Precise positioning in the road transport sector

An estimate of the economic and social benefits of the use of augmented GNSS in the road transport sector

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Executive Summary

Road transport for this report includes passenger and freight transport, fleet management, transport logistics and the related support services that manage operations in the transport sector and road infrastructure support.

The transport and logistics sector was an early adopter of GNSS technology, using it to track vehicles, freight movement and is already widely adopted. In recent years the sector has experienced a growing need for greater accuracy, reliability, integrity and increased interoperability. These are required to support integration with complimentary intelligent systems to get greater efficiencies and competitiveness in logistics, reduce fuel consumption and maintain and service the infrastructure that supports it.

Areas where GNSS technologies have become important include:

- Fleet and Logistics Management — the precise position of fleet vehicles monitored in real time to assist in the management and optimisation of route selection, driver fatigue, fuel efficiency and timing.
- Container Management – Precise positioning has been adopted to automate and manage port container operations.
- Road Maintenance – Road authorities use positioning information to gather valuable information in the assessment of road corridors. Data capture is used for assessment of road geometry, condition and asset management.
- Intelligent Transport Systems (ITS) – a natural extension on fleet management, maintenance and tolling concepts.
- Direct Heavy Vehicle Charging – integration of reliable positioning systems to evaluate road usage and charge appropriately for heavy vehicles. Combined-service (heavy vehicle charging, fleet management, safety management).

Intelligent Transport Systems have already begun roll-out in Europe, USA and Japan. However, in regard to the specific precise positioning navigation aspects of C-ITS[1] Australia currently lacks the supporting positional infrastructure (via CORS[2] coverage) and the survey grade road base data to effectively facilitate certain functionalities at (largely) the 'where in lane' level of C-ITS. This can include functionalities such as those related to vehicle safety, which would require both precise positioning information and car sensor information to reliably make intelligent safety decisions based on the immediate road environment.

The Road Transport and Transport Storage and Handling sectors have jointly benefited from the use and application of augmented GNSS. Combined output from these sectors is estimated to have been between $154 million and $213

[1] See section 2.4

[2] Continuously Operating Reference Stations.

million higher in 2012 than it would otherwise have been without the benefit of augmented GNSS.

By 2020 combined output is projected to be between $534 million and $916 million higher than it would otherwise have been, as a result of greater use in cooperative intelligent transport systems and in freight and container management at ports and transfer nodes.

Realisation of these outcomes in 2020 depends on continued expansion of augmented GNSS services.

Key Findings

- Positioning across the transport sector has many varied applications including freight and logistics, vehicle charging, intelligent transportation systems and container management.
  - Existing freight and logistics systems typically don't require cm level positioning, however they do require the high reliability and integrity that can be provided by augmented GNSS.
  - Automation of freight facilities and transfer hubs have specific accuracy tolerances requiring reliable cm level precise positioning.
- Accuracy requirements vary depending on the application. However reliability, integrity and interoperability across multiple systems can be as important as positional accuracy in some circumstances.
- Significant improvements in productivity have been achieved from the use of augmented GNSS in transport applications. Further improvements are possible. Their realisation will depend on further development of applications as well as extension of augmented GNSS services.

1 Introduction

ACIL Allen Consulting, in partnership with SKM and Lester Franks Surveyors and Planners, has been commissioned by the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education to assess the value of augmented positioning services in Australia.

The purpose of this report is to provide an understanding of the economic and social benefits of precise positioning information within the transport sector. This information is to allow better informed decision-making and assist in identifying areas for growth and investment from both the private sector and government. It will also provide context to the National Positioning Infrastructure Plan being developed by Geoscience Australia.

2 Transport use of Precise Positioning

2.1 The road transport sector

Road transport is critically important to the social, cultural and economic success of Australia, from our city centres to remote communities. With freight and passenger transport likely to almost double by 2020 Australia's transport system is facing many challenges including, congestion, accessibility and rising fuel prices.

A solution to this challenge is the adoption of new technologies that facilitate more efficient use of the current transport infrastructure and more effective output from available resources.

Whilst the road transport sector has been relatively slow to embrace new technologies relative to some other sectors, there has been a shift over the last several years towards more integrated, intelligent transport systems. This includes technologies such as in-vehicle telematics that can communicate with transport management systems, monitor vehicle movements and integrate them into a wider transport logistics.

These systems, supported by positioning technologies achieve commercial benefits by maximising the efficiency of freight logistics through higher productivity vehicles used in ways that are consistent with safety and environmental standards.

Generally the use of positioning across the road transport sector varies with each application. However there is an overarching requirement for positioning reliability, integrity and increasingly interoperability between different platforms.

Future directions of integrated positioning systems are envisaged through concepts such as heavy vehicle monitoring and intelligent access platforms (to be discussed below), which have requirements both for positioning accuracy, integrity and reliability.

These concepts point strongly towards the introduction of complete Intelligent Transport Systems (ITS) which may realise and combine a number of the applications described below within a precise positioning environment. This is driven by the need for greater efficiency in transport logistics to maintain competitiveness.

2.2 Logistics and Fleet Management

Positioning technology has been implemented in a number of applications to facilitate, manage and forecast the movement of freight, bulk materials handling and haulage.

There are numerous examples of standalone GNSS integration amongst logistic management systems, with information from this study being sourced from TOLL, Linfox and QUBE logistics.

Such positioning information generally only requires accuracies at the metre level and positional updates are not critically reliant on timing. Typically, under current operational conditions, these applications do not require GNSS augmentation at this point in time. However as discussed later in this report, provision of greater precision and integrity will facilitate further applications in managing fleets of trucks and in tracking movement of goods being transported. This is what augmented GNSS provides.

Benefits

The benefits of positioning across freight and logistics are estimated to be in accord with the following:

- reduction in fuel consumption, estimated at 10 per cent.
- 3 % increase in driver productivity from improved logistics management
- minimises idle time to ensure continuity of operations
- improved fleet efficiency (identifying areas of underperformance)
- more efficient time management and route optimisation

2.3 Direct Heavy Vehicle Charging

Road Transport Infrastructure is one of the only remaining public sector assets yet to undergo major economic reform, whilst there have been a number of steps taken to implement change comprehensive structural reform has not taken hold in the sector.

Moving to more direct heavy vehicle charging involves replacing the existing schemes with a variable usage charge based on the axle loading of each heavy vehicle and the distance and route (road type) of individual trips. This would provide charges that more closely reflect the costs incurred from heavy vehicle traffic. This would deliver benefits by encouraging:

- the use of more efficient routes by heavy vehicles where there is a choice available, as the charge for using a road is more directly attributed to the cost of a particular heavy vehicle trip
- a more efficient heavy vehicle fleet mix, as operators over time make vehicle choices based on minimising the total heavy vehicle charging costs of road use.

At present there a number of mechanisms being considered for collecting relevant data to support direct heavy vehicle charging. The favoured method is the use of in-vehicle (IVU) telematics linked to GNSS technology[3].

Whilst the accuracies associated for this application aren't required at the sub-metre level, there is significant emphasis on the reliability of service (and hence positioning service) to relay and record correct information to the system operators.

Such reliability will most likely require GNSS augmentation given the issues associated with poor satellite coverage in denser urban areas. The importance of accuracy in this area will depend, to some extent, on the nature of the location based charging and dynamic method adopted for data collection of variable parameters.

Benefits

The expected benefits from charging heavy vehicle behaviour include

- lower total heavy vehicle operating costs for a given freight task
- improvements in road safety from having fewer, more productive vehicles on the road
- avoided cost of road wear from more efficient use of the existing road network
- changes in vehicle operating costs from switching to larger, more productive vehicles, partially offset by potential increases in kilometres travelled by such vehicles
- potential fleet management operator benefits, from the use of information provided by in-vehicle units
- safety benefits from the use of in-vehicle technology, resulting in lower crash costs and reduced injuries and
- improved environmental outcomes from more intelligent management of road networks.

[3] Business Systems to Support Heavy Vehicle Charging – COAG Road Reform Plan October 2011

Overall, initiatives such as the COAG heavy vehicle reform suggest positive net benefits in the order of $5 billion to $7 billion over 30 years. The contribution of positioning systems to this net benefit would be speculative, however as a concept it leads into the development of intelligent transport systems which do have a precise positional requirement and it is likely that future systems will all be embedded amongst Cooperative Intelligent Transport Systems (see section 3.4 below).

Assuming a take-up of 8,400 vehicles, Intelligent Access Programs (refer Appendix A) are estimated to generate a net present value (that is, present value of benefits less costs) of $264.2 million over seven years (allowing for two implementation years) and a benefit cost ratio of 5.4. Across all applications, the authorities' net present value is estimated to be $80.9 million and the operators NPV $183.3 million. These results do not appear highly sensitive to assumptions about benefits and costs.

Net benefits will be realised through more direct road use charges with the introduction of distance-location charging methods (supported via GNSS) anticipated capturing a projected $6 billion across fleet wide introduction (COAG, 2011)

2.4 Cooperative Intelligent Transport Systems C-ITS

C-ITS facilitates the connection of road users to their road environment via the connection and exchange of real-time information about the road environment, such as

- vehicles, infrastructure, non-infrastructure features and other objects
- road and traffic conditions
- events
- threats and potential hazards.

The exact positioning requirements that have been broken down are as follows:

1. Road-Level Applications – Metre level positioning at approximately 1 sec (1 Hz)
2. Lane-Level Applications – Sub metre level positioning at approximately 1 Hz
3. Where-in-Lane Level Applications – Decimetre level positioning at 0.1 sec (10 Hz).

Currently, such ITS systems are being realized in Europe, Japan and USA where they have access to a Space Based Augmentation System that can fulfil the positioning requirements of the system. However, Australia does not currently possess such positioning augmentation levels and as such is currently not in a position to reliably support the implementation of ITS.

There is the inherent risk that without infrastructure development (be it at ground or space borne augmentation) that Australia will miss out on both the many environmental, safety and economic benefits that such systems support.

Benefits

There is considerable evidence collected from within Australia and abroad that ITS can produce reductions in accident rates and improvements in transport efficiencies (ACIL Tasman 2008). This reasoning for the safety improvements has been reinforced by information from the case studies discussed below. It is derived from improvement in understanding by the driver and the relationship between direct road environment information and current position.

Improvements to the efficiency of transport can also yield environmental benefits. For example, it is estimated that ITS will produce fuel savings of between 2% and 13% and reduce emissions by between 5% and 15% (Standing Committee on Transport and Regional Services, 2002).

Putting this in context, in 1998 Australia's transport sector contributed about 12% to the total of Australia's greenhouse gas emissions, with road transport accounting for 81% of these emissions. It is therefore estimated that the potential ITS reduction of road transport related emissions of 5-15% could reduce Australia's total greenhouse gas emissions by between 0.5% and 1.5%.

2.5 Container Terminal Management

The movement of containers is facilitated by large mobile straddles which are able to attach/detach containers (various straddles accommodate different container sizes) and transport them to a desired location. Of importance to effective operations is the locality of such containers as they are moved around the holding facilities. The typical accuracies required to effectively manage such operations are +/- 3 cm in the horizontal plane.

As such, precise GNSS is used to capture locality data of containers, referenced to a regularly updated site locality plan (facilitated via regular survey), at the loading points from the straddle.

The overall potential benefits of full site automation facilitated through precise positioning can be extrapolated from the Patricks estimate of $55 million per site, per year. Further benefits can be defined as (below);

- fuel and transport efficiency
- reduced machine wear and tear
- pavement / asphalt management
- improved safety (reduced collisions and transport related risks)
- reduced driver injuries due to remote straddle operation
- route optimisation
- reduction of labour through automation

- storage management
- fleet monitoring.

Such productivity benefits are currently being realised from existing automated and semi-automated sites across the country. It is estimated that fully automated facilities, such as those in place at Fisherman Island (Patricks), have reduced current staff levels by up to 50%. Sites operating under semi-automation have reduced levels of staff by up to 33% and have recorded mass savings in a number of key areas.

Previous to the adoption of GNSS as part of the container management process, hand-audits were conducted as part of the management process which required full site shutdowns and limited verification process. Inefficiencies associated with such practice added an additional 20-30% cost with overall processes.

On the basis of fuel costs estimated at 1000 litres per straddle per day (continuous operation), a perceived 30% reduction in fuel from smoother operation (as provided from estimates provided by Patricks) and controlled speeds puts an estimate of savings around 109,500 litres of fuel per Straddle per year, or an approximate saving of close to $200,000 per year at current diesel prices.

2.6 Future Applications and Developments

Advances in GNSS through both improved satellite coverage and augmentation will drive a number of transport related technologies within the coming decade. It is clear that positioning (at a standalone accuracy level) is already used as a logistics tool in a vast majority of major commercial operations, however with positioning improvements will come more advance applications and benefits.

The two primary examples of this future direction requiring centimetre level positioning is through automation (particularly relating to port and loading facilities) and the inevitable advent of C-ITS.

Telematics is the specific technological capacity to locate vehicles in space and time and is at the core of C-ITS. With the advances in positioning technology and its augmentation with supporting infrastructure, GNSS is becoming the primary form of navigation linked to telematics and is at the heart of current and future intelligent transport systems. Australian investment in C-ITS has been more than matched by advances internationally, however with appropriate infrastructure and system development, the expectation is that Australia will benefit greatly from implementation of such systems. The range of services being provided or explored include both domestic and commercial vehicular operations including:

- in-vehicle navigation
- stolen vehicle recovery

- automatic crash notification and may-day services
- fleet management
- logistics/supply chain management
- hazardous goods management
- electronic toll collection.

3 Economic impacts

Economic impacts in the transport sector can be driven by several factors. Increases in productivity deliver direct benefits to operations from lower costs, lower congestion and more efficient movement of goods which leads to productivity improvement across the sector.

3.1 Productivity impact on industry costs

We have estimated productivity improvements through evidence collected from the case studies, our estimates of current and future levels of adoption, published research and reports and from interviews with industry participants.

Estimates of accumulated productivity impacts and cost savings for the transport sector for 2012 and impacts likely to accrue by 2020 are summarised in Table 1 and Table 2 respectively. The represent productivity improvements attributable to the use of augmented GNSS that have accumulated since it was first used in the sector.

Table 1 shows estimates of the contribution of augmented GNSS to savings in operating costs of around $189 million to $232 million in 2012 in the transport and handling sectors compared to the situation where augmented GNSS had not been available. The low estimate reflects a high confidence on the level of adoption. The higher figure reflects an estimate based on our observations of industry practice but which could not be confirmed with certainty.

Table 2 shows our estimates of the contribution of augmented GNSS to savings in operating costs of around $545 million and $772 million in the transport and handling sectors as a result of further adoption of the technologies discussed in this report. The significant difference between the estimates for 2012 and 2020 is the inclusion of additional benefits from the adoption of intelligent transport systems. To achieve these benefits, it would be necessary for augmented GNSS services to be expanded.

Table 1 **Productivity estimates and cost savings for the road transport sector 2012**

	Sector	Assumptions	Impact on costs	Percentage of sector output	Impact on costs	Percentage of sector output
			Low case	Low case	High case	High case
Container Management	Transport support services and storage	Full automation across selected large volume ports Based on adoption levels between 30% and 35%	$ 70,580,250	0.16%	$ 82,343,625	0.18%
Heavy Vehicle Charging	Road transport	Leads to improved roads maintenance and road network management Around 18% savings in costs. The low and high estimates are based on adoption between 1% and 1.5%	$ 33,873,204	0.07%	$ 50,809,807	0.11%
Fleet Management	Road transport	35% Fuel and Transport efficiency Benefits realised in pavement management Decrease onsite staff by up to 40% The low and high estimates are based on adoption estimates between 70% and 10%	$ 84,752,750	0.19%	$ 98,878,208	0.22%

Note: Productivity is expressed as savings in labour and materials to overall sector output

Data source: SKM and ACIL Allen analysis, based on case studies and research

Table 2 **Productivity estimates and cost savings for the road transport sector 2020**

	Sector	Assumptions	Impact on costs	Percentage of sector output	Impact on costs	Percentage of sector output
			Low case	Low case	High case	High case
Container Management	Transport support services and storage	Full automation across large volume ports Based on adoption levels between 40% and 45%	$ 94,107,000	0.21%	$ 141,254,583	0.31%
Heavy Vehicle Charging	Road transport	Adoption of Distance / Location charging – 20% savings in costs. Based on adoption of 2% and 3%	$ 67,746,409	0.15%	$ 84,683,011	0.19%
Fleet management	Road transport	Impact of logistics management 30% fuel savings, 50% reduction in labour costs. 40% adoption for low case 50 % adoption for high case	$113,003,667	0.25%	$141,254,583	0.31%
Intelligent Transport Systems	Road transport	Expanding positional infrastructure supports adoption Low case assumes 10 % adoption High case assumes 15% adoption	$270,487,500	0.59%	$405,731,250	0.89%

Note: Productivity is expressed as savings in labour and materials to overall sector output

Data source: SKM and ACIL Allen analysis, based on case studies and research

The economic impact of these productivity improvements falls under two sectors within the national accounts. The direct impact of productivity improvements from fleet management, heavy vehicle charging and intelligent transport systems falls within the Road Transport sector. The direct impact of productivity improvements in container management falls within the Transport and Handling sector.

The productivity impacts in Table 1 and Table 2 have been combined and are reported in Table 3 and Table 4 below. These productivities refer to cost savings.

Table 3 **Productivity impact on the road transport sector**

	Low case	High case
2012	0.260%	0.327%
2020	0.987%	1.419%

Note: Productivity impact is on costs

Data source: ACIL Allen and SKM

Table 4 **Productivity impact on transport and handling**

2012	0.156%	0.182%
2020	0.207%	0.309%

Note: Productivity impact is on costs

Data source: ACIL Allan and SKM

3.1.1 Impact on sector output

The productivity impacts summarised in Table 3 and Table 4 were used as inputs to ACIL Allen's Computable General Equilibrium (CGE) model, Tasman Global[4], to estimate the impact that theses productivity improvements from the use of augmented GNSS had on the Australian economy in 2012 and the potential benefits that could arise by 2020[5].

The results from this modelling for output from the utilities sector are shown in Table 5.

Table 5 **Increases in sector output**

	Low case	High case	Low case	High case	Low case	High case	Low case	High case
	2012	2012	2020	2020	2012	2012	2020	2020
	$ million	$ million	$ million	$ million	%	%	%	%
Road transport	96	137	442	752	0.2	0.3	0.7	1.1
Transport storage and handling	58	76	92	164	0.1	0.1	0.1	0.2
Total	154	213	534	916	0.1%	0.2%	0.3%	0.6%

Data source: *ACiL Allan*

The table shows that combined output from the two sectors was between $154 million and $213 million higher in 2012 as a result of the use or application of augmented GNSS. This represents 0.1 per cent and 0.2 per cent of total output for the sector.

[4] See overview report for a full description of the CGE modelling approach,

[5] Note that the productivity shocks for other sectors discussed in this report were also entered into the model at the same time.

The combined output of the two sectors is projected to be between $534 million and $916 million higher by 2020. This represents 0.3 per cent and 0.6 per cent of total output for the sector. The projections suggest that significant economic benefits for the transport sector are possible with further adoption of intelligent transport and related logistics systems, drawing on augmented GNSS.

To realise these projected benefits there will need to be wider availability of augmentation infrastructure. This might be from the expansion of a CORS network or through provision of space based or other augmentation systems. This might arise from investment either by the private or by the public sector. Maintaining as much compatibility as possible between systems will be important if the potential of augmented GNSS is to be fully realised.

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Appendix A Case Studies

A.1 Logistics and Fleet Management

The source for this case study is QUBE logistics. QUBE Logistics operates services covering road and rail transport, warehousing and distribution, container parks and related services, and intermodal logistics hubs including rail terminals and international freight forwarding.

Positioning technology has been implemented amongst a number of applications to facilitate, manage and forecast the movement of freight, baulk materials handling and haulage.

Box 1 Measuring and monitoring truck movements

> "We have the technology to automatically track and measure truck movements. Drivers in charge of highly sophisticated vehicles should not have to put up with outdated paper-based record keeping. Not when we have the IT and satellite technology to record and report real-time movements,"

Source: Lindsay Fox speaking at the Asia Pacific Economic Cooperation's (APEC) Supply Chain Connectivity Symposium in Singapore in May 2009 that 'black box' technology for trucking management was crucial in promoting efficiency and safety.

There are numerous examples of standalone GNSS integration amongst logistic management systems, such as those used by companies such as TOLL, Linfox and QUBE logistics. Typically, such positioning information operates outside the parameters of precise positioning requirements with accuracies only applicable on the metre level and positional updates not critically reliant on timing.

In saying that, installation of more intelligent vehicle management systems (discussed below) to provide greater relationships to the existing road environment are becoming increasingly prevalent amongst intelligent management decisions such as route optimisation, fuel efficiency, machine maintenance and driver management.

The ability to provide and integrate higher level positioning information (at the where-in-lane level) in the future is becoming a part of these logistics management systems and will facilitate more effective operation.

A.1.1 Benefits

The benefits gained by the adoption of positioning technology in general to improve freight logistics and fleet management include:

- reduction in fuel consumption, estimated at 10%
- 3 % increase in driver productivity from improved logistics management
- minimises idle time to ensure continuity of operations
- improved fleet efficiency (identifying areas of underperformance)
- more efficient time management and route optimisation

- driver risk assessment leading into improved health and safety.

A.1.2 Adoption Costs

Initial adoption costs are relatively minor and consist of largely initial hardware costs that are often packaged as part of overarching fleet management services. Typical stand-alone units commonly implemented amongst these applications are less than $5,000.

A.1.3 Productivity Estimates

Logistics is only effective when there is an adequate supply of information about what is happening at each point in the supply chain, and when available alternatives are well known and understood. By accessing spatial and locational data in real time as part of a more integrated intelligent transport system real productivity gains are possible through improved and more sophisticated logistics management.

Real-Time positioning (whilst not necessarily precise in nature amongst current applications) is now being incorporated within logistics management with custom built evaluation tools and route modelling software that account for vehicle fixed and variable costs, fuel costs and labour costs. Such applications allow for complete financial visibility and viability in real-time to be provided for instant feedback regarding fleet management decisions and dynamic scenario planning.

The productivity estimates outlined above do not require precise positioning. However, provision of greater precision and integrity will facilitate further applications in managing fleets of trucks and in tracking movement of goods being transported.

A.2 Direct Heavy Vehicle Charging

This case study is drawn from the Road Reform Plan drawn up by the Council of Australian Governments in 2011.

Road Transport Infrastructure is one of the only remaining public sector assets yet to undergo major economic reform, whilst there have been a number of steps taken to implement change comprehensive structural reform has not taken hold in the sector.

There are a number of current and emerging challenges that are driving the case for reform, including the delivery of better road freight infrastructure and improving the direct pricing of that infrastructure. One key area which is being currently assessed is heavy vehicle charging. Current road charging methods, funding flows and incentive arrangements for heavy vehicle users and road providers do not necessarily encourage the efficient use, investment, operation, maintenance and management of road transport infrastructure. This in turn imposes avoidable costs on industry, governments and the community.

The existing heavy vehicle charging scheme recovers costs associated with heavy vehicle traffic on the network. It does this using two methods: through a 'Road User Charge' (RUC) collected through the fuel excise; and though separate heavy vehicle registration charges.

Moving to more direct heavy vehicle charging involves replacing the existing schemes with a variable usage charge based on the axle loading of each heavy vehicle and the distance and route (road type) of individual trips. This would provide charges that more closely reflect the costs incurred from heavy vehicle traffic. This would deliver benefits by encouraging:

- the use of more efficient routes by heavy vehicles where there is a choice available, as the charge for using a road is more directly attributed to the cost of a particular heavy vehicle trip
- a more efficient heavy vehicle fleet mix, as operators over time make vehicle choices based on minimising the total heavy vehicle charging costs of road use.

At present there a number of mechanisms being considered for collecting relevant data to support direct heavy vehicle charging. The favoured method is the use of in-vehicle (IVU) telematics linked to GNSS technology[6].

Whilst the accuracies associated for this application aren't required at the sub-metre level, there is significant emphasis on the reliability of service (and hence positioning service) to relay and record correct information to the system operators. The importance of accuracy in this area will depend, to some extent, on the nature of the location based charging and dynamic method adopted for data collection of variable parameters.

Table 6 below, which is sourced from COAG's road reform plan, analysis the various mechanisms by which data can be collected against the relevant parameters for adoption, methods include odometers, tachographs, IVU's and dynamic On Board Mass, all of which except on board mass are capable of measuring distance. In vehicle telematics units are also capable of measuring location.

[6] Business Systems to Support Heavy Vehicle Charging – COAG Road Reform Plan October 2011

Table 6 **Assessment of variable data collection options against key factors**

	Odometers	Tachographs	Hubodometers	IVU – GNSS linked	Dynamic On Board Mass
Data quality and accuracy	Low	High	Low-Medium	High	High
Susceptibility to tampering	High	Low-High	Low-Medium	Low	Medium
Market Capacity	High	Low-Medium	Low-Medium	High	Medium-High
Prevalence in Heavy Vehicle Fleet	Nil	Low	Low	Medium-mostly in large fleets	Low
Set Up Costs	Nil	High	Low-Medium	Medium	High
On Going per Annum	nil	Medium	Low	Low-Medium	Medium
Enforcement Costs	High	Medium	Medium	Low	Low-Medium

Data source: SKM

The findings of the assessment identified in vehicle telematics (IVU linked with GNSS) as the most suitable method for the collection of distance and location based information to support more direct heavy vehicle charging.

A.2.1 Current Implementation

Whilst IVU linked with GNSS technology is considered the most suitable approach to facilitate heavy vehicle charging, its use is currently limited across the sector as implementation is only voluntary at this stage.

One such implementation is the Intelligent Access Program (IAP), which uses the GNSS to monitor heavy vehicles' road use, giving transport operators flexible access to the Australian road network to suit their specific business and operational needs. In return, IAP provides road agencies with confidence that heavy vehicles are complying with the agreed road access conditions.

Long distance road user charging

Two new types of road user charging, both requiring positioning technology, are possible by 2020: mass-distance (and possibly location) based charging for heavy vehicles, and urban congestion charging.

Under IAP (A voluntary initiative), GNSS technology is used to record the movement of trucks on a limited number of defined routes. Trucks are limited to certain weights in order to protect roads from damage costs – roads deteriorate with use, and the amount of deterioration is strongly related to axle weight (known as the fourth power rule). IAP trucks are allowed to carry heavier loads than would normally be permitted, in exchange for paying additional charges to compensate for the additional damage to the roads.

Congestion charging

Further to IAP and Heavy Vehicle Reform Charging mechanisms, urban congestion charging is another potential use of positioning technology. Vehicles would be charged according to location and time of day, with high prices in peak periods in congested areas, and lower prices otherwise. Such price signals have proved effective in reducing congestion in Singapore and Stockholm, using standalone GNSS technologies within IVU.

There is also an effective congestion pricing scheme in London using a more primitive and costly numberplate recognition technology. The schemes are best introduced as part of the package where public transport capacity is improved in order to accommodate extra passengers diverted from road, and the extra revenue is spent on economically worthwhile transport projects

Congestion charging is frequently proposed in Australia, for example by Infrastructure Australia and ACIL Allen. However there is opposition from some state governments and road users. There is a substantial challenge to explain the benefits, and substantial preparation would be needed to set up and trial the system and to put in place the associated public transport improvements. For the purposes of the study is assumed that congestion charging is not likely by 2020 in the low case and some estimate of congestion charging in the high case.

A.2.2 Benefits

The expected benefits from changing heavy vehicle behaviour include lower total heavy vehicle operating costs for a given freight task and improvements in road safety from having fewer, more productive vehicles on the road.

In addition the ability to link technology with programs such as AIP which will collect and allow analysis of road freight movements could be used for both improved fleet management and for the road transport industry to optimise heavy vehicle operations in terms of safety, efficiency and productivity[7], potential benefits include:

- avoided cost of road wear from more efficient use of the existing road network
- changes in vehicle operating costs from switching to larger, more productive vehicles, partially offset by potential increases in kilometres travelled
- potential fleet management operator benefits, from the use of information provided by in-vehicle units
- safety benefits from reduced vehicle kilometres and from the use of in-vehicle technology, resulting in lower crash costs and reduced injuries and
- improves environmental outcomes from more intelligent management of road networks.

[7] COAG Road Reform Plan, (CRRP), 2011, Business Systems to Support Heavy Vehicle Charging, http://www.roadreform.gov.au

A.2.3 Adoption Costs

At this stage, the adoption costs related to road charging reforms are fairly minimal with explicit hardware costs for standalone GNSS IVU within the order of hundreds of dollars. The majority of current and proposed expenses will be within the wider adoption of the system used to collate, evaluate and administer the charging mechanisms.

As the requirement for more precise positioning grows so too will the costs associated with developing appropriate augmentation infrastructure.

A.2.4 Productivity Estimates

Productivity estimates are probably best estimate in terms of future benefits at this stage, with minimal current realisations of benefits.

Overall, initiatives such as the COAG heavy vehicle reform suggest positive net benefits in the order of 5 to 7 billion over 30 years. The contribution of positioning systems to this net benefit would be speculative.

Overall and assuming a take-up of 8,400 vehicles, IAP is estimated to generate a net present value (that is, present value of benefits less costs) of $264.2 million over seven years (allowing for two implementation years) and a benefit cost ratio of 5.4. Across all applications, the authorities' net present value is estimated to be $80.9 million and the operators' net present value $183.3 million. These results do not appear highly sensitive to assumptions about benefits and costs (ACIL Tasman 2008).

Net benefits will be realised through more direct road use charges with the introduction of distance-location charging methods (supported via GNSS) anticipated capturing a projected $6 Billion across fleet wide introduction (CRRP 2011).

A.3 (Cooperative) Intelligent Transport Systems – CITS

This case study is drawn from AUSTROADS. Austroads is the association of Australian and New Zealand road transport and traffic authorities. Austroads promote improved Australian and New Zealand transport outcomes by providing expert technical input to national policy development on road and road transport issues

C-ITS facilitates the connection of road users to their road environment via the connection and exchange of real-time information about the road environment, such as

- vehicles, infrastructure, non-infrastructure features and other objects
- road and traffic conditions
- events
- threats and potential hazards.

This allows the end user to be better informed and safer decisions in regard to transportation networks. In order to achieve this, the system needs to exchange data with respect to each vehicle's location, direction and speed amongst other data requirements. (AARB Project Team 2012).

C-ITS is the natural extension of a combination of technologies and system developments including fleet management and logistical systems, toll systems, freight management and of course a range of positioning techniques such as triangulation methods, re-identification and standalone GNSS systems. Where C-ITS differentiates itself from other transport related management systems is in the requirement for advanced precise positioning.

The exact positioning requirements that have been broken down are as follows:

1. Road-Level Applications – Metre level Positioning at approx. 1 sec (1 Hz)
2. Lane-Level Applications – Sub Metre level positioning at approx. 1 Hz
3. Where-in-Lane Level Applications – Decimetre level positioning at 0.1 sec (10 Hz).

Currently, such ITS systems are being realized in Europe, Japan and USA where they have access to SBAS that can fulfil the positioning requirements of the system. However, Australia does not currently possess such positioning augmentation levels and as such is currently not in a position to reliably support the implementation of ITS.

There is the inherent risk that without infrastructure development (be it at ground or space borne augmentation) that Australia will miss out on both the many environmental, safety and economic benefits that such systems support.

Benefits

The benefits of such systems are:

- improved Safety features
  - collision warning
  - emergency braking
  - speed limitation and safety distance
  - road condition assessments
  - intersection and road feature information
- route optimisations
- vehicle management and road maintenance
- fuel optimisation
- increased system(s) interoperability.

Intelligent transport systems integrate currently available and emerging information, computer, communications and vehicle-sensing technologies into transport infrastructure and vehicles in order to monitor and improve the safety, efficiency, management and operations of vehicles and transport systems. There is considerable evidence collected from within Australia and abroad that ITS can produce considerable reductions in accident rates and improvements in transport efficiencies (ACIL Tasman 2008).

Improvements to the efficiency of transport can also yield environmental benefits. For example, it is estimated that ITS will produce fuel savings of between 2% and 13% and reduce emissions by between 5% and 15% (Standing Committee on Transport and Regional Services, 2002).

Putting this in context, in 1998 Australia's transport sector contributed about 12% to the total of Australia's greenhouse gas emissions, with road transport accounting for 81% of these emissions. It is therefore estimated that a reduction of road transport related emissions could reduce Australia's total greenhouse gas emissions by between 0.5% and 1.5%.

A.3.1 Adoption

Whilst ITS has been implemented across mainly USA and Japan (in its initial stages), Australia is not in the current position to be able to support the roll-out whilst positioning remains ambiguous. However, there is movement to place Australia in a position to be a fast adopter of the technology.

The key features to the positioning component that need to be specifically addressed include:

1. accuracy
2. integrity
3. continuity
4. availability
5. interoperability
6. timeliness.

Project adoption costs for C-ITS include indicative capital expenditure between low level hardware (Single frequency GNSS) to high level hardware (GNSS combined with Locata and IMU) ranging to several thousand dollars per unit.

Requirements for certain GNSS and positioning sensors are dependent on a number of predictions such as the availability of future positioning augmentation. One of the biggest cost dependencies will be influenced by market uptake (AARB 2012).

A.4 Container Terminal Management

This case study is based on consultation with Patrick Pty Ltd who operate four container terminals throughout Australia (Melbourne, Brisbane, Sydney and Fremantle. The company has the capacity to manage up to 3.9 million TEU (Twenty Equivalent Units) of assets per year. Typically, there are two facets to container management: waterside operations (vessel unloading); and transport operations (truck unloading). The effective storage of containers within the dock space is of critical importance to best practice.

The movement of containers is facilitated by large mobile straddles which are able to attach/detach containers (various straddles accommodate different container sizes) and transport them to a desired location. Of importance to effective operations is the locality of such containers as they are loaded/unloaded.

As such, precise GNSS is used to capture locality data, referenced to a regularly updated site locality plan, at the detachment/loading points from the straddle. This information is then linked to an overall management system, which when imposed with certain site constraints, will effectively position every container its content, mass and other useful information as it is moved through the transportation process.

Figure 1 **Container terminal operations**

Data source: Patrick 2012

Such information on locality is important to a number of areas of business operation including improving transport and fuel efficiency, effective container organisation, and even detail such as management of asphalt/pavement stress and conditions.

East Swanson dock in Port Melbourne is a semi-automated site reliant on an augmented GNSS system comprising two localised base stations broadcasting correction (at DGPS level) to the 36 operational straddles around the facility. The required accuracies to efficiently operate within this system and reliable position containers are plus or minus 30 centimetres. It is worth also noting that no height component of the DGPS information is used within location services and constraints relating to time of container dispatch are used to determine the stacking order of multiple containers.

Within fully automated sites, such as Fisherman's Island in Brisbane, the accuracy requirements have been increased to plus or minus 2 centimetres due to the requirements of the automation process.

In addition to effective container management, the additional bonus of full site automation is that pavement/asphalt stress is reduced due to the dynamic location of loading bays which are regularly shifted in the order of metres to reduce continual loading stress. Costs have been estimated at approximately $1 million per year in loading bay maintenance, with larger costs for redevelopment works on cycles of about 5-10 years. Reduction in loading stress reduces these ongoing maintenance and overhaul costs by approximately 35%.

A.4.1 Benefits

The overall potential benefits of full Automation throughout Patrick sites have been estimated at 55 million per site, based on current day figures.

- fuel and transport efficiency
- reduced machine wear and tear
- pavement / asphalt management
- improved safety (reduced collisions and transport related risks)
- reduced driver injuries due to remote straddle operation
- route optimisation
- reduction of labour through automation
- storage management
- fleet monitoring.

A.4.2 Adoption Costs

The investment into automation of port facilities was largely underlined by the advent of the worker strikes of 1998, with Patrick identifying the need for a reliable and efficient system to be developed to improve potential lost operation risks, increase efficiency and minimise safety risks.

Initial investment outlay in the late 1990's was in the order of $250 million given the more excessive equipment costs during that period. However recent figures quoted have seen development and system upgrade costs reduce to approximately 1.5 million per site.

Patrick has recently announced the full automation of its Port Botany site in Sydney comprising 44 fully automated Straddles. The investment in this system totalled $348 million.

A.4.3 Productivity Estimates

Productivity estimates are currently being realised from operations particularly associated with automated and semi-automated straddles.

It is estimated that fully automated facilities, such as those in place at Fisherman Island, have reduced current staff levels by up to 50%. Sites operating under semi-automation have reduced levels of staff by up to 33% and have recorded mass savings in a number of key areas.

Previous to the adoption of GNSS as part of the container management process, hand-audits were conducted as part of the management process which required full site shutdowns and limited verification process. Inefficiencies associated with such practice added an additional 20-30% cost with overall processes.

Fuel Costs have been estimated at 1000 litres per Straddle per day (continuous operation), a perceived 30% reduction in fuel from smoother operation and controlled speeds puts an estimate of savings around 109,500 litres of fuel per Straddle per year, or an approximate saving of close to $200k per year at Current Diesel Costs.

> "The redevelopment will increase our throughput by almost 50,000 containers per year and, with additional investment in future years, will give us the ability to increase to more than 2.8 million containers per year in line with increasing demand. " (Patrick 2011)

A.4.4 Safety

There are obvious safety benefits to adopting automation as part of operations. These include reductions in driver fatigue and strain, collisions and loading incidents.

> "In the first year of automation at our Brisbane AutoStrad™ Terminal, we achieved a 75% reduction in safety incidents, increasing to a reduction of 90% in following years. It is only logical that we look to replicate this success at our biggest container terminal at Port Botany." (Patrick 2011)

Appendix B Level of Adoption

The demand for transport and the availability of vehicles is often changing quickly; real time access and analysis of these variables can yield significant cost savings. As such, there is a fundamental underlying interest in maximising productivity benefit through adopting intelligent transport systems.

The transport industry was one of the first to employ GPS as means of tracking vehicles and freight movement and is already widely adopted. Tracking goods in transit now utilises GNSS which increasingly utilises integrated systems of GNSS and electronic mapping systems for total integrated systems (such as in car navigators) (ACIL Tasman 2008). As previously mentioned, this is widely adopted, however does not relate directly to precise positioning applications due to the relatively low accuracy requirements of the system at approximately the 10m level.

In regards to container management, full automation adoption is likely across the majority of Australia's port facilities due to the efficiencies that large projects (as demonstrated by Patrick) are currently demonstrating. The current industry adoption of semi-automated facilities sits at an estimated 80% with full automation representing the remainder. Full automation adoption rates are likely to change significantly over the coming decade as advances in GNSS positioning, reliability, coverage and compliance coupled with demonstrated realised long term benefits, convince the industry to become reliant on automation.

B.1 Adoption Factors

Adoption is driven by a number of factors. More broadly speaking, the classic textbook reference by Rogers (1964) identified a five-step decision process involved in technology adoption and diffusion:

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

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

B.1.1 Fleet Integration

Given that C-ITS tries to relate the driver to the immediate environment, including other vehicles in the network, the effectiveness across various applications is not completely realised until all (or at least the vast majority) of vehicles have the system installed. This is a significant challenge due to the costs of updating vehicles across many different demographics and could be a 40 year exercise if not specifically enforced by regulatory agencies such as the TCA.

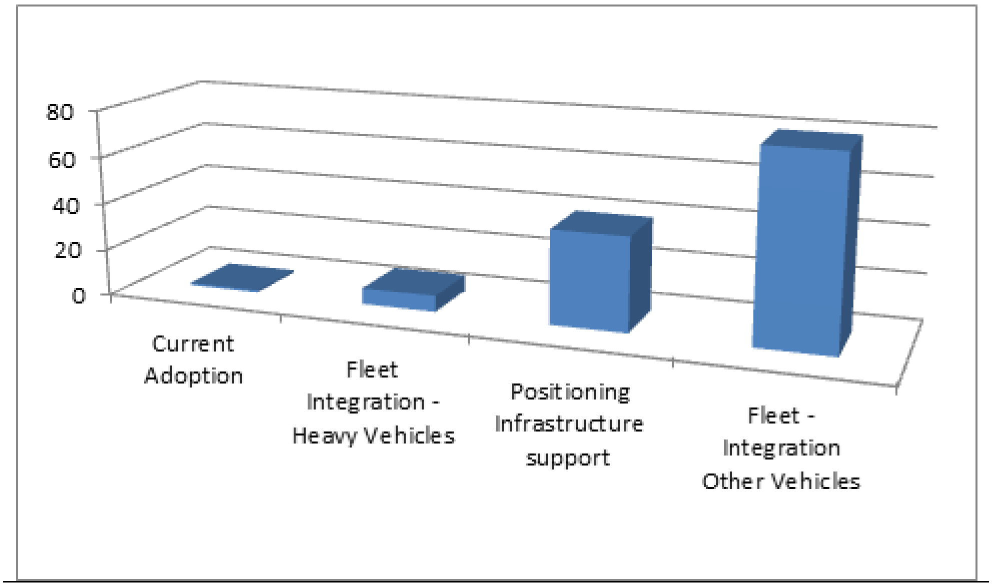
A more likely and immediate scenario is to see adoption of C-ITS across smaller sample road users, most likely Heavy Vehicles. This is much more probable and realistic given the relative reduced numbers and greater operator net benefits (after allowing for adoption costs).

B.1.2 Positioning Infrastructure to support where in lane positioning

To realise the full benefit from C-ITS, in particular the safety benefits, sub metre, where in lane positioning is a requirement. This is a significant challenge to support given the breadth of Australia's road networks and would require substantial upfront investment.

An indication of the impact on adoption levels of development of systems and infrastructure is provided in Figure 2. The graph demonstrates the estimated rise in adoption level as the various adoption factors are overcome through developments.

Figure 2 **Stages in adoption of C-ITS**



Data source: SKM

Figure 3 shows the levels of Adoption of C-ITS as adoption impediments are overcome. There is likely to be a significant increase in adoption of C-ITS when accurate positioning infrastructure becomes more widely available. This is likely to involve not only the extension of more traditional augmented GNSS systems but also extension of GNSS consistent systems into tunnels and metropolitan areas aided by technologies such as Locata. The ability of GNSS receivers to report position seamlessly between different positioning infrastructures can be expected to increase the demand for such systems by transport operators.

As these are partially or fully overcome there will be a direct correspondence with transport adoption of positioning systems and technologies. Table 7 below is speculative but an attempt to project the likely technological advances in positioning adoption factors.

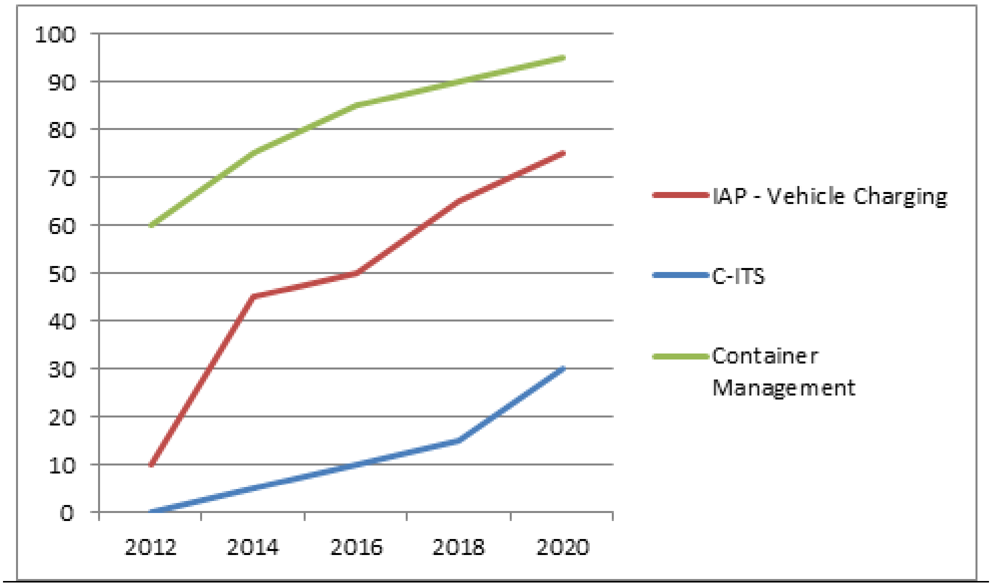
Table 7 **Estimated timeframe for overcoming adoption factors – Transport**

	Optimistic	Medium	Conservative
Fleet Integration - Heavy Vehicles	2014	2018	2020
Positioning Infrastructure Support	2016	2020	2025
Fleet Integration - Other Vehicles	2020	2030	2040

Data source: Data source: SKM

Figure 3 below displays the likely increase in adoption of GNSS precise positioning technologies amongst the Transport sector. Three curves have been estimated based on the implementation of GNSS positioning amongst transport applications identified throughout the case studies.

Figure 3 **Adoption rates**



Data source: SKM

Appendix C Social and Environmental

Given the anticipated growth in transport networks and activities Australia wide over the coming decade there is an increased emphasis on the sustainable management and use of existing and new infrastructure. As such, the growing reliance of intelligent platforms like C-ITS will play a critical role in providing information to best utilise the many existing and projected new users of transport networks.

Reducing congestion, fuel consumption and the carbon footprint associated with road users will all be greatly aided by the implementation of positioning amongst interactive transport management systems. This will be achieved through the correct and reliable relay of the spatial relationship between vehicle position and greater road environment.

Box 2 Reducing environmental impact

A commitment from Woolworths' transport to reducing its environmental impact of its fleet, including a goal to reduce carbon dioxide emissions by 25 per cent per carton by 2012 has led to an investment in transport management systems to reduce truck trips and drive supply chain efficiency.

The rollout involved specifically designed trailers and technology to plan, optimise and track outbound freight movements. The technology optimises transport movements from distribution centres (DCs) to stores and utilises truck back loading capacity.

Reported benefits include "real time" visibility of the vehicle fleet which enables proactive management of deliveries into stores.

Source: Woolworths 2010

Not only will environmental concerns be addressed through the integration of intelligent spatial information through a common platform, but improvements in safety for all road users will mark a significant step forward for a community of road users who have been exposed to a prolonged environment of hazardous road conditions and severe injury and fatality associated with road accidents.

Precise positioning is already realising many in-vehicle safety features (as previously discussed) in other countries. As it begins its adoption in Australia, not only will it support the immediate vehicle safety of drivers, it will also gather intelligence to support better and safer use of the larger surrounding road networks and all commuters who are dependent upon them.

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