The Allen Consulting Group

Economic benefits of high resolution positioning services

Final Report

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Abbreviated terms used in this report

CGE	Computable General Equilibrium
GDP	Gross Domestic Product
GNSS	Global Navigation Satellite Systems
GPSnet	A real-time network of continuously operating reference stations that provides Victoria-wide satellite position correction data to users
MelbPos	A real-time network of continuously operating reference stations that is part of GPSnet and is currently operating in Melbourne and its environs
MMRF model	Monash Multi–Regional Forecasting model
RTK	Real-time Kinematic
RTN-CORS	Real-time Network of Continuously Operating Reference Stations
SunPOZ	A real-time network of continuously operating reference stations that provides satellite position correction data to users in south-east Queensland
SydNet	A real-time network of continuously operating reference stations that provides satellite position correction data to users in the Sydney metropolitan area and some regional centres of New South Wales
UHF	Ultra High Frequency
VHF	Very High Frequency
VicPos	A Victoria-wide sub-metre accuracy network service that is generated by GPSnet and is available up to 200 kilometres from the outermost stations in the network

Executive summary

Introduction

Substantial technological advances have been made in recent years to improve the accuracy of the global positioning system. Today, precise positioning technology uses multiple frequency Global Navigation Satellite Systems (GNSS) receivers to achieve real-time or near real-time accuracy of two centimetres. This degree of accuracy opens up a range of new commercial applications for improving production and processing efficiency in industries such as agriculture, mining and construction.

Precision GNSS technology has the capacity to automate many manual tasks, boost agricultural crop yields, facilitate just-in-time supply chain management, improve the deployment of resources for asset maintenance and deliver significant cost savings in materials — to name just a few examples.

At present, precision GNSS technology has been adopted to varying degrees by a number of industries in Australia, facilitated by numerous private networks. However, consultations undertaken over the course of this study suggest that widespread adoption across a broader array of industries is being held back by the relatively high cost of accessing the technology, the lack of network coverage to deliver the service and the uncoordinated manner in which networks have been rolled out to date.

The Victorian Department of Sustainability and Environment has recently developed a real-time network of continuously operating reference stations (RTN-CORS) called GPSnet. This GNSS network is expected to overcome many of the above mentioned constraints by making precision GNSS more widely available at relatively low cost.

GPSnet is currently operating its high accuracy real time service (MelbPos) in Melbourne and its environs, but does not yet extend to other parts of Victoria or other states and territories.[1] In its May 2008 budget, the Victorian State Government provided funding to allow for the extension of GPSnet to cover all of Victoria in a staged rollout that is scheduled for completion in 2011.

There are real time networks of continuously operating reference stations operating in other states. Government-owned networks are in operation in New South Wales (SydNet), Queensland (SunPOZ) and the Northern Territory. A private network exists in Perth. These networks are expected to grow substantially in the coming years.

1 GPSnet currently generates a state-wide sub metre accuracy service (VicPos) that is available up to 200 kilometres from the outermost stations in the network.

This study

The objective of this study is to estimate the current and future economic benefits (measured in terms of contributions to national GDP) resulting from the uptake of various applications of precision GNSS technology in three key industry sectors — mining, agriculture and civil engineering/construction. Preliminary investigation and modelling is also undertaken for applications of precision GNSS to asset mapping, which is currently being used in the utilities and public works sector.

The purpose of the study is to provide a conservative estimate of the potential benefits of precision GNSS to the Australia's economy, based on the case studies in the three industry sectors outlined, not a comprehensive estimate of the full economic benefits. Additional benefits of precision GSS, such as from application improvements in the handheld consumer market, or to other industry sectors such as road transport logistics or sea freight container loading, are beyond the scope of this study. In addition, the study has looked at gross benefits as opposed to determining rates of return on investment. That is, the study is not a benefit cost analysis, and therefore does not consider research and development costs, capital infrastructure costs or the operational cost of delivering the network service.

Future benefits are estimated for two different adoption scenarios over a twenty year timeframe out to 2030. The first scenario involves an assessment of productivity gains achieved in a situation where a standardised real-time network of continuously operating reference stations, such as GPSnet is rolled out across Australia, thus promoting uptake of GNSS technology. The other scenario examines the benefits that may ensue under a 'base case' in which future growth in GNSS technology continues without being underpinned by a national rollout of a standardised network. Under this scenario, adoption of precision technologies is assumed to continue to grow – facilitated by 'organic growth' of private area networks — but at a slower rate than what could be achieved with a rollout of a standardised national network.

The economic value of productivity gains from applications of precision GNSS in the agricultural, mining and constructions sectors are modelled using a computable generalised equilibrium model — the Monash Multi–Regional Forecasting (MMRF) model run by the Centre of Policy Studies at Monash University. MMRF is a multi-sectoral, multi-regional dynamic model of the Australian economy. It produced estimates of the 'first round' economic benefits to firms as a result of assumed cost savings and/or higher output levels. It also captured the second round benefits accruing to upstream and downstream industries, which were incorporated into the GDP changes.

Indicative estimates of the benefits of applying precision GNSS to asset mapping in the utilities and local government sectors are made by examining the potential savings in capital and operating costs accruing from the technology. These benefits are modelled outside the computable generalised equilibrium framework.

Estimates of productivity gains and technology uptake have been made in consultation with industry experts – including GNSS equipment suppliers, end-users in each industry and researchers involved in trialling the technology. The study has also drawn on existing literature and reviews of precision guidance and automation. This material, together with information gathered through consultations, was used to develop several case studies of applications of the technology in each industry sector. These case studies have underpinned the empirical modelling.

The case studies

A number of case studies were selected to examine the benefits of precision GNSS across the agriculture, mining and construction sectors. The use of precision GNSS technology to assist with asset mapping tasks was also examined. The case studies were selected to best demonstrate the benefits of precision GNSS technology and include a mix of applications that are currently being used on a commercial basis and other applications that are more prospective in nature. The case studies are not representative of all of the applications of precision GNSS technology in agriculture, mining and construction.

Agricultural applications

- *Controlled traffic farming* is a technique that involves constraining the movement of tractors to permanent ‘tramlines’ or wheel tracks year after year. Precision is achieved by fitting tractors with a GNSS guidance system and automated steering. Having designated wheel tracks on the farm results in higher crop yields (due to less soil compaction) and lower fuel costs.

- *Inter-row sowing* is a technique used by farmers whereby seeds are sown at precise locations, usually in between rows of crops from the harvests of previous years, so as to maximise crop yields.

Mining applications

- *Accurate selective mining* is a relatively well established technique in the industry involving the fitting of GNSS equipment to excavators so that operators can be guided as to precise locations to dig.

- *Autonomous haul trucks* is an application that is still at the trial stage but one that appears to have strong commercial prospects. It involves the use of precision GNSS as a means to enable mine haul trucks to operate autonomously without a driver.

Construction and civil engineering applications

- *Site surveying* has been revolutionised by precision GNSS technology. It allows surveyors to determine the coordinates of groundmarks instantly and with a very high degree of accuracy. The accuracy and reliability obtained by precision GNSS means that less site re-work is required thus benefiting both surveyors and construction parties relying on the survey information.

- *Machine guidance on earthmoving equipment* has been one of the biggest growth areas for precision GNSS equipment. Precision GNSS technology allows for site plans to be programmed into earthmoving equipment, such as bulldozers, excavators and graders. The earthmoving equipment can then be controlled to conform to the site plan via the use of continuously updated GNSS positioning information.

Asset mapping

- *Precision GNSS technology is beginning to be applied to asset mapping.* It can be used to accurately locate and map infrastructure assets such as pipelines, stormwater drains and underground cables. This capability is particularly useful for organisations that manage large networks of infrastructure assets such as local government councils and utility companies. It can result in cost savings in undertaking the mapping task and also improve the efficiency of asset maintenance.

Sectoral analysis

Precision GNSS technology is already being used to some extent in the agricultural, mining and construction industries, and some utilities and local governments in Australia are trialling the use of the technology for mapping their assets.

The gross benefit flowing from existing uptake in the agricultural, mining and construction sectors is estimated to range between $829 million and $1486 million per annum, depending on the size of productivity gains assumed. This represents a contribution to national GDP of between 0.08 per cent and 0.14 per cent.

Application of precision GNSS to asset mapping by utilities and local government Australia-wide is estimated to result in operating cost savings of $435 million to $870 million per annum and capital cost savings of up to $2.3 billion per annum.

Table ES.1

CURRENT AND FUTURE BENEFITS DUE TO PRECISION GNSS

Sector	2008 $ million	At 2030 with a standardised national network ($ million, 2008 values)
Agriculture	152 – 206	1005 – 1357
Mining	371 – 744	4614 – 9347
Construction	306 – 535	1057 – 1897
All three sectors	829 - 1486	6675 - 12636

Note: Analysis limited to the three sectors listed in the table. The ‘all sector’ total does not equate to the sum of individual sector benefits because interaction effects in the economy are accounted for when productivity gains to all sectors are modelled simultaneously as opposed to being modelled individually. A discount rate of 7 per cent was used to convert 2030 values into today’s dollars.

With reference to Table ES.1, applications of precision GNSS in open cut mining are estimated to be delivering between $371 million and $744 million annually. Benefits to the mining sector are considerably greater than those generated by agriculture, and slightly higher than construction. This is principally because mining contributes more to GDP than each of the other sectors ($38 billion per annum as opposed to $5.4 billion for agricultural grains and $23 billion for construction). Thus productivity gains in this sector produce a proportionally greater impact on the national economy.

Current uptake of precision GNSS technology in the broadacre cropping sector is estimated to be delivering an annual benefit of between $152 million and $206 million. The current benefits being experienced by the construction sector are more than twice this amount, at between $306 million to $535 million.

The main reasons for the relatively high benefits in the construction sector are that:

- even relatively small improvements in productivity in construction generate significant positive benefits for the economy because the non-residential construction sector is four times the size of the agricultural cropping industry;
- it has strong linkages with a large number of industries in the Australian economy; and
- in the long run, a positive shock to the construction industry generates significant benefits for the economy as nearly all other industries benefit from having physical capital or infrastructure provided at a lower cost.

A more productive construction sector can also produce more physical capital or infrastructure than would otherwise be the case and this helps the industry deliver significant economic benefits across the economy.

The broadacre cropping industry, being predominantly export-oriented, does not have the linkages to the rest of the economy as construction does and it is also significantly smaller than the construction and mining industries. The large potential benefits of adoption of precision GNSS in the cropping industry do not flow through to benefits for the rest of the economy to the extent that occurs in the construction industry.

Future benefits as at 2030

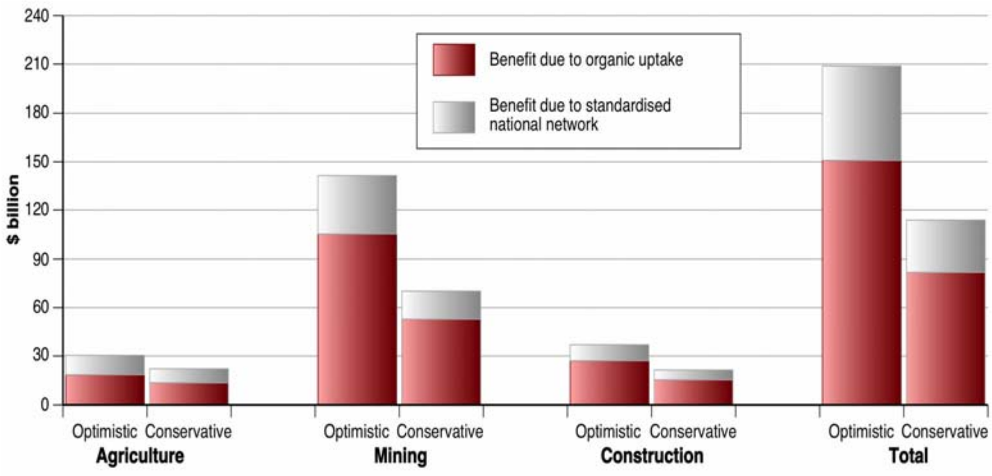
The study found that when applied to the agriculture, mining and construction industries, precise positioning technology has strong prospects to produce considerable future benefits. Based on a scenario whereby a standardised network is rolled out across Australia, the technology is estimated to increase Australia's GDP by between $6.7 billion and $12.6 billion in today's dollars by 2030 (Table ES1). This equates to a percentage increase in GDP of between 1.1 and 2.1 per cent.

Cumulative benefits

In dollar terms, it is estimated that GNSS has the potential to generate cumulatively between \$73 billion and \$134 billion net present value over the next twenty years, depending on the assumed size of productivity gain (Figure ES.2). Additional cumulative benefits of between \$32 billion and \$58 billion (gross) could be generated with the national rollout of a standardised network — as a result of the assumption that this would speed up adoption rates and in some cases increase the ultimate level of adoption.

Figure ES.2

PRESENT VALUE OF FUTURE PRODUCTIVITY GAINS — 2009-2030



As noted previously, these results do not represent a comprehensive estimate of the benefits of precision GNSS in Australia, rather a conservative estimate of the potential benefits to Australia's economy based on the agriculture, mining and construction case studies outlined in this report. In addition, the estimated benefits do not take into consideration the cost of building the network, operating the service, and any associated research and development costs, nor do the estimates take account of any cost differentials between a single nation–wide network of precision GNSS infrastructure relative to the present environment of multiple private networks.

The overall benefits of between 1.1 and 2.1 per cent increase in GDP by 2030 compare favourably with the GDP impact of other significant innovations in information technology and work practices, such as 2.7 per cent per year from the economic benefits of e-commerce (National Office for the Information Economy, 2000), 2.6 per cent from the economic benefits of increased participation in the information economy (Allen Consulting, 2002), and up to 5 per cent from the rise of internet retailers and e-commerce (International Monetary Fund, 1999).

Chapter 1

Introduction

1.1 Background

Substantial technological advances have been made in recent years to improve the accuracy of the global positioning system. Today, precise positioning technology uses multiple frequency Global Navigation Satellite Systems (GNSS) receivers to achieve real-time or near real-time accuracy of two centimetres. This degree of accuracy opens up a range of new commercial applications for improving production and processing efficiency in industries such as agriculture, mining and construction.

While precision GNSS is still in its infancy, the potential benefits are thought to be considerable. The technology has the capacity to automate many manual tasks, boost agricultural crop yields, facilitate just-in-time supply chain management, improve the deployment of resources for asset maintenance and deliver significant cost savings in materials — to name just a few examples.

At present, precision GNSS technology has been adopted to varying degrees by a number of industries in Australia. The surveying industry, for example, has strongly embraced GNSS while in agriculture only a relatively small proportion of farmers currently utilise the technology. Widespread adoption across a broader array of industries is being held back by the high cost to firms of accessing the technology, the lack of network coverage to deliver the service and the uncoordinated manner in which networks have been rolled out to date.

The Victorian Department of Sustainability and Environment has recently developed a real-time network of continuously operating reference stations (RTN-CORS) called GPSnet. This GNSS network is expected to overcome many of the above mentioned constraints by making precision GNSS more widely available at relatively low cost.

GPSnet is currently operating in Melbourne and its environs, but does not yet extend to other parts of Victoria or other states and territories. In its May 2008 budget, the Victorian State Government provided funding to allow for the extension of GPSnet to cover all of Victoria in a staged rollout that is scheduled for completion in 2011. This situation is similar to that in New South Wales, Queensland, the Northern Territory and Western Australia, where the initial focus of the installation of real-time networks of continuously operating reference stations has been in urban areas.

The objective of this study was to estimate the national economic benefits in three industry sectors — mining, agriculture and construction. Uptake of GNSS technology (and in some cases precision GNSS technology) has already occurred in each of these three sectors but in each sector there also remains significant potential for continued uptake. The study sought to estimate the *current* benefits of precision GNSS that have arisen from adoption to date and the *projected* benefits that are likely to be generated over the next twenty years as the technology matures and becomes more widely adopted.

Future benefits were estimated for two different scenarios. One scenario involved an assessment of productivity gains achieved in a situation where a standardised national network is rolled out across Australia, thus promoting uptake of precision GNSS technology. A second scenario was modelled to examine the (smaller) benefits that may ensue under a ‘base case’ in which future growth in precision GNSS technology is not underpinned by a national rollout of a standardised network. Under this scenario, adoption of precision technologies was assumed to continue to grow – facilitated by ‘organic growth’ of private area networks — but at a slower rate than what could be achieved with a coordinated rollout of standardised national network.

1.2 An overview of precision GNSS technology

Provided that a signal can be received, GNSS enables users with an appropriate receiver to determine their position anywhere outdoors on earth by using signals broadcast by satellites orbiting the globe. The distance between a satellite and a GNSS receiver can be derived based on the time it takes for a signal to be transmitted from the satellite to the receiver. Using different signals from different satellites, the GNSS receiver computes the position of the device’s antenna. However, the accuracy of GNSS can be degraded and made unreliable due to, amongst other things:

- atmospheric effects, which impact on the speed of signals;
- radio-frequency interference; and
- multipath effects caused by spurious signals being reflected off the surrounding terrain (for example, buildings and trees) which can impact on the quality of positions.

Standalone GNSS systems without corrections are generally accurate to an order of 5 to 10 metres. In extreme cases, errors can be hundreds of metres (Millner et al, 2007).

One option for improving the accuracy of GNSS is through differential processing of information from a fixed reference point (that is, a base station). A base station is typically located in a fixed or semi-permanent location and consists of a GNSS receiver, GNSS antenna, radio and radio antenna. The base station gives a permanent reference point and supports positioning by broadcasting correction data that can be inferred as the difference between the positions indicated by the satellite systems and the known fixed position. Depending on the distance between the base station and the receiver, position accuracy can be up to one metre.

Another, more sophisticated, option is to correct the satellite signals using real-time kinematic (RTK) technologies. This can operate on a single base station or via a network of base stations. Accuracy is typically improved to centimetre accuracy. Single base stations with RTK correction can be purchased for approximately $6,600 (with limited radius). However, for ‘top of the line’ *geodetic* base stations with a greater radius (at most 20 kilometres) the cost can be up to $25,000. There are also installation and surveying costs to correctly establish the station’s reference point and ongoing costs to maintain the base station.

Presently those wishing to use precision GNSS technology have the option of either installing their own base station or subscribing to one of the private wide area networks around Australia. While the private networks can be designed to deliver two-centimetre accuracy, it is often the case that the corrections data provided through these networks are only accurate up to 10 centimetres because they rely on base (rather than reference) stations that are sometimes several hundred kilometres apart. This level of accuracy is insufficient to deliver the full benefits of precision GNSS technology. Base stations are typically temporary project applications that are not referenced to state and national mapping datum. The accuracy of base station readings decreases as the distance from the base station increase.

The GPSnet developed by the Victorian Department of Sustainability and Environment uses a network of *geodetic* receivers. The advantage of a CORS network is that there are numerous fixed points of reference and information from these fixed points are processed in a computer model that generates corrections that can be used on GNSS receivers within the entire network. CORS networks generate consistent accuracy regardless of user range from the reference stations. In a rural region, GPSnet could offer two-centimetre accuracy to farmers using networked-RTK corrections technology. Corrections data would be delivered though the internet to farms and then transmitted to tractors with GNSS receivers through standard UHF /VHF transmitters. Networked corrections have the added benefit of year-to-year accuracy as the network is continually monitored.

1.3 The analytical approach

The economic value of productivity gains from applications of precision GNSS in the agricultural, mining and constructions sectors are modelled using a computable generalised equilibrium model — the Monash Multi–Regional Forecasting (MMRF) model run by the Centre of Policy Studies at Monash University. MMRF is a multi-sectoral, multi-regional dynamic model of the Australian economy. It produced estimates of the ‘first round’ economic benefits to firms as a result of assumed cost savings and/or higher output levels. It also captured the second round benefits accruing to upstream and downstream industries, which were incorporated into the GDP changes.

MMRF contains a representation of each region as an economy in its own right. Being dynamic, the model is able to produce sequences of annual solutions connected by dynamic relationships.

The study sought to value the size of *gross benefits* as opposed to determining rates of return on investment. That is, the study was not a benefit cost analysis because costs were excluded. For example, no account was taken of research and development costs, or the cost of delivering the network service.

Part 1

Case studies

Chapter 2

Precision GNSS in agriculture

2.1 Introduction

The Australian cropping industry is one of the most advanced in the world and is at the forefront of innovative production and post harvest processing techniques. GNSS technology can facilitate high levels of precision in seed placement, harvesting, fertilising, spraying pests and monitoring crops.

Agricultural applications of GNSS technology apply predominantly to the grains industry, the major crops being wheat, barley and rice. It is estimated that 30 per cent of broadacre grain crops in Australia are now grown with the use of some form of GNSS technology (McCallum, undated 3). A study of broadacre wheat growers in Western Australia and South Australia found that approximately 15 per cent of growers are using GNSS technology that provides sub-10 centimetre accuracy (Kondinin Group, 2006).

Precision farming is also being practised, to a lesser extent, by the sugar, cotton, and horticultural industries. The cotton industry was one of the earliest adopters of precision technology to guide precise positioning auto-steer devices mounted to farm machinery. GNSS networks have been established in some rural areas but given the limited coverage and accuracy of these networks, it is more common for farmers to purchase their own base stations. Today, nearly all cotton farmers that use precision GNSS technologies operate their own base stations or share a base station with a neighbour (Lorimer, 2008).

There are two main applications of precision farming — controlled traffic farming and inter-row sowing.

2.2 Controlled traffic farming

Controlled traffic farming is a technique that involves constraining the movement of tractors to permanent ‘tramlines’ or wheel tracks year after year. Precision is achieved by fitting tractors with a GNSS guidance system and automated steering. Under conventional cropping, farmers operate machinery ‘round and round’ the paddock and all areas are potentially subject to traffic because the trajectory of wheels is not fixed. Having designated wheel tracks on the farm reduces soil compaction from heavy farm machinery. As noted by Tullberg et al, (2003):

> [The designated wheel tracks] are sacrificial, compacted areas on which no crop is normally planted, providing firm conditions conducive to greater tractive efficiency and improved timeliness, by allowing operations to continue in soil moisture conditions that would inhibit random traffic.

While the ‘sacrificial’ compacted area typically comprises about 12 per cent of the paddock, the higher yields obtained in the ‘untrafficked’ areas more than compensate for the reduced yields in the compacted tracks (Schofield et al, 2007). By keeping heavy traffic off the majority of the paddock it is possible to improve soil structure and water holding capacity, both of which contribute to higher crop yields. And low compaction can reduce the amount of water run-off and soil erosion, which are significant problems in some farming regions — both from a public environmental perspective and from a private perspective.

In Australia, controlled traffic farming was first adopted in the early 1990s, mainly in Queensland. It is estimated now that over one million hectares of farmland across Australia is under some form of controlled traffic farming (Tullberg et al, 2003). In Victoria, adoption has been mainly limited to raised beds (a particular form of controlled traffic farming). Anecdotal information indicates that about 100,000 hectares is currently under controlled traffic farming in Victoria, although this has not been verified by a survey (Schofield et al, 2007). Early applications of the technique used physical markers in the paddock as guidance. Now, with the cost of GNSS technology and ‘autosteer’ kits declining, a greater proportion of farmers are contemplating precision guidance.

Yield benefits

Controlled traffic farming has been demonstrated to increase crop yields by between 5 and 50 per cent (Table 2.1). The factors underpinning the yield gains are varied and include:

- increased soil water holding capacity, better water and root penetration;
- improved timeliness of operations, for instance, it enables earlier sowing immediately following rain and timely application of herbicides, insecticides and fertiliser (due to better traction);
- less crop damage when machines are used to apply sprays and fertiliser mid season;
- more precise input placements, particularly fertiliser and pesticides; and
- greater use of ‘opportunity cropping’ (in some regions), including double cropping and planting a crop in dry years.

The variation in reported yield gains reflects the fact that the estimates have been obtained from a mixture of trial data (where yields are measured under controlled conditions) and farmer observations. Furthermore, the data are based on a variety of crop types and growing regions across Australia.

Table 2.1

ESTIMATES OF INCREASED CROP YIELDS

Source	Estimates
Tullberg (1997)	22.8% increase over three years (wheat) 5% increase over three years (Sorghum) 14.9% increase over three years (maize)
Grant (1998)	30% to 50% increase
Ball (1998)	30% to 50% increase
Krampl (1998)	15% increase
Tullberg, Ziebarth, and Li (2001)	14% increase
Rohde and Yule (2003)	22% increase
Li et. al (1998)	27% increase
Gaffney and Wilson (2003)	15% increase

Source: Details of these studies are reviewed in Schofield et al (2007).

Input cost savings

In addition to improved yields, controlled traffic farming can reduce farming costs. Practitioners of the system report:

- reduced labour costs by adopting a zero till system;
- lower powered tractors and subsequent savings on fuel due to better traction when wheels travel on compacted surfaces;
- reduced spray volumes because guidance systems allow herbicides and insecticides to be applied at night when evaporative losses are lower; and
- less wasteful overlapping of sprays.

Table 2.2 summarises the size of these potential cost savings. Estimates were obtained from a review of previous studies undertaken by Schofield et al (2007).

Table 2.2

ESTIMATES OF INPUT COSTS SAVINGS

Item	Source	Estimate
Insecticide use	Brownhill (1998)	33 per cent reduction due to reduced overlapping
Labour costs	Mason et. al (1995)	28 per cent to nearly 50 per cent reduction with zero tillage
Seed, spray and labour	Birch (1999)	15 per cent reduction
Labour and fuel	Krampl (1998)	25 per cent reduction in labour cost and 33 per cent reduction in fuel costs
Machinery investment	Mason et. al (1995)	25 per cent reduction in capital investment

Source: Schofield et al (2007), p 251.

Other benefits

The use of controlled traffic farming techniques can also give rise to environmental and social benefits. Some of these impacts are;

- *Reduced water run off and soil erosion.* Controlled traffic farming has been found to reduce the amount of run off and soil erosion from cultivated paddocks due to improved retention and penetration of water in less compacted soil (references cited in Schofield et al, 2007). Soil erosion is a major ‘off-site’ environmental problem in some catchments. Soil loss is also an ‘on-site’ problem as it can cause yield reductions.

- *Reduced impact on water quality*. By applying inputs such as fertilisers, herbicides and insecticides precisely where they are needed for plant growth or pest control, there is less risk of chemicals entering waterways and degrading water quality.

- *Reduced greenhouse gas emissions.* Reduced fuel usage in controlled traffic farming has external benefits through lower levels of greenhouse gases being emitted (such as carbon dioxide) relative to traditional farming practices.

- *Reduced stress to farmers.* Controlled traffic farming techniques reduce the physical stress to farmers, as there is a greater degree of automation in farming processes. Emotional stress can also be reduced as these techniques promote fewer crop failures (Schofield et al, 2007).

While the Allen Consulting Group did not include values for these environmental or social benefits in this study, the on-site benefits of reducing soil loss and improving water retention were captured indirectly through the assumed yield increases.

2.3 Inter-row sowing

Inter-row sowing is a technique used by farmers whereby seeds are sown at precise locations, usually in between rows of crops from the harvests of previous years, so as to maximise crop yields.

Sowing new crops in between existing crop rows minimises soil borne disease and negates the need for the farmer to clear crop stubbles from previous harvests — this eliminates the need for costly stubble management equipment such as slashers, rollers and discs (McCallum, undated). Existing crop stubble can be used to support the growth of new crops by providing protection from elements and physical support for vertical crop growth. Better herbicide efficacy is also achievable as a result of precise application.

Inter-row sowing is a sophisticated and relatively complex farming practice relative to controlled traffic farming because it requires specialised machinery for cultivation and sowing. Specially designed seeders are required that can cater to different crop row width requirements and it is also common for seeders to be fitted with residue wheels to push aside fallen stubble (one of the benefits of inter-row sowing is that it negates the need to clear the stubble of the previous crop before sowing a new crop) (Ground Cover, 2006). Specialist fertilising and herbicide placement equipment are also used to extract the full benefits of inter-row sowing. Spraying equipment that is attached to GNSS-equipped tractors has its own antenna and guidance system thus providing highly accurate placement of inputs and the ability of the trailing equipment to steer independently of the tractor (McCallum, undated 1). This technology delivers the level of accuracy that is required to implement inter-row sowing practices.

Yield benefits

Inter-row sowing has been demonstrated to increase crop yields by between 5 and 30 per cent (Table 2.3). The factors behind the increase in crop yields that are achievable as a result of inter-row sowing include:

- a reduction in susceptibility to root disease;
- the protection that is provided by existing crop stubble;
- the ability to place seeds in positions where they will capture residual nutrition in the soil;
- the ability to place seeds so as to take maximum advantage of sunlight to keep crops dry therefore reducing leaf disease or alternatively shade to maintain moisture (with optimal conditions dependent upon the type of crop and soil and climatic conditions);
- the capacity to increase sowing rates; and
- the ability to achieve high precision in the application of fertilisers and herbicides thus extracting maximum benefits from inputs.

The ability to retain stubble gives rise to some additional factors that may contribute to higher yields, such as:

- improved weed control,
- higher levels of soil organic matter,
- improved soil moisture retention; and
- reduced harvesting losses in lentil crops, as stubble provides support for crops and allows easier and faster harvesting — as the crop is prevented from lying on the ground.

Table 2.3

ESTIMATES OF INCREASED CROP YIELDS

Source	Estimates
McCallum (undated)	A three-year study on wheat yields in South Australia found yield increase of about 8%.
McCallum (undated)	An experiment on canola yields found yield increases of about 30% with yield increases as high as about 80% in some cases.
Whitlock (2008, pers. comm.)	Yield increases due to disease avoidance may be in the order of 5% to 7.5%.
Daniel & Simpfendorfer (2007)	7 trial of inter-row sowing resulted in an average yield increase of 5% and a range of 1% to 9%.

Input cost savings

Input cost savings (predominantly fertiliser and herbicides) resulting from inter-row sowing have been estimated to range between 3 and 10 per cent (Whitlock, 2008 and Brownley, undated).

2.4 Limits to industry uptake

According to consultations with industry experts, further penetration of precision guidance in agriculture is currently being constrained by a combination of factors including

- relatively high up-front costs of equipment change-over;
- unreliable or limited network coverage;
- high up-front cost of installing a base station (in the absence of a network); and
- the need for new managerial skills to implement the technology.

The cost of equipping tractors with GNSS and changing over to precision agriculture is not cheap. According to Jones and O'Halloran (2006) the cost of an automated GNSS steering kit with the capability of 10 centimetre accuracy is approximately $30,000 including installation. It costs an additional $15,000 to upgrade to 2-centimetre accuracy.

The cost of purchasing a single base station for own agricultural use has declined in recent years and is now estimated to be as low as $6,000 (Lorimer, 2008). But the cost per farm varies depending on property layout, farm size and the requirements of the guidance systems. Some estimates put the cost of a base station at $50 000 (Branson, 2004). The provision of a national network of reference stations would obviate the need for farmers to develop their own base stations and has the potential to lower cost of the technology through enhanced economies of scale, thus improving the uptake of precision GNSS.

Controlled traffic farming is, however, very different to traditional cropping methods and therefore requires a degree of managerial skill and training to implement the technique. According to a case study of controlled traffic farming published by Land and Water Australia (Schofield et al, 2007), the typical package of practices embodied by this farming system includes

- field survey and development of a field layout design, with removal if necessary of contour banks and alignment down the slop to manage run-off and reduce water logging;
- matching of wheel track widths of all cropping machinery and implements, usually at three metres or multiples thereof — this may include machinery modification or replacement;
- matching planting equipment and spray equipment (for example, a nine metre chisel plough seeder and an 18 metre boom spray respectively);
- installation of a tractor guidance system and sometimes automated steering;
- zero till and chemical weed control; and
- more night operations when temperature, humidity and wind conditions are better.

All these factors were taken into account in our economic modelling of benefits (Part 2 of the report), which required projections of future adoption trajectories to be made.

Chapter 3

Precision GNSS in mining

3.1 Introduction

The mining sector has been a rapid adopter of GNSS technology, with some of the first applications being taken up in the early 1990s. Australian mine sites were among the first in the world to use high precision technology. Based on consultations undertaken in this study, mining firms and GNSS equipment suppliers to the mining industry are regarded as being at the forefront of innovation in precision GNSS technology and its applications.

Today, almost all mines use GNSS for site surveying (Seymour, 2005). The technology is also used to monitor equipment location, assist in mine site surveying and provide real time data that allow dozer and grader operators to identify areas to dig as well as digging depths (Carter, 2005).

GNSS applications are mostly confined to open-cut mining operations as it is impossible to establish GNSS coordinates underground. Most mine sites in Australia operate in areas where there is no existing precise positioning GNSS infrastructure. As a result, the pattern of adoption of precision GNSS technology has been for individual mines to purchase and install their own private networks (Lorimer, 2008).

In open-cut mines, precision guidance is being used as a means of improving productivity in ore extraction and site preparation, the latter including the construction of haul and access roads (Lorimer, 2008). The range of existing applications of the technology is detailed in Box 3.1.

Box 3.1

APPLICATIONS OF PRECISION GNSS TECHNOLOGY IN THE MINING INDUSTRY

Uses of GNSS technology in the mining industry include:

- Vehicle tracking and dispatch — the precise position of mining trucks and other equipment can be monitored in real time and mine managers can assign trucks with the most efficient route given their position.
- Material tracking — GNSS systems can be used to determine the material that each truck is carrying and where each load was dumped. Truck operators can get real time information on where to dump each load.
- Drill guidance — GNSS guidance can be used to precisely position drills in accordance with the location of resources and drill depths can be accurately programmed.
- Haul road grading and maintenance — GNSS technology can be used to ensure that haul roads are made and maintained to design.
- Geological mapping — GNSS can assist in the creation of accurate geological maps and reduce the costs involved in producing maps relative to more traditional methods.
- Control of bench height — the grade of mined benches can be continuously monitored without the need for a manual survey.
- Mine site surveying — surveying can be done with high accuracy and with less labour. General mine site design can be optimised with the use of GNSS technology.
- Accurate selective mining — GNSS positioning technology combined with onboard display monitors enable excavator operators to mine in exact accordance with mine plans and ore locations.
- Autonomous haul trucks — use precision GNSS technology to steer truck and control driving, parking and dumping operations without the need for a driver

Source: Based on Jarosz and Finlayson, 2002.

Of the numerous applications listed in Box 3.1, this study focused on two as a means of developing an insight to the nature and magnitude of benefits of precision guidance systems in mining. The two that were selected were:

- *Accurate selective mining* — a relatively well established technique in the industry involving the fitting of GNSS equipment to excavators so that operators can be guided to precise locations to dig.
- *Autonomous haul trucks* — an application that is still at the trial stage but one that appears to have strong commercial prospects. It involves the use of precision GNSS as a means to enable mine haul trucks to operate autonomously without a driver.

3.2 Accurate selective mining

Accurate selective mining requires that excavators be fitted with precision GNSS equipment that can identify the precise location of the machine as well as the excavator bucket. The excavator cabin is fitted with an onboard display so that the operator can guide the shovel with a high degree of accuracy to pre-determined locations and depths.

The process of fitting an excavator with precision GNSS technology starts with the loading of a design file on to the machine's onboard computer. The design file typically contains information on the spatial location of blocks of ore and the design of the mining pit including access and haul roads. When in use, the design information is overlaid with the current position of the excavator and this information enables the operator to accurately extract the required minerals. As the excavation progresses, the GNSS system updates the topography of the mine. The onboard display lets the operator know when new sections of ore are being extracted (Jarosz et al., 2002).

Selective mining technology is currently being used by about 15 per cent of open-cut mines in Australia (Seymour pers. comm., 2008). However, up to 55 per cent of mines are estimated by Lorimer (2008) to be potential candidates for the technology based on today's economic environment.

Benefits

Accurate selective mining allows a greater volume of ore to be extracted whilst also extracting fewer waste products. Consequently, higher yields can be extracted from mine sites and processing and sorting costs can be reduced as fewer waste products are extracted. The technology is particularly valuable in conditions where the ore that is being mined is indistinguishable from waste products and in conditions of poor visibility (Seymour, 2008).

Application software is available to assist mine site managers to calculate the productivity of the excavators. Data such as this can then be used to better assess digging techniques and operator skills and generally allows for more informed decisions to be made about mine operations. The productivity of mining operations was found to increase by four per cent as a result the availability of such information and the making of more informed decisions (Seymour, 2008).

A recent review of the benefits of accurate selective mining as applied to an Australian zinc mining operation delivered increases in mine output (as measured by the annual quantity of ore milled) of about two per cent. Grades of ore mined also improved following the adoption of accurate selective mining.

Other benefits of the technology include:

- the ability to reduce or eliminate digging in areas where ore is sparse, sometimes referred to as 'over-dig';
- lowers the incidence of leaving or missing pockets of valuable ore in the ground;
- improves occupational safety — allows for the accurate representation of hazardous areas such as loaded blast areas or areas that are underlain by old underground workings; and
- enables the construction of more even benches and this can allow vehicles to move around the mine site more efficiently (Seymour, 2005).

3.3 Autonomous haul trucks

Autonomous haul trucks use precision GNSS technology to steer truck and control driving, parking and dumping operations without the need for a driver. The technology involves fitting haul trucks with GNSS equipment that accurately controls the navigation of the truck. Each truck is also fitted with onboard controllers linked to the truck's computer system to control engine functions and also steering, braking, dumping and obstacle detection (Hughes, 2002).

The operation of the technology requires that a pit database be compiled containing data on the boundaries for loading areas, dumping areas and haul road areas. The database also contains the required travel course for the trucks. The boundary data are derived by using a light vehicle fitted with a high precision GNSS. The light vehicle is driven around each boundary perimeter so that the coordinate data can be collected and then transmitted to a central computer. The travel course data are derived by manually driving the autonomous dump truck along the required course at the required speed so as to allow the onboard computer to record the course data.

Benefits

The principal benefit of this innovation is labour savings, but the technology also has the potential to:

- improve mine safety by reducing accidents, particularly those caused by human error;
- improve mine productivity by reducing haul truck travel cycle times (that is, the time taken, once loaded to travel to the dumping area and dump the loaded product and then return to the loading area);
- enable the trucks to dump material with a high degree of precision to a pre-determined dump pattern as demonstrated by tight, regular rows of dumps; and
- allow for reductions in maintenance costs (Hughes, 2002).
- lead to greater operational efficiencies, lower production costs and more attractive working conditions (Rio Tinto, 2008).

A number of small scale and large scale trials of the technology are currently underway. In 2007, Codelco, a copper mining company operating in Chile introduced autonomous haul truck technology on an industrial scale at its Gabriela Mistral mine project (Codelco, 2007). The introduction of autonomous trucks has enabled the company to reduce its truck fleet after it was found that the autonomous trucks could be worked for more hours per day than manually operated trucks. Further, the autonomous trucks are expected to deliver savings in fuel costs and maintenance and repair costs (International Mining, 2008).

Successful trials of the technology and the continued efforts of GNSS equipment manufacturers in this area indicate that the technology will very likely be adopted by Australian mining companies in the near future. Rio Tinto has recently made public its desires to implement autonomous haul truck and other GNSS-based technology at its iron ore operations in Western Australia (Box 3.2).

Box 3.2

RIO TINTO'S PLANS FOR 'MINE OF THE FUTURE'

In January 2008, Rio Tinto announced its plans for the automation of its mine to port iron ore operations in the Pilbara region of Western Australia. The package of automation measures that the company plans to introduce includes a driverless truck fleet.

Rio Tinto plans to commission the Komatsu Autonomous Haulage System sometime in 2008. The system will allow for a fleet of off-highway trucks to be operated without drivers. By 2010, Rio Tinto expects that the autonomous driving technology will be widely deployed across the company's mining operations.

Other aspects of automation that are being planned by the company include:

- mine operations in the Pilbara to be controlled at a Remote Operations Centre situated in Perth, 13 000 kilometres away from the mine site;
- driverless trains to carry iron ore to port on a large portion of the company's 1 200 kilometres of track; and
- remote control 'intelligent' drills.

Rio Tinto aims to be the leader in integrated and automated mining and transport in the Pilbara iron ore.

A significant component of the company's automation plans is the formation of an alliance with Komatsu to develop and deploy haulage and mining solutions using autonomous technologies.

Source: Rio Tinto 2008 and International Mining, 2008.

In 2000, Rio Tinto, Komatsu and Modular Mining Systems conducted an autonomous haul truck development project at the Tarong coal mining operations in Queensland. The project sought to demonstrate the operation of autonomous haul trucks and assess their operational performance and the impacts on current mine practices. Productivity testing found that the autonomous haul trucks were able to complete typical transport cycle routes 10 and 20 per cent faster than manually operated trucks. Dumping patterns were also improved and precision dumping in accordance with a pre-determined dump pattern was achieved. A risk management study associated with the development project found that substantial risk reduction was possible through the application of autonomous haulage (Hughes, 2002).

3.4 Limits to further industry uptake

To date the pattern of adoption of precision GNSS in the mining sector has been for individual operations to purchase and install their own private network. The private uptake of precision GNSS technology has led to situations where two adjacent mines, owned by the same company, have incompatible precise positioning reference stations and networks (Lorimer, 2008).

Consultations with industry suggest that incompatibility of GNSS technology used at different mining operations may be constraining the rate at which new applications of the technology are being developed and adopted. The existence of a national precision GNSS network would foster greater compatibility of the technologies used by mining operations and this would assist suppliers of GNSS equipment to design and market more standardised applications that can be marketed to industry. Service providers, such as maintenance contractors, surveyors and transport operators, would also more easily be able to provide services to a range of different mine sites if all sites were operating with compatible precision GNSS systems.

Chapter 4

Precision GNSS in construction

4.1 Introduction

The civil engineering and construction industry includes the building of roads, highways, rail, bridges, harbours and water and electricity infrastructure. There are numerous existing and potential applications of GNSS technology in this sector. The majority of major construction projects now utilise precision guidance in site surveying and earthmoving.

In regard to earthmoving, adoption rates of machine control systems are steadily increasing and information obtained from suppliers of precision GNSS equipment indicates that the growth in sales of machine control systems in construction are among the highest of any precision product line. To date, the majority of users of precision technology in construction have used their own on-site base stations to get accurate GNSS coordinates (Lorimer, 2008).

Site surveyors have widely embraced GNSS technology and most surveying firms engaged on large civil construction projects now use GNSS for determining positions in the field.

4.2 Site surveying

Using conventional surveying methods to determine the initial coordinates for a construction site plan usually requires that a team of surveyors be on-site for a number of days so that they can locate and mark (usually by pegging) critical points. Even relatively small construction projects require a team of surveyors to be on-site for one to three days. The surveying tasks include locating groundmarks; running a number of manual calculations; setting up a series of control or reference points; site pegging and continued re-checking.

Precision GNSS technology allows surveyors to determine critical coordinates instantly without the need for calculations and with a very high degree of accuracy. The high accuracy obtained from the use of precision GNSS means fewer mistakes are made and checking processes can be performed quickly and easily. Importantly, the accuracy and reliability obtained by precision GNSS means that less site re-work is required thus benefiting both surveyors and construction parties relying on the survey information. The use of precision GNSS allows for surveying to be undertaken on an ongoing basis in accordance with the needs of the project so that surveyors can work in conjunction with earthmoving and other vehicle operators delivering overall efficiencies in project management.

GNSS has revolutionised many surveying tasks, to the extent that survey teams on large projects, for example the construction of freeways and pipelines, now use the technology as a matter of course. The technology is also used by larger land survey companies on smaller projects, such as the construction of communications towers.

Precision GNSS technology is not applicable to all positioning tasks in land surveying as some projects require a high degree of accuracy in the vertical dimension, which precision GNSS cannot, as yet, deliver. In addition, many smaller surveying jobs are still best served using traditional surveying techniques.

Benefits

Precision GNSS technology, as applied to land surveying, results in significant benefits in terms of time and labour savings. These benefits, and others, are outlined in Table 4.1.

Table 4.1

BENEFITS OF PRECISION GNSS IN LAND SURVEYING

Benefit	Details
Time savings	• Negates the need to set up control points when starting a new project – 0.5-1 day saved per project • Reduces time spent doing manual calculations • Reduces time spent in the office – from 40% to around 10% per project • Time savings of up to 75% for large projects and 60% for small projects are possible
Labour savings	• Reduces the number of surveyors required for a project – from 50 to about 10 for large projects • Allows for the use of non-survey staff to do simple mapping tasks that would otherwise require a qualified surveyor
Safety improvements	• Reduces the need for traffic disruptions, such as lane closures, and associated risk to survey and road workers
Infrastructure savings	• Reduces the need for maintenance of ground marks

Source: Allen Consulting Group consultations and information from Trimble's website: http://www.trimble-productivity.com/features/index.cfm

Consultations undertaken by the Allen Consulting Group found that fees charged by field surveying companies are approximately 50 per cent lower for large projects and 20 per cent lower for smaller (2-3 day) projects when precision GNSS technology is used.

Surveying for the construction of Melbourne's EastLink expressway was recently completed using precision GNSS. The use of GNSS enabled the survey work to be done with 10 to 12 fewer surveyors than would be required were a traditional approach to surveying undertaken. The technology was found to enable on-site surveyors to be more productive than they otherwise would have been (Landmark, 2006).

4.3 Earthmoving applications

The application of machine guidance technology to earthmoving machinery has been one of the biggest growth areas for precision GNSS equipment. Precision GNSS technology allows for site plans to be programmed into earthmoving equipment, such as bulldozers, excavators and graders. The earthmoving equipment can then be controlled to conform to the site plan via the use of continuously updated GNSS positioning information. The earthmoving machines still require a driver, but the driver is assisted by an on-screen site plan and accurate positioning information.

Conventional earthmoving involves a significant amount of rework, or machine passes, to provide an accurate finish. In addition, conventional methods require surveyors to be continually on site to stake out routes. Precision GNSS technology, however, significantly reduces the amount of rework and in some cases completely negates the need for surveyors to stake out routes. As a result of such benefits, machine guidance technology is used on most major construction projects throughout Australia including the EastLink expressway (Box 4.1).

Precision GNSS technology is not applicable to all earthmoving projects as some projects may not require the accuracy or may be too small to warrant use of machine guidance.

Box 4.1

MACHINE GUIDANCE AND THE EASTLINK EXPRESSWAY

Key earthmoving machines used for the construction of the EastLink expressway were fitted with precision GNSS receivers that enabled each machine to accurately compute its position in real time. Onboard computers fitted to the machines used location and programmed information on the site plans to determine the correct tracking and alignment for the machine and this could all be done while the machine was in use.

The GNSS technology enabled new sections of work to be loaded on to onboard computers within seconds and all relevant data was readily provided to the machine operator on an onboard display. Machine operators were then able to operate machines manually using the continually updated data or machines could be set to operate on a predominantly automatic mode with oversight provided by the operator.

The use of the technology resulted in large savings in time; improvements in efficiencies and increased accuracy of the constructed works. Once earthmoving applications are completed, detailed work files are stored for future use such as in instances where modifications to the infrastructure are required. The accuracy and ease of access of the completed work files assists in asset modification and also regular maintenance and servicing tasks.

Source: Landmark 2006, *The Official Magazine of Victoria's Spatial Information Industry*, Issue 25, March.

Benefits

Precision GNSS technology, as applied to construction earthmoving, results in significant benefits. These benefits are outlined in Table 4.2.

Table 4.2
BENEFITS OF PRECISION GNSS – EARTHMOVING IN CONSTRUCTION

Benefit	Details
Time savings	• Reduces project time significantly – savings of between 30 and 80% are possible • Negates the need for surveyors to physically stake out routes • Negates the need to navigate machines around stakes and pegs • Reduces the frequency with which dirt is moved around a site by up to 60% • Reduces the time spent conducting as-built surveys
Capital savings	• Productivity of bulldozers, excavators and graders is significantly increased • Reduces the amount of re-work by up to 70% • Reduced need for support machines • Reduced downtime
Labour savings	• Fewer workers are required for a project
Safety improvements	• Reduces the number of workers on a site and in close proximity to machines, particularly workers with grade stakes and string lines
Quality improvements	• Work is generally more accurate – e.g. grader trimming

Source: Allen Consulting Group consultations and information from Trimble's website: http://www.trimble-productivity.com/features/index.cfm

4.4 Limits to further industry uptake

To date, the adoption of precision GNSS technology by land surveyors has been high. Most land surveyors now own GNSS equipment, and this is particularly the case with larger surveying companies. However, such equipment is not used on all projects as precision GNSS networks are often not available and the establishment of a temporary network using private base stations is not always viable, particularly for smaller projects. Therefore, in the absence of a national network, uptake is likely to be limited in rural and regional areas. And for smaller projects, investment in a temporary network to cover the construction is unlikely to be economically feasible.

The adoption trends for machine guidance are similar, although rates of uptake have not been as high as those in land surveying. Machine guidance is now used on most large infrastructure projects, such as roads, freeways and pipelines. However, many smaller projects do not require the same level of accuracy and may not involve the scale required to justify the extra costs of setting up a dedicated network. Thus, the existence of a standardised national network would be of great value for these types of projects and those located in rural and regional areas.

Chapter 5

The use of GNSS technology to map assets

5.1 Introduction

Another application of GNSS technology is its capability to accurately locate and map infrastructure assets such as pipelines, stormwater drains and underground cables. This capability is particularly useful for organisations that manage large networks of infrastructure assets such as local government councils and utility companies. The technology can be used to provide asset location coordinates at high accuracy. Conventional asset mapping methods typically rely on 'relative positioning' — that is, the position of assets are identified relative to the position of landmarks such as a nearby fence or street corner.

Asset mapping has an established technology base and is commercially available, although uptake to date in Australia has been relatively limited due to the lack of a cost-effective means for councils and public works departments to access reliable GNSS signals for their region. There are, however, several notable exceptions. Two case studies detailing the use of precise positioning GNSS infrastructure for asset mapping in Australia are detailed below. A third case study details the use of the technology in Alaska.

Energex

The Queensland energy distribution organisation, Energex has recently upgraded its systems to allow for high precision asset mapping (Box 5.1).

Box 5.1

ASSET MAPPING AT ENERGEX

The Energex asset mapping system uses precision GNSS technology to accurately identify and map the location of the company's assets — including, about 50 000 kilometres of overhead and underground powerlines and cables, 43 000 distribution transformers and 600 000 electricity poles. The technology also allows the company to plot the locations of its customers on electronic maps.

Energex uses its mapping system to aid its response to problems encountered during extreme storm activity. When storms occur, Energex is able to identify where the likely problems will be and can the dispatch the right people to the correct location in less time than otherwise would be required.

The technology also assists the company in expanding its infrastructure base to new population centres as highly accurate maps can be generated to indicate exactly where new assets should be placed.

The locations of company's fleet of service vehicles (of about 800 in total) can also be continually monitored so that the best crews can be identified to perform work in certain areas. The technology also enables the company to identify areas of priority for maintenance and management. For example, the company spends about $80 million per year on vegetation management such as trimming trees that are encroaching on power lines. The company's asset mapping systems will enable it to determine where exactly it needs to direct its efforts rather than requiring all assets be continually monitored. Energex has indicated that cost savings in the order of 10 per cent are achievable as a result of the use of GNSS technology to undertake its asset mapping.

Source: P. Smith 2008, 'Mapping Programs are Going Places', *The Australian Financial Review*, 15 July, p. 35.

City of Greater Dandenong Council

The City of Greater Dandenong Council recently used precision GNSS technology to collect and record data on stormwater assets within its boundaries. Precision GNSS allowed for the storm water assets (predominantly storm water pits and the pipes that service the pits) to be accurately recorded in terms of horizontal and vertical accuracy (see Box 5.2).

Box 5.2

CITY OF GREATER DANDENONG COUNCIL

The Council is responsible for an 800 kilometre network of covered stormwater drains, over 28 000 drainage pits and 80 kilometres of open drains. The total replacement cost of the drainage network is estimated at about $120 million. The Council undertook its GNSS mapping project because it needed an accurate database containing details of its drainage and stormwater assets. Existing documentation of the assets held prior to the completion of the project were based on design drawings and therefore did not capture any modifications that had been made during construction nor any minor changes made to the network over time. Having information in its database that did not accurately reflect the assets held by the Council had created confusion and miscommunication.

Having an accurate database allows the Council to improve its drainage management plan. It also enables the Council to undertake a better assessment of asset conditions and ensure that asset valuation is done accurately.

The Council relied on the MelbPos precision GNSS network to undertake the majority of the project work. It is estimated that the existence of the MelbPos network allowed the City of Greater Dandenong to complete the project at a cost of about 40 per cent less than would be required in the absence of the network. Without precision GNSS technology at all, the costs involved in undertaking such a project would be prohibitive.

Source: Landmark, 2006 and Dandenong Council

Anchorage Water and Wastewater Utility

Similarly, the Anchorage Water and Wastewater Utility has found significant value in having its assets precisely mapped (Box 5.3).

Box 5.3

ANCHORAGE WATER AND WASTEWATER UTILITY

Anchorage Water and Wastewater Utility is the largest water and wastewater utility in Alaska and has long been an early adopter of GNSS technology. Since the early 1990s, the Utility has implemented Geographic Information Systems to digitise hardcopy maps of service areas and assets. Despite the use of this technology, the spatial information that the Utility had available inaccurate and difficult to use. The original hardcopy maps that were used by the Utility were 500 scale maps and as such the Utility found that the location of water and sewer assets were off by as much as 500 feet.

Given that many of the company's assets are buried in snow for much of the year, the inaccuracies of the company's systems made it very difficult for the company's workers to locate assets to conduct repair and maintenance work. The company has now adopted precision GNSS technology to accurately map its assets.

The information available will increase the efficiency of field crews in locating assets (particularly in winter when many assets are covered in snow) and help to reduce emergency response times. Having knowledge of the precise location of assets will also ensure that the Utility is better prepared to respond to emergency situations such as natural disasters.

Source: Trimble website customer story 2007, Anchorage Water and Wastewater Utility Asset Mapping Project, http://trl.trimble.com/docushare/dsweb/Get/Document-390382/022501-130_AWWU_CS_MGIS_0907_LR.pdf, Accessed 13 August 2008.

Benefits

The benefits of using GNSS to facilitate asset mapping can be grouped into two broad categories:

- *Labour savings associated with undertaking the mapping task* — the technology allows for the mapping of assets to be conducted more quickly and cheaply than would otherwise be the case. Without precision GNSS technology many asset mapping programs are prohibitively costly and may not be properly carried out or may not be carried out at all. GNSS technology is an enabler of large-scale, multi-suburb, precision asset mapping projects.
- *Benefits arising as a result of having better, more accurate information on where assets are located and their condition*. The benefits under this category include savings in asset maintenance operating costs and improved asset performance. For example:
  - Savings in costs and time in locating assets — once accurately mapped, assets can be quickly and easily located and this assists in maintenance and replacement tasks but also importantly can assist in cases of emergency where assets have to be reached as quickly as possible.
  - Reduced incidence of damage to assets — having awareness of precise asset locations can reduce the incidence of accidental damage to underground assets that often happens during digging for construction and other projects.
  - Improved asset maintenance — asset maintenance and management plans can be designed and carried out with greater effectiveness particularly if the asset mapping exercise identifies assets that previously had not been recorded. With better knowledge about the location and status of individual assets, maintenance schedules can be deployed more efficiently on a 'just in time' basis as opposed to undertaking maintenance before it is really needed.
  - Improved asset performance — asset mapping allows for the modelling and analysis of asset performance under different conditions, for example, the performance of stormwater assets during extreme weather events.
  - More accurate asset valuation — allows target rates of return on assets to be set with the accurate knowledge of assets held.

5.2 Limits to further industry uptake

Information obtained from consultations indicated that, with some exceptions, local governments and utility companies are at the very early stages of adoption with regard to the application of precision GNSS technology to asset mapping.

For local governments, the costs involved in establishing a wide network of base stations are in many cases prohibitive. Information provided by stakeholders to this study indicated that many local governments would not adopt precision GNSS technology for asset mapping unless a network of base stations was provided by a third party. It would therefore seem that a service such as standardised national network would increase the uptake of GNSS, depending on the cost to councils of accessing the service.

For utility companies with greater financial resources than local government, the constraints to adopting the technology are not as great, and the positive value experienced by early adopters such as Energex should soon lead other major utilities to investigate the technology. The installation of a standardised national network would accelerate the rate of adoption in the utility sector, particularly for those utilities with assets spread over a wide operational area.

Part 2

Economic modelling

Chapter 6

Methodology

6.1 Overview of approach

The current and potential, future economic benefits of GNSS in each of the three sectors reviewed in Part 1 (agriculture, mining and construction) were modelled using the following steps[2]:

- Existing levels of adoption and productivity improvements experienced in each sector as a result of GNSS were identified, based on the case study findings and available literature;
- The economic value of these productivity 'shocks', in terms of dollar changes in GDP, were modelled using the Monash Multi-Regional Forecasting (MMRF) model — a generalised equilibrium model of the national economy.
- Future benefits from the technology were modelled by making judicious assumptions about the rate and maximum extent of future adoption of various GNSS applications in each sector, and the likely range of productivity gains that could be achieved by firms adopting the technology.
- Conservative and optimistic productivity gains were specified for each sector, representing the likely range of possible outcomes.
- A twenty-year timeframe was used for the analysis. Future benefits were measured relative to a 2008 baseline. That is, the benefits already being experienced to date from the technology were netted off the calculation of future benefits.
- The stream of future benefits was discounted to a net present value using a discount rate of seven per cent, consistent with advice provided by the Productivity Commission to the Commonwealth Office of Best Practice Regulation (Harrison, 2007).
- Two future adoption scenarios were modelled for each sector. One scenario involved an assessment of industry uptake in a situation where a standardised national network is rolled out across Australia. The other scenario examined the (smaller) benefits that may ensue under a 'base case' in which future growth in GNSS technology is not underpinned by a national rollout of a standardised network. Under this scenario, adoption of precision technologies was assumed to continue to grow – facilitated by 'organic growth' of private area networks — but at a slower rate than what could be achieved with a national rollout of a standardised network.
- The difference in benefits calculated for these two scenarios represents the incremental or additional benefit attributable to a national rollout of a standardised network, before considering the possible cost differentials between the two scenarios.

2 The benefits of precise positioning GNSS technology in other industry sectors including the consumer handheld market were not modelled.

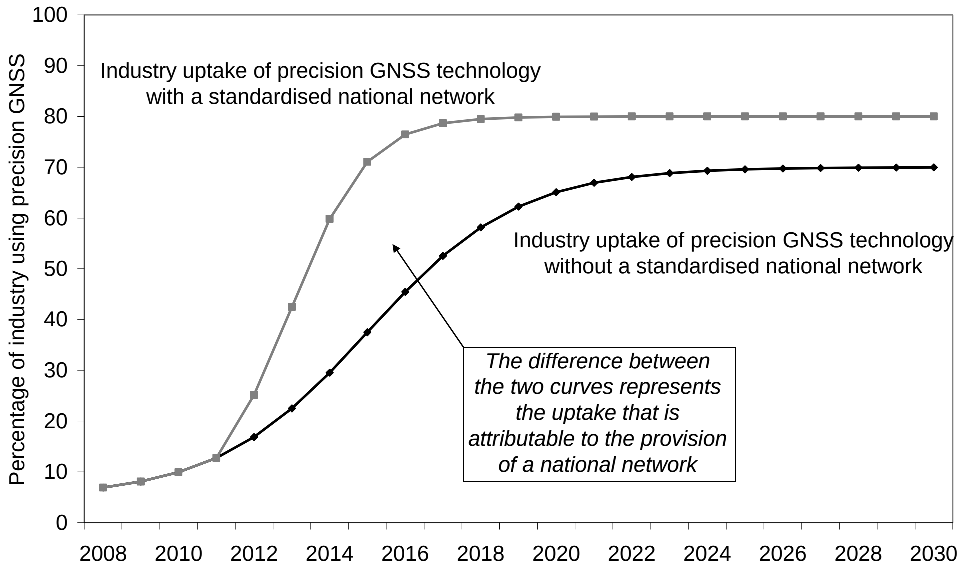
- Based on advice from our consultations, we made the assumption that the unit (per firm) productivity gains experienced under the national rollout scenario are identical to those that could be achieved using a private network.

6.2 Conceptual adoption model

Assumptions on industry uptake were incorporated into the analysis using a sigmoid function to describe adoption rates and levels through time. The sigmoid function (commonly referred to as an 'S' curve) is often used to characterise the uptake of new technology. A graphical example of an 'S' curve adoption profile is provided in Figure 6.1 below.

Figure 6.1

CONCEPTUAL ADOPTION MODEL FOR PRECISION GNSS



The rate of increase of adoption of a new technology is most often slow in the early years following its release and confined mainly to a small group of industry innovators. Rates of increase in adoption start to increase after a number of years as knowledge of the new technology spreads. Over this period, technological applications are often refined and costs fall and this also helps increase the rate of adoption. Following this period there is some slow down in the rate of adoption as the last sections of the market adopt the technology and then market saturation is reached. For some technologies, disadoption may occur if the technology becomes superseded by other new innovations. In this study, however, no disadoption is assumed to occur over the 20 year timeframe for the analysis.

The conceptual adoption model depicted in Figure 6.1 is based on several generic assumptions that were applied to all sectors:

- A standardised national network could be established and operational in major regional centres by 2012.

- From 2012 onwards, there are two adoption curves – one for each adoption scenario. The lower curve represents an 'organic growth' adoption profile in the absence of a standardised national network. The upper curve represents the adoption profile given the existence of a standardised national network. The gap between the two curves is a measure of the additional uptake attributable to the national rollout.
- A standardised national network was assumed to result in an *accelerated rate* of adoption and a *higher maximum level* of adoption due to the technology being made more widely available to users in regional areas and at lower cost, due to the economies of scale that could be achieved. Advice received from our consultations also suggested that a standardised national network would result in improved coordination and technical standards, thus promoting the development of applications that could be used anywhere in Australia (unlike the current situation whereby there is seldom full compatibility across different networks). This would further enhance future uptake.

6.3 Productivity and adoption assumptions

Table 6.1 sets out the productivity gains and current and future adoption levels assumed in the analysis.

Estimates of productivity gains and technology uptake were made in consultation with 24 industry experts – including GNSS equipment suppliers, end-users in each industry and researchers involved in trialling the technology. The study also drew on existing literature and reviews of precision guidance and automation.

Details underpinning these estimates are provided in Appendix B.

Table 6.1
PRODUCTIVITY AND ADOPTION ASSUMPTIONS

	Unit productivity gain		Adoption		
	Conservative	Optimistic	2008 level	Maximum with a standardised national network at 2030	Maximum without a standardised national network at 2030
Agriculture					
Controlled traffic farming and inter-row sowing	25%	35%	5% of cropped land	80%	70%
Mining					
Accurate selective mining	5%	10%	15% of mine sites	80%	65%
Autonomous haul trucks	10%	20%	0%	60%	50%
Construction					
Precision site survey[A]	0.4%	0.6%	60% of projects	90%	72%
Earthmoving machine guidance[A]	1.3%	2.6%	15%	60%	40%

[A]Productivity gains for site survey and machine guidance are expressed as effective gains to the construction sector, based on the assumption that site survey and earthmoving comprise 2 per cent and 13 per cent, respectively, of the cost of a typical construction project.

6.4 Determining industry-wide productivity gains

The industry-wide productivity gain in each year of the period 2008 to 2030 was calculated by multiplying the unit productivity gain by the proportion of the industry sector adopting the technology. This industry-wide figure was used to 'shock' the MMRF model.

This calculation was made for both adoption scenarios — the 'with standardised national network' scenario and the 'with out' scenario. A worked example is contained in Appendix B.

6.5 Asset mapping — a different analytical approach

Using GNSS to assist with the task of asset mapping has the potential to benefit the utilities sector and the public works sector — including local, state and federal government capital works. The modelling of economic benefits resulting from cost savings and improved asset performance were undertaken outside the MMRF framework, as these benefits accrue to multiple sectors – not all of which are adequately represented in the Monash model.

An alternative method was used to estimate the approximate magnitude of gross savings on operating and capital costs associated with utility services and public works:

- We examined the aggregate operating costs of local governments ($8.7 billion per annum), based on Australian Bureau of Statistics figures, and assumed that precision asset mapping could generate a cost saving of between 5 and 10 per cent.
- We also examined the aggregate capital expenditures of local governments in Australia ($213 billion) and assumed that precision asset mapping could reduce capital investment requirements by between 5 to 10 per cent due to more efficient asset maintenance.
- For the utilities sector, aggregate capital expenditures are estimated by the Australian Bureau of Statistics to be $15 billion per annum. It was assumed that, again, asset mapping could reduce this expenditure by 5 to 10 per cent.

The cost savings of 5 to 10 per cent were based on information obtained from Energex, which indicated that this utility company has been able to achieve cost savings in the order of 10 per cent since adopting GNSS for performing asset mapping (see Box 5.1).

Chapter 7

Modelling results

7.1 Current benefits being generated by GNSS

Precision GNSS technology is already being used to some extent in the agricultural, mining and construction industries. The gross benefit flowing from existing uptake is estimated to range between $829 million and $1486 million per annum, depending on the size of productivity gains assumed (Table 7.1). This represents a contribution to national GDP of between 0.08 per cent and 0.14 per cent.

Of this total benefit, applications of GNSS in open cut mining are estimated to be delivering between $371 million and $744 million annually. Benefits to the mining sector are considerably greater than those generated by agriculture, and slightly higher than construction. This is principally because mining contributes more to GDP than each of the other sectors ($38 billion per annum as opposed to $5.4 billion for agricultural grains and $23 billion for construction). Thus productivity gains in this sector produce a proportionally greater impact on the national economy.

Current levels of uptake of precision GNSS technology in the broadacre cropping sector is estimated to be delivering an annual benefit of between $152 million and $206 million. The current benefits being experienced by the construction sector are more than twice this amount, at between $306 million to $535 million.

Table 7.1

CURRENT AND FUTURE BENEFITS DUE TO PRECISION GNSS

Sector	2008 $ million	At 2030 with a standardised national network ($ million, 2008 values)
Agriculture	152 – 206	1005 - 1357
Mining	371 – 744	4614 - 9347
Construction	306 – 535	1057 - 1897
All sectors	829 - 1486	6675 - 12636

Note: The 'all sector' total does not equate to the sum of individual sector benefits because interaction effects in the economy are accounted for when productivity gains to all sectors are modelled simultaneously as opposed to being modelled individually. A discount rate of 7 per cent was used to convert 2030 values into today's dollars.

The main reasons for the relatively high benefits in the construction sector are that:

- even relatively small improvements in productivity in construction generate significant positive benefits for the economy because the non-residential construction sector is four times the size of the agricultural cropping industry;
- it has strong linkages with a large number of industries in the Australian economy; and

- in the long run, a positive shock to the construction industry generates significant benefits for the economy as nearly all other industries benefit from having physical capital or infrastructure provided at a lower cost.

A more productive construction sector can also produce more physical capital or infrastructure than would otherwise be the case and this helps the industry deliver significant economic benefits across the economy.

The broadacre cropping industry, being predominantly export-oriented, does not have the linkages to the rest of the economy as construction does and it is also significantly smaller than the construction and mining industries. The large potential benefits of adoption of precision GNSS in the cropping industry do not flow through to benefits for the rest of the economy to the extent that occurs in the construction industry.

7.2 Future benefits as at 2030

The study found that when applied to the agriculture, mining and construction industries, precise positioning technology has strong prospects to produce considerable future benefits. Based on a scenario whereby standardised precision GNSS technology is rolled out across Australia, the technology is estimated to increase Australia's GDP by between $6.7 billion and $12.6 billion in today's dollars by 2030 (Table 7.1). This equates to a percentage increase in GDP of between 0.9 and 1.7 per cent.

7.3 Cumulative benefits

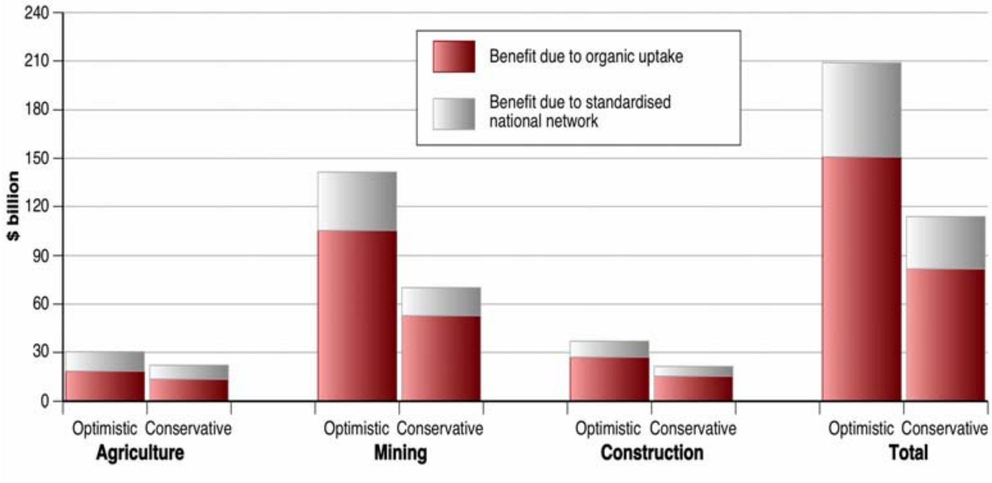
For the three industry sectors considered in this study, GNSS is estimated to generate between $73 billion and $134 billion, net present value (gross) over the next twenty years, depending on the assumed size of productivity gain (Figure 7.1). This is a lump sum figure.

Additional benefits of between $32 billion and $58 billion (gross) could be generated with the national rollout of a standardised network — as a result of the assumption that this would speed up adoption rates and in some cases increase the ultimate level of adoption.

The total benefits are estimated to be between $105 billion and $192 billion. Based on the assumptions used in the analysis, about one quarter of the value of this total benefit is estimated to be attributable to the standardised national network.

Figure 7.1

PRESENT VALUE OF FUTURE PRODUCTIIVITY GAINS — 2009-2030



Agriculture

'Organic' uptake of precision GNSS technology in the broad acre cropping sector is estimated to deliver (in lump sum, net present value terms) $12 billion to $16 billion in benefits for the Australian economy over the 2009 to 2030 period. A national rollout of a standardised network would generate *an additional* $9 billion to $12 billion in benefits for the Australian economy.

The estimate for the 'organic growth' scenario is approximately 30 times greater than the benefit estimate made by the Allen Consulting Group in its 2007 study of the benefits of GPSnet to Victorian agriculture. There are several reasons for this large difference:

- the 2007 study was confined to agricultural crops in Victoria;
- the study only quantified 'first order' or direct benefits to Victorian farmers — not the downstream and upstream benefits to industry suppliers and processors etc.; and
- the study did not incorporate the benefits of inter-row sowing, as the focus was on controlled traffic farming.

Mining

'Organic' uptake of precision GNSS technology in the open cut mining sector is estimated to deliver (in present value terms) $49 to $97 billion in benefits for the Australian economy over the 2009 to 2030 period. Based on assumptions underpinning the analysis, a national rollout of a standardised network would generate *an additional* $17 to $36 billion in benefits.

Construction

Under the 'organic growth' scenario, the deployment of precision GNSS technology in the construction sector is estimated to deliver $12 billion to $21 billion in net present value for the Australian economy over the next twenty years. A national rollout of a standardised network would generate an *additional* $6 to $10 billion in gross benefits.

Asset mapping

Based on our consultations with a number of utilities and councils that are currently using GNSS to map their assets, it is evident that cost savings ranging between five and ten per cent are being achieved on operating and capital costs. An indicative value of this aggregate benefit at a national level, assuming GNSS was taken up by all utilities and councils, is presented in Table 7.2. Annual operating cost savings of $0.9 billion could be realised and up to $2.3 billion in capital costs could be saved by having better inventories of asset location and condition.[3]

Table 7.2
POTENTIAL SAVINGS DUE TO PRECISION ASSET MAPPING

	Operating cost savings[1] $ million pa	Capital cost savings[1] $ million pa
Local governments	435 to 870	405 to 810m
Utilities	Not estimated	750 to 1500m
Total	***435 to 870***	***1155 to 2310***

[1] Assuming asset mapping delivers savings of 5 to 10 per cent in operating and capital costs.

7.4 Conclusion

The findings of this study indicate that precision GNSS technology has strong prospects to produce considerable benefits. Based on our consultations and research, future levels of uptake of this technology and the ensuing productivity gains in three sectors (agriculture, mining and construction) are estimated to increase Australia's GDP by between 0.9 and 1.7 by 2030.

A national rollout of a standardised network would deliver additional benefits by promoting greater and faster uptake of the technology, plus stimulating additional investment in the development of new applications. Our modelling found that with the establishment of a standardised national network total benefits of the technology could lead to a 1.1 to 2.1 per cent increase in national GDP by 2030.

These results are not intended to represent a comprehensive estimate of the benefits of precision GNSS, rather they provide a conservative estimate of the potential benefits to Australia's economy based on the case studies outlined in this report. In addition, these benefits need to be weighed up against the cost of building a network, operating the service, and any associated research and development costs.

[3] The second-order benefits that may be obtained as a result of the use of precision GNSS infrastructure use in asset mapping have not been modelled.

Analysis of network development and operation costs is beyond the scope of this study.

In broad terms, the results of this study are consistent with those of other studies that have quantified the potential benefits of innovations in technology and work practices. In the late 1990s and early 2000s, a number of studies were conducted to determine the economic benefits of increased use of information technology, the internet and e-commerce. These studies found that the benefits of such technologies and business practices were significant and of a similar, if not larger, scale to the benefits of precision GNSS technology as determined in this study.

- In 2000, the National Office for the Information Economy in 2000 studied the economic benefits of e-commerce in Australia and concluded that e-commerce had the potential to increase Australia's GDP by 2.7 per cent per year over the 10-year study period (National Office for the Information Economy, 2000).
- A 2002 study on the economic benefits of the information economy found that increased participation in the information economy[4] would increase Australia's real GDP by up to 2.6 per cent (Allen Consulting Group, 2002).
- A study prepared by the International Monetary Fund found that the rise of internet retailers and e-commerce generally had the potential to increase GDP in developed countries by up to 5 per cent (International Monetary Fund, 1999).

[4] The specific benefits modeled included 'business to business' benefits such as efficiency improvements and improved supply chain management; and 'business to customer' benefits such as better service offerings and lower prices resulting from internet and information technology use by businesses.

Appendix A

People consulted in the preparation of this report

The Allen Consulting Group thanks the following people who contributed their time and knowledge to assist this project.

Table B.1

PERSONS CONSULTED IN THE PREPARATION OF THIS REPORT

Name	Organisation
Andrew Jarosz	Curtin University of Technology
Andrew Whitlock	Victorian Department of Primary Industries
Brent Stafford	Navteq
Brett Whelan	Australian Centre for Precision Agriculture
Chris Seymour	Auto Positioning Systems
Colin Macintosh	Auspat Land Surveys Australia
Del Rains	Thiess
Don Yule	CTF Solutions
Ian McLachlan	Barwon Water
Ken Adams	VicRoads
Lance Wallace	TruEnergy
Luke O'Neil	CAT
Mark Judd	Geomatic Technologies
Martin Nix	Leica Geosystems
Martin Wong	Greater Dandenong City Council
Matthew McCallum	McCallum Agribusiness Consulting
Neil Other	Topcon Positioning Systems
Paul Andrews	Ultimate Positioning
Rick Whitworth	City of Greater Geelong
Rob Lorimer	Position One Consulting
Sean Taylor	Komatsu Australia
Scott Hade	VicRoads
Shane Jackson	Connell Wagner
Troy Jensen	Queensland Department of Primary Industries

Appendix B

Technical appendix

B.1 The MMRF model

The economic value of productivity gains were modelled using a computable generalised equilibrium (CGE) model. The Centre of Policy Studies at Monash University was engaged to estimate changes in GDP for each sector, using the Monash Multi–Regional Forecasting (MMRF) model. MMRF is a multi-sectoral, multi-regional dynamic model of the Australian economy. Each State and Territory is modelled as a mini-economy and within each State and Territory are 53 industry groupings.

Each region is modelled as an economy in its own right, with region-specific prices, region-specific consumers and region-specific industries. Since MMRF is dynamic, it is able to produce sequences of annual solutions connected by dynamic relationships. MMRF is ideally suited to determining the impact of region or industry-specific economic shocks. In this instance, the model is used to determine the impact of industry-specific economic shocks.

In this study, MMRF was used to produce estimates of the ‘first round’ economic benefits to firms as a result of assumed cost savings and/or higher output levels. It also captured the second round benefits accruing to upstream and downstream industries, which were incorporated into the GDP changes.

The modelling approach was to determine the economic benefits that could be derived from the use of precision GNSS in each industry — agriculture, mining and construction — in isolation. Modelling was also used to determine the aggregate economic benefits that could be derived from the use of precision GNSS in all three industries.

A total of 16 model runs were conducted by the Centre of Policy Studies. This comprised four runs for each of the three sectors and another three runs for all sectors combined. The runs are outlined in table B1.

Table B.1

MODELLING RUNS

Adoption scenario	Optimistic productivity gain	Conservative productivity gain
Agriculture		
With rollout of a standardised national network	Run 1	3
Without rollout of a standardised national network	2	4
Construction		
With rollout of a standardised national network	5	7
Without rollout of a standardised national network	6	8
Mining		
With rollout of a standardised national network	9	11
Without rollout of a standardised national network	10	12
All sectors combined		
With rollout of a standardised national network	13	15
Without rollout of a standardised national network	14	Run 16

B.2 Sectors 'shocked' in the MMRF model

Benefits to the agricultural sector were assumed to be confined to the broadacre cropping industry. Thus, productivity shocks were applied to the MMRF 'grains' industry.

In the case of mining, adoption of precision GNSS technology such as accurate selective mining and autonomous haul trucks is applicable only to open cut mining operations (and not underground mines). This was modelled by applying the productivity shocks to proportions of the MMRF 'coal' and 'metal ores' industries that use open cut mining techniques.[5]

[5] Approximately 75 per cent of Australia's coal industry uses open cut mining operations (see Australian Coal Association, Australian Coal Industry Overview, http://www.australiancoal.com.au/overview.htm) and we assume that for other minerals, the proportions mined using open cut techniques is also 75 per cent.

For the construction sector, the productivity shocks were applied to the MMRF ‘other construction industry’ category. This includes non-residential construction such as that for roads, highways, rail, bridges, harbours and water and electricity infrastructure.

B.3 Current share of GDP attributable to each industry sector

The respective sizes of the industries used to model the economic benefits are detailed in Table B2. The largest industry, as measured by valued added is the coal and metal ores industry, while the smallest is the agricultural grains industry.

Table B.2

MMRF INDUSTRY VALUE ADDED (2005)

MMRF industry	Industry value added ($b)
Agricultural grains	5.4
Coal and metal ores	38.1
Other construction	23.2

Source: Centre of Policy Studies.

B.4 Derivation of industry-wide productivity gain — worked example

A worked example of the method used to determine the industry-wide productivity shock for a hypothetical industry is demonstrated Table B1. The assumptions underpinning the worked example are that the per firm productivity benefit available to adopters of precision GNSS technology is 10 per cent and that rates of adoption are as per those contained in Figure 6.1.

In this example, the total cumulative productivity shocks for the hypothetical industry are detailed in column C (total cumulative productivity benefit with no standardised national network) and column E (total cumulative productivity benefit with a standardised national network) of Table B1. These data would then be used to shock the relevant industry in the MMRF model.

Table B.3

WORKED EXAMPLE

Year	Column A Unit productivity gain (%)	Column B Cumulative adoption with no standardised national network (%)	*Column C Cumulative industry-wide productivity gain with no standardised national network (%) (column A *column B)*	Column D Cumulative adoption with standardised national network (%)	*Column E Cumulative industry-wide productivity gain with national standardised national network (%) (column A * column D)*
2008	10.0	6.9	***0.7***	6.9	***0.7***
2009	10.0	8.1	***0.8***	8.1	***0.8***
2010	10.0	9.9	***1.0***	9.9	***1.0***
2011	10.0	12.7	***1.3***	12.7	***1.3***
2012	10.0	16.9	***1.7***	25.2	***2.5***
2013	10.0	22.5	***2.2***	42.5	***4.3***
2014	10.0	29.5	***3.0***	59.8	***6.0***
2015	10.0	37.5	***3.8***	71.1	***7.1***
2016	10.0	45.5	***4.5***	76.4	***7.6***
2017	10.0	52.5	***5.3***	78.7	***7.9***
2018	10.0	58.1	***5.8***	79.5	***7.9***
2019	10.0	62.3	***6.2***	79.8	***8.0***
2020	10.0	65.1	***6.5***	79.9	***8.0***
2021	10.0	66.9	***6.7***	80.0	***8.0***
2022	10.0	68.1	***6.8***	80.0	***8.0***
2023	10.0	68.8	***6.9***	80.0	***8.0***
2024	10.0	69.3	***7.0***	80.0	***8.0***
2025	10.0	69.6	***7.0***	80.0	***8.0***
2026	10.0	69.7	***7.0***	80.0	***8.0***
2027	10.0	69.8	***7.0***	80.0	***8.0***
2028	10.0	69.9	***7.0***	80.0	***8.0***
2029	10.0	69.9	***7.0***	80.0	***8.0***
2030	10.0	70.0	***7.0***	80.0	***8.0***

B.5 Productivity and adoption assumptions

Agriculture — productivity

The productivity gains to agriculture due to uptake of GNSS were modelled on the basis of two key applications — controlled traffic farming and inter-row sowing. Unit gains of between 25 and 35 per cent were assumed on the basis of the following:

- Controlled traffic farming practices has been observed to deliver an average yield gain of approximately 10 per cent. While higher yield increases have been demonstrated for some crops in certain locations, the reported results from past field trials tend to be skewed upward due to trials being established on soils and in locations most favourable for controlled traffic farming.
- The 10 per cent gain is consistent with the assumption used in a recent case study of controlled traffic farming published by Land and Water Australia (Schofield et al 2007).
- Controlled traffic farming has been reported to result in decreased machine operating costs (principally fuel, labour, maintenance and other input costs) of the order of 15 per cent across all crops/regions. Again, higher savings in input costs have been demonstrated in some instances, however the reported results from past field trials tend to be skewed upward due to trials being established on soils and in locations most favourable for controlled traffic farming.
- Inter-row sowing has been reported to deliver average yield gains of approximately five per cent.
- The cost savings associated with inter-row sowing are in the order of 3 to 10 per cent (Whitlock, 2008 and Brownley, undated).

Long term multifactor productivity growth in Australian agriculture has averaged 4.5 per cent per annum over the ten years to 2005-06 (Productivity Commission, 2006).

Agriculture — adoption profile

A single adoption profile was used to model uptake rates of controlled traffic farming and inter-row sowing (Figure B1). The adoption assumptions were based on the following:

- The current level of adoption of precision GNSS technology in agricultural cropping activities is estimated to be about 5 per cent of cropped land.
- In the 'with a standardised national network' scenario, it was assumed that a maximum of 80 per cent of crop land on specialist cropping farms would be converted to controlled traffic farming and inter-row sowing by 2021. In the 'without a standardised national network' scenario, the maximum level of adoption was assumed to be 70 per cent, but this would not occur until 2030.
- The provision of a national network has a positive impact on rates of adoption by bringing adoption forward and increasing the maximum rates of adoption. The provision of a national network of reference stations is expected to reduce the cost of access to the technology for farmers.

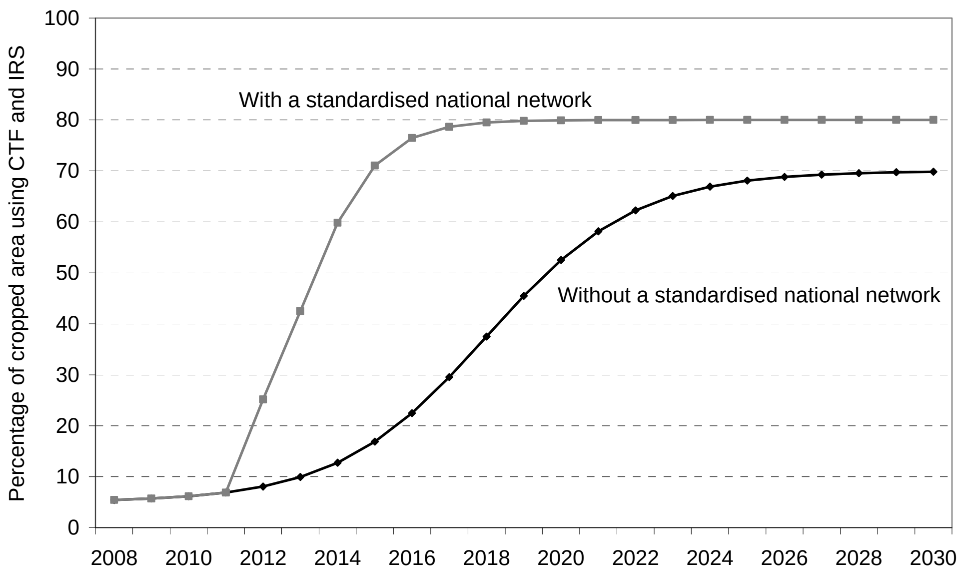
The relatively high levels of adoption are based on the reasoning that

- the cost of autosteer GPS kits is falling rapidly and within ten years this equipment will probably be fitted as standard equipment to most new tractors;
- a standardised national network will have widespread coverage and be considerably cheaper than the existing requirement for farmers to invest in base stations; and

- we have confined the analysis to specialist cropping farms which, in the past, have displayed a propensity for rapid uptake of innovative farming techniques where these techniques are demonstrably more profitable than conventional practices (Productivity Commission, 2005).

Figure B.1

ADOPTION OF CONTROLLED TRAFFIC FARMING AND INTER-ROW SOWING



Note: CTF refers to controlled traffic farming and IRS refers to inter-row sowing.

Mining — productivity

Accurate selective mining was assumed to boost mine site productivity by between 5 and 10 per cent. This estimate was informed by the following:

- A recent review of the benefits of accurate selective mining as applied to an Australian zinc mining operation delivered increases in mine productivity of around 6 per cent.
- Output (as measured by the annual quantity of ore milled) was able to be increased by about 2 per cent after implementing accurate selective mining technology and practices. Grades of ore mined also improved following the adoption of accurate selective mining.
- The accurate selective mining technology also allowed for the generation of information on the productivity of mine machines and operators thus enabling mine managers to make informed decisions on operations. The productivity of mining operations was found to increase by an additional 4 per cent as a result the availability of such information and the making of more informed decisions (Seymour, 2008).

The adoption of autonomous haul trucks was assumed to produce a potential productivity gain of between 10 and 20 per cent. This estimate was based on figures reported from productivity testing by Rio Tinto in 2000.

Mining — adoption profile

Accurate selective mining and the use of autonomous haul trucks are very different applications of precision GNSS technology and for this reason separate adoptions profiles were modelled for each application.

Accurate selective mining

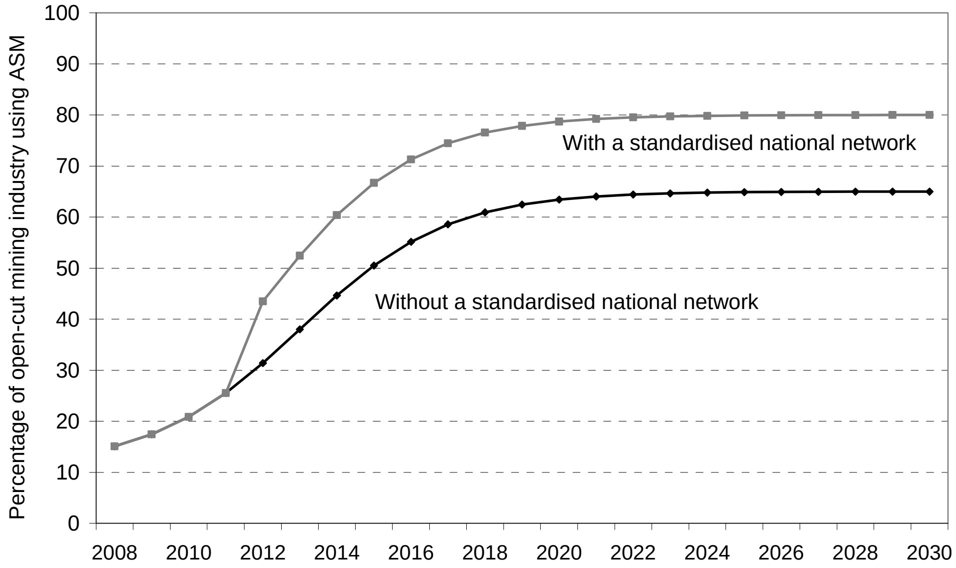
The adoption profile displayed in Figure B2 incorporates assumptions about projected rates of uptake of accurate selective mining.

- The current level of market penetration is estimated to be about 15 per cent (Seymour, pers. comm., 2008).
- It is currently estimated that about 55 per cent of the open-cut mining operations are potential candidates for the adoption of accurate selective mining using precision GNSS machine control technology (Based on Lorimer, 2008). Given a forecast period that spans until 2030 and that the cost of precision GNSS technology is likely to fall over that time, it is assumed that the maximum rate of adoption will reach about 65 per cent in the absence of a national network.
- The provision of a national network is expected to boost the maximum rate of adoption to about 80 per cent.
- The provision of a national network is not expected to make a significant change to the adoption profile (for example, the difference between the two adoption curves is not as great as was the case in agriculture).
  - Most mines already have a base station network in place as used for mine survey work so the provision of a national network is not expected to boost market uptake by a significant margin (Seymour, pers. comm.).
  - The mining industry is dominated by large operators with ample financial resources allocated to technology, research and development. The costs involved in establishing a base station at a mine site are not as prohibitive for mining operations as they are for agricultural operations.
  - Mining industry participants tend to prefer using their own base stations, rather than those of a third party as it allows them to control, maintain and adapt the technology to suit their needs.
- Rates of adoption are initially relatively rapid as the market for this type of technology in the mining industry is already well developed. It is assumed that most of the early adoption has taken place and now that the benefits of the technology have been clearly established, adoption rates will grow quite rapidly.
- The adoption path under a national network scenario follows that of the ‘without a standardised national network’ scenario. The key difference between the two scenarios is only that maximum rate adoption is greater under the ‘with a standardised national network’ scenario.

- The national network does not bring forward adoption for companies that are willing to adopt precision GNSS technology as most of these companies will invest in the technology via establishment of a private network. The national network was assumed, however, increase the maximum rate of adoption due to greater penetration among smaller operators.

Figure B.2

PROJECTED ADOPTION OF ACCURATE SELECTIVE MINING



Note: ASM refers to accurate selective mining.

Autonomous haul trucks

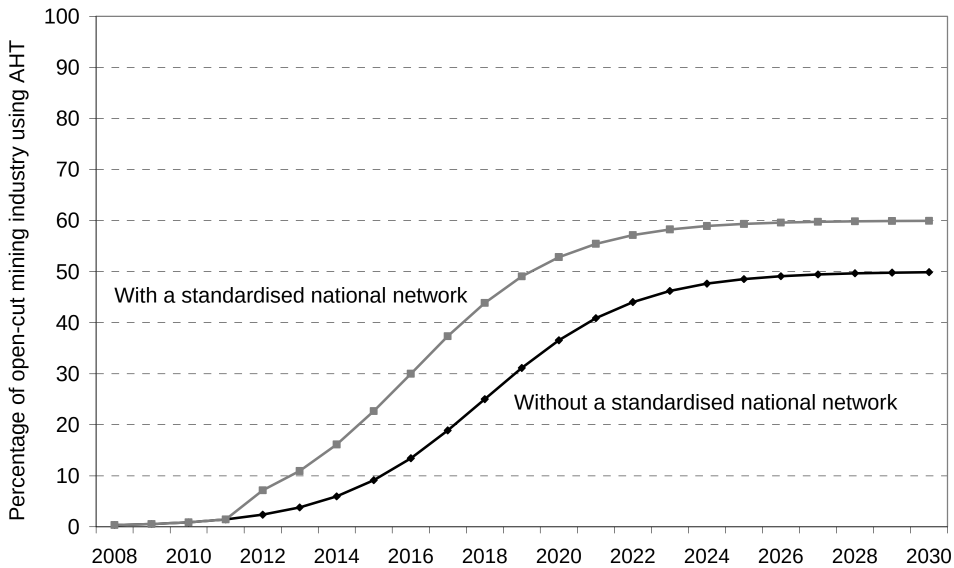
The adoption profile displayed in Figure B3 incorporates assumptions about projected rates of uptake of autonomous haul trucks.

- Mining operations in Australia are not yet using autonomous haul trucks.
- The willingness to use the technology is evident as per trials already undertaken and to be undertaken by Rio Tinto.
- It is a difficult technology to implement as consistent GNSS signals are needed (often at the bottom of deep mines) and there are many moving vehicles around mine sites.
- As a new technology, the rate of adoption will be relatively slow in the early years as only the most innovative and large-scale operations adopt the technology and therefore the slope of adoption curve is relatively flat in the early years.
- It is a significant undertaking to adopt autonomous haul truck technology and therefore it is assumed that the maximum rate of adoption is low relative to other applications of precision GNSS — in this case it is assumed that the maximum rate of adoption is 50 per cent in the absence of a standardised national network and 60 per cent were a standardised national network provided.

- It is assumed that the provision of a national network brings some adoption forward as the existence of a national network would ‘spark’ the interest of some companies who would otherwise have not considered the technology.

Figure B.3

PROJECTED ADOPTION OF AUTONOMOUS HAUL TRUCKS



Note: AHT refers to autonomous haul trucks.

Construction — productivity

The use of GNSS in site survey tasks is estimated to have increased productivity of surveyors by between 20 and 30 per cent. As surveying comprises about two per cent of the cost of a typical, large construction project, the effective unit productivity gain to an average construction project was assumed to be between 0.4 and 0.6 per cent. The 20 to 30 per cent productivity improvement used in this study was based on industry consultations, which suggested that fees charged by field surveying companies are approximately 50 per cent lower for large projects and 20 per cent lower for smaller (2-3 day) projects when precision GNSS technology is used.

The utilisation of machine guidance in earthmoving jobs on construction sites was assumed to increase productivity at construction sites by between 1.3 and 2.6 per cent. Consultations with industry indicate that overall productivity savings in earthmoving are somewhere between 10 and 20 per cent. As earthmoving constitutes about 13 per cent of the cost of a typical construction project, the effective gain to a construction project was calculated to be 1.3 to 2.6 per cent.

Historical industry-wide productivity improvements in the construction sector have averaged 2.4 per cent per year over the ten years to 2005-06 (Productivity Commission, 2006).

Construction — adoption profile

The use of precision GNSS in land surveying is very different to the application of precision GNSS technology to earthmoving and for this reason separate adoptions profiles were modelled for each application.

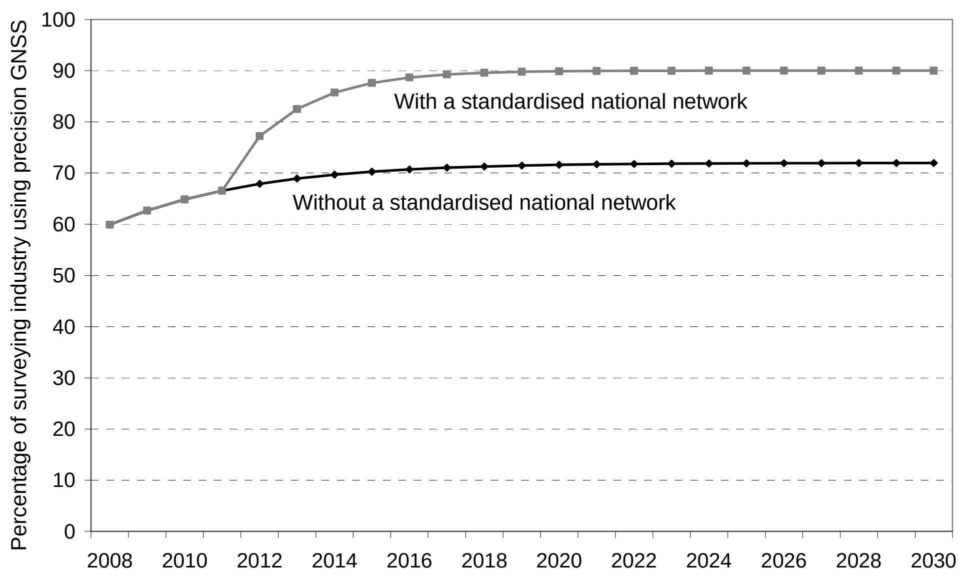
Land surveying

The adoption profile displayed in Figure B4 incorporates assumptions about projected rates of uptake of precision GNSS in surveying.

- Precision GNSS is already well utilised by the surveying industry — about 60 per cent of the surveying industry already uses precision GNSS.
- GNSS technology is applicable to about 90 per cent of the surveying sector and this maximum level of uptake will only be reached in a situation where a standardised national network is established.
- The use of the technology is already well-advanced and therefore uptake rates from this point in time onwards increase relatively steadily (i.e. periods of rapid increases in uptake have passed).
- The existence of a standardised national network does 'bring forward' some uptake of the technology in the surveying industry and also increases the maximum level of uptake.

Figure B.4

PROJECTED ADOPTION OF PRECISION GNSS IN SURVEYING



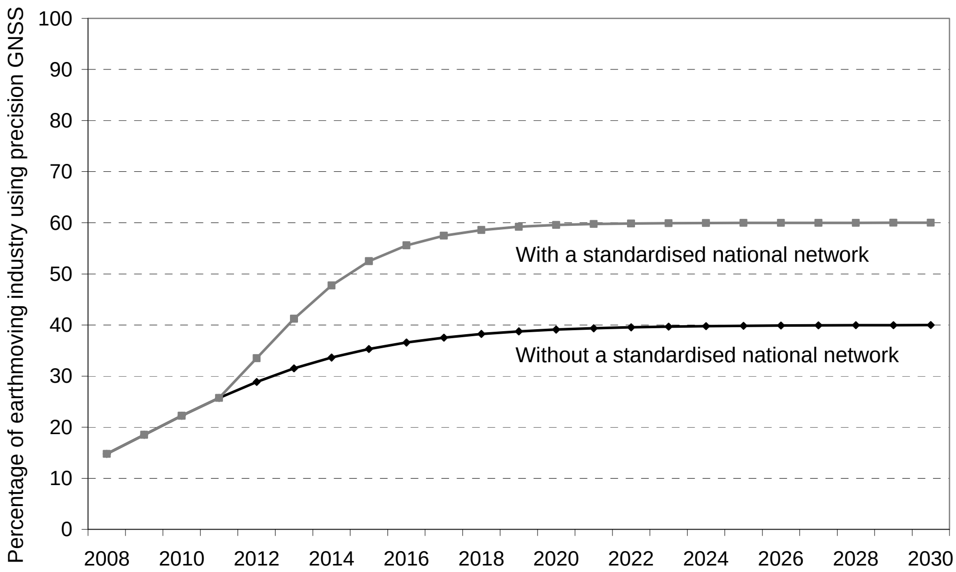
Earthmoving

The adoption profile displayed in Figure B5 incorporates assumptions about projected rates of uptake of machine control in earthmoving.

- The current level of market penetration is estimated to be about 15 per cent (Based on Lorimer, 2008 and anecdotal evidence).
- Precision GNSS technology is applicable to about 60 per cent and this maximum level of uptake will only be reached in a situation where a standardised national network is established.
- The use of the technology is already well-advanced and therefore uptake rates from this point in time onwards increase relatively steadily (i.e. periods of rapid increases in uptake have passed).
- The existence of a national network does 'bring forward' some uptake of the technology in the surveying industry and also increases the maximum level of uptake.

Figure B.5

PROJECTED ADOPTION OF PRECISION GNSS IN EARTHMOVING



B.6 Detailed results

Table 7.3

PRESENT VALUE OF FUTURE PRODUCTIVITY GAINS DUE TO PRECISION GNSS ADOPTION — 2009-2030

	Agriculture	Mining	Construction	All sector total
	$ billion	$ billion	$ billion	$ billion
Conservative productivity gain				
Without standardised national network	11.9	48.7	12.0	72.6
Added benefit of accelerated and higher uptake due to standardised national network	8.6	17.4	6.0	31.9
Total	**20.5**	**66.1**	**18.0**	**104.6**
Optimistic productivity gain				
Without standardised national network	16.2	96.9	21.2	134.4
Added benefit of accelerated and higher uptake due to standardised national network	12.0	36.1	9.9	58.0
Total	**28.2**	**133.1**	**31.0**	**192.4**

Note: Sector totals do not equate to the sum of individual sector benefits because interaction effects in the economy are accounted for when productivity gains to all sectors are modelled simultaneously as opposed to being modelled individually.

Appendix C

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