OF CAPITAL IMPORTANCE: ASSESSING THE VALUE OF THE NEW ZEALAND GEODETIC SYSTEM

FINAL REPORT

Prepared for

LAND INFORMATION NEW ZEALAND

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THE TASK

This report is the response to a brief from Land Information New Zealand (LINZ) to establish the economic foundation for funding a modern geodetic system for New Zealand. The overall approach taken in this report is:

- To consider broadly what is involved in a geodetic system in terms of content, structure, accuracy and institutional arrangements;

- To identify the users and providers of such a system;

- To provide appropriate interpretation and clarification of relevant standards and compatibility issues; and,

- To evaluate the arguments and methodological approaches in economics that provide a robust case regarding investment in the New Zealand geodetic system particularly as to supply, demand, availability, maintenance and access questions.

Understandably, the geodetic system is embedded in technology, institutions and arrangements - old and new. Consequently, the review of its economic facets should include discussion of the processes, procedures and people employed in creating and using a geodetic system. Also, important structural elements, presently undergoing alteration, have the potential to impact any evaluation process significantly.

Valuing a geodetic system is not straightforward. If it were, much of the work involved in preparing this report would be superfluous. Therefore, a core purpose of this report is to provide an understanding of the complexity of assessing the worth of a modern geodetic system as well as outlining the major implications of that complexity. Methodologies for evaluation are also considered and recommendations made as to the most suitable.

Economic studies of geodetic (survey control) systems should be regarded as being in their embryonic stage, i.e., whilst they have advanced somewhat in recent years, procedures have not yet reached a stage where they can be applied routinely. As a complicating factor, the major technological discontinuity that has occurred through the development of Global Positioning System (GPS) measurement procedures has also altered many of the traditional costs and cost structures associated with geodetic systems. As a result, although this report is based on an interpretation of relevant literature, and on a consideration of illustrative examples, some of the commentary will have to be viewed as propositions and hypotheses for the future and in need of further research.

A number of key economic questions arise. These should be properly subjected to suitable empirical investigation in any future studies which might follow this report. Quite simply, the necessary empirical data with integrity is not just in short supply at present, it is virtually non-existent. Consequently, we believe that gathering such information should form a core element of an extended and more complete study.

EXECUTIVE SUMMARY

"If the (national geodetic and topographic) archive were not provided, many of those requiring…information would no doubt make alternative provision of a sort, but the nation would lose the benefits of continuity of national standards, and of a common referencing system, and the duplication of effort would lead to wasteful incompatibility."

Sir David Serpell Chairman of the Ordnance Survey Review Committee 1979

Like governments everywhere, the New Zealand central, regional and local governments rely on having the necessary geographical information to support a wide range of functions. In fact, some 80% to 90% of information required by government has to be tied to specific locations spatially (Tomlinson, 1993). In addition, many other organisations and agencies in both the public and private sectors have similar needs. The result has been a huge investment, over time, in various mapping and database creation projects primarily aimed at ensuring high quality decision-making.

The geographic information required for such decision-making includes that of the natural world (e.g., topography, water resources, soils, geology, vegetation, population and climate) as well as those physical features which humankind has added (transport systems, utilities and services, communication systems, structures, buildings etc). Then there are the administrative constructs which need to be recorded for key functions of managing a modern state, e.g. land ownership patterns, jurisdictional boundaries and tax collection.

More recently, the collection, handling and usage of geographically-related data has been revolutionised by technological advances such as Geographical Information Systems (GIS). In particular, the data-gathering component has been radically altered by the universal access to the Global Positioning System (GPS). Users are not charged for access to the GPS signals themselves and the equipment is becoming increasingly user-friendly. However, users do still incur costs and for some applications, in both the cadastral and engineering surveying fields, use of GPS is not currently warranted compared to conventional methods.

Building and maintaining the geodetic system infrastructure has been the responsibility of successive New Zealand governments who have invested in excess of $250 million during the 20th century alone in this spatial infrastructure. (Source: Annual Reports of the Department of Lands and Survey, the Department of Survey and Land Information and Land Information New Zealand. Expenditure has been inflation-adjusted to 1998 dollars.) The tangible result has been an extensive

network of physical monuments, plus measurements, which provide a three-dimensional mathematical framework so that information can be recorded accurately and consistently in space and across time. The extension, e.g. in areas of increased settlement and development, and maintenance of the system is both physical and mathematical. It presently requires an expenditure of some $3 million per annum on direct geodetic maintenance and administration.

The current New Zealand geodetic system draws on strong traditions. In the times of the British Empire, "trade followed the flag". Similarly, development in New Zealand has had reliable and timely surveying and mapping coverage as its essential forerunners. In turn, such surveying and mapping programmes have depended explicitly on the existence of an accurate, comprehensive and homogeneous geodetic system.

Geodetic systems have always been wedded to technology and technological change but also to patterns of land settlement and development. However, the advent of the Global Positioning System, now almost an everyday tool, means that some of the concepts and techniques which comprise the geodetic tradition have to be carefully revisited. Crucial technical and economic questions follow, not only about the type of geodetic system which is required for the challenges of the next decade and beyond, but also the best way to achieve this economically, efficiently and effectively. One particularly important consideration is whether the geodetic system needs to be independent of technology and, therefore, able to cope with various technologies and their various strengths and limitations. (This matter, which is essentially one of flexibility, is dealt with in the body of the report.)

Turning to value, the geodetic system has little intrinsic value in itself. Its value flows mainly from its contribution as a necessary, mostly essential, input to various positioning purposes, products and services. Certainly, it can and does provide value as a reliable *de facto* spatial standard if it possesses the key characteristics of integrity, spatial accuracy and reliability, receives proper maintenance, and allows availability and accessibility. The crucial feature of **spatial compatibility** flows from such characteristics and it is this property which has the potential for providing considerable benefits in the GIS arena.

The problems inherent in identifying and quantifying the benefits flowing from any geodetic system are considerable.

- It has significant public-good properties and these are considered at length in the Appendices to this report.

- The input from the geodetic system has become embedded in the various positioning and mapping products over time and extracting the contribution of the geodetic system itself is not simple.
- Whilst certain establishment and maintenance costs incurred by the state are available, the costs accrued by the private sector in using and contributing to the geodetic system are far less easy to unravel. This requires intensive further investigation.
- The actual usage of the geodetic system, especially by people other than professional surveyors, is not well-established. This user-group includes the important building and construction sectors, the utility sectors as well as the ever-increasing GIS industry.
- Many of the benefits (and beneficiaries) flow from indirect users of the geodetic system and may actually be one or even two steps removed. Yet, such flow-on benefits can be considerable.

The set of benefits identified as resulting from usage of the geodetic system mostly revolve around avoided costs and the quantum of avoided costs clearly alters with the particular task and level of usage.

The first approach taken here compares the New Zealand land-titling and survey situation with that pertaining in certain other jurisdictions where title insurance is the norm. Whilst a number of assumptions are required, and very conservative estimates are made, the total calculated annual benefit (costs avoided) from not requiring title insurance in New Zealand is assessed as exceeding $100 million per annum. This is clearly a joint-benefit spread between the Torrens titling system and the cadastral survey system which is itself underpinned by the geodetic system.

A second approach assesses usage of the geodetic system by service providers, especially professional surveyors. In the first service sector which was examined, namely cadastral surveying, the costs avoided by having cadastral surveys connected to the geodetic system are estimated to be worth at least $4.6 million per annum. Then, for the service- sectors of building and construction, the cost savings resulting from the availability of the geodetic system are estimated to lie between $3.8 million and $6.4 million. Whilst both of these calculations have had to use secondary and sometimes incomplete data, it must be stressed here that the assumptions and calculations made are also highly conservative. For example, the residential building component of the industry was factored out of the calculation whereas there will clearly be occasions when the geodetic system is utilised to good effect. In addition, the value to utilities and territorial local authorities has not been included, again because necessary data was not available.

The third approach taken in this report is to examine the geodetic system by using a variant of network economics. This takes the view that a significant benefit provided by the geodetic system lies with the capacity of the system to provide spatial compatibility between different datasets and especially in GIS applications. First, it is argued that when users know that the spatial information is based on the geodetic system, they should not have to incur transaction costs in searching for and verifying that the datasets are compatible. In turn, building in such compatibility also has the potential to reduce costs significantly by eliminating or reducing the costs of transforming the datasets. This is especially true when these sets have been collected at different times by different agencies for different purposes. Because of the paucity of data presently available to determine such potential cost-savings, this section of the report is mostly descriptive. However, in noting that thirty-one regional and local authority councils had installed GIS systems up to 1995, the number now holding licenses for the Digital Cadastral Data Base (DCDB) has increased significantly to sixty-one local and regional councils.

We also observe that the overseas experiences that do exist, mostly based on empirical studies, point consistently to significant and broad-ranging benefits from compatibility in data usage with benefit-cost ratios between 1.7:1 and 4.5:1. Such researchers were themselves very conservative in their approaches, and we would also suggest that potential cost-savings from compatibility are likely to have increased significantly as GIS users add ever more data layers to improve their spatial analysis.

In looking ahead, we note that a new-model geodetic system is being developed for New Zealand although there are still some necessary implementation questions to be resolved. We recommend that further research, especially empirical research, into the benefits and costs of the alternative approaches for the geodetic system is not just desirable, it is imperative.

Amongst the aspects which should be addressed are:

- An assessment of the gap between expectations and reality with respect to the capabilities of the new geodetic system. This gap affects the overall assessment of the likely use and underlying value of the system.

- There is a need to address the lack of detailed knowledge about the varied uses and users of the geodetic system, existing and potential. Inasmuch as the value of the system is dependent on its usage, the needs of these users should be thoroughly explored. Also, there is presently a problem in separating out multiple-use and multiple-user environments.

- A close examination of the time lags between use of the geodetic system and full manifestation of benefits is required. For example, we have assumed here that cadastral surveys only receive relatively small benefits on 1st generation surveys, e.g. from access to geodetic origins, and that more considerable benefits flow from 2nd generation and subsequent surveys.

- A parallel issue is to examine the differences in the needs of the users of the system compared to the needs as perceived by the developers of the system.

- The separation out of the self-interest versus the public interest in the use of the geodetic system especially given the wide variety of applications flowing from the geodetic system.

- We suggest that there are a number of methods available to approach such matters including both cross-sectional and longitudinal surveys as well as carefully selected case studies. In this regard, mention must be made of the particular need to ensure that a proper taxonomy of usage be developed.

- There also needs to be ongoing assessment of the different ways in which benefits arise from use of the geodetic system: direct and indirect; tangible and intangible; current and anticipated; and, short-term and long-term.

- Case studies of major projects and activities using and not using the geodetic system especially examples of “with and without” should also be undertaken.

1. THE GEODETIC SYSTEM: THE OLD AND THE NEW

1.1 A Background Description of the Geodetic System

Seen simply, the geodetic system is a framework of physical marks or monuments, firmly attached to the earth's surface, each with a unique position derived by accurate measurements and placed in such locations so as to support a wide range of community needs. Usually, horizontal positions are described either in terms of a curvilinear coordinate system (i.e., latitude and longitude), or in terms of a three-dimensional, rectangular coordinate system that has its origin at or near the centre of mass of the earth. Such rectangular systems, many of which now require international co-operation to define, may be transformed into localised plane coordinate systems (i.e., into X and Y or Northings and Eastings), by means of a mapping projection.

Traditionally, the third coordinate (i.e., the coordinate in the vertical direction) has been used to indicate the measured height above some selected datum (usually mean sea level) and treated separately. This separation has often been reflected both in the physical points and in the survey techniques used for their determination as well as in user needs.

Thus far, the tangible elements of a typical geodetic system (often called a survey control system) have consisted of the physical framework of permanent, regularly maintained reference points, together with their associated technical metadata, data and records. Properly **installed <u>and</u> maintained,** it has specific features which normally include:

- Comprehensive countrywide coverage of permanent coordinated control points, which provide;
- spatial relationships of known accuracy expressed in recognised and reputable formats, and which;
- facilitate coordinated capture and presentation of spatial information (directly or indirectly) especially topographic and cadastral information in digital and analogue form,
- in two, three or four (time) dimensions, and which;
- enable information to be recorded in space consistently across time and provides for proper integration of such information databases.

A nationwide survey control system provides compatibility and homogeneity of spatial data as well as specified accuracies for such data. Much of the modern economic value of such a control system is derived from these features. By contrast, a local control system, however precise, is specific as to locality and project and serves but a narrow and limited function. The control used for setting out works on a construction site, e.g., a dam site, is one example.

Some twenty years ago, Bomford (1980), an acknowledged doyen of the 20th century geodetic community, succinctly presented the objectives of a geodetic framework as:

"(a) To constitute the main framework on which less precise observations may be based, which in turn may form the basis for topographical and cadastral maps.

(b) In combination with observations of latitude, longitude and gravity to assist in determining the size and shape of the earth, and the form of its external equipotential surfaces.

(c) To detect and record movements of the earth's crust."

Bomford reflected the prevailing terminology in surveying /mapping which essentially broke down a **survey control system** into successive levels of **geodetic (first order) control** and then **second**, **third** and even **fourth order** control with accuracy decreasing, and density increasing, as the order number increased.

In more recent time, the term "geodetic system" has been used increasingly to refer to the entire survey control framework and not just the "top" order. In this report, the terms **survey control system** and **geodetic system** should be regarded as synonyms.

1.2 Geodetic Systems: The Old Basics

The traditional method of establishing a geodetic survey control system was relatively straightforward. It remained mostly unchanged (other than through small incremental improvements in instrumentation) from the late 1700s until the advent of electronic distance-measurement in the 1950s.

Having measured an accurate baseline, originally with rods, but later with invar tapes, the structural web of control points was then extended through observing angles in an ongoing series of well-conformed triangles. These stretched across the countryside closing eventually on to another baseline. The network of physical monuments, usually placed on elevated positions to assist observation, had to be occupied physically by skilled and specialised surveyors taking repetitive and exhaustive angle observations. The surveyors were usually, but not always, permanent employees of a centralised national surveying/mapping agency.

Procedures and accuracies were closely prescribed and closing errors, deriving mostly from small but accumulative observation errors, were adjusted through complex and painstaking mathematical calculation, again using specially trained personnel. As Close and Winterbottom (1924) described affairs some 75 years ago:

*"**Principal Triangulation** or **Geodetic Triangulation** is the main triangulation of a country carried out with every refinement of care. The sides vary in length from about 10 to 50 miles (although rays of well over 100 miles have been used). No precaution is neglected, and the computations are most exact and laborious… Principal triangulation is slow and expensive."*

Having established the initial geodetic (first order) networks or chains, similar procedures were then used to install ever more dense networks of survey control points at second order and third order levels. Triangulation was often supplemented by various levels of traversing with theodolite and tape to provide even denser horizontal survey control at fourth-order levels which became the framework on which cadastral surveys were often based.

In this model, vertical control was invariably separated from its horizontal sibling. The vertical networks, at their highest order, consisted of a series of interconnected benchmarks that tended to run from port to port (tide-gauge to tide-gauge) mostly following transportation routes. Some secondary networks simply radiated from an established "local datum" with cross-closures used to contain incremental errors and eliminate blunders. Tertiary vertical networks were often determined by vertical angle observations between the stations which formed the horizontal survey control network.

There was an inevitable decline in spatial accuracy as the nets extended, and the density of points increased, with further accumulation of observation errors. However, the adjustment-of-observations processes meant that relative positions of the points were usually of sufficient accuracy, and their absolute position on the earth's surface sufficiently well known, so as to facilitate the ensuing comprehensive topographic and cadastral surveying and mapping at various scales.

The geodetic system that evolved was characterised by:

- substantial set-up (fixed) costs that could only be sustained by large, government-funded producers, usually National Mapping Organisations (NMOs);
- learning effects that improved outputs gradually by lowering costs with increasing adoption;
- coordination effects which conferred advantages to those who cooperated in using the system (e.g., other public agencies);
- national effects whereby the costs and benefits were mostly accrued by individual states. Not only did technology prohibit the extension of these networks across oceanic areas but political boundaries also formed constraints upon network extent even within continents.

One significant outcome of the creation process was that large installation costs, and the need for highly specialised skills, effectively meant that the geodetic system took on the shape of a natural monopoly, almost by definition. In addition, because government itself required the system for a number of public-good functions (e.g., for national mapping, defence, and development needs), access and usage by others for a variety of purposes was seen as a normal, necessary, and relatively inexpensive consequence. Financial charges for access (almost invariably zero or near-zero) tended to reflect this fact, particularly where there was a regulatory requirement to connect surveys to the geodetic system.

However, it is essential to note that for many activities involving surveys and surveyors, connection to the geodetic system was neither necessary nor of any particular benefit to the direct consumer of the survey services. For example, a site survey for determining building site topography can function quite adequately on a “local” system that is site-specific.

From a structural point of view, building a traditional survey control framework can be likened to building a road network or a water supply system. All are essential components of the infrastructure needed for a modern society and all need to be maintained. This maintenance (renewal/rebuilding) of a geodetic system has taken two forms: physical maintenance and mathematical maintenance.

Physical maintenance, namely replacing destroyed reference marks and re-coordinating them, is a rather obvious necessity with inventories in a number of jurisdictions revealing an attrition rate on ground marks ranging from 1% to 3% per annum. However, physical maintenance must be accompanied by mathematical maintenance where the users are able to get up-to-date information on the coordinates, the reliability of these coordinates and any changes in their mathematical underpinning, e.g. changes in the datum. Both of these maintenance components are now being affected significantly by technological changes.

1.3 Geodetic Systems: The New Basics

The first of two significant technological advances, both of which have had substantial impact on surveying control establishment and enhancement, came with the introduction of Electronic Distance Measurement (EDM) in the 1950s. This equipment not only permitted the strengthening of the control systems themselves by direct measurement of long lines (rather than short baselines that had to form one side of a well-conditioned triangle) but also revolutionized actual survey techniques. Geodetic networks could be densified with much greater speed and accuracy.

The second, more dramatic, technological advance has been the advent of the Global Positioning System (GPS). Frankly, its overall impact on the surveying and mapping world has been without precedent. It allows the accurate measurement of three-dimensional coordinate differences between points separated by hundreds of kilometres in a matter of hours. Line-of-sight constraints, that lay at the heart of old methods of establishing geodetic networks, are no longer an issue. Costs of network establishment and maintenance have fallen dramatically.

While the impetus for developing the GPS came from the express desire of the United States military to have a positioning capability that is real-time, high-precision and global, it quickly attracted a wide range of users. These users include; survey practitioners, applied researchers, GIS data gatherers and civilian navigators. All have seen it as a valuable and cost-effective method for fixing position and gathering spatial information. Its cost-effectiveness is enhanced by the fact that there is no charge for access to the GPS signals. However, these cost-benefit advantages come with a lack of control over some GPS features. All users are reliant upon the accuracy and stability of the GPS satellite orbits with these being determined by external international agencies.

A global network of GPS tracking stations, each with known coordinates defined in terms of a three-dimensional centre of mass coordinate system, track the GPS satellites continuously. This enables their orbital positions at any instant to be defined with great accuracy.   By simultaneously measuring from two stations of unknown position to a common set of GPS satellites, it then becomes possible, with the appropriate software, to determine the vector differences between these two stations. These differences can be further processed to enable the determination of both the three- dimensional distance and

the azimuth between the two points. However, if one already knows the position of one of these points then, depending upon how far away the second point might be, it becomes possible to determine the position of the second point in real time.
Thus, it should be apparent that the primary factors that influenced the substantial cost of development of conventional geodetic networks (i.e., time-consuming, line of sight measurement techniques) are gone. Indeed, it is now possible to establish a network of continuously tracking GPS receivers, each at a point of known position, and to position other points with respect to this array rapidly and accurately. This process is well illustrated in Sweden where a network of 21 permanent reference stations operates at around 200 km intervals. As Ottoson and Jonsson (1998) report, these are to provide:

- Single and dual frequency data for relative GPS measurement
- Differential corrections for broadcasting to real-time users
- Act as high-precision control points
- Monitor integrity of the system, and
- Provide data for studies of crustal dynamics

Institutionally, it is also important to note that the United States has made a commitment to ongoing civilian access to the GPS system. Indeed, the uses of the system are now so widespread that denial of access would create major, worldwide civilian disruption.

There is little doubt that the physical structure of future geodetic systems will also be radically different to the traditional one. On density, Murer and Eggenberger (1998) show that in one Swiss example, 50 new GPS monumented stations have effectively ”replaced” 650 of the old-style triangulation points. Moreover, Augath and Jahn (1998) maintain that, because more than 50% of the total costs go into establishing control points and witness marks, it would be more economic to have a system which makes GPS data available continuously. In Canada, Hamilton and Doig (1993) have postulated that:

“It is highly probable that the larger survey firms will be operating at least one reference receiver, it may be as a service available…Whatever it is, it will be market driven. In smaller centres, surveyors may form a consortium that operates a GPS service for themselves – and possibly for others.”

To conclude this section, a number of caveats must be articulated.

First, GPS will not totally replace traditional methods, especially in urban canyons or in areas where there is substantial vegetative cover. Furthermore, the surveying community has made a substantial investment in total station technology. This investment will not be written off in either the short term or medium term. Consequently, the geodetic system of the future needs to be sufficiently robust and flexible to support a variety of measurement techniques, both the new and the traditional.
Secondly, control of the geodetic reference frame now rests with international science agencies. This is because they determine the highly accurate orbital positions of the GPS satellites that are needed by the largely civilian surveying community. Consequently, New Zealand is linked inextricably to, and dependent on, the global science community in a way that was never true in the past. This global interdependence, and the resulting global coordinate systems, also facilitate and support defence mapping agreements, international science initiatives (particularly with respect to tectonic plate motion and global sea level rise), national boundary delimitation, and international navigation arrangements (particularly air routes).

Thirdly, the need will remain for a physical framework of points that together will form the geodetic system. Such points will need to be permanent, secure and accessible. Moreover, although the number of physical geodetic marks may reduce, there will be a greater reliance on these marks with a greater vulnerability. Physical security will become much more important. Overall, there is little doubt that the physical structure of a national geodetic system of the year 2020, although still fundamentally an information system, will be radically different from that of 1990.

2. THE GEODETIC SYSTEM: USERS AND PROVIDERS

2.1 Introduction

Historically, it has been the surveying profession which has been most intimately acquainted with the survey control system, this by virtue of the complexity of creating such a system. Its creation has required complicated equipment and, for many, the process was seen almost as a "black art". For example, a theodolite would be brought out, set up and finely adjusted in mysterious but methodical fashion. Measurements would be taken to invisible objects on distant hills; maps and plans with curious symbolism were consulted; sets of figures written down followed by series after series of lip-pursing calculations with a "real" calculator. This was a task for a well-trained, methodical surveyor and few bystanders were unimpressed.

Typically, the major direct users of such a survey system have been central government (e.g. to support national topographic and hydrographic mapping as well as the building of a national cadastre), regional and local government (e.g. resource planning and infrastructure development) and private industry (e.g. land subdivision).

However, many other users of the geodetic system did so in a more indirect and rather removed way. That is, they often relied on general-purpose survey and mapping products, underpinned by the geodetic system, to which they added their own particular type of spatial information. The aviation and tourism industries are prime examples of such users. For these users, the geodetic system was a useful, low-cost method which not only guaranteed the overall integration of their data, but also guaranteed safety.

While some types of civil engineering construction have relied on the geodetic system (particularly those with a broad regional extent), local higher-accuracy, "stand-alone" systems were occasionally installed. Regional construction activities that have typically relied upon the geodetic system include schemes for water reticulation and disposal as well as irrigation and dam projects - the latter having particular economic impacts in terms of their inundation potential. Even where construction activities have had some spatial flexibility (e.g., in roading works), they have still had to fit within "envelopes" created by the land ownership pattern, a pattern that is itself underpinned by cadastral surveys that derive their position and homogeneity from the geodetic system.

It is instructive to contrast this scenario with that which has developed in the last decade. Whilst the technology is still impressive, any person with sufficient spare money can purchase a user-friendly, hand-held GPS receiver that will inform them, at least to navigational accuracy (+/- 100m), where they are anywhere on the earth's surface. While some people may become confused due to the essential differences between the three-dimensional GPS coordinate system and the two-dimensional coordinate system that underlies their reference map, it is only a matter of time before such confusion is removed by the introduction of new or upgraded geodetic systems and/or better transformation software.

In addition, as real-time, high accuracy, differential (RTK) positioning systems become increasingly user friendly, so GPS technology will move from the realm of being the tool of the professional surveyor to that of a tool used by the general public. In other words, and by implication, the geodetic system itself will be used increasingly by a public unfamiliar with some of its nuances, but still expectant as to its quality.

Part of the increasing use of GPS lies with the demands by both the public and private sectors for large quantities of spatial data, much of which derives its meaning and worth from the spatial attribute implicitly provided by the geodetic system. While the collection of such data has exploded in concert with a growth in the applications and use of Geographical Information Systems (GIS), its integration and usefulness is severely compromised, and may be impossible to achieve, without a consistent and unique underlying geodetic system. Indeed, it is no exaggeration to suggest that most, if not all, GIS systems in use in New Zealand today (some of which manage hundreds of millions of dollars worth of assets), would be severely compromised without a national geodetic system.

The end uses of such spatial databases are usually spatial analyses that depend on a number of separate layers or data-bases from different sources and times being "overlaid" in an effort to identify, measure and monitor various causes and effects. When spatial positions in one layer do not correspond sufficiently closely with similar point positions on every other layer, either the analysis cannot be completed or, more dangerously, spurious results can occur.

Looking ahead, Calvert *et al* (1997) also envisage a GIS future as one in which the required data will be accessed by end-users running a spectrum of GIS types ranging from simple to complex and who will only pay for the data as it is used. They also suggest that users will use intelligent systems to locate the appropriate data and will not need to store and have to manage the data themselves. Rather, they will seek to access and use the latest version as and when it becomes necessary. The implications for those who are custodians

and/or owners of the data are significant especially in terms of the liability for data quality and integrity.
The issue of data integration deserves further comment. It is the underlying geodetic reference system that enables this integration to occur, particularly when datasets are constructed by different organisations. Indeed, this is even more pronounced as data collection tools move from being locally based (e.g., GPS receivers, total stations) to satellite based (e.g., multispectral remote sensing, radar etc).

"Spatial integration of the data is based on consistent geometric referencing systems and on reasonable comparability in the resolution of the different datasets. This means that the same coordinate system must be used for the spatial referencing…" (Groot, 1997)

Looking internationally, the geodetic system has been considered as a key foundation which underpins the creation of Spatial Data Infrastructures (SDIs) each of which serves a particular area of application. In turn, when such SDIs are networked, or capable of being networked, the result then becomes a National Spatial Data Infrastructure (NSDI).

Such NSDIs are conceived to be an umbrella of policies, standards and procedures that will encourage data-sharing within and among organisations. The goals are to foster more efficient production, management and use of geospatial data while minimising investments which lead to unnecessary duplication of datasets. The successes or failures of these NSDIs are also seen as dependent on the degree of harmony and data connectivity which can be obtained and at what cost?

2.2 Responsibility for Providing the Geodetic System

Many governments have provided a geodetic system, not simply because of the economic public good arguments which can be brought to bear, but also because of their own needs and those of society for adequate surveying and mapping products. For example, the 1970s Director-General of Britain's Ordnance Survey argued strongly that topographic maps underpinned national security and property rights and that such information must be up-to-date, homogeneous and spatially continuous over the entire national territory. (Smith, 1979)

The criterion of homogeneity, in particular, requires that there be both a common reference system and common specifications which, in turn, demands a sound geodetic system. Smith (1979) also argued that, while the necessary surveys could be provided by the private sector, government input was still needed to ensure that adequate specifications were set and quality control was achieved. Consequently, governments do need to look ahead and engage themselves in the identification of needs and in setting strategies.

Nevertheless, since that time, there have been significant changes in the way in which the role, responsibilities and requirements of National Mapping Organisations have been perceived by governments worldwide as Table 1 shows.

Country	Freedom of information	Cost recovery and pricing	Copyright protection	Participation in value-added
United States	Yes	6% recovery; dissemination cost pricing	No	No
New Zealand	Yes	77% recovery helped by land transaction levy	Yes	Yes
Germany	No	Low cost recovery (10%) at Lander level	Yes	Yes
France	No	47% recovery: prices > than marginal cost	Yes	Yes
Australia	Yes	Average 25% recovery; prices > marginal cost	Yes	Yes
Great Britain	No	78% recovery; prices > marginal cost	Yes	Yes

Table 1: International comparisons of national mapping agencies (Derived from Coopers and Lybrand, 1996)

Note 1. By virtue of the restructuring of DoSLI, the cost-recovery level from levies on land transfers now approaches 100%.

Note 2. Since 1996, the New Zealand agency LINZ mandate means that it does not engage in value-adding activities.

In principle, significant change in economic ideology has driven much of the organisational and administrative changes and especially the policies on cost-recovery and pricing.

However, despite such reforms, virtually all external analysts and consultants have continued to see the geodetic system as being a public good and, moreover, fundamental to future national developments. For example, the 1996 review of the New South Wales Land Information Centre, while recommending some sweeping organisational changes, also noted that:

"ACIL considers that the LIC's core purpose is logically restricted to the fundamental layers of the land information system – the survey framework, the photographic databases, and the cadastral and topographic databases, with associated surface features. These primary spatial databases are crucial to the development of other integrated data layers, as well as being of direct interest to a wide range of government and non-government agencies. The primary spatial databases can be viewed as providing the syntax and elementary data dictionary for building a coherent land information system. As such they constitute a basic infrastructure investment which the government needs to have undertaken in a co-ordinated manner given its own objectives." (ACIL, 1996)

As another example, in Britain in 1995, the Ordnance Survey began a major project known as the National Interest in Mapping Service Agreement (NIMSA). An underlying principle was that some mapping-related activities are not only essential to the public interest but should remain stolidly non-commercial. Under NIMSA, the eighteen services which the Government will help fund include *"maintaining the horizontal and vertical control networks across the whole country."* (Surveying World, 1998)

The Ansell-Collins (1995) report into DoSLI followed a similar line in considering that a Department of State be maintained to hold responsibility for the core public good activities, including the spatial databases, and that any service or product supplied should be restricted to core public good information. They saw these databases as including: cadastral; survey plans and data; topographic database; geodetic and national levelling network; Crown land register; and EEZ database amongst others.

The recently retired Director of Ordnance Survey has also emphasised the national interest in mapping namely that;

"…the public interest arising from the mapping of areas which would not otherwise be mapped if the judgement was made solely in terms of revenue generated by sales of that mapping alone (and)… the inescapable requirement for the creation or maintenance of

the underpinning infrastructure of the mapping (notably the geodetic framework) which is widely used by other bodies and by the public and where charging for use is either inappropriate or impossible (such as for use of the National Grid).” (Rhind, 1997b)

Rhind (1997a), also made a further telling point regarding the modern survey/mapping framework that:

“Curiously, the advent of computerised tools makes the availability and nature of this framework even more important; computers are much less able than trained humans to cope with uncertainty, inconsistency, and missing information. To be effective, the framework must now be in a standardised, easily understood, frequently updated, and well-documented form. ***Everything must now be explicit****.”* (with Rhind’s emphasis)

The matter of who funds the new geodetic system has not been a matter of debate. The Swedish SWEPOS system, for example, was a government-funded initiative that relied, in part, upon arguments associated with shipping safety. The differential corrections are broadcast using an FM network operated by the same organisation which is responsible for Swedish public sector radio and television channels. (Ottoson and Jonsson, 1998). The geodetic benefits, in terms of providing a homogeneous and consistent spatial reference framework on a real-time basis, were included within this greater public good.

Looking internationally, the surveying community is a key contributor to many of the geodetic systems, especially those surveyors who perform cadastral surveys. Usually, they have to meet regulatory requirements that not only specify internal survey requirements and accuracies but also frequently require that all such surveys be connected to the geodetic system. In essence, each time surveyors attach work to the system, they are including more monumented and coordinated points thus improving the spatial coverage and density of the system.

It is relevant to observe that not all of these second-tier providers and users have been quick to adopt GPS and thus not all are able to derive the benefits inherent in systems such as SWEPOS. Brooke (1998) has suggested that the slower uptake is due to:

- Small firms being unable to afford the capital investment.
- Traditionalists waiting cautiously to see what actually happens.
- A perception that GPS actually takes longer.
- Traditional survey techniques are more efficient anyway, and

- Worries about the rapid technology redundancy.

It is also clear that while GPS will become a dominant technology, it will not be the panacea to all surveying problems. As noted earlier, sky visibility (or, more correctly, lack of sky visibility) will continue to limit some applications. This can be a particular problem in heavily built-up areas and where there is dense vegetation.

2.3 The issue of spatial accuracy

Like their international counterparts, surveyors in New Zealand make use of the control points and coordinates derived from the geodetic system in various surveying tasks: cadastral, engineering, construction, mapping, hydrographic surveying and so on. Mostly, high standards of accuracy and consistency are called for.

Surveyors properly distinguish between relative errors, i.e., the inaccuracies that may exist between two points, and absolute errors, which are considered to be the errors in the position of a point with respect to a defined global coordinate system. Because of the nature of survey errors, cadastral survey specifications in particular have normally included a distance-independent term plus a distance-dependent term. These are combined to determine the relative accuracy between two points. For example, the New Zealand Survey Regulations 1972, specified that lengths of lines on plans should not differ from true length by more than 0.01m plus 0.001 m for each 10 metres (Class A) and that traverses should not misclose by more than 1:5000 (Class A). The new surveying regulations effectively define absolute accuracy by specifying the relative accuracy between all boundary points and the local origin, e.g. as defined by the permanent reference marks.

In urban areas, the general intention has been to achieve sub-decimetre accuracy and the classic rule-of-thumb for many New Zealand cadastral surveyors has been to ensure that the positional accuracy is such that the “correct” position falls somewhere on top of the typical 35 cm^2 wooden cadastral peg.

As Table 2 below (overleaf) demonstrates, this approach fits quite well with the expectations of the New Zealand public regarding the accuracy of their property boundaries as revealed in a survey of the public perceptions on cadastral matters by Hoogsteden *et al* (1992). A considerable proportion of those surveyed (sample of 260 households) expect their boundaries to be exact: 55% of the urban residential sample, and 30% of the rural sample. In the urban residential context, very few (10%) of respondents expect a spatial accuracy worse than 150mm. Understandably, in the case of rural properties, expected accuracies are not as exacting.

The preparation of surveying products, such as topographic maps or hydrographic charts, also involves careful consideration of the necessary, and expected, relative and absolute accuracies. Apart from production specifications, one simple way of viewing positional accuracy is to set plottable accuracy against map-scale. For example, taking 0.5 mm as achievable plotting accuracy effectively implies an acceptable positional inaccuracy of 12.5m at a 1:25,000 map scale.

	Existing Proximity	**Preferred Proximity**	**Commercial Accuracy**	**Urban Accuracy**	**Rural Accuracy**
Exactly on boundary	31%	45%	57%	55%	30%
Within 25mm	9%	10%	14%	20%	5%
Within 150mm	22%	19%	11%	15%	21%
Within 300 mm	19%	12%	11%	7%	24%
Within 1 metre	17%	11%	4%	2%	18%
More than 1 metres	2%	2%	4%	0.6%	2%
Number of replies	242	249	28	175	87

Table 2: Boundary Proximity and Desired Accuracy (Source: Hoogsteden *et al*, 1992)

This approach can be carried over directly to the spatial accuracies required for GIS applications. While accepting that the positional accuracy of the data set is a critical parameter in determining its value as a contributory framework, most GIS applications are not prone to excessive accuracy requirements. As Tomlinson (1993) commented with regard to the spatial accuracy requirements of GIS in Victoria, Australia.

"…less than perfect graphical representation is acceptable provided that it is possible to access "legal" measurements whenever applicable. High precision would be extremely difficult and costly to achieve, involving input of cadastral boundary coordinates from survey measurements. It would not significantly add to the value of the information and would add few additional measurable benefits."

For most GIS applications, apart from local studies, the most common frame of reference is provided by one of a number of geodetic coordinate systems. It is essential for GIS and spatial analysis that all data are referenced to the same coordinate system. If this does not happen there can be no consistent statement of its spatial accuracy. Where data are used from a number of sources, and particularly where the area of study crosses boundaries, it is the underlying reference system that provides not only the mechanism for integration, but also the means of assessing its overall spatial accuracy.

Many GIS users appear more concerned with currency, completeness, consistency and correctness of the data they purchase and acquire rather than high levels of spatial accuracy as Table 3 below from Burrough and McDonnell (1998) shows. However, there are others for whom spatial accuracy is extremely important. Major utilities require urban mapping accuracies of better than 0.2 metre. Some have commissioned resurveys and the input of cadastral data to achieve base mapping of this order of accuracy.

1. Currency
    - Are data up to date?
    - Time series

2. Completeness
    - Areal coverage – Is it partial or complete?

3. Consistency
    - Map scale
    - Standard description?
    - Relevance

4. Accessibility
    - Format
    - Copyright
    - Cost

5. Accuracy and Precision
    - Density of observations
    - Positional accuracy
    - Attribute accuracy – qualitative and quantitative
    - Topological accuracy
    - Lineage – When collected, by whom, how?

6. Sources of error in data
    - Data entry or output faults
    - Choice of original data model
    - Natural variation and uncertainty in boundary location and topology
    - Observer bias
    - Processing
        - Numerical errors in the computer
        - Limitations of computer representations of numbers

7.	Sources of errors in derived data and in the results of modelling and analysis Problems associated with map overlay Classification and generalization problems Choice of analysis model Misuse of logic Error propagation Method used for interpretation

Table 3 : Factors affecting the quality of spatial data (From Burrough and McDonnell (1998))

3. PUBLIC PROVISION OF THE MODERN GEODETIC SYSTEM

The modern geodetic system is an information resource wrapped up in a set of technological processes. Mostly, it is used as a primary input in the production of a position-fixing service. The tangible output is usually expressed in some co-ordinate form. In turn, this position-fixing information is then incorporated into various spatial information products such as land titles, topographical and other maps, plans and data-bases.

Generally, there are certain core features of technological systems which determine their economic performance and value: (i) the nature of the knowledge; (ii) the size and shape of the spillover mechanisms whereby people other than the direct consumer obtain benefits (or incur costs); (iii) the receiver competence, that is, the absorptive capacity on the part of various actors and stakeholders; (iv) the connectivity between various parts of the system; and (v) the vigour of variety creation and selection mechanisms.

Few economic studies of the value of a geodetic system exist. Mostly, it has been implicitly assumed to be a public good although simply asserting that this is the case is no longer sufficient. Apart from public good issues (as detailed in Appendix II), determining what should be provided in terms of a modern geodetic system, and who should provide it, requires two steps.

The first step is deriving a conceptual economic model, the second is conducting an empirical investigation. For ease of presentation, the economic concepts, both theoretical and applied, are discussed in detail in Appendix I of this report. The unavailability of sufficient data limits the degree of empirical work which can be undertaken at present. (However, this should be a core component of any future research in this area.) Consequently, the assessment of the total value of the geodetic system at this stage can only be indicative.

3.1 The New Zealand Geodetic system: A brief history

The establishment and evolution of the New Zealand geodetic system has been well documented by Lee (1979) and more recently by Lee and Adam (1997). Perceptions of the current status and future options for the New Zealand Survey system are also covered by authors such as Grant and Blick (1998) and Blick and Rowe (1997) whilst this same topic formed the basis of a national seminar/workshop entitled Geodesy Beyond 2000. (LINZ, 1997).

It is inappropriate to repeat here the historical development of the New Zealand geodetic system chapter and verse. Rather, key “path dependency” events and processes are described which have led the geodetic system to its present structure.

- Major Palmer’s report in 1874 which recommended: major triangulation (principal coverage); secondary triangulation coverage where settlement was likely; and, tertiary provision where land was already sold but poorly surveyed. He also advocated a system of sound cadastral surveys and record maps.
- Turnbull-Thomson’s decision (post-1876) to extend the Otago meridional circuit approach nationally and not to pursue Palmer’s triangulation recommendation at that point. (In fairness, there were pressing and valid reasons for this decision at the time.)
- Ongoing competition for resources between the cadastral survey function and control surveys – the former mostly winning.
- Disruption and delay of geodetic-quality triangulation by World War One and necessary post-war economies.
- The proven usefulness of the control system for the topographic mapping programme which was required urgently with the outbreak of World War Two.
- The establishment of the “Geodetic Datum 1949” which really enabled the first national homogeneous control system.
- The ongoing earth deformation taking place within New Zealand throughout the creation of the geodetic system, which was unknown at the time (for good reason), but which would act as a significant distorting factor over time.
- The standardisation of surveys and procedures, especially cadastral surveys, and connection of cadastral surveys to the meridional system and, later, the geodetic system.
- The active pursuit by the Department of Lands and Survey, with government support, funding and commitment to complete the national topographical coverage at 1 inch to the mile, and the subsequent metric 1:50 000 series. This programme was heavily dependent on the geodetic system.
- The conversion through digitisation of cadastral record maps to create a Digital Cadastral Data Base (DCDB).
- Active adoption of new technology, such as EDM and GPS, for control surveys as it became available.

3.2 Changing a Reference Datum

It is not intended to deal with the technical intricacies of adopting new datums which many countries including New Zealand are currently considering. However, as noted earlier, there is a large group of indirect users of the geodetic system who have built and continue to build databases, e.g. for managing natural resources, for environmental purposes or for utility management. Those responsible for managing large geographic databases are often more concerned about a change in datum, and also changes to map projections, than survey precision. As Collier (1997) points out:

"…what is required is a careful re-thinking of the benefits of a new datum for the majority (rather than the specialist minority) and how those benefits can be passed on with minimum impact and expense and maximum benefit. The issue is not straightforward…"

Some of those who actually understand the technical implications of a new datum have already expressed concern about the cost of converting large databases to a new datum. It is quite likely that there are others who are unaware of the ramifications and, as Bevin (1998) has pointed out, a shift of five metres may actually be more dangerous than one of 200 metres. This is because the (lay)persons making use of the system are quite capable of spotting a significant shift but may miss one of a few metres.

Algebraic transformations to obtain consistency are an essential element in any new datum. In this regard it is worth noting that the Ordnance Survey (OS) has created two transformations for the conversion of OS National Grid coordinates to WGS84 ones. The 2-metre accuracy has been placed in the public domain; the 20cm accuracy one is embedded in a transformation service operated by OS itself. Commentary regarding the transformation issue has also been forthcoming from the GIS industry in New Zealand.

"…a process needs to be designed which will advise of changes to the reference frame, before the changes are presented to the GIS user community. This imposes either an obligation on LINZ; or a commercial opportunity for an organisation to add value to Datum 2000 by becoming a "Change Moderator" that protects the vast majority of GIS users from the constantly shifting sands of the geodetic framework." (Critchlow, 1997)

3.3 Statutory Responsibility for Geodetic System Provision in New Zealand

Presently, LINZ maintains the national survey control system as a horizontal and vertical reference system. However, there is a legislative and institutional history which deserves consideration. As background, it is also important to note the extent of wider reform which has taken place in New Zealand over the past fifteen years aimed at enhancing economic and technical efficiency. This has seen:

- Conglomerate ministries broken up into focused business units.
- Commercial activities privatised throughout the public sector.
- Contestability and competition in service delivery to the extent feasible in the remaining core public sector.
- Permanent secretaries of line agencies replaced by fixed-term chief executives.
- Their performance contracts as well as budgetary appropriations explicitly linked to outputs.
- Autonomy to allocate inputs and expenditures to achieve such outputs.
- Separation of policy, regulatory and operational functions.

Of the more recent legislation dealing with the geodetic system, the Survey Act 1986 clearly spelt out the objectives of the then surveying and mapping provider, namely the Department of Survey and Land Information (DoSLI).

"The purposes of this Act are:
(a) To provide for the efficient administration of the Department:
(b) To facilitate the issue of title to Crown land:
(c) To authorise, integrate, and extend the survey and mapping systems supporting secure tenure:
(d) To ensure the provisions of topographic, cadastral, and other land data bases to adequate standards for the efficient administration, enjoyment, and development of the resources of New Zealand…" (Survey Act 1986, Section 4)
(Ancillary Note: subsection (a) above was later repealed.)

In more detailed terms, the responsibility for the New Zealand geodetic system lay with the Surveyor-General where:

"The functions and duties of the Surveyor-General shall be-
(a) *To administer, coordinate, maintain, and extend geodetic control networks and traverses, precise levelling or other precision measurements forming the National*

> *Survey Control System, and to maintain the salient permanent reference marks governing or providing subsidiary controls for title surveys…."* (Survey Act 1986, Section 11)

It is relevant here that, of the nineteen functions and duties set out in this legislation, it is the geodetic system which receives first mention. More recent legislation in the form of the Survey Amendment Act 1996 essentially replicated the sentiment of its predecessor as to the geodetic system by again listing it first as the task of:
"To administer, coordinate, and ***arrange*** *for the maintenance and extension of geodetic control networks and traverses, precise levelling or other precision networks…"* (Survey Amendment Act 1996, Section 3) (Emphasis added)

The change to the wording was necessary to reflect the funder-provider split of DoSLI into Land Information New Zealand (LINZ) and TERRALINK and the term *"to arrange for"* is itself carefully described. Flowing from this Act, the Surveyor-General is allowed to delegate functions within the Department and to contract them out as appropriate.

3.4 Political Commentary

The attitude to, and understanding of, the overall surveying and mapping processes by New Zealand politicians are important factors in ongoing political and financial support of such functions. However, the wry observation of Bomford (1979) regarding national topographical mapping in Australia may sometimes apply, in New Zealand as elsewhere, in that:

"Alas, there are no votes in mapping"

Consequently, some of the more recent comments of New Zealand politicians concerning the survey system bear repeating here:

"Interests in the land underpin much of the activity that occurs in a modern market economy. For this country in particular, land has been a basic resource that has been developed over the years, and it has generated, either directly or indirectly, a significant part of our national income. It is therefore of vital concern to the whole community that the Government provides an appropriate infrastructure to support interests in the land.

This infrastructure must do four things: it must establish parameters for defining land property rights; it must provide for the recording of those rights; it must determine land information standards; and it must maintain core geographic information to which the public may have access." (Hon. Simon Upton (Acting Minister of Survey and Land Information) Hansard 8 May 1996 12447 Survey Amendment Bill Second Reading)

In the same debate, the Labour opposition also made an interesting comment in noting that:

"Land information is a public good as well as a private good." (Sutton, Hansard 8 May 1996 12449 Survey Amendment Bill Second Reading)

A little later in the same year, there were further observations in the House of Representatives that have a particular bearing on the contribution of the survey system as will be shown later:

"There is a particular issue about the linkages between databases. We are talking about databases held by survey, held by land titles and held by valuation – different land-related information about boundaries, about titles, and about valuations and also issues about Maori land ownership…Mr Gordon's submission was that the automation of these linkages between databases should be a core function, Cabinet, we understood, had decided that this was a non-core function. I do not believe that Cabinet necessarily made the correct decision…" (White, Labour) Hansard 13536 27th June 1996 Debate on the Survey Amendment Bill)

Such comments are particularly interesting when one considers the likely future for the Geographic Information industry in New Zealand. Many of the spatial databases inherent to this industry are heavily underpinned by the geodetic system. They are especially dependent on being able to integrate much of their newly-gathered information, often obtained by using GPS systems with output on WGS 84, with the older spatial information products based on the existing geodetic system.

Certain conclusions and recommendations of the Ansell-Collins (1995) study report on DoSLI were noted earlier in this report especially those regarding core databases. This report was actually followed by a Cabinet paper later in the same year. In that paper it was agreed *inter alia* that the Government's core outcomes and general requirements for land property rights and land information were to be adopted as shown in Table 4 overleaf. It is quite apparent that each of the core outcomes required by government and many of the general government requirements from LINZ are underpinned spatially (physically and mathematically) by the geodetic survey system.

Core Outcomes Required by Government	**General Government Requirements from the Department**
<u>Outcome One</u>: The on-going delivery of an efficient regulatory framework that establishes: (i) Parameters for definition and dealing in land property rights; and (ii) standards and specifications for provision of land data	• Framework for land property rights including provision of legislative (including regulation) and operational policy advice • Monitoring of regulatory compliance, efficiency and outcomes • Regulation of core spatial framework and standards
<u>Outcome Two</u>: The establishment of clearly defined, marketable and secure land property rights, and maintenance of the resulting records, to underpin economic activity in New Zealand	• Certainty of title, by registration and sound survey definition • Maintenance of and access to the Land Titles Register • Legal framework, including definitions of rights and provision of the State guarantee • Maintenance of survey system and cadastral records • Quality assurance processes • Alignment of land tenure systems
<u>Outcome Three</u>: The efficient management of Crown land related liabilities and responsibilities through either: (i) efficient management and disposal of surplus Crown land assets and land related liabilities; or (ii) efficient oversight and/or management of Crown land purchase and disposal regulatory instruments.	• Crown land register and documents • Public property management, disposal and acquisition services • Crown liability and contaminated sites management • Management of legal claims against the Crown • Statutory and regulatory land investigations
<u>Outcome Four</u>: The ongoing maintenance of publicly available core geographic information that supports the constitutional framework, national security and emergency service responses.	• Constitutional framework requirements • Electoral and administrative boundaries • Authoritative record of geographic placenames • Topographic mapping with: - national coverage and consistent standards - degree of quality and quantity defined by NZDF, Police, Fire Service, Ambulance, Search and Rescue, Agricultural, horticultural and forestry ministries (biological disasters) - provision of geographic placenames and electoral and administrative boundaries • Provide protocols for access to core information by other users

Table 4: Core Outcomes and General Requirements required by Government from LINZ

4. PLACING A VALUE ON THE GEODETIC SYSTEM

As an information resource, the geodetic system has complex economic characteristics. To date, a typical geodetic system has fulfilled the criteria to be a natural monopoly, two or more overlapping systems would be expensive, and potentially confusing duplicates. This would lead to conflicts and contradictions in land information and, quite likely, would impact adversely on property rights and interests sooner or later. Also, there are large development costs which have acted as an effective barrier to entry anyway. This is coupled with small marginal costs of reproduction and dissemination of geodetic information, e.g. control point coordinates.

A geodetic system also has important public good features. Exclusion from the system is possible but difficult (non-excludability) and there is a significant presence of non-rivalness (simultaneous and non-consumptive usage is possible). However, access and usage is appropriable. Those who benefit from the system are identifiable and some costs can be appropriated to them either directly or indirectly through charges, levies or taxes.

Through legislation and action, New Zealand governments have effectively dictated that geodetic control and information should be made available generally and that no social benefit accrues from restricting access to the geodetic system. The practical result of this policy has been the provision of essential geodetic information to professional surveyors and others at what is essentially zero cost.

4.1 Value as an Asset

During this century, over $250 million (inflation-adjusted to 1998 dollars) has been spent by successive New Zealand governments on creating, extending and maintaining the geodetic system as recorded in the relevant departmental reports over time. This system is now made up of more than 60,000 control points. (This figure for financial investment in the system is inherently conservative. For example, full cost accounting only came into use in the late 1980s.)

To this should be added a further contribution to the geodetic system, both physically and financially, by other government departments such as the former Forest Service and Ministry of Works. Whilst undertaken for different purposes, geodetic and survey control produced by these agencies was integrated into the central system. In addition, there has been a further large, but presently unquantified, expenditure. This contribution comes mostly from professional surveyors in their placing of permanent reference marks to comply with cadastral survey regulations. The main purpose for this is to aid future referencing of property and reinstatement of boundaries. The cost of such placement and survey has been borne by their clients usually at the time of subdivision and is to the benefit of these clients as well as future landowners.

However, despite the sizeable investment in the geodetic system, most economists would properly regard such expenditure as a sunk cost and that only future additional costs, i.e. physical and mathematical maintenance, should be tested against future benefits.

One broadbrush approach towards viewing the value of the geodetic system is to consider the contribution it makes to the New Zealand land titling and survey system given a present cost of the geodetic system ranging around $3 million per annum. A variation on Porter's (1985) value-chain approach is to be used here. (The value chain method traces how products gain value and incur costs as they pass through stages of a production process. Obtaining competitive advantage is the main purpose of such analyses.)

Consider the geodetic system as one contributory stage in obtaining security of tenure and, especially, in reducing costs when transacting real property. As example, consumers in some states in the United States rely heavily on title insurance. In fact, many lending institutions are not prepared to advance mortgages without such insurance. In practice, private insurance companies effectively operate alongside public land-recording systems making use of their own title-verification systems. They will only insure a title if their records, often supplemented with further research, indicate that the title is sound. Accurate field surveys, specially prepared, are also usually required to underpin this assessment of soundness of title. The total costs of insurance are passed on to consumers over and above any public records processing costs or professional legal fees.

As can be seen in Table 5 below, the value of residential, commercial/industrial and rural property in New Zealand can be considered conservatively to be of the order of $260,000 million. This is made up of a land value component of $105,373 million with value derived from improvements contributing a further $154,960 million.

GROSS VALUATIONS ($000s)				
No. of Valns	**Capital Value**		**Land Value**	
	Roll	**Equalised**	**Roll**	**Equalised**
1590032	360,789,391	260,337,832	160,102,598	105,372,535

Table 5: National Valuation Statistics as at 1st July 1998 (Source: Quotable Value)

It is also appropriate to comment here that some 1.6 million properties appear in the national valuation statistics. Yet, there are almost 3 million individual land parcels in New Zealand and the survey system is required to support all of these. With specific reference to domestic housing, which makes up a significant proportion of the total property value, New Zealand does have a high level of owner-occupied dwellings compared with many western nations. In fact, the 1996 Census revealed that of the 1.27 million occupied dwellings, 68% were privately owned. (New Zealand Official Yearbook, 1998)

The New Zealand land titling and survey system effectively underpins the national land and property portfolio which has been alienated from the Crown over the past 160 (almost) years. The system enables accurate and reliable transfers of property to take place speedily and efficiently. The size of the property market in New Zealand can be judged from the statistics for the 1997/98 year as shown in Table 6 below.

	Total (All Sales)	Total Price ($m)	Turnover (%)
Houses	84,236	12,008	9.1
Flats	21,985	2,752	10.1
Sections	14,748	662	27.5
Commercial	3,928	1034	7.4
Industrial	3,998	833	9.1
Rural	4,823	971	4.1
Lifestyle	9,463	1285	9.6
Other	2,328	344	2.7
Total	145,509	19,889	

Table 6: New Zealand Property Sales for year ended June 1998 (Quotable Value, 1998)

Note 1: The total sales number includes non-market sales

Note 2: Turnover rate is the number of sales compared to the number of gross assessments, that is, all properties on district valuation roles including non-rateable properties, expressed as a percentage. Average turnover time in years can be derived from the turnover rate.

Compared with a North American scenario such as that described above, it could be argued that the effective cost-savings per annum to New Zealand property owners on transfer in 1997/98, from **not** having to obtain title insurance, approximates to $118.3 million per annum. (This is based on the gross equalised value of $260,338 million, an 11-year period between sales and a 0.5% title insurance premium.). In a separate order-of-magnitude calculation, one could also take the total sales for the 1997/98 year of $19, 888 million from Table 4 and, by also applying the 0.5% premium, this would give a total cost saving of $99.4 million.

The title registration and underlying controlled survey system together provide the key **What-Where-Who** requirements needed for reliable and cost-effective property transactions. The title system provides the legal requirement and the survey system provides the crucial spatial information as to: Where does the property lie?; What is its size and shape?; What are the surrounding parcels?; and, What is the clear delimitation of its position and extent on the ground? While it is clear that the two systems complement each other, it is equally clear that the title system has little value if there is no spatial referencing component (i.e. definition as to location). By contrast, a survey system can operate and provide benefits without a title system.

If we are to assume for the moment that the survey system is, at minimum, an equal (50/50) partner in the cost-savings, then each component enables cost-savings approaching $50 million per annum to be enjoyed compared to some other jurisdictions.

4.2 Value as a service

In this parallel approach, value is seen as being derived from the geodetic system in terms of the benefits which the system contributes towards resolving particular and individual customer problems **as an intensive technological product/service**. In practice, persons with a skilled knowledge of the geodetic system assist clients who can be individuals, agencies, government departments or corporates.

The benefits for these clients flow from cost-savings in having survey control available. It can also result from the fact that previous survey work on the same site or nearby has been connected to the geodetic system. Some researchers have proposed that **benefits only occur when there is a second-generation survey** rather than at the first connection to the geodetic system (Angus-Leppan and Angus-Leppan, 1990). While this is a powerful argument, a case can be made that first generation surveys do extract some benefit from the geodetic system, e.g., orientation.

In adopting a conservative stance, the argument for only including the benefits of 2nd generation and subsequent cadastral surveys is adopted here. It is accepted for cadastral surveys but holds less sway for surveys in sectors such the construction industry, e.g. vertical heights for setting out utilities where connection to a survey control benchmark assists *ab initio*. At this point, we will separate out the value-as-a-service into cadastral surveying and engineering-type surveying, e.g. building and construction and concentrate on these. (We acknowledge, naturally, that there are many other important users including the scientific community.)

4.3 Cadastral value

Studies elsewhere in the world on the value contribution of a survey control system cite potential cost-savings in cadastral surveys ranging from 20% upwards. Some commentators, e.g. Angus-Leppan and Angus-Leppan (1990) have also followed the line taken above. That is, that the connection of 1st generation cadastral surveys to the geodetic system convey a small benefit to the first client whilst 2nd generation and subsequent surveys accrue up to 26% cost savings. With respect to 2nd generation surveys, it is important to note that there are a large number of surveys which are undertaken to redefine property boundaries for clients although no records of such are actually submitted to the authorities.

Because value-in-service benefits from the geodetic system have become built into the New Zealand cadastre, it is not possible to construct a before-and-after or a with-and-without situation easily. However, the recent work of Hamilton and Doig (1993) in the Canadian Maritime Provinces did enjoy that advantage. Not only had there been an expensive and extensive revamping of the survey control framework, 95% of cadastral surveys had been connected over a 25-year period. When questioned, experienced practitioners estimated that the cost of cadastral surveys would increase by between 20% and 60%, depending on site and locality, if the geodetic system fell into disrepair.

Similar comments were made in New South Wales in 1996 by senior professional surveyors who estimated cost-savings in cadastral surveys from an integrated survey system as ranging from 20% to 40%.

Recent statistics on the size of the cadastral surveying industry in New Zealand are not available although some relevant information was sourced from a 1993 survey of New Zealand Institute of Surveyors (NZIS) members. The results of the survey were based on a significant response from 363 practising members (62%) with an Annual Practising Certificate (APC). (Only surveyors with an APC, or people under their direct supervision, are permitted to undertake cadastral surveys.) By taking the average annual income of survey practitioners, applying an inflation index and adjusting by an appropriate multiplier for overheads etc, the 1998/99 surveying sector (as made up of 610 NZIS corporate members), is estimated to be not less than $100 million.

Clearly, professional surveying offices range from the sole practitioner to the multi-disciplinary, multi-office large practices and the cadastral surveying component also varies significantly. Experienced commentators have estimated that cadastral surveying activities in New Zealand range from between 25% to 40% of the total workload and a value of 30%, on average, will be adopted here. This suggests that there is a cadastral surveying sector of not less than $29 million per annum.

Taking a conservative approach, but still assuming that at least 80% of cadastral surveys are 2nd generation, and that a minimum of 20% cost savings flow from the existence of the geodetic system, this suggests a minimum annual benefit of $4.6 million per annum results from the cadastral surveying function alone. Significant additional benefits would also lie with users beyond the professional surveying community who make ongoing use of the cadastral information and records.

4.4 Building and construction value

The type of survey work covered by this category includes site surveys undertaken prior to and during construction, building layouts, topographic surveys, quantity determination for earthworks, mapping control and vertical and horizontal surveys. Unlike the cadastral function, the building and construction industry does derive benefits (mostly cost-savings) from 1st generation surveys as well as subsequent ones. The savings are based on activities such as:

- Geodetic control providing accurate elevation, an important requirement for much engineering survey work.
- Design plans can be accurately related to the ground situation through the geodetic system.
- With extensive projects, and particularly long route surveys, fieldwork can be reduced because of the surrounding survey control system and reducing propagation of errors as construction progresses.
- In situations where prolonged delays occur or where construction destroys on-site control, re-establishment can occur quickly and with certainty from geodetic control.

(It should be noted that cadastral surveys, such as boundary redefinitions, often accompany building and construction work. However, they are included in the cadastral component above and care is required so as not to double-count usage and benefits.)
On the size of cost-savings in building and construction from having a geodetic system, professional opinion ranges from 13% cost-savings in the engineering surveying component (Angus-Leppan and Angus-Leppan, 1990) to 10% on 1st generation and 30% on 2nd generation (Ross, 1977) and 20% to 25% overall (from Hamilton and Doig, 1993).

For the year ended 31 March 1997, there was $10 billion of gross fixed capital investment on building and construction in New Zealand (New Zealand Official Yearbook, 1998). This reflects a steady increase during the 1990s having reached $8.6 billion in 1995 and $9.3 billion in 1996. In terms of the surveying component, there seems to be reasonable agreement among those surveyors and engineers consulted that, on average, it makes up between 0.3% to 0.5% of total building and construction costs. However, in some complex engineering situations, the engineering survey figure has been known to reach 1% of costs.

That said, new residential dwellings and alterations made up $3.6 billion in 1997 and in New Zealand these buildings tend to be low rise and mostly do not require specialist engineering surveying. Consequently, this amount is factored out of calculations.

This would put the engineering surveying component in the year ended March 1997 at between $19 million (0.3%) and $32 million (0.5%). Using a cost-saving figure of 20% resulting from the availability of the geodetic system suggests that the benefits are at least $3.8 million and could easily reach $6.4 million or more.

4.5 Value as a network

In seeking to assess its value, the geodetic system can usefully be examined using the concepts of network economics and especially network externalities. Simply put, positive network externalities mean that the utility and value of one particular unit increases as more units are sold, e.g. fax machines. (We discuss in detail in the Appendices how the geodetic system could be viewed as a type of economic network.) Basically, this is because it can enable different datasets to be linked together because it provides compatibility. It is this potential for compatibility which offers significant benefits.

In many ways the geodetic system has already become a sensible standard for spatial data-gathering when the users are involved with more than localised private information. The compatibility provided by a geodetic system also acts to reduce transaction costs in terms of searching and verifying that the different datasets are actually compatible. It also reduces costs by eliminating or significantly reducing the costs of transforming the various datasets especially when these datasets are collected by different organisations at different times for different uses and users. A common reference system, and datum, is necessary in order to align or "fuse" these datasets. Failing this, the result is datasets which are heterogeneous and incompatible rather than homogeneous and compatible.

In looking for where the benefits (positive externalities) from geodetic system compatibility actually lie, it appears that much of it will be with GIS-users who need to merge different datasets. Observation suggests that these users are more likely to be those authorities and agencies involved with managing major planning, development and construction activities, e.g. central, regional and local authorities. For these and others, wider environmental decision-making is a particularly important function requiring compatibility between different themes or layers of spatial information. To these groups should be added the sizeable GIS capacity being created by utility managers. In this context, it is worth noting that in 1995, thirty-one city councils and regional councils had installed GIS systems (Azimuth, 1995) and we would assume that the number has increased significantly since then.

Again, at this stage of investigation, we have had to look elsewhere for some indication of the size of the avoided costs which flow from the compatibility potential which the geodetic system provides. One North American study some fifteen years ago (Epstein and Duchesneau, 1984) presented benefits-cost ratios **flowing from compatibility alone** as lying between 1.7:1 and 4.5:1.

We would argue strongly that, with the passage of time, such benefit-cost ratios are low. One reason is that GIS usage has proliferated. So has the rate of individual data-gathering. Second, many GIS users now wish to add many more data-layers to improve their spatial analyses. The potential reduction in costs for aggregating datasets if they are compatible, i.e. based on the geodetic system, is significant and could be exponential. We recommend that this important aspect of value should be closely investigated in any future research.

VALUE CATEGORY	ESTIMATED VALUE (Per annum)
Value from title/survey savings	**$99.4 million to $118.3 million**
Cadastral value	**> $4.6 million**
Building/Construction value	**$3.8 million to $6.4 million**
GIS value	**Benefit/cost ratio > 2.0**

Table 7 : Summary of estimated value contributions from geodetic system

4.6 Other Value Issues

The geodetic system also provides a valuable framework in supporting many other activities, for example, where a mapping infrastructure allows economic analysis of the inundation of major dam projects. Another example is where value is derived through having access to historical data from which the probability of a natural event, e.g. an earth quake, can be assessed. Once again these benefits are acknowledged although the actual economic contribution made is clearly difficult to quantify.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Seen overall, this report is primarily a descriptive analysis concerning a complex meeting-place – where a technology-based spatial positioning infrastructure and economic analysis come together.

To date, the geodetic system has been perceived as a central part of the national spatial information infrastructure and has been treated as a necessary societal investment. For its own interests alone, government will need to ensure that an effective geodetic system is maintained.

The geodetic system is spread widely and is used extensively for a wide variety of uses. There is direct usage by LINZ together with direct and indirect usage by: other government agencies; various administrative bodies, e.g. local and regional authorities; those managing utilities; and also by the private sector especially in data-gathering and position-fixing for the land and property development sectors.

The geodetic system, and its usage population, is in a stage of technological transition with the advent of the Global Positioning System, especially from the viewpoint of maintaining and using the geodetic system. In effect, whilst parts of the present physical and mathematical system have been made obsolescent by GPS already, it (GPS) is unlikely to totally replace the present system anyway. Furthermore, the geodetic system has to support a range of technologies as employed by different sets of users.

Access to GPS in the medium term is likely to continue and to be without any charges. Whilst this can be treated as a free good, there is likely to be increasing private sector value-added activity in providing GPS services for differential-type services in a marketplace situation. In part, these could act to displace certain parts of the present geodetic system. However, if displacement does occur, the results still need to be consistent with the rest of the geodetic system otherwise there will be inconsistency and incompatibility.

Although the geodetic system has displayed some reasonably strong public-good characteristics in the past, mainly because of natural monopoly, non-rivalness, non-excludability and no-extra-cost features, this situation has begun to change substantially. First, the natural monopoly position of the geodetic system itself is being usurped by the

Global Positioning System. Secondly, and flowing from GPS, there is a strong likelihood that there could be private sector provision of continuously-available reference receivers especially in the larger urban areas. Here again, this could possibly lead to uncoordinated systems. Consequently, all of these do need to work to a common referencing system if unnecessary duplication and risk of inconsistent or erroneous results are to be avoided.

There is increasing usage of GPS for direct data-gathering by a multiplicity of users who would formerly have been reliant on other spatial information services and products based directly or indirectly on the geodetic system.

The GIS industry is expanding significantly, if not exponentially. Significant users include local and regional government whose activities are closely involved with resource management, planning and development activities. The capacity to knit different databases together (compatibility), whilst maintaining spatial accuracy and integrity in a cost-effective manner, is becoming a crucial consideration for risk management.

The fact that the geodetic system has become embedded in many different products and services is a critical element in assessing its value. This means that not only is it difficult to extract the value of the system as a separate entity but that many users have, quite literally, come to take it for granted. In addition, there is a lack of detailed information on the actual usage of the geodetic system and, with this, the actual value which users derive from it either directly or indirectly.

Whilst mostly using surrogates in this study, and being seriously limited as to data, the actual benefits of the geodetic system are considered to be significant especially in the ongoing stream of benefits which flow from its underpinning of the land titling system. The contribution to the security of tenure, especially on transfer, is conservatively estimated to be worth tens of millions of dollars.

In the cadastral surveying sector, having earlier surveys connected to the geodetic system enables subsequent surveys to be performed more economically and a measurable economic benefit results from these cost savings. Such savings of 20% and more are passed on to clients directly because of the competitive nature of the marketplace. In this preliminary assessment, we have calculated the benefit flow to be at least $4.6 million but we must stress that this is highly conservative and the value will almost certainly rise as more and better empirical data becomes available.

The costs which are avoided in the building and construction sectors, arising from the availability of the geodetic system, are also substantial. Whilst survey costs are only a small fraction of this sector, the actual size of the sector means that cost savings in excess of $4 million are easily proven. Once again, these calculations are most conservative. However, it has become quite apparent that substantial and increasing benefits flowing from the geodetic system lie with the potential economic benefits which the geodetic system can provide to the GIS user-community in terms of compatibility when melding different spatial datasets together. Given that overseas studies place the benefit cost ratios close to 2:1 (at minimum), and with the burgeoning size of the GIS industry, we suggest that very large benefits can be obtained. However, such benefits do depend on users being informed and understanding how, when and where these benefits can be enjoyed.

5.2 Looking Ahead

There is a clear need for a wider-ranging and forward-looking study which assesses properly and fully the value of investing in each of the various components of a modern geodetic system. Such a study would also reveal more fully the actual and likely use of the geodetic system in the future.

There is also a need for far more detailed information on the determinants of both demand (e.g. willingness to pay, price-elasticity of demand, externalities) and supply (relative and absolute size of sectors, performance and substitutability between public and private sectors). This information is not readily available at present.

On the cost side, there should be a detailed determination, though international comparisons of expenditure ratios and outcomes, to provide appropriate benchmarking.

Operational effectiveness in the provision of the geodetic system needs to be accompanied by convenient access to the system by present and potential users. Given the concern which is being expressed by some sectors of the GIS industry regarding datum changes, it is imperative to provide adequate information to agencies, organisations and firms alike. This should include information regarding not only the benefits to be obtained from using the geodetic system properly but also the possible dangers and pitfalls as the shape and structure of the system itself changes. In effect, this also means early warnings and discussions regarding likely significant changes.

As occurs at present, there is an ongoing need to ensure that survey control of adequate quality, as undertaken for other purposes, is integrated into the wider geodetic system but without compromising its integrity.

There is a genuine need for more knowledge and information about the actual usage of the geodetic system together with more definitive data regarding current and ultimate consumer satisfaction with the system. Here we recommend that emphasis should be placed on in-depth consumer probes probably based on surveys and carefully selected case-studies. This should be accompanied by carefully designed cross-sectional and longitudinal studies across the various sectors using the geodetic system.

One particular area of future interest (and likely benefits) lies with the potential flowing from an automated survey system especially with enhanced access to the geodetic database. In extending the geodetic framework to the cadastral parcel level, this will effectively provide a continuous and consistent geodetic system flowing down from a few permanent tracking stations to a network of reference points and on to individual boundary markers. Whilst presently difficult to measure, an attempt should be made to quantify such benefits resulting from automation beginning with monitoring of usage levels.

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Appendix I

THE GEODETIC SYSTEM AS A PUBLIC GOOD

Testable Hypotheses

Certain technical economic requirements underlie the ongoing provision and production of the geodetic system where the choice is (i) should the production of geodetic information be undertaken by the public sector; (ii) contracted out to the private sector; or (iii) simply be left to the private sector.

First, on public sector production, does the good – geodetic information – fulfil the conditions for being a public good? A second requirement for public sector production is that the least-cost means of production is a single provider. Essentially, this would also mean exploring the conditions for a natural monopoly. It would also be necessary to examine the extent to which alternative institutional settings alter the nature of the geodetic system.

Following the approach used by the USGS in valuing geological mapping, the following hypotheses could usefully be tested empirically to suggest answers to the public good economic questions raised above. (However, this study is confined to a conceptual approach.)

Hypothesis 1: (Non-rival in consumption) The marginal cost of an additional user of the geodetic system is zero.

Hypothesis 2: (Jointness in supply) There is effectively no *a priori* private provision of core geodetic information.

Hypothesis 3: (Free Rider) Ex post, if goods/services arising from the geodetic system are being provided, then exclusion is problematic.

In addition, there are several additional hypotheses which flow from consideration of the geodetic system as a natural monopoly.

Hypothesis 4: The average per-unit costs of creating and maintaining the actual geodetic system are inversely related to the level of output.
Hypothesis 5: The cost function for the production of geodetic information is sub-additive.

Sub-additivity may arise from several sources. For example, there may be cost advantages, e.g. accumulation of human capital, in having a centralised group of experts producing national geodetic information. There may also be economies of scope where there are common cost components, e.g. high accuracy survey information obtained for one purpose is used in the production of other products/services.

Hypothesis 6: The demands for geodetic system outputs are independent and not substitutes.

Hypothesis 7: Private sector production of geodetic information will focus on small areas of geodetic system production and will be less accessible.

Hypothesis 8: Where there is only private production of geodetic information, there will be less information, it will be more specific and more costly.

Much of the information required to test such hypotheses simply does not exist and time constraints have not permitted the gathering of empirical data at this stage. Indeed, as will be shown below, actually gathering such information poses very complex questions on aspects such as product/service definition, demand, costing, pricing, willingness-to-pay and, especially, value. Consequently, the hypotheses are discussed rather than tested empirically at this time but should form a significant component of future research.

The value of information

As an entity, information often sits placed outside the tidy universe of economists. It is a multi-faceted commodity with a chameleon-like propensity to take on different economic-good characteristics depending on the circumstances. As an information resource, the geodetic system carries many of the complex economic characteristics which all information goods and services possess. These are considerable: non-depletion in use; unpredictable demand patterns; limited *a priori* knowledge of value; being both an investment and a consumption good; ownership and liability problems; and so on.

It is also important to distinguish between (i) the value of the information content and (ii) the value of the associated information resources, (i.e. the services, technologies and systems that store, process, analyze, package and deliver.) In addition;

- The product *information* cannot be defined easily and there is no easy measurement unit of value.
- Usually, the information is not consumed in use or destroyed. It is non-depletable in use and mainly non-rival in consumption.
- It may be used and invested simultaneously thereby complicating any price-equals-value assumptions.
- The *a priori* knowledge of the value of information to the potential user is incomplete.
- The integrative relationship between existing knowledge and the new information is complex and highly dependent on context. That is, determining the value to *that* user at *that* time for *that* purpose is no trivial matter.
- In turn, information may be useless unless or until it is combined with other items of information.
- Information can display characteristics of both private and public goods, depending on circumstances, and has the potential for both positive and negative externalities.

In particular, proper assessment of the utility and the value of information goods/services depends upon and changes with: the individual user; the situational problem; the external environment; existing knowledge; the time-frame; behaviour patterns, e.g. ability and skills; data and information quality; cause and effect linkages; and, aggregation across individuals and time. These are not minor economic and evaluation issues and the modern geodetic system needs to be examined carefully in terms of economic good criteria. Equally, because GPS is going to be such a dominant technology for extending, maintaining and using the geodetic system, it too needs to be tested as an economic good.

Market failure

Governments often intervene when significant market failures are observed, or assumed. Such failures mostly involve natural monopolies, public goods, uncertainty and risk, and externalities.

The political economist Adam Smith advocated specific but limited roles for the state to intervene in providing goods namely; defence, safety, justice and the public works which it would not pay private individuals to produce. Others have added to this intervention list since – upholding internal law and order, enforcing contracts, promoting competition, controlling the money supply and **guaranteeing certain essential services are provided**.

In this instance, it is worth noting immediately that some of the essential services which rely heavily on products and services built on the geodetic system do include defence and emergency services.

Then there is the necessary distinction between private and public goods. Pure private goods are efficiently distributed by markets. Pure public goods are markedly different when they exhibit the two key properties described in Samuelson's (1954) seminal public goods tract: *non-rivalness in consumption* and *non-excludability*. Although relatively rare anyway, pure public goods generally become a public *responsibility*, e.g. for financing, but this does not sanction public *production*.

Impure public goods and services occur when excludability (non-excludability) and rivalry (non-rivalry) are not present in a pure form. Club goods are impure goods which have excludable benefits which are partly non-rival (Cornes and Sandler 1986) Many goods once seen as pure public goods are now considered impure, e.g. national parks. Also a single production process may produce multiple outputs – pure-public, pure-private and impure - all of which then need separate attention on economic matters such as access, pricing and value.

Non-Rivalness

Briefly, non-rivalness means that one person's use does not reduce the amount available for others – it is indivisible with simultaneous and equal enjoyment possible.

In the geodetic system we have an economic good which is substantially non-rival – use of the system does not reduce the amount available for others nor does it depreciate the source or value of the information. Whilst physical access to geodetic monuments is technically rival, in reality this almost never occurs and surveyors competing to occupy a trigonometric station is a rather far-fetched scenario.

In a traditional geodetic system, access to the spatial relationships, i.e. the datum, the projection, the data, the records and the coordinates, is also essentially non-rival. Once the information has been acquired, it can be reused by the purchaser at no additional cost. It can also be passed on to someone else and simultaneous access and usage can occur.

In addition, New Zealand cadastral surveyors are required to submit full details of:

- the main-frame survey control they have utilised;
- the survey control and marks adopted from earlier surveys (e.g. on a meridional circuit);
- the survey control that they install themselves.

Such information is then available to subsequent surveyors and there has not been any great tradition of "private" survey control systems.

Turning to GPS, for many users the GPS signals are currently non-rival especially those making use of high-accuracy differential GPS and relative positioning using the carrier phase observable. The GPS information stream is indivisible-in-production; the effort required to produce and transmit a set of basic information for position-fixing is the same regardless of the number of GPS receivers "consuming" it. To a degree, GPS information is also indivisible-in-use; continuous streams of information are necessary and breaks in acquisition can require remedial action.

When it comes to the broadcasting of correction signals, as with real-time kinematic GPS work, the non-rivalness aspect has another facet In essence, it is rather like a lighthouse used in the navigational sense. Use by one ship does not consume the light nor reduce use by others. This does assume that users enjoy sufficient access to suitable parts of the electro-magnetic spectrum to enable the broadcast of the necessary corrections for real-time differential GPS.

Non-appropriability and excludability

Non-appropriability occurs when market failure makes it difficult for firms or individuals to use standard markets and pricing to appropriate the full social benefits or charge the full social costs arising from the production. Sometimes even identifying the users can be difficult. Excludability means just that - being able to exclude certain people from access. This is usually on the basis that they are unable or unwilling to pay for such access.

In fact, excludability and appropriability are more difficult to untangle here mainly because the geodetic system is partially passive. That is, control points can be observed from a distance and preventing physical access to such control is clearly extremely difficult. Equally, its nature as an information system makes it difficult to identify all users, especially repeat users, who have access to core coordinates. In terms of payment, the value placed upon it is especially difficult to assess quite apart from the difficult task of attempting to extract payment. However, the advent of a dynamic datum with changing coordinates and relationships might yet alter this feature.

Excludability and appropriability are rather more interesting and relevant concepts when it comes to the case of GPS. First, the range of users is large and dispersed. In practice, the GPS signals are currently non-excludable and non-appropriable again especially when using high-accuracy differential GPS and relative positioning. Of course, at the extreme, excludability would occur if the signals could be turned off. Limiting access to certain selected information is also possible through the application of AS (encryption) and SA (erroneous clock and orbit data).

In summary, geodetic information and geodetic information resources, separately and together, can readily display many of the economic characteristics of heterogeneity, non-rivalness, non-appropriability, indivisibility in production and non-divisibility in use.

Natural Monopoly

Natural monopolies are almost invariably characterised by fixed development costs which are inflexible, frequently irretrievable, technologically uncertain and, above all, very large.

It is a striking feature of geodetic systems that they have been constantly dominated by a single very large provider which is almost invariably the national or state surveying and mapping government agency. Similarly GPS has been dominated by the U.S. military although GLONASS has the potential to be as a genuine competitor especially since it does not have Selective Availability (SA) and Anti Spoofing (AS) features which cause some difficulty to some users/uses of GPS.

As elsewhere, there has been evident lumpiness in the investment necessary to create a geodetic system in New Zealand. Geodetic systems have not been cheap to build and maintain and they also require specialised skills bases. Such a large investment effectively acts as a barrier to entry were anyone willing to build another system and many of the features of natural monopoly apply.

Increasing returns to scale (economies of scale) exist when the marginal cost is less than the average cost and unit costs decrease as output increases. In such cases, economic efficiency requires that there should be a limited number of producers. However, the underlying assumptions for scale-economies are substantial and the attributed benefits may actually lie with changes in technology, inputs, product mixes, equipment and skills specialisation. Such reservations notwithstanding, some industries have such significant returns to scale that only one firm (organisation) should operate as a natural monopoly.

Economies-of-scope occur when it is cheaper to combine production of two or more products in a single firm than produce them separately. Typical sources of such economies include inputs displaying almost public-good features, which are then used repeatedly at little or no cost in different production areas and the acquisition of flexibility in production processes. In terms of a geodetic system, the actual physical output of the system, in the form of spatial-positioning coordinates, can be copied and disseminated at minimal cost.

“Free-rider” and “no-extra-cost”

Two other aspects of public goods provision also arise: the *“free rider” problem* and the *no-extra-cost* issue. When goods/services cannot be sold in a normal market, other strategies are needed on charging. If users reveal their true preferences, a solution lies with providing the goods publicly and then taxing (pricing) according to the expressed preferences. But when asked, users tend to conserve their own scarce resources by indicated zero or minimal preference and becoming “free riders”.

Prospects of exclusion from, or charges for, pure-public and even near pure-public or impure goods do raise the additional issue of *no-extra-cost* (allocative efficiency). The classic textbook case is the lighthouse which is basically non-rival in use and exclusion from its navigational assistance is obviously difficult although charging for lighthouse use has occurred (Coase 1974). A user discouraged by charges then represents a social economic loss even if the price charged to all were just sufficient to meet long-run expenses. If the marginal cost of provision is zero, welfare economists would argue that the price should also be zero to maximise total utility. Unfortunately, zero price means no revenue and long-run provision then requires payment from the public purse or by a philanthropist.

Where exclusion is possible, a counter argument exists where:

"No cogent general case can be made for the free distribution of a good or service – even though marginal cost is zero – if total costs are positive and have to be covered somehow. Where it is possible to exclude non-paying users, charging the beneficiaries need not be any less economical or less equitable than charging the general tax-payers, many of who may neither directly nor indirectly benefit from the service."

Externalities

Externalities occur when production or consumption by someone imposes costs on, or provides benefits to, others. Usually, benefits are regarded as positive externalities and costs as negative externalities. In this sense, a pure public good is a particular form of externality since provision for a group of consumers confers benefits on others mainly because of non-excludability.

Some important positive externalities associated with the geodetic system include (i) ensuring consistency in the collection of data (producer externality), (ii) providing users with access to the same data (network externality), and providing efficiency of decision-making (consumer externality). (Following Coopers and Lybrand, 1996)

Appendix II

THE VALUE OF THE GEODETIC SYSTEM

Relevant value concepts

Questions such as *How much is this coordinate worth to you?* or *What value would you place on a trigonometric station?* could easily lead into a minefield of semantic implications. The term *value* is multi-faceted although *exchange value* and *use value* are the principal qualifiers which continue to apply in economic circles.

Exchange value involves a formal amount of money being exchanged for a particular entity. That is, as a result of the exchange, the entity receives a monetary value because that is what someone is willing to pay for it and price remains a powerful marketplace meeting point between potential suppliers and buyers. Exchange value itself needs to be qualified because we must include not only a formal dollar price which potential users are willing to exchange but also the time and effort which they may be willing to invest in order to receive benefits from, say, a geodetic information process or service.

Value-in-use is basic to exchange value because use value establishes the conditions for the exchange of one thing for something else. It is particularly helpful in explaining the demand side of market theory (as per utility) and assists in underpinning the development of a value-added approach to evaluating information services. It is also important to note yet another important related value concept here, namely *opportunity cost* or the best alternative forgone. For the users of the geodetic system, this would revolve around what alternative course of action a potential user might employ if the system were not there.

An asset?

Economic arguments in support of public investment in the geodetic system essentially centre on a proposition that such expenditure will yield society greater benefits than costs.

On the cost side, one starting point is to treat any earlier expenditure on the geodetic system simply as a sunk cost. That is, the expenditure is history. The direct costs of provision which then need to be considered are mainly those of refining and upgrading the geodetic system into whatever form is deemed appropriate.

A philosophical alternative would be to regard the geodetic system as a spatial information infrastructure asset – an asset which will deteriorate and depreciate unless it is maintained appropriately. This approach would reflect the American Financial Accounting Standards Board (1986) definition that:

"Assets are probable future economic benefits obtained or controlled by a particular entity as a result of past transactions or events…it embodies a probable future benefit that involves a capacity, singly or in combination with other assets to contribute directly or indirectly to future net cash inflows." (FASB, 1986)

However, some commentators, e.g. Mautz (1981), have attacked this type of cash flow assumption because benefits from government facilities are likely to be in the form of social services rather than cash flows. In fact, Mautz has presented a case that facilities such as city parks should be viewed as liabilities rather than assets.

Another relevant point is that, while businesses can convert assets into cash to meet debts, many public sector assets are less easy to sell in the marketplace. Selling the old geodetic system, i.e. coordinates and monuments, could be problematical because of the rivalness, excludability and appropriability arguments outlined earlier. However, the points made by Smith and Murray (1998) about private providers moving into broadcasting corrected GPS signals for general positioning use is apposite here.

Finally, regarding the geodetic system as an asset to be maintained is also complicated by the fact that the increasing use of GPS arguably changes the utility of some of the physical components of the geodetic system. The issue then becomes one of deciding which parts or components of the geodetic system need to be enhanced, and in what order, particularly from the point of view of delivering the appropriate support infrastructure.

The geodetic system as a value chain

Porter's value chain framework (1985) provides one possible analytical approach to assessing the value of the geodetic system. Widely used for representing and analyzing the logic and processes of value creation **in firms,** it has especial use as a framework for the analysis of firm-level competitive strengths and weaknesses. The fundamental notion is that products gain value and costs as they pass through the vertical stream of production within the firm: design, production, marketing, delivery and service. The dominant purpose of a value-chain analysis is to establish how, where and when a firm can obtain competitive advantage in the marketplace.

The template set of generic activity categories as devised by Porter are: inbound logistics; operations; outbound logistics; marketing; and sales and service. The technique seeks to identify critical value activities together with the strengths and weaknesses, costs and assets, which are aligned to each activity. In particular, the cost drivers of scale, capacity, utilisation, vertical integration, location, timing, learning, policy decisions are useful for dissecting costs. They also enable comparisons to be made with similar operations elsewhere and relevant benchmarks are a natural consequence.

A simple construct of a geodetic system would show the major economic inputs driving provision costs as comprising the equipment and logistic components, e.g. equipment and transport, to which must be added the costs of skills needed for fieldwork and the subsequent office work. The manipulation, presentation and distribution of the outputs which are primarily coordinates (in three dimensions) flow from this process. Many of these components are essentially private goods and can be produced in a competitive commercial world, e.g. through outsourcing.

Certainly, value chain analysis can help by directing attention to cost structures such as unit production costs. However, while aspects such as unit costs and marginal costs are clearly relevant, the actual typology and underlying value-creation logic of the value chain approach are not ideally suited for a comprehensive analysis of value activities in a service industry or an information service system such as a geodetic system.

It is also true that, rather than advancing competitive advantage, the actual value-in-use which flows from the geodetic system actually revolves around features such as consistency (standards), reliability, compatibility, comprehensiveness and homogeneity. For each of these, untangling the added value can be difficult

Value in standards and compatibility

The standards/compatibility relationship can take different forms. If manufacturers independently choose identical technical standards for goods (or services) then *de facto* compatibility results. There is also the possibility that a firm can, by sheer market dominance, establish standards which others simply copy. There again, compatibility follows as a logical consequence for those who lead and those who follow them.

Standards may be established by mutual consent within an industry (institution) or, perhaps, by the direct coercion of government. Equally, competitors may seek incompatibility deliberately and so adopt a winner-takes-all approach. However, it is important to note that establishing standards, by whatever means, does not necessarily lead to compatibility.

Governments at various levels also use standards for specific control processes. The justification rests mainly with a perceived or demonstrated need to protect the public interest, e.g. the principle of *caveat emptor* is seen as inadequate. Also, as substantial purchasers of goods and services, governments themselves often wish to achieve compatibility through arranging or even prescribing standards.

Most governments, whether at local, state, national or international level do seek to prevent, or at least reduce, duplication and waste. Imposing standards in order to achieve a substantive degree of compatibility in equipment and services within and between departments, agencies and allied institutions holds considerable attraction. However, common standards are a necessary, but not sufficient, condition for consistent datasets.

In looking at the geodetic system, government provision of survey control in the form of monuments and coordinates is “guaranteed” to ensure certain spatial accuracies and this essentially provides a *de facto* standard. By requiring cadastral surveys to be connected, it also effectively sets a *de jure* standard in that sector. For other uses and users, the accuracy standard inherent in the geodetic system is simply made available for anyone who wishes to adopt it.

Value in compatibility flows from the adoption of the geodetic system as a common standard in different positioning exercises. As a result, the products which flow from such activities can then be knitted together at lower cost than if different survey control systems are used.

The Overall Structure of Value and Benefits

The geodetic system provides benefits to people directly and/or indirectly **once it is used**. Whilst an argument can be mounted that a geodetic system has no intrinsic value in itself, and only provides value-in-use, this argument does need some careful dissection.

A general approach to describing and deriving the information value (benefits) of the geodetic system might include:

An *input benefit* approach (manifest value)

Benefits are derived from direct costs incurred including any levied charges. Additional benefits received by users are determined through ascertaining indirectly the expressed willingness-to-pay for access to geodetic information. This includes any search costs and transaction costs involved in identifying, locating, ordering, receiving, installing and verifying geodetic information. As an alternative approach, a survey using willingness-to-pay techniques could be used to identify and quantify value. However, such surveys have to contend with a "free-rider" problem. Thirdly, the cost of obtaining substitutes could be used as a surrogate for the value gained from the existing system.

A *process benefit* approach (consequential value)

Here, the size and type of benefits are derived from examining the actual value-in-use aspects of the geodetic system information. This includes frequency of use and degree of use. Using information tracing and impact analysis (value-added) approaches, first-order gains or benefits (including cost savings and productivity gains) can be identified and quantified.

An *output-benefit* approach (societal value)

These are second-order benefits accruing to society as a whole. Improved knowledge and understanding about spatial relationships, better use and management of natural resources and enhanced awareness of geophysical features are typical examples.

A *risk-avoidance* benefit approach (option value)

Knowing that the geodetic system will be there, if and when the option to use it is exercised, also has a value to individuals and organisations, including government itself. One way of determining this benefit is whether, and how much, potential users are willing to pay, perhaps indirectly through taxation, to ensure supply of the geodetic system.

An *existence benefit* approach (intrinsic value)

Intrinsic value is actually an extension of the option value. There may even be an altruistic motive, e.g. ensuring an inter-generational archive exists which has some asset value. It is also true that the opportunity to gather certain geodetic information may be time-related and, once the opportunity has passed, it is lost irreversibly. For example, whilst tide gauges were often installed for monitoring tidal movements for local shipping, the information gathered is now assisting in assessing the presence and size of global warming.

These concepts of value can be applied to the geodetic system in a descriptive manner using two separate but allied approaches: the geodetic system as a **value service** and as a **value network.** (It is important to note that some of these five benefit categories listed above actually overlap in parts. Any attempt to quantify them must take care not to "double-count" benefits.)

Costs

As an asset, the geodetic system requires maintenance for physical deterioration, lack of completeness (integrity) and obsolescence. For a geodetic system, this first means replacing and coordinating missing and destroyed marks. It also means ensuring that the integration of acceptable surveys into the system is maintained and that the various survey output flows economically into outputs such as the digital cadastral database. Taking a wider view of maintenance, the development and growth in the wider economy could also drive cost aspects such as densification and replacement.

Assuming that some level of maintaining the geodetic system is to continue, the cost structure will reflect the checklist of key processes. These core processes in implementing maintenance are:

- Conducting field inventories to ascertain status of the system.
- Re-engineering the design of the new geodetic system.
- Physical reinstatement of control points which have been destroyed or moved at the desired location, density and accuracy to meet modern needs.

- Reconnaissance, and emplacement of new control points, again at the desired location, density and accuracy.
- Surveying and coordination of new and replacement points.
- Computational recalculation of points on a new datum, should that be necessary.
- Preparation and maintenance of necessary databases for users of the geodetic system including educational information.
- Packaging and dissemination of the data and metadata.
- Overseeing ongoing operational costs including administration of contracts and performance of those contracts.

Clearly, there will be scope and scale efficiencies to be gained through careful selection and prioritisation of maintenance functions according to need and benefit, e.g. urban Central Business Districts versus rural high country. Also, while the availability of new technology should act to drive down unit costs, ongoing programme performance is required on critical levels and ratios. Costs are also dependent on activities being undertaken on an orderly basis, area by area, to optimise productivity.

Costs and input per unit of output, for example, should be considered under this heading. Alternatively, the process of contracting out can be used as a partial surrogate. Projecting and forecasting of likely maintenance functions and costs should throw light on identifiable future demands on a rolling basis. It should also throw light on costs and factor requirements with such forecasting performed on the risk-absorbing basis of (i) adverse conditions (ii) no change in conditions and (iii) favourable conditions.

For those making use of the geodetic system, there is another set of costs which reflect the costs of connecting to the system for the purposes of position-fixing and spatial data-gathering. Many of the overall survey costs would occur regardless of whether the survey work is based on the geodetic system or not. However, there are additional costs which include:

- Acquiring the necessary background information, i.e. obtaining information such as location diagrams, status reports, coordinates etc. either in person (requiring travel time and costs) or online via computer databases.
- Additional fieldwork in locating suitable physical marks, verifying them and connecting the survey to them.
- Additional calculations, for example, calculating and applying transformation vectors.

Generally, these additional costs are passed on to the client, as in the case of private-sector work, or become part of the total cost framework in the case of in-house work by local authorities or government agencies.

One potential area of additional cost associated with indirect usage of the geodetic system, i.e. GIS applications, lies with the possibility of making serious mistakes arising from incompatible data. As Smith and Murray (1998) point out:

"Transformations between existing reference systems (maybe very old) and the new are not necessarily comprehensively understood or defined and so the existing mapping and the new positioning do not match – in some cases by tens or hundreds of metres. Neither is wrong they are just incompatible…. Without these transformations, they are at least dangers of duplication and wasted effort and at worst real danger where positions apparently mutually compatible are not, in fact, the same."

The geodetic system as a value service

In this approach, value is seen as deriving from the geodetic system in terms of the benefits which the system contributes towards resolving particular and individual customer problems **as an intensive technological product/service**.

Typically, the benefits and value result from an intervention between the client (or consumer) and the geodetic system by individuals and firms possessing specialised technical knowledge and skills. (These intermediaries are often but not necessarily surveyors). There is often a significant asymmetry of knowledge between client and practitioner in terms of knowing how to access the geodetic system, and obtain value from it. The asymmetry is the very reason that the client approaches the specialist practitioner and the client follows and trusts the practitioner. In practice, most firms possess an intensive, and expensive, technology and they are also highly labour intensive with an expensive staff of professionals. High equipment costs and expensive professional time are the key drivers of cost for the consumer-client.

Use of the geodetic system is characterised by selection, combination and order-of-application of resources and activities directed at the particular position-gathering task (problem) in hand. The professionals schedule activities and apply resources in a fashion that is dimensioned and appropriate to the client's problem. Not only is there high professional commitment and responsibility, it is the professional's knowledge base which provides value and which limits overall costs with features of production such as quality assurance.

Benefits for agencies, organisations and individual citizens from the geodetic system occur when surveys (position-fixing or spatial data gathering) are connected to the survey control system. These are dominated by ***process benefits*** which include cost-savings in having survey control available for cadastral and engineering survey services, improved land development and land registration procedures. Other benefits can lie in improved security of land tenure with reductions in litigation costs, e.g. where boundary disputes or encroachments occur, and in some instances, there can be lower mortgage-related transaction costs.

Studies elsewhere by Angus-Leppan and Angus-Leppan (1990), Ross (1977) and Larson (1971) have mostly argued that the benefits of the survey control systems flow from cost savings which can be made because the system is available, accessible and maintained to an appropriate standard, both physically and mathematically. The size of benefits related to survey costs are illustrated in Table 8 below

SURVEY COST SAVINGS		
CADASTRAL SURVEYS		
• RESIDENTIAL	1st Generation	0%
	2nd Generation	25% (Weighted Average)
• COMMERCIAL	1st Generation	0%
	2nd Generation	26% (Weighted Average)
• IDENTIFICATION SURVEYS		25%
ENGINEERING SURVEYS		
• BUILDING		13%
• OTHER		5%
GREATER SECURITY OF TENURE		
• COORDINATE UPGRADE AS EVIDENCE		4%

Table 8: Cost savings as a percentage of cost for unit surveys (Adapted from Angus-Leppan and Angus-Leppan, 1990)

However, it is most important to acknowledge that many of these benefits only arise because the system is more efficient for second-generation surveys and because certain procedural improvements become feasible. No large benefits come to a client when the connection to the geodetic system is first made. However, there will be secondary benefits to certain agencies. For example, the fact that a cadastral survey is properly connected to the geodetic system can enable an agency compiling composite maps, plans and databases to streamline planning, handling and examination and so reduce costs.

Any move towards a coordinated cadastre, although not a legal coordinate, also requires a coordinate system of high precision supported by an adequate control system.

One of the difficulties of assessing the value-in-service of the New Zealand geodetic system is that the benefits are currently built into the system because many surveys, cadastral surveys in particular, have been connected into the system for some considerable time. However, if the geodetic system were allowed to decay or become obsolescent, these benefits would clearly reduce over time. Unfortunately, the fact that the benefits have become embedded makes it very difficult to undertake a “with-and-without” study and surrogate studies will have to suffice here for now.

How large then could such benefits be? A 1990s Canadian study provides some indication. (Hamilton and Doig, 1993). As background, the survey control system in the Canadian Maritime Provinces (New Brunswick, Nova Scotia and Prince Edward Island) was significantly overhauled in the 1970s and 1980s with many tens of thousands of new survey control points being installed and connected to the overall survey system.

In 1993, by which time some 95% of cadastral surveys were connected, the survey control framework was assessed by private-sector practising surveyors as resulting in a saving in field work of between 20% and 60% depending on the size and location of the task. Similar savings were estimated by surveyors working in the engineering surveying, construction and utilities industries. As one practitioner observed:

“It is estimated that if our present control system was to fall into disrepair, the cost of surveys would rise by 40%. This means an additional $500 to the cost of the average survey in our province.” (Gunn, 1993)

Closer to New Zealand, the President of the Association of Consulting Surveyors of New South Wales was quoted in 1996 as saying that the savings from the integrated survey system (based on the geodetic system) would be between AUS$100 and AUS$200 per survey. Given that the typical suburban boundary redefinition in New South Wales at the time was costing around AUS$500, the reported levels of saving would be substantial.

The Geodetic System as a Value Network

The geodetic system will now be examined as a “network” using the term in a rather different sense to that used elsewhere in this report. In this perspective, the geodetic system is treated as a changing technological system with some striking similarities to various other goods/services which have been analysed using “network economics”, and especially the very important concept of network externalities.

The fundamental property, and major economic feature, of networks is that they display network externalities in the form of positive consumption and production externalities. A positive consumption externality signifies the fact that the utility derived from use (and the value) of a unit of the good increases with the number of units sold. Good examples are fax machines and word-processing software.

In economic parlance, this should be interpreted as meaning that the value of a unit increases with the expected or anticipated number of units to be sold. In purer economic terms this means that the demand curve does slope downwards but that the curve itself **shifts** upward with increases in the number of units expected to be acquired

The perception that there are, or will be, positive network externalities, i.e. network economies, increasing returns to adoption or local positive feedback – all terms used synonymously in the literature – are a significant feature of diffusion processes of many modern technologies. The presence of such externalities can have significant influence on the innovation decisions on the supply side and adoption decisions on the demand side. Part of the impact of the new geodetic system including GPS rests with the rate of diffusion of the technology.

Katz and Shapiro (1985) show that the level of industry output is greater under compatibility than at any equilibrium with some incompatible firms. Intuitively a firm benefits from a move to compatibility if (i) the marginal externality is strong (ii) it joins a large coalition and (iii) competition does not increase to a significant degree by its action. On the other hand, the coalition benefits from a firm joining its standard if (i) the marginality is strong (ii) the firm that joins the coalition is strong and (iii) competition does not increase significantly as a result. In both cases the second and third criteria may create incentives that conflict. They also show that if the costs of achieving compatibility are lower for all firms than the increase in profits because of compatibility, then the industry move toward compatibility is socially beneficial.

However, in some networks the utility of the composite good is not the sum of the respective qualities. The quality may be the minimum of the qualities of the components parts as occurs with voice quality of telecommunications. Thus significant quality coordination problems arise in a network with fragmented ownership. It can be shown that an integrated monopolist producing two components A and B of different quality, and with a joint quality of the minimum, will charge less than two vertically integrated monopolists each producing one component only.

Taking two complementary goods X and Y, the value of good X increases as more of the complementary good Y is sold and vice versa. Also the value of X increases as more of it is sold and the demand curve shifts upwards. However, while the positive feedback loop may be explosive and even exponential initially, the demand curve eventually takes on a downward shape with larger and larger number of units in place. This is because of the fulfilled expectation formulation of network externalities. Put simply, demand will increase if there are immediate and large external benefits to network expansion and the network is small. Because the fulfilled expectations demand increases initially, it could be described as displaying positive critical mass under perfect competition.

Equally, it can be argued that a monopolist who can influence expectations but who is unable to price-discriminate will support a smaller network and will charge higher prices than perfectly competitive firms because of classic profit-maximisation decision-making. Furthermore, this tendency towards restricted production is stronger, and will lead to lower production levels, than perfect competition with lower total surplus being the result. Thus, the existence of network externalities cannot be claimed as a substantive reason in favour of a monopoly market structure either.

Turning to networks and spatial information systems, it was shown earlier that a core function of standards in spatial systems is to enable the definition, description, structure, encoding, and transfer of information to different users, applications and systems. However, it is the potential for compatibility which offers real and substantial benefit opportunities. Often, the successful application of GIS is only possible with a sound framework and the ability to link datasets together.

A case can be made that the combined spatial information product will only be as strong as its weakest component and a lack of spatial accuracy in one data-set will affect the composite product. This risk is especially high when the datasets are collected by different organisations at different times for different uses and users. A common reference system (and datum), whilst not essential, is highly desirable in order to align or “fuse” the contributing datasets. Failing this, the result is datasets which are heterogeneous and incompatible rather than homogeneous and compatible.

We saw earlier that there is invariably a need for common and accepted user-community views on standards as to content, quality, delivery and access in order to avoid discrepancies, confusion and duplication. We also found that in many ways the geodetic system has become a sensible standard for spatial data-gathering where the users are involved with more than localised private information. The potential for compatibility also acts to reduce transaction costs in terms of searching and verifying that the different datasets are compatible. It also reduces costs by eliminating or significantly reducing the costs of transforming the various datasets.

In the GIS world in particular, added value is created from linking different GI sets together and also by reducing costs for new data gathering by aggregating existing sets. Rhind (1997) properly observes that with two spatial datasets, only one combination is possible whereas with 20 different data sets for the same area there are 190 pairs of data sets and more than a million combinations overall. While any two original items, e.g. data-sets, are useful and have value in themselves, it is the complementarity and compatibility which enables a new good to be created with additional value. The value of this compatibility can best be illustrated using the concept of network externalities.

In looking for where the benefits (positive externalities) from geodetic system compatibility actually lie, it appears that much of it will be with GIS-users who need to merge different datasets. Observation suggests that these users are more likely to be those authorities and agencies involved with managing major planning, development and construction activities, e.g. regional and local authorities. Certainly some tasks are individual and site-specific. However, many other tasks especially wider environmental management means that decision-making is a particularly important function requiring compatibility between different spatial themes or layers of spatial information.

Once again, it is the avoided costs (process benefits) which dominate here although there is a significant element of input benefit where there is an indirect willingness-to-pay to avoid search and transactions costs. The needs of decision-makers can only be met by incurring additional costs to obtain the required compatibility.