate of the economic benefits that access to, and use of, spatial information has had on the New Zealand economy.
- Without barriers to adoption scenario. In this scenario the potential unrealised productivity benefits identified from the case studies (see Table 6) have been added. The difference between this scenario and the base case with spatial information scenario provides an estimate of the economic benefits that could have arisen if barriers to the uptake of current spatial information technologies had not existed across the identified opportunities.

It should be noted that the estimated productivity benefits do not account for any potential benefits from *future* improvements to spatial technologies or from new applications of spatial information technologies within the New Zealand economy for which productivity benefits could not as yet be identified.

Table 6 **Direct impact of spatial information on total factor productivity**

	Quantifiable historical productivity	Estimated productivity without adoption barriers
Crops	1.25	1.88
Bovine cattle, sheep and goats, horses	1.25	1.88
Other animals	1.25	1.88
Raw milk	1.25	1.88
Wool	1.25	1.88
Forestry	5.25	5.71
Fishing	3.44	3.44
Meat products	0.25	0.38
Dairy products	0.25	0.38
Other processed food	0.25	0.38
Coal	0	0
Oil	0	0
Gas	0.63	0.78
Electricity	0.63	0.78
Petroleum & coal products	0	0
Iron & steel	0	0
Other mining	0	0
Nonferrous metals	0	0
Nonmetallic minerals	0	0
Chemicals, rubber, plastics	0	0
Wood and paper products; publishing and printing	0.25	0.38
Textiles and clothing	0.25	0.38
Other manufacturing	0.25	0.38
Water	0.63	0.78
Construction	0.75	1.13
Trade services	0.77	1.15
Transport	2.10	3.15
Communications services	0.82	0.82
Other business services	0.23	0.46
Recreational and other services	0.23	0.46
Government services	0.52	1.04
Dwellings	0	0

Data source: ACIL Tasman calculations and estimates

The case studies reported in the previous chapter(s) discussed a wide range of benefits to government and industry from the use and application of spatial information systems. Section 0 discussed the sector-by-sector inferences for the economic modelling carried out here (i.e., explained the productivity 'shocks' summarised in Table 6 above).

Due to the complexity of estimating the productivity improvements by specific input, all productivity improvements have been implemented as total factor productivity improvements. In reality, many applications of the spatial information technologies will have had a differential impact on the demand for labour versus the demand for capital as well as affecting the demand for a range of other inputs such as petrol, chemicals and fertilisers.

To isolate the economic impacts of productivity improvements associated with the uptake of spatial information technologies within the New Zealand economy, all other settings in *Tasman Global* have been held constant across the scenarios (including population, labour supply, unemployment rates, tax rates, natural resource supplies and all other productivity improvements). In reality, some of these variables would also have been affected – for example, changes to real wages are likely to have changed participation or unemployment rates and even net migration rates.

4.2.2 Results

The results for the two modelled scenarios are reported in Tables 3 and 4.

Table 7 **Macroeconomic impacts of adoption of spatial information technologies**

	Units	Quantifiable historical productivity scenario	Without adoption barriers scenario
Real GDP	%	0.65	0.92
	2008 $m	1,164	1,645
Real GNP	%	0.63	0.89
	2008 $m	1,055	1,498
Real private consumption	%	0.64	0.90
Real investment	%	0.66	0.93
Capital stock	%	0.07	0.10
Real wages	%	0.63	0.86
Real exports	%	0.71	0.99
	2008 $m	362.5	505.3
Real imports	%	0.65	0.92
	2008 $m	333.4	468.7
Net real foreign trade	2008 $m	29.1	36.6
Terms of trade	%	–0.20	–0.27

Data source: Tasman Global modelling estimates

Table 7 shows the changes in a range of macroeconomic variables, while Table 8 presents a detailed breakdown of the estimated changes in real GDP and real GNP. To simplify interpretation, all results have been presented as changes relative to the Without Spatial Information scenario.

Table 8 **Decomposition of changes in real GDP and real GNP (2008 $)**

	Quantifiable historical productivity scenario	Without adoption barriers scenario
	$m	$m
Change in value added	88	123
Change in tariff revenues	9	12
Other tax revenue changes	127	178
Productivity effects	940	1,331.4
Total change in real GDP (income side)	**1,164**	**1,645**
Change in terms of trade	–102	–138
Change in net foreign income transfers	–6	–8
Total change in real GNP	**1,055**	**1,499**

Data source: Tasman Global modelling estimates

4.2.3 Quantifiable historical impacts of spatial information

Real GDP

The use of modern spatial information technologies has resulted in productivity improvements in the adopting sectors of the New Zealand economy. These productivity improvements have resulted in improved use of New Zealand's scarce labour and capital and allowed the economy to increase overall output compared to what would have otherwise been possible. Based on our conservative estimates of the productivity improvements, *Tasman Global* modelling estimates that, in 2008, New Zealand's real GDP increased by 0.65 per cent, or $1,164 million (in 2008 $), as a direct result of the uptake of spatial technologies (Table 7 and Table 8). If resource availability impacts had also been estimated, the estimated GDP impacts would no doubt be significantly greater.

Changes in real GDP can be analysed in more depth by decomposing the changes in value added, tax revenues and productivity effects (i.e. changes in income side of GDP). As shown in Table 8, just over 80 per cent of the increase in real GDP is directly associated with the estimated productivity improvements, 12 per cent is associated with increased net tax revenues due to increased economic activity. The remaining 7 per cent of the increase in real GDP is due to increased real returns from factors which results from higher accumulated capital stocks and allocative efficiency benefits associated with the reallocation of factors in the economy (note that the supply of land, labour and natural resources were assumed to be the same across all scenarios).

Real GNP and terms of trade

Although changes in real GDP is a useful measure for estimating how much the output of the New Zealand economy has changed, a better measure of economic welfare is real GNP.[98] This is synonymous with real gross national disposable income (RGNDI) reported by Statistics New Zealand. GNP is equivalent to GDP plus net foreign income transfers, and changes in real GNP is equivalent to changes in real GDP, plus changes in net foreign income, plus changes in terms of trade (which measures changes in the purchasing power of a regions exports).

The productivity improvements associated with the adoption of spatial technologies reduced production costs and boosted total production. Most, but not all, of these cost reductions are passed on to final consumers including foreigners – and this results in a decline in New Zealand's terms of trade compared to the without spatial scenario. The decline in terms of trade (of an estimated –0.20 per cent, see Table 7) means that New Zealanders have had to export more goods and services to pay for their imports[99]. Although the (small) decline in terms of trade to some degree offsets the growth in real GDP, total economic welfare of New Zealanders is still significantly greater as a result of the historical adoption of modern spatial information technologies. In particular, real GNP in 2008 is estimated to have increased by 0.63 per cent, or $1,055 million, as a direct result of the quantifiable productivity improvements generated from the use of modern spatial information technologies (see Table 7 and Table 8).

Other macroeconomic variables

Household consumption and investment increase by 0.64 and 0.66 per cent, respectively, while capital stock is estimated to be 0.07 per cent higher as a result of the productivity increases associated with the adoption of spatial technologies (Table 7).

A notable result is that the productivity improvements associated with the adoption of modern spatial information technologies is estimated to have increased real exports by $363 million in 2008. The increased exports have enabled New Zealanders to purchase more foreign goods and services (largely manufactured goods such as cars, electronic goods, clothing etc) with real imports estimated to have increased by $334 million. In aggregate, net foreign trade (exports minus imports) is estimated to have risen by $29 million (see Table 7).

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[98] More specifically, in *Tasman Global*, changes in real GNP are equivalent to changes in equivalent variation (using the Slutsky measure of income effects). See Pant (2007) for more details.

[99] Note, however, that total production has also increased, but part of the increased production needs to be used to support demand for foreign products.

The modelling assumption that labour supply and unemployment remains constant means that the modelling results show no employment gains. However, workers are clearly better off due to an estimated real wage increase of 0.63 per cent due to the productivity improvements associated with the uptake of spatial information technologies (Table 7).

4.2.4 Without barriers to adoption scenario

Due to the larger productivity gains under our 'without adoption barriers' scenario, the overall economic impacts under this scenario are larger with real GDP increasing by 0.92 per cent in 2008, or approximately $1,644 million. This implies that barriers to the uptake of modern spatial information technology have resulted in New Zealand forgoing $481 million in potential real economic output (Table 7) compared to what actually happened.

In welfare terms (i.e. real GNP), the estimated possible historical productivity improvements of using spatial information technology without adoption barriers is approximately $1.5 billion. This implies that barriers to the adoption of spatial information technologies have resulted in New Zealanders forgoing around $443 million in potential welfare (Table 7) compared to what actually happened.

Gains are apparent in all other macroeconomic aggregates, with real household consumption and real wages estimated to be 0.26 and 0.23 per cent higher under the 'without barriers to adoption' scenario when compared with the quantifiable historical productivity scenario (i.e., with spatial information but also with barriers to adoption).

A Economic modelling

A.1 The *Tasman Global* model

***Tasman Global* – a state, national and global scale model**

ACIL Tasman's computable general equilibrium model *Tasman Global* is a powerful tool for undertaking economic impact analysis at the regional, state, national and global level.

There are various types of economic models and modelling techniques. Many of these are based on partial equilibrium analysis that usually considers a single market. However, in economic analysis, linkages between markets and how these linkages develop and change over time can be critical. *Tasman Global* has been developed to meet this need.

Tasman Global is an analytical tool that can capture these linkages on a regional, state, national and global scale. *Tasman Global* is a large-scale computable general equilibrium model which is designed to account for all sectors within an economy and all economies across the world. ACIL Tasman uses this modelling platform to undertake industry, project, scenario and policy analyses. The model is able to analyse issues at the industry, global, national, state and regional levels and to determine the impacts of various economic changes on production, consumption and trade at the macroeconomic and industry levels.

A Dynamic model

Tasman Global is a model that estimates relationships between variables at different points in time. This is in contrast to comparative static models, which compare two equilibriums (one before a policy change and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues where both the timing of and the adjustment path that economies follow are relevant in the analysis.

In applications of the *Tasman Global* model, a reference case simulation forms a "business-as-usual" basis with which to compare the results of various simulations. The reference case provides projections of growth in the absence of the changes to be examined. The impact of the change to be examined is then simulated and the results interpreted as deviations from the reference case.

The database

A key advantage of *Tasman Global* is the level of detail in the database underpinning the model. The database is derived from the latest Global Trade Analysis Project (GTAP) database which was released in 2008. This database is a fully documented, publicly available global data base which contains complete bilateral trade information, transport and protection linkages among regions for all GTAP commodities.

The GTAP model was constructed at the Centre for Global Trade Analysis at Purdue University in the United States. It is the most up-to-date, detailed database of its type in the world.

Tasman Global builds on the GTAP model's equation structure and database by adding five important features: dynamics (including detailed population and labour market dynamics), detailed technology representation within key industries (such as electricity generation and iron and steel production), the ability to repatriate labour and capital income, a detailed emissions accounting abatement framework and explicit representation of the states and territories of Australia.

Nominally the Tasman Global database divides the world economy into 120 regions although in reality the regions are frequently disaggregated further.

The GTAP database also contains a wealth of sectoral detail (Table 9). The foundation of this information is the input-output tables that underpin the database. The input-output tables account for the distribution of industry production to satisfy industry and final demands. Industry demands, so-called intermediate usage, are the demands from each industry for inputs. For example, electricity is an input into the production of communications. In other words, the communications industry uses electricity as an intermediate input. Final demands are those made by households, governments, investors and foreigners (export demand). These final demands, as the name suggests, represent the demand for finished goods and services. To continue the example, electricity is used by households – their consumption of electricity is a final demand.

Each sector in the economy is typically assumed to produce one commodity, although in Tasman Global, the electricity, diesel and iron and steel sectors are modelled using a 'technology bundle' approach. With this approach, different known production methods are used to generate a homogeneous output for the 'technology bundle' industry. For example, electricity can be generated using coal, petroleum, gas, nuclear, hydro or non-hydro renewable based technologies – each of which have their own cost structure.

Table 9 **Sectors in the Tasman Global database**

	Sector		Sector
1	Paddy rice	32	Diesel (incl. nonconventional diesel)
2	Wheat	33	Other petroleum, coal products
3	Cereal grains nec	34	Chemical, rubber, plastic products
4	Vegetables, fruit, nuts	35	Mineral products nec
5	Oil seeds	36	Ferrous metals
6	Sugar cane, sugar beef	37	Metals nec
7	Plant- based fibres	38	Metal products
8	Crops nec	39	Motor vehicle and parts
9	Bovine cattle, sheep, goats, horses	40	Transport equipment nec
10	Animal products nec	41	Electronic equipment
11	Raw milk	42	Machinery and equipment nec
12	Wool, silk worm cocoons	43	Manufactures nec
13	Forestry	44	Electricity
14	Fishing	45	Gas manufacture, distribution
15	Coal	46	Water
16	Oil	47	Construction
17	Gas	48	Trade
18	Minerals nec	49	Road transport
19	Bovine meat products	50	Rail and pipeline transport
20	Meat products nec	51	Water transport
21	Vegetables oils and fats	52	Air transport
22	Dairy products	53	Transport nec
23	Processed rice	54	Communication
24	Sugar	55	Financial services nec
25	Food products nec	56	Insurance
26	Beverages and tobacco products	57	Business services nec
27	Textiles	58	Recreational and other services
28	Wearing apparel	59	Public Administration, Defence,
29	Leather products		Education, Health
30	Wood products	60	Dwellings
31	Paper products, publishing		

Note: nec = not elsewhere classified

The other key feature of the database is that the cost structure of each industry is also represented in detail. Each industry purchases intermediate inputs (from domestic and imported sources) primary factors (labour, capital, land and natural resources) as well as paying taxes or receiving subsidies.

Factors of production

Capital, land, labour and natural resources are the four primary factors of production. The capital stock in each region (country or group of countries) accumulates through investment (less depreciation) in each period. Land is used only in agriculture industries and is fixed in each region. *Tasman Global* explicitly models natural resource inputs as a sector specific factor of production in resource based sectors (coal mining, oil and gas extraction, other mining, forestry and fishing).

The labour market

By default, *Tasman Global* assumes that the economic changes do not raise unemployment above the so-called natural rate of unemployment in the long term. Any shifts in the demand for labour are assumed to be offset by changes in real wages sufficient to prevent the emergence of unemployment above the natural rate. This is the "full employment assumption". This assumption can be relaxed over the short to medium term.

Carbon emissions

The model also has a detailed greenhouse gas emissions accounting, trading and abatement framework that tracks the status of six anthropogenic greenhouse gases (namely, carbon dioxide, methane, nitrous oxide, HFCs, PFCs and SF_6). Almost all sources and sectors are represented; emissions from agricultural residues and land-use change and forestry activities are not explicitly modelled.

The greenhouse modeling framework to not only allows accounting of changes in greenhouse gas emissions, but also allows various policy responses such as carbon taxes or emissions trading to be employed and assessed within a consistent framework. For example, the model can be used to measure the economic and emission impacts of a fixed carbon tax in single or multiple regions whether trading is allowed or not. Or, it can used to model the required carbon tax needed to achieve a desired cut in emissions based on various trading and taxation criteria.

Highly detailed energy sector

Tasman Global contains a detailed representation of the energy sector, particularly in relation to the interstate (trade in electricity and gas) and international linkages across the regions represented. To allow for more detailed electricity sector analysis, and to aid in linkages to bottom-up models such as ACIL Tasman's *GasMark* and *PowerMar*k models electricity generation is separated from transmission and distribution in the model. In addition, the electricity sector in the model employs a 'technology bundle' approach that separately identifies different electricity generation technologies (brown coal, black coal, oil, gas, hydro, nuclear and other renewables).

Standard model results

Tasman Global solves equations covering industry sales and consumption, private consumption, government consumption, investment and trade. The model therefore produces detailed microeconomic results, such as:

- output by industry;
- employment by industry; and
- industry imports and exports.

Tasman Global also produces a full range of macroeconomic results, for each Australian state and the rest of the World including:

- total economic output;
- total employment;
- gross national product (GNP);
- gross domestic product (GDP);
- gross state product (GSP);
- private consumption;
- public consumption;
- investment;
- imports; and
- exports.

The model can also produce details of greenhouse gas emissions, measured in thousand tonnes of CO_2 equivalent per annum.

All of these results (and more) are produced on a year-by-year basis. Frequently a 20 year projection is produced; however, this can be altered to fit the needs of the particular economic impact assessment being undertaken.

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