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Submission to the

House of Representatives Standing Committee on

Infrastructure and Communications

Inquiry into the Role of Smart ICT in the Design and Planning of Infrastructure

July 2015

1. Introduction

NICTA thanks the House of Representatives Standing Committee on Infrastructure and Communications for the opportunity to submit a response to the Inquiry into the Role of Smart ICT in the Design and Planning of Infrastructure.

NICTA has made representations to the Australian Government Productivity Commission 2014 Inquiry into Public Infrastructure[1] – attached in full at Appendix A – and to the Australian House of Representatives Standing Committee in March 2015[2] on the critical role of Smart ICT in the design, planning and operation of infrastructure.

This submission expands the earlier submissions, explores application areas that are fundamental to Australia's economic prosperity, and makes recommendations for immediate action. It incorporates NICTA's continuous thinking in areas of fundamental science that increase economic productivity, describes projects that demonstrate the potential of current technologies, and makes recommendations regarding how government can promote Smart ICT in infrastructure.

Simply put, investing in infrastructure is much more than 'pouring concrete'. NICTA recommends that the Committee support four tangible actions, in turn supported with regulation and linking actions to future infrastructure funding:

Recommendation 1: Encourage data creation and access for existing and new infrastructure Smart ICT needs data to work. Harnessing currently available sensor and measurement capabilities and making the data widely available can generate real gains today. Requiring all new infrastructure built to have comprehensive data gathering capabilities provides the data infrastructure needed for smart ICT.

Recommendation 2: Enable robust evidence-based decision-making Analyse and model historic and predictive infrastructure-related data to make smarter infrastructure investments. By more systematically gathering data regarding strategic decisions on infrastructure, the quality of such decisions can be improved.

Recommendation 3: Re-think infrastructure as more than the physical The physical component of infrastructure (roads, bridges, rail, ports and so on) will remain dominant, though it is not the entire solution. Infrastructure is built for a purpose (for example moving goods and people). Future infrastructure can contribute to this goal by deploying better algorithms (for example adaptive variable pricing schemes) in addition to the construction of physical infrastructure. By focussing on the problems which infrastructure aims to solve, one can take a broader view of what infrastructure is, and find cheaper and better solutions to pressing problems.

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[1] See Appendix A: NICTA Submission to Productivity Commission Inquiry on Public Infrastructure – April 2014

[2] Presentation to the Standing Committee, 24 March 2015

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Recommendation 4: Mandate use of Smart ICT in upgrades and new infrastructure The federal government can require that only projects demonstrating use of smart ICT can access its infrastructure funding. The federal government can also use its influence in national and state regulations to encourage the use of Smart ICT.

We would welcome the opportunity to further discuss these recommendations with the Committee.

2. Why Smart ICT for Infrastructure?

'Smart ICT' has created a fundamental shift in how infrastructure should be planned for, built and maintained now and in the future. 'Smart ICT'[3] comprises a range of tools, techniques and capabilities made possible by digital technology that can be applied to the various stages of the public infrastructure investment process. New data analytics and optimisation techniques can now provide unprecedented insight into major projects at critical points.

Australia can no longer simply pour infrastructure budgets into concrete. Our infrastructure investments during the last decade have not improved productivity, so we must understand where to spend and how to use smart ICT, in particular to improve freight and logistics and to improve urban mobility. These are large economic sectors that can have a profound effect on GDP[4]:

- Logistics and freight employs 1.2m people and adds $131.6B to the Australian economy
- A 1% improvement in logistics productivity increases GDP by $2B
- Road congestion is set to cost Australia $20.4B by 2020. A 10% reduction in congestion adds $2B to GDP

Even modest improvements in infrastructure efficiency will reap large dividends for Australia.

The need for new infrastructure to support growth is evident from several trends:

1. That the world is increasingly urbanised, with forecasts of 75% of the planet's population living in urban areas by 2050;
2. That our largest cities, Sydney, Melbourne, Brisbane and Perth and Melbourne, are forecast to double their population in the same period[5]; and
3. That the growth in wealth and population in Asian nations will drive a significant boom in quality agricultural produce, creating an opportunity for Australian producers if we are ready to capture it.

Less evident is how existing infrastructure can be better used to meet demand, and how Australia can better use available evidence to make good decisions on where and how to invest.

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[3] There is no universally accepted unique definition of 'Smart ICT.' In this document we use it to mean to a range of tools and techniques that include advanced information and communications technology (ICT) such as data analytics, optimisation, modelling & software systems, networked sensors, integration with mobile devices and new ways of gathering data, such as social media and crowd-sourcing.

[4] Bureau of Infrastructure, Transport and Regional Economics.

[5] www.abs.gov.au/ausstats/abs@.nsf/products/AC53A071B4B231A6CA257CAE000ECCE5?OpenDocument

Underutilisation of infrastructure assets is rife across Australia – in both the private and public sectors.

Most vehicles owned by private citizens are used less than 5% of the time, and when they are driven with an average 1.3 passengers. Many toll roads have been built which have consistently lost money due to over-optimistic demand prediction while public roads are over-used.

'Peak load management' has long been an operating constraint in power and telecommunications sectors; though both those sectors have spent much of the past two decades testing and implementing demand management approaches such as variable pricing to delay spending on new capital. Such smarter control algorithms can be widely applied to develop demand management techniques for infrastructure.

The above challenges are solvable because of the opportunity for far greater data-driven decision-making than previously possible. This opportunity is driven by three broad technology trends:

1. The increasingly instrumented, measured and 'sensed' world (the so-called Internet of Things) – so we know better than ever how things are working
2. Ever-increasing computational power to process the new data, and
3. The growth in algorithmic capabilities (better mathematical bases for programming computers to carry out the complex tasks which allow us to solve problems better than before)

These technological capabilities can be combined to enable modelling of real world environments with higher accuracy and granularity, and they can support improved scenario modelling (both at city and national scales). These are new opportunities.

Smart technology is often considered to be 'future-oriented'. However NICTA's recommendations are possible *right now*. There are simple and specific steps government can take that will greatly enhance the efficiency of Australia's infrastructure. NICTA is willing and able to help make these changes.

Changes that are implementable right now include:

- Harmonising data formats to create nationally consistent arrangements for infrastructure data storage and access – as NICTA did for the mortgage processing industry in 2007 saving an estimated $75 million a year[6] or as we did for most Australian States' household travel surveys in 2014;
- Develop and deploy innovative technology to map, model, design and operate infrastructure – as NICTA has done with water utilities and bridge asset managers, explained in our Productivity Commission submission (in appendix A); and,
- Examine the productivity benefits of Smart ICT through initiatives such as multimodal public transport systems or increased transparency of data and transaction flows across

[6] https://www.nicta.com.au/category/research/media-releases/speeding-up-valuations-from-two-days-to-two-hours/

complex supply chains (e.g. through port community systems – see later in this document).

3. Evidence-based decision-making for existing and new infrastructure

Infrastructure is not merely the responsibility of the civil engineer. While the majority of infrastructure spending is allocated to roads, bridges and rail, 'Infrastructure' is so much more. Rethinking infrastructure as intrinsically and essentially supported by ICT will not happen overnight, and history suggests that there will be resistance ('technological inertia') from those who feel that computer scientists are invading 'their turf'[7]. But the future seems clear – without the capabilities of Smart ICT, Australia's infrastructure spending will continue to grow, and, as has been the case in the last decade, the problems that need solving will be left unsolved.

As sociologist Susan Leigh Star[8] argues, infrastructure is

- *Embedded* (sunk into and inside other structures – it is thus hard to draw boundaries);
- *Transparent or invisible* (it can be taken for granted, and you only tend to notice it when it breaks);
- *Linked with conventions of practice* (the assumption that it is all about concrete is taken for granted, and those without the skills of concrete engineering can be excluded as 'non-expert');
- *Embodies standards* (standards are central to civil infrastructure, such as the rules on widths of roadways, but standards are even more important, and more powerful in the area of data and ICT);
- *Built upon an installed base* (its rarely truly greenfield);
- *Fixed in increments* (not all at once or globally).

Under this view, a piece of software (implementing an algorithm) that adjusts variable road-tolls in response to current (and predicted) demand is just as much infrastructure as the road pavement itself.

By focussing on the problem to be solved (for example movement of goods and people throughout a city), solutions arise that may not involve the construction of more road surfaces. NICTA looks forward to the day when new ICT technology solutions are woven into existing assets to increase capacity, such as:

- ICT modelling that optimises current traffic signalling in urban areas to reduce the drag on productivity caused by congestion;
- Informing preventative maintenance on major infrastructure such as bridges, road and rail networks to lower costs and reduce disruption;

[7] 'Technological inertia' is the phrase used by economic historians to describe (the entirely predictable) resistance to new technologies, often by those with a strong vested interest in the status quo. Reducing this inertia can facilitate faster adoption of new technologies. See Joel Mokyr, Technological Inertia in Economic History, *The Journal of Economic History* 52(2), 325-338, 1992 and Arnulf Grubler, *The Rise and Fall of Infrastructures: Dynamics of Evolution and Technological Change in Transport*, Physica-Verlag, Heidelberg, 1990.

[8] Susan Leigh Star, The ethnography of infrastructure, *American Behavioral Scientist* 43, 377-391, 1999

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- Integrating crowd-sourced social media into traffic management operations, for improving incident notification, and reducing clearance times and congestion; and,
- Making motorways "smart" with dynamically tuned ramp-metering algorithms, significantly reducing travel times and lifting throughput in peak periods.

Machine learning can be used to develop comprehensive models of current and predicted demand, and then link these predictions to adaptive public transport systems and variable road and parking pricing. This more accurate understanding of future demand will inform better infrastructure investment.

The same premise that justifies building new road, bridge and rail assets – serving existing and forecast growth in population – holds for all other social infrastructure, such as schools, hospitals, sporting and cultural facilities. Underpinning wise investment in these areas is a deep and evolving understanding of demographic patterns: population densities, family size, age profiles, and so on. These and many other factors shape local demand, and they vary both spatially (by geographic location) and temporally.

Example: Robust demographic predictive modelling. Working with a planning agency in one Australian state, NICTA is building a dwelling production infill model incorporating data-driven planning assumptions and methods. This more fine-grained model uses many more data sources as input than is possible with conventional techniques and will be used to better inform infrastructure project selection across all classes of infrastructure including school asset planning.

The prediction method is based on discovering relationships between all potentially relevant data and the historical record of where and when new dwellings have been developed in existing urban areas. NICTA applies machine learning and data fusion techniques to discover these relationships and build the models, working with, and informed by planning experts. Machine learning models can be trained with historical data, allowing predictions to be compared against the historical records and current departmental assumptions, and generating estimates of confidence in the modeling output and a view of which input factors are most relevant.

NICTA has applied this approach successfully in a number of different domains ranging across predictive maintenance, crime prediction and predicting where road traffic incidents will occur.

A major challenge in infrastructure investment is the basis on which the decisions are made. There are now proven and robust cost-benefit analysis approaches that incorporate techniques to overcome the optimism bias reflected in many project proposals. For more than a decade, the UK government has required budgeting to formally reference the experience and outcomes of similar projects in all forecasts[9] (so-called reference class forecasting). Smart ICT, in the form of machine learning[10] applied to all available historical data could further improve the accuracy with which infrastructure projects are costed. One of the great strengths of machine learning is

[9] https://www.gov.uk/government/publications/green-book-supplementary-guidance-optimism-bias

[10] Machine Learning facilitates evidence-based decision making in the presence of uncertainty. It does this by combining disparate pieces of information and distils the results in a way to make better decisions. Machine Learning is the science that banks and retailers use to predict take up of new products and services to great effect. The power of machine learning stems from its capacity to use all available data to make predictions, far beyond the power of conventional statistical techniques. See www.mckinsey.com/insights/high_tech_telecoms_internet/an_executives_guide_to_machine_learning

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its ability to draw on all available data sources to make predictions, far beyond the power of conventional statistical techniques.

Such ideas are not new; they were a key part of last year's Productivity Commission report[11] that noted "unrealistic cost and demand forecasts also arise due to strategic misrepresentation. That is, proponents of a project often have a personal stake in it proceeding and so have an incentive to make it appear better than it really is". Even with the best will in the world, without the data (and means to analyse it) poor decisions will continue to be made.

For example, applying machine learning techniques to demographics generates better insights into brownfields urban growth rates ('urban infill') and can help inform planning for greenfields urban developments. These techniques can make effective use of a much wider range of input data sources than existing practice based on conventional statistical techniques. Presenting this information in 'spatially rich' contextual environments, fusing data from multiple sources and developing analytics tools to support data-driven decision-making will unlock new levels of infrastructure insight into demand. Optimisation science can then be used to better understand how to provide for this future demand.

Example: Open data and flexible models boost productivity: National Map and Terria Analytics

Working for the Australian Department of Communications and working closely with partner Geoscience Australia, NICTA's Terria team developed the software for the National Map initiative (www.nationalmap.gov.au), placing government spatial data, which was previously difficult to access, into the hands of community, software developers and industry. The sort of searchable data that is available is varied and includes data about broadband coverage, location of surface water and waste management facilities, infrastructure developments such as gas lines, and electoral boundaries.

This initiative is acting as a key enabler of innovation to boost government and industry productivity, prompting new business and providing better services to the community. The National Map website also acts as an incentive to government to release more data, in a searchable and reusable format, into the community. This platform saves departments reinventing the same tools and also allows the whole community to see a single view of all the infrastructure and resources in any location. The long-term productivity benefits will be substantial.

Terria™ has developed a suite of web-based analytics tools to extract insight and make probabilistic predictions using data in a web-based mapping environment. These tools are built from state of the art machine learning algorithms designed specifically for large-scale spatial inference.

Smart ICT can improve all stages of the infrastructure lifecycle – not just in design and planning, but also in construction, operations and maintenance – and achieve significant government spending efficiencies.

Examples of how government policy could accelerate adoption and use of Smart ICT across both public and private sectors, driving greater productivity in key areas of the economy, from consistent urban and demographic planning through to traffic management, supply chains, emergency response and more include:

[11] http://www.pc.gov.au/__data/assets/pdf_file/0003/137280/infrastructure-volume1.pdf, page 102.

Evidence-based Planning and Design Build smart infrastructural assets in the right place at the right time, and at the right scale, using detailed historic data as evidence.
Possible policy intervention: Mandate the documentation and sharing of all relevant data so that learning from past projects is possible. Often this is hidden under the label of 'commercial-in-confidence', but if the rule applies to all, and applies to public infrastructure, then all players are impacted (and benefited) equally.

Efficient Construction Use integrated optimisation and planning techniques to be as efficient as possible while building and to minimise disruption to surroundings during construction. Integrate both design and construction activities to minimise what the British call "optimism bias" – the chronic track record of underestimated costs, overestimated revenues or utilisation measures, overvalued local development effects and underestimated environmental impacts[12].
Possible policy intervention: mandate (as required by the UK Government department of transport) that such empirically calibrated methods be used for all major infrastructure projects, linking federal funding to the demonstration of these techniques in project proposals.

Intelligent Operation Increase the efficiency of infrastructure assets using Smart ICT, that is, through sensors and analytics and optimisation techniques. Integrate infrastructure with other parts of the network and activities using the asset. Ensure flexibility in design that allows both hardware such as sensors or physical components and software to be upgradable as new technologies emerge.
Possible policy intervention: *Link federal infrastructure funding to project proposals that incorporate this kind of Smart ICT and demonstrate integration into the wider infrastructure base. Further require that operating data is made widely available for the most efficient operation of the asset and to guide future investment[13]. Require that new physical assets are instrumented fully and the data is made available widely to allow the development of services for better management of physical infrastructure assets. Require that non-physical infrastructure such as control software design be considered in all proposed new infrastructure.*

Maintenance Extend asset life through predictive analytics to ensure assets last longer, reducing costs and improving safety and efficiency.
Possible policy intervention: Require any federally funded proposals for upgrading existing infrastructure to be based on fine-grained data relating to specific maintenance actions, rather than crude whole-of-asset analyses. Ideally require improved instrumentation when upgrades occur.

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[12] Bent Flyvbjerg, Design by Deception: The Politics of Megaproject Approval, *Harvard Design Magazine,* Spring 2005.
[13] For example, the California Department of Transport makes many kinds of data available to encourage both academic and commercial innovation (see http://www.dot.ca.gov)

4. Three actionable areas: Freight and logistics, Urban mobility and Agriculture

Three areas of our economy call out for new infrastructure and are perfect candidates for the immediate application of smart ICT:

1. **Freight and logistics** contributes between 9-14% of Australia's GDP (depending on various reports), underpins the export sector and urgently requires cost reduction and improved productivity.
2. **Urban mobility** must be as 'smart' as possible to maintain or improve transport efficiency as cities grow – allowing individuals to move as freely as possible by the most optimal mode of transport
3. **Agriculture** requires refined decision-making tools and supply chain management to ensure we capture the benefits of Asian growth while exploiting Australia's natural comparative advantage.

Freight and Logistics – Optimise for sustainability and efficiency amid uncertainty

Government policy and regulations have much to contribute to support innovation and efficiency in this sector. By capitalising on the vast array of data in this complex system, government has the opportunity to create immediate productivity gains though Smart ICT.

Moving goods around Australia is a greater challenge than in many other developed nations and, due to our export focus, of greater importance. Freight and logistics represents nearly twice the contribution to GDP in Australia compared to Europe and the USA. Australia has both vast line haul challenges given our size and extremely complex last mile logistics given the density of our urban areas.

These challenges are complicated further in the import/export sector as Australia is at the 'end of the line' – that ports have little transhipment cargo to defray fixed expenses – and typically 85% of goods delivered to major metropolitan ports are for delivery within a 20km radius of that port. Add to this the highly fragmented nature of the logistics sector: hundreds of companies operate with minimal barriers to entry, leading to varying rates of technology adoption and use and consequently poor decision-making at a holistic level. As NICTA has identified previously, by collecting data from current infrastructure systems (such as transport networks) and building evidence-based data-driven models, infrastructure performance can be more effectively measured and operating inefficiencies identified. Medium-to-longer term large-scale planning decisions can now be made with far greater certainty.

Example: Port Botany Rail Sydney's sea freight is forecast to more than triple its container capacity from 2M TEU[14] to 7M TEU in the next 15 years. Currently 86% of containers move through the port area by road. This is unsustainable given Sydney's current road configuration. Can rail accommodate more container volumes, and if so how does the sector encourage modal shift from road to rail?

NICTA worked with all key participants in the Port Botany rail supply chain to develop a data-driven dynamic model of freight operations to understand capacity of the existing network and its bottlenecks, with a view to increasing performance. The results indicate that significant capacity is accessible through

[14] Twenty-foot equivalent units

operating performance improvements, rather than requiring additional capital investment for constructing new infrastructure.

NICTA's analysis demonstrated that a potential rail track upgrade estimated to cost up to $200m could be delayed by 15-20 years through applying a new optimised freight movement schedule.

Freight and logistics optimisation can be applied to many multi-party, highly competitive sectors, providing, often for the first time, a fact-based analytic tool that can be used to identify and prioritise improvement initiatives.

By collecting data from current infrastructure systems and building evidence-based data-driven models, infrastructure performance can be more effectively measured and operating inefficiencies identified, medium-to-longer term large-scale planning decisions can be made with greater certainty. Additionally, better integrated decision-making can be made on how major infrastructure facilities – such as airports for example – will affect other infrastructure such as road and rail links, transport interchanges and inter-modal terminals. New optimisation techniques that can factor in this kind of real world complexity and operating constraints in ways which have not been possible until recently.

Example: Dynamic Freight Map NICTA's initiate to map, analyse and optimise Australia's freight movements. The starting point of the project is to map and visualise sea freight movements in and out of Australian ports for a period of 15 months.

The goal of the project is to maximise the efficiency of "end-to-end" supply chains in and out of Australia through lowering total cost and time, increasing the output of current infrastructure and provide a framework for optimum allocation of future investments. To achieve this goal, we are effectively combining NICTA's domain, machine learning and optimisation expertise. The visibility that this system provides will allow better mapping of freight to transport modes as well as new opportunities for dynamic pricing models.

Urban Mobility – Analytics resolve congestion issues

Urban traffic congestion remains a largely unsolved problem – ranking as a priority issue for each of Australia's recently elected State Premiers. Smart ICT has potential to accelerate novel solutions to this challenge:

1. By fusing existing data sources to create a better understanding of how the transport system is operating and how demand is growing, we can optimise the current transport system in real time – such as is done with "smart" motorways (see M4 example), inject predictive phasing of traffic lights, inform route selection and scheduling for public transport, or indicate where to invest in new road capacity;

2. Improved demand management by allowing the use of tools such as dynamic pricing to control demand on toll roads, for parking or ultimately road user pricing. A second part of this is improved information for travellers and freight operators so they can make better decisions on transport modes, routes and time of travel; and,

3. On a longer time scale, understanding demand patterns and combining this with demographic trends allows the kind of urban redesign which grows more housing near precincts where jobs are growing and creates the kind of density which makes public transport viable in more places.

Developing accurate data-driven models of where people want to go, by which mode at what time and for what purpose is a start. Such a platform can be used to understand supply and demand imbalances, test and track the impact of initiatives including new mobility options such as light rail, integrated mobility (see BusPlus example, below), demand management techniques, intelligent transport systems such as smart motorways, and so on. This platform can also be used to track and analyse the benefit of past initiatives, to feed into models for new investment and ameliorate optimism bias.

Example: Transport Analytics as a Service. NICTA is continually developing and refining tools that apply machine learning to urban mobility. These integrate 'big data' analytics, transport modelling, traffic management and transport economics, with the intent to reduce congestion, improve road planning and provide traveller information services. As a system, these tools will be the foundation for understanding how, where, when and why congestion occurs and how to mitigate its effects in real-time. This will inform future transport infrastructure planning and investment.

Transport authorities typically collect a wide range of data from the road network, from real-time traffic volumes to incident management logs and public transport information. Currently, much of this data is not used in an integrated way. The core innovation of the NICTA system is a platform to integrate and fuse transport data from all current and future data sources and to incorporate this fused data into transport models built using the most advanced analytic techniques. This can then feed into operations, planning and traveller information services.

International and local evidence shows that this kind of superior situational awareness in the transport system leads to shorter and more reliable travel times for private vehicles, buses and trucks. The City of Dublin used better information systems to reduce bus travel times by 10%, and by making Sydney's M4 motorway "smart" we predict 40% faster travel times (see example following).

NICTA's vision is that Australia will develop a large scale urban transport modelling and data platform that will have utility across all transport modes and provide better insight into how to operate, plan and invest across different kinds of transport infrastructure. This vision is one requiring considerable research and engineering effort, allowing all stakeholders to make the most informed transport decisions.

A recurrent concern for city planners is how to increase the use of public transport. The past decade has seen a proliferation of 'apps', journey planners and the like that provide greater visibility of transport options to the commuting public. Within this frame, off-peak public transport provides an extreme example, being frequently inefficient, poorly used and expensive. This does not need to be the case: integrated data-driven systems can allow optimised, integrated transport solutions.

Example: BusPlus – Multimodal public transport NICTA has designed a "hub and spoke" off-peak public transport option which uses taxis to aggregate passengers for busesto provide improved service, greater passenger convenience and lower carbon emissions. This service is particularly beneficial during off-peak times, when public transport is frequently inefficient, poorly utilised and expensive to deliver.

NICTA's solution came from solving low public transport utilisation in Canberra, by introducing a hub and spoke model to the problem. Hubs are designed to be linked by buses, which run frequently (typically every 15 minutes) to facilitate public transport. Passengers are connected to these hubs by taxis, which will bring them to their nearest bus stop by simply booking a trip online, by phone or by downloading the app – and only 15 minutes before they need to go.

The strength of this solution is that the BusPlus system plans the whole route – pickup at your local stop, bus travel, and a taxi waiting at the other end to complete the journey. Passengers may share taxis – up to three passengers per taxi, and when necessary, minibuses can also be used as shuttles. The net result is an on-demand service that is 30% faster end to end and cost neutral.

Australia can use its existing assets better. 'Smart Motorways' refer to those that have included 'Intelligent Transport Systems'[15] (ITS) such as ramp metering, variable pricing, hard shoulder running and similar techniques to extend the life of existing roads and achieve closer to optimal throughput in the busiest times of the day. ITS initiatives are a ready example of Smart ICT in action: they leverage instrumentation – sensors, monitors and related hardware – to collect and transmit mobility data, connect this data through the network and apply intelligence – the user-facing programs and efficient processing algorithms – to enhance personal mobility.

Example: Ramp metering for Sydney's M4 In late 2014, NICTA investigated a component of the managed motorway concept on Sydney's M4, with cooperation from the NSW RMS. The purpose was to evaluate the performance of ramp metering in managing traffic on selected sections of the M4.

NICTA developed a new ramp metering system and traffic data analytic tool, simulating coordinated ramp signals along the entire managed motorway section, to optimise control performance. The traffic data analytic tool uses motorway detector data and SCATS data to an estimate origin-destination matrix.

The historical traffic data shows recurrent congestion during the evening peak hours, in particular the section Westbound between Cumberland Hwy and Roper Road. Applying machine learning and simulation in targeted ways, NICTA demonstrated:

Travel time reduction: travel time during the most congested period for trips travelling west along the M4 mainline from Prospect to Roper Rd is reduced from 16 minutes to 9 minutes, registering a benefit of more than 40% in travel time;

Capacity improvements: on the most congested part of the M4, an additional 1000 cars an hours can move through the system smoothly – equivalent to an extra physical lane; and,

Economic impact: during one year, these savings represent 400,000 commuter hours – equivalent to 300 people working for a year. The direct economic cost equates to about $22m a year, excluding additional social and environmental costs.

Agriculture – grow and export more competitively

Many sectors of Australia's economy warrant the application of Smart ICT. Agriculture is called out for special attention in many forums, given its historical role in our society, its 3% contribution to GDP, its more than $38B in export income[16] and its prospects for growth. Last year's report from McKinsey and Company, *Compete to Prosper: Improving Australia's global*

[15] Intelligent Transport Systems (ITS) is a broad term that refers to the use of computers for back-end software, networks, and sensors to better manage and control transport outcomes across all modes. Well-known examples include adaptive traffic light technologies such as SCATS, Variable Message Signs and techniques such as Ramp Metering for managing "smart" motorways.

[16] http://dfat.gov.au/trade/topics/Pages/agriculture.aspx

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competitiveness, highlighted agriculture as by far Australia's most competitive industry when compared with the US. The federal government's Agricultural Competitiveness whitepaper released on 3 July this year recognises and prioritises both the need for new infrastructure (largely roads and dams) and the desire to 'farm smarter' – providing access to advanced technologies and practices including better research and development.

Two things that can be done now to increase Australia's agricultural competitiveness are

1. Developing a more robust decision-support tool for farmers fusing historical data sets (weather, soil types, crop yields, and so on) in a far more granular[17] way that has been done to date, providing more robust prediction capability to increase future crop yield; and,
2. Superior supply chain management to reduce the cost of exports and increase global competitiveness. While it costs more to move a container of goods 20km across a metropolitan city than it does to ship that container from an Australian port to Shanghai, we have work to do. NICTA's work developing port community systems is a ready example of how Australia can inject Smart ICT to better design and planning of agricultural supply infrastructure.

Example: Port Community System. NICTA has worked with around 200 domestic and international supply chain participants to draw attention to the value of Port Community Systems (PCS). A PCS is a neutral and open computer system that allows supply chain participants to rapidly and securely exchange information after a single submission of data.

Australian container freight supply chains suffer massive inefficiencies due to fragmented multi-party transactions, inadequate information sharing and variable IT penetration:

- A single container movement can require 120 transactions with up to 50% having data items unnecessarily repeated, increasing error rates
- Supply Chain Participants (SCPs) communicate through multiple channels and interact with multiple proprietary IT systems via multiple screens
- Issue identification is reactive, not predictive, and exacerbated by limited visibility of container identifiers, and cargo, at many stages across the supply chain.

PCSs enable public and private stakeholders to optimise, manage and automate port and logistics processes, facilitating commercial interactions between supply chain participants. This generates a lower cost of goods for consumers and higher returns for exporters as efficiency gains are realised, by reducing re-keying of data and consequent data entry errors, simplifying and automating processes, generating real-time alerts and enabling more effective fleet (vessels, trucks and locomotives) operations. Australia currently ranked 49th out of 200 countries[18] for its port efficiency based on time, complexity and cost. A PCS can make radical improvements. For example, Morocco[19] reduced waiting times by 45% after the introduction of a PCS.

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[17] For example, in enough detail for a farmer to make decisions for parcel of land within their farms

[18] Doing Business Reports, World Bank "Trading Across Borders Indicators"

[19] http://portfinanceinternational.com/features/item/2017-morocco%E2%80%99s-portnet-national-single-window-for-foreign-trade-cuts-waiting-times-45

5. Conclusion

Infrastructure is the foundation of Australia's economy, particularly in transport (road, rail, air, sea and their relevant supply chains), utilities (water, energy, communications), the built environment (cities, buildings, bridges) and communications networks. Each of these require large capital items that operate inefficiently, have a large impact on GDP and productivity, have suffered from chronic under-funding and excess demand, are highly regulated and historically 'innovation-resistant' cultures. They are also very expensive to upgrade and build.

To increase operational efficiency of Australia's infrastructure, to lower costs for both operations and maintenance and move to evidence-based investment of scarce funds, we can leverage Smart ICT in every aspect of the infrastructure asset lifecycle.

Smart ICT enables active demand management by accessing and presenting data needed to understand demand and the analysis to apply optimal demand shaping. It makes better use of existing data, and fuses new data sources. Machine learning and optimisation techniques – such as mathematical modelling, simulation, visualisation – provide predictive insights to highlight ways of improving operational efficiency, to uncover latent capacity in existing systems, and improve demand prediction to strengthen investment decisions.

Smart ICT enables superior and more insightful consideration of issues at the design and planning stages, and reduces risk and uncertainty – addressing "optimism bias" during the build phase and informing operational efficiencies throughout the life of assets. As computational power and algorithmic complexity grows, these techniques and tools will provide even greater ability to reduce cost and improve productivity.

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Australia's economic success during the next few decades relies on increasing productivity across each sector of the economy. Ensuring the use of Smart ICT in the design and planning of public infrastructure, matched through construction and operations will enable major projects to be designed, built and managed with greater efficiency and productivity than is currently the case, resulting in better value for public money.

NICTA recommends that the Committee take all actions possible to encourage data creation and access for existing and new infrastructure, enable robust evidence-based decision-making, re-think infrastructure as being more than the physical, and mandate **use of Smart ICT in investment in upgrades to existing, and creation of new, infrastructure.**

Contacts

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About NICTA

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NICTA is funded by the Australian Government through the Department of Communications and the Australian Research Council. NICTA is also funded and supported by the Australian Capital Territory, New South Wales, Queensland and Victorian Governments, the Australian National University, the University of New South Wales, the University of Melbourne, the University of Queensland, the University of Sydney, Griffith University, Queensland University of Technology, Monash University and other university partners.

APPENDIX A

NICTA Response to the Public Infrastructure Productivity Commission Issues Paper and Draft Report

March 2014

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Introduction

NICTA thanks the Productivity Commission for the opportunity to submit a response to the Public Infrastructure Issues Paper and Draft Report.

NICTA understands the importance of productivity enhancing infrastructure development to boost growth and create jobs in the current economic environment:

> "As the G20 Finance Ministers and Central Bank Governors in Sydney stated earlier this year, the Council on Federal Financial Relations agreed that productive infrastructure is critical to Australia's future competitiveness and economic growth.
>
> It is imperative that Australia invests in infrastructure projects that address debilitating bottlenecks and build the capacity Australia needs for the 21st Century.
>
> Infrastructure spending can provide a short-term economic boost by stimulating construction activity, and ensure long-term prosperity by increasing the productive capacity of the Australian economy.
>
> Investing in the right infrastructure can also boost Australian incomes by improving quality of life, and increasing productivity, including by tackling congestion, reducing business input costs and by helping firms better link with their employees and customers.
>
> As Australia's historic investment boom in the mining sector slows, there is an imperative to support investment and real activity across the country.
>
> The acceleration of infrastructure expenditure is a challenge, given that the fiscal positions of both Commonwealth and State Governments remain constrained. All levels of government are therefore looking at ways to address funding constraints."[20]

As Australia's largest Information Communications Technology (ICT) research organisation, NICTA consider this policy direction by Federal and State Governments indicates a genuine desire to ensure that any new infrastructure development is optimised for productivity from its beginning to end, and for the public investment consideration process to ensure the best value for money. Fortunately, there is a new and better way to achieve this.

Recent technological advances (or 'Smart ICT') over the last three years have created a fundamental shift in how infrastructure should be planned for, built and maintained in the future. New data analytics and optimisation techniques, for example, can now provide unprecedented insight into major projects at critical points.

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[20] http://jbh.ministers.treasury.gov.au/media-release/010-2014/ Media release from Federal Treasurer announcing asset recycling partnership between Commonwealth and States, 28 March 2014.

For the purposes of this paper, Smart ICT [21] will be a term used to describe a range of tools, techniques and capabilities made possible which can be applied to the various stages of the public infrastructure investment process.

NICTA proposes that Smart ICT should be integrated into the design, funding, construction and operational phases of public infrastructure, and that it becomes a standard part of the consideration process for any new investment.

Specifically, in terms of the Inquiry NICTA seeks to address the scope for reducing the costs associated with designing, funding, constructing and operating such infrastructure.

We welcome a number of the findings in the Commission's draft report, including[22]:

- There are numerous examples of poor value for money arising from inadequate project selection;
- Without reform, more spending will simply increase the cost to users, taxpayers, the community generally, and the provision of wasteful infrastructure; and,
- Data problems beset the detailed analysis of the costs and productivity of public infrastructure construction, and of the effects of various policies. A coordinated and coherent data collection process can address this and improve future project selection decisions.

Infrastructure should not be viewed as simply 'pouring concrete'. Given the fiscal constraints of the economy, investment in public infrastructure needs to provide the best value for public money.

NICTA argues public infrastructure investment can be better informed, funded, designed, constructed and operated by using Smart ICT – which leads to better value for governments, business and taxpayers and greater productivity from the assets themselves. Smart ICT can also optimise the use of existing infrastructure and enable better decision-making about which new infrastructure to invest in the future.

Smart ICT – what is it and what can it do?

Smart ICT is not just sensors and new devices. It includes the latest tools and techniques such as data analytics, optimisation, advanced modelling and software systems.

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[21] A range of tools and techniques that include advanced (ICT) such as data analytics, optimisation, modelling & software systems, networked sensors, and integration with mobile devices and new ways of gathering data, such as social media and crowd-sourcing.

[22] Productivity Commission draft report summary of issues 13 March 2014

http://www.pc.gov.au/projects/inquiry/infrastructure/draft

Areas where smart technology can greatly benefit public infrastructure include:

- predicting future demand for freight and passenger traffic movements in key transport corridors around Australia;
- informing preventative maintenance on major infrastructure such as bridges, road and rail networks;
- optimising rail container handling between port quaysides and inland intermodal terminals to improve goods flow both ways;
- integrating crowd-sourced social media into traffic management operations, improving incident notification, and reducing clearance times and congestion.
- assisting managed motorways to operate with dynamically-tuned ramp-metering algorithms, lifting throughput in peak periods; and,
- optimising traffic signalling in urban areas to reduce the drag on productivity caused by congestion.

The following sections include examples of where Smart ICT has improved the performance or reduced the cost of infrastructure across the different stages of the infrastructure lifecycle.

Smart ICT in planning or design

Over the last two or three years, data analytics has come of age. Smart ICT has developed to a degree where it can greatly inform the planning process and find new, unexpected ways to reduce cost through the latest data modelling techniques and tools.

The latest 'machine learning' can integrate data from multiple sources, 'fill in the gaps' where databases miss records, build 'non-parametric' models that don't need expert opinion to define core operating assumptions, and apply multiple filters to algorithms that can predict with high accuracy what outcomes are likely.

By collecting data from current infrastructure systems (such as transport networks) and building evidence-based data-driven models, infrastructure performance can be more effectively measured and operating inefficiencies identified. Medium-to-longer term large-scale planning decisions can now be made with far greater certainty. Additionally, better integrated decision-making can be made on how major infrastructure facilities -such as airports for example – will affect other infrastructure such as road and rail links, transport interchanges and inter-modal terminals. These can be addressed through new optimisation techniques that factor in real world complexity and operating constraints in ways which have not been possible until recently.

> ***Example 1: Port Botany Rail:*** Sydney's sea freight is forecast to more than triple its container capacity from 2M TEU[23] to 7M TEU in the next 15 years. Currently 86% of containers move through the port area by road. This is unsustainable given Sydney's

[23] twenty-foot equivalent units

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current road configuration. Can rail accommodate more container volumes, and if so how does the sector encourage modal shift from road to rail?

NICTA has worked with all key participants in the Port Botany rail supply chain to develop a data-driven dynamic model of freight operations to understand capacity of the existing network and its bottlenecks, with a view to increasing performance. The results would indicate that significant capacity is accessible through operating performance improvements, rather than requiring additional capital investment for constructing new infrastructure.

NICTA's analysis demonstrated that a potential rail track upgrade estimated to cost up to $200m could be delayed by 15-20 years through applying a new optimised freight movement schedule.

The same approach can be applied to many multi-party, highly competitive sectors, providing, often for the first time, a fact-based analytic tool that can be used to identify and prioritise improvement initiatives.

Australia's infrastructure spans greenfields and brownfields developments. Given our dense urbanisation, new infrastructure is often a question of balancing demand growth within existing corridors. Here, data analytics and optimisation provides useful intelligence when prioritising new investments.

Example 2: Dam-wall overflow flood event: Advanced data analysis is particularly useful in anticipating risk and advising on appropriate action in unexpected scenarios such as disaster management. NICTA modelled the flow of water from a potential spill at Warragamba Dam in Western Sydney. This enables authorities to make informed decisions on the optimal evacuation paths of 70,000 residents in flood-affected regions – potentially saving lives. Data comes from multiple sources and is fused together to give an accurate height-based picture of flows, indicating over time which roads become impassable – providing better information for the state emergency services (SES), police, transport managers and other authorities. The modelling specifically informs which residents should be evacuated in which order, with frequently counter-intuitive insights that could literally mean the difference between residents being safely evacuated or not.

Design of new infrastructure should integrate the less visible ICT components: sensors, actuators and networks that will enable data-driven models to continually calibrate an asset for operational efficiency. Thus for infrastructure planners and operators an alternative to lane widening can be to increase freeway capacity through relatively low-cost and fairly easily installed technology that may satisfy demand for a decade or more. In this way, smart ICT can preserve the performance of very expensive transport assets and extend the life (i.e., increase the productivity) of those assets.

Example 3: Managed Motorways: Recent modelling by NICTA of a West Australian freeway expansion project indicated that existing peak congestion can be addressed either by a $300M addition of an extra lane for 4kms, or by the application of much less expensive smart sensors in the road surface connected to ramp meters (dynamically managed traffic light metering). The latter would see more than a 40% increase in throughput. Melbourne's M1 is already using some of these technologies to optimise traffic flow and shows that the technique works in real systems.

Smart ICT in construction

Data analytics and optimisation can unlock significant value during the construction phase of major infrastructure projects. Project management – prioritising, scheduling and managing the delivery of multiple components, trades and essential services – is an already complex optimisation task. Rarely does a project proceed without some major component being rethought, replanned and redesigned, with knock-on effects across the balance of the project. Complicated construction projects can be managed more efficiently by using Smart ICT to deal with changing externalities and priorities.

Example 4: Sydney Light Rail: The NSW Government's light rail public transport project is looking to improve Sydney's traffic congestion between Circular Quay and Randwick. Closing parts of the route to other modes of transport raises questions about meeting mobility demand within and across the city. Large-scale complex models based on historic and live feeds of data will allow transport decision-makers to visualise where and when congestion will occur and 'hot spots' will emerge.

NICTA has predicted, for example, where & when congestion will occur when a major thoroughfare like George Street is closed, such as for a special event. Data modelling enables transport system managers to evaluate the impact of a range of interventions to the main traffic management system, such as using variable message signs (VMS) to alert drivers of alternative routes, or simulating new routes, e.g. diverting bus traffic to the eastern side of the CBD.

Data analytics can also be used to minimise the community impact from disruptions.. As Sydney's light rail infrastructure will take several years, optimising the construction plan around constraints can help planners understand the impact of street closures on business, vehicular and pedestrian traffic. Modelling street closures can be done well ahead of time to understand the impact on adjacent streets, on public transport capacity and on passenger and freight traffic flows. With visibility of information flows from SCATS (Sydney Coordinated Adaptive Traffic System), PTIPS (Public Transport Information and Priority System), taxi and car sharing companies, congestion bottlenecks can be predicted and measures to mitigate those bottlenecks can be tested to ensure that local communities and businesses have adequate time to prepare for the changes.

Smart ICT in operations

The financial, telecommunications and retail sectors are now regularly integrating data analytics given the volume and complexity of data in their operating environment Infrastructure

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planners and providers need to do the same. In NICTA's work with many public and private sector organisations, identifying and analysing data to optimise business is increasingly becoming one of the most critical factors to success, providing deeper insight and consequently more informed decision-making.

Another attribute of major infrastructure projects is the need to accommodate changing use and demand profiles through their long life cycles. Managing change in the use of critical infrastructure is a reality of growing cities and growing economies. What was designed in one decade, or one era, may change as the surrounding city changes. As a result, its important to model future states to predict the impact of changing demand profiles on existing infrastructure and maintenance and re-investment decisions.

Maintenance of infrastructure

In many infrastructure projects, preventative maintenance is around 10% of the cost of reactive repairs and maintenance. Predictive tools can help prioritise maintenance spend to those elements most likely to fail, thus avoiding or delaying major capital outlays.

Smart ICT can ensure that infrastructure is operated as efficiently as possible. From automatically monitoring a bridge and reporting its structural health status, to dynamically and optimally adjusting the timing of traffic signals, Smart ICT can ensure that infrastructure can automatically respond to demand and new environmental changes to achieve better operational performance.

Example 5: Water Utilities:

Developing more accurate preventative maintenance scheduling has the potential to save the Australian water industry up to $700M per annum. Australia's water utilities manage 140,000km of critical water mains, or an $80Bn water pipeline network. Each year, around 7,000 breaks occur, costing taxpayers roughly $1.4Bn in reactive repairs & maintenance and consequential damage.

NICTA, in collaboration with several water utilities, has developed a new approach to predict the likelihood of water pipe failure. The software creates a statistical model of each pipe within a network using multiple internal and external data sets including current and historic data related to the age, type, material, and size of a pipe, as well as soil composition, external pressure and other factors. By using all the available data, enables a greater number of faulty pipes to be identified and repaired before they break, leading to significant cost savings.

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Example 6: Sydney Harbour Bridge: Sydney's Harbour Bridge has several thousand structural components each of which need to be monitored and maintained. As with other major public infrastructure assets, the Sydney Harbour Bridge requires ongoing maintenance. Current practice requires bridge inspectors to visually inspect every one of the many thousands of bridge components at least once every two years. As the structure ages, demands on inspectors increase and more frequent inspections may be required.

NICTA has developed instrumentation and data analysis systems that combine to provide detailed structural health monitoring of individual components on bridges. Advanced monitoring algorithms detect irregular movements in the structure, while allowing for inherent movements and the impact of the harsh environment. This information is distilled for the asset manager, who can then schedule targeted precautionary inspections that may result in maintenance work being undertaken. The primary benefits to government and taxpayers are greater efficiency, more productive bridge inspections and reduced disruption to bridge users as a result of more timely maintenance.

Call to Action

Australia's economic success during the next few decades relies on increasing productivity across each sector of the economy. Considering the use of Smart ICT in the public infrastructure planning, development and operation process will enable major projects to be designed, built and managed with greater efficiency and productivity than is currently the case, so result in better value for public money.

Smart ICT will enable better, more insightful consideration of the issues and decision-making at the planning stage, minimise risk and uncertainty during the build phase and provide higher operational efficiencies throughout the life of the asset. As computational power and algorithmic complexity grows, these techniques and tools will provide even greater ability to reduce cost and improve productivity.

The financial services, telecommunications and retail sectors have in recent years adopted new innovative technology and tools (or Smart ICT) to fundamentally transform their business models and processes.

It is proposed that the Commission recommends that the use of Smart ICT be integrated into all aspects of the public infrastructure investment process: planning, design, development and operations.

Infrastructure Australia evaluation criteria for projects should also include consideration of how Smart ICT can be used to optimise productivity in this process.

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