Australasian Transport Research Forum 2013 Proceedings
2 - 4 October 2013, Brisbane, Australia
Publication website: http://www.patrec.org/atrf.aspx

Applying Benefit-Cost Analysis to Intelligent Transportation Systems (ITS) and the Australian context

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Abstract

An "Intelligent Transportation System" (ITS) is a broad term encompassing a wide-range of individual technologies, from simple "smart signs" to real-time electronic monitoring and management of traffic flows. The use of such technologies is often touted as a way of easing traffic congestion, increasing safety, improving environmental quality, and eliminating the need for construction of new road or transit capacity by using existing capacity more effectively. However, actual measurement and analysis of the total costs and total benefits of ITS is rarely done, even though ITS can require a substantial capital and ongoing operating investment. This paper will review the (rather sparse) literature on benefit-cost analysis of ITS; identify the specific technological components which make up ITS; discuss how to apply a benefit-cost methodology to a generic ITS 'project'; and explore how benefit-cost analysis of ITS in Australia's capital cities might properly proceed.

1. Introduction

An "Intelligent Transportation System" (ITS) is a broad term encompassing a wide-range of individual technologies, from simple "smart signs" to real-time electronic monitoring and management of traffic flows. The use of such technologies is often touted as a way of easing traffic congestion, increasing safety, improving environmental quality, and eliminating the need for construction of new road or transit capacity by using existing capacity more effectively.

However, actual measurement and analysis of the total costs and total benefits of ITS is sporadically done, even though ITS can require a substantial capital and ongoing operating investment. Specifically, this paper will review the relatively sparse literature on benefit-cost analysis of ITS; identify the specific technological components which make up ITS; discuss how to apply a benefit-cost methodology to a generic ITS 'project'; and explore how benefit-cost analysis of ITS in Australia's capital cities might properly proceed. Steps for further research will then be discussed.

The value of this exercise is that it provides an example of how benefit-cost analysis of ITS could be approached and an initial exploration of its applicability in major Australian urban areas.

2. The meaning of 'ITS'

2.1 Technology and transport

Modern transport policies and facilities rely heavily on technology. Road pricing, for example, typically uses transponders (or cameras in some cases) to obtain information about vehicles using roadways. This information is then digitised and processed using information technology to bill users, collect fees and identify and assess penalties for noncompliance. In urban transit, unified automatic fare collection systems such as 'smart cards', and 'smart signs' that tell travelers where trains and buses are in the system and their estimated times of arrival are almost commonplace. Looking into the future, there has been some experimentation internationally with "VKT" (vehicle-kilometres-travelled) charges in which drivers are charged not just for the time and place of road usage but the length of travel as well (Gordon and Peters 2013).

The potential benefits of such technology in optimising urban transport are quite clear. But 'Intelligent Transport Systems', or ITS, to use standard parlance, can be quite costly. Such systems also require careful planning design and implementation. A good idea in theory can become an albatross in practice if poorly implemented and if benefits and costs are not well understood.

Regarding costs, transponders, IT systems, compliance systems and the like can require hundreds of millions or even billions of dollars in both operating and capital outlays. A notable international example is the London road congestion pricing scheme that created an additional 123 million pounds in revenue for transit investment in 2008; however roughly 40% of the revenue goes to collection costs alone (Peters and Gordon 2009).

Of course London's congestion pricing system is especially complex being a cordon price that requires extensive monitoring of the full network of roads within the pricing zone. Congestion pricing along single roads requires much less in the way of technology, which, in turns, lowers the cost. Even in these simpler deployments, however, costs will not be negligible.

2.2 Australian examples

The experience of Australian cities in implementing technology has been offered some cautionary tales as well as a few successes. On the problematic side has been Sydney transit, which has been far behind schedule with implementation of a transit smart card to allow seamless transfer across transit modes. Its incarnation in the form of 'MyZone' has been plagued with problems of availability (initially many newsagents refused to carry it because of poor incentives and the card was difficult or impossible to obtain in many parts of the city) and still falls short of a true smart card. (Lucas 2010) Meanwhile, Melbourne's 'myki' card, similarly well behind schedule and over budget, was plagued by problems even in its initial and limited roll-out (ABC 2010).

Application of technology to roads is relatively more advanced. For example, Victoria's road department, VicRoads, has a fairly robust suite of technology employed to manage traffic with good results overall (VicRoads 2013). Sydney has not been as thorough in this regard, even though it was a pioneer in automated traffic management systems, with its invention of the Sydney Coordinated Adaptive Traffic System, (SCATS) which has been implemented worldwide, including in Victoria (SCATS 2013).

Overall technology clearly is an integral part of better managing urban transport in Australia (and elsewhere) and there have also been successful examples of technology deployment as well. But a full understanding of ITS costs and its associated benefits is only spottily available in local areas, much less nationally.

2.3 Defining ITS

The preceding discussion indicates that while ITS is used often as a term of art, it's meaning is unclear. What is ITS? In fact, it is not one technology, but a collection of disparate technologies, some not so new, applied to a series of disparate transportation problems. One definition is as follows: "Intelligent transportation systems (ITS) apply well-established technologies in communications, control, electronics, and computer hardware and software to improve surface transportation system performance." (US FHWA 2000) ITS has been defined by another source as "those transport systems that apply information, communication and other forms of high technology, to the efficient and safe movement of goods and people, across a suburb, across a city, across the continent, or across the globe." (Australian Parliament 2002) Definitions like this are typical: broad and nonspecific.

In fact there seem to be three ways to look at ITS as a term. These levels can be seen as going from the bottom-up of on-the-ground technology to the top-down of a full system.

(1) ITS can be a broad label covering a whole range of individual investment projects that happen to employ some sort of 'smart' technology. This is indeed how the label is often employed. For example ramp-metering and digital signage are now fairly low-tech and in the case of the latter quite common. Yet many would consider these 'ITS' because there is the use of technology to manage some aspect of the transport system in a dynamic and at least notionally interactive way.

A common element of ITS here would be the collection and use of information to speed traffic flow. The ITS rubric in this sense does exclude a lot of types of technology, such as road surfacing and 'dumb' traffic lights and static signs. But it does include a diverse range of other technologies ranging from the simple ones already mentioned to camera-based speed and parking enforcement through to VKT charging systems and the as-of-yet science fiction notion of Personal Transit Vehicles.

Analytically a term with this much scope may not be particularly useful. It does have the advantage of linking varied means to particular ends in a conceptual sense. But lines between technologies can be fuzzy and subject to interpretation. However this component-based definition does at least have some concrete definition in that it focuses on very specific and clearly defined interventions which can be closely evaluated if desired

(2) A broader conception of ITS is one that looks at technological means broadly as a series of interrelated component programs, with varying degrees of scale, as parts of a larger 'machine' designed to serve specific ends. The US FHWA (2000) report quoted above groups such components functionally, with one cut being:

- Freeway, Incident, and Emergency Management, and Electronic Toll Collection
- Arterial Management
- Traveler Information Systems
- Advanced Public Transportation Systems
- Commercial Vehicle Operations
- Interopability issues;

Another classification is to group investments by common technologies. A possible cut, again from the US FHWA report, is:

- Sensing, typically the position and velocity of vehicles on the infrastructure
- Communicating, from vehicle to vehicle, between vehicle and infrastructure, and between infrastructure and centralized transportation operations and management: centers
- Computing, processing of the large amounts of data collected and communicated during transportation operations
- Algorithms, typically computerized methods for dynamically operating transportation systems.

This sort of approach is more system-based, seeing the linkages between technologies and their proximate and/or ultimate purposes in achieving some sort of systematic outcome. Analytically this has more power to it, though its limitation is that it remains constrained by engineering and technical definitions of outcome.

(3) ITS finally could be seen as a complete system where technology is the means towards achievement of distinct social, economic and policy ends. This sort of thinking is in a sense likely what inspired the label in the first place, i.e. the use of technology for 'smart' system management. One large analytical advantage of this sort of conception is that mere technical advancement is not accepted as a good in and of itself but only good if it improves social welfare in some way. Although some may assume that new technology applied to transport is always a net gain, in fact this is the question that needs to be answered by policymakers when considering such technology. As will be seen below, however, although many use the term with this broad sense in mind they typically go back to more narrow technical measures when delving into program assessment.

2.3 An early ITS concept

This multiplicity of definitions raises the question of how the concept arose in the first place. It is useful to look at an early version of it, in this case the IVHS America Strategic Plan issued in May of 1992. IVHS stands for "Intelligent Vehicle Highway System" and the strategic plan was an early attempt to codify arguments for technology-intensive highway development. The plan boasted "IVHS can improve safety, reduce congestion, enhance mobility, minimize environmental impact, save energy, and promote economic productivity in our transportation system. It will multiply the effectiveness of future spending on highway construction and maintenance and will increase the attractiveness of public transportation. IVHS will be as basic a transportation raw material as concrete, asphalt, or steel rail."

The "Long-Term" objectives of the plan contained milestones that were planned to be at least initially adopted in the time-frame of 2002 - 2011. These included "Area-wide, full-featured systems to manage intermodal surface transportation nationwide in large urban areas and major rural corridors. Multi-modal demand-responsive information systems. Area-wide transportation control integrated with optimal routing. Transparent borders for commercial vehicles - Fully integrated transportation user-fee collection systems. Automated vehicle operation on specially equipped roadways. Fully automated Mayday systems with coordinated dispatching and Intersection hazard warnings."

This sort of high-blown rhetoric, which has been nowhere near achieved in the US or elsewhere, does indicate that of the three definitions offered above, the third is perhaps closest to its original inspiration. In other words ITS as an inspiration revolved around the notion that technological innovation could be applied system-wide in a transformative manner.

3. Benefit-cost analysis of ITS

3.1 The academic literature on ITS benefit-cost analysis

The basic question of benefit-cost analysis is whether the incremental cost of the proposed investment yields an incremental benefit at least equal to the amount of that cost (and perhaps additionally generate "sufficient" increases in local economic activity, expand regional employment base or whatever other metric that decisionmakers think is important, though the net return measurement is paramount). Before analyzing the benefits and costs of something, one needs to know what it is you are analyzing and this, as we have seen, is perhaps almost impossible when using a term so loosely defined as ITS.

Perhaps for this reason, actual measurement and analysis of the total costs and total benefits of ITS, considered explicitly as ITS, is rarely done. Brand (1994) has written one of the early articles on the subject in which he applies standard benefit-cost analysis to the discrete transportation investments typically bundled under the ITS label. He basically argues that ITS benefit-cost analysis should be approached like any other transportation investment except that the ‘causal chain’ should be carefully understood. In other words although discrete and disparate, individual ITS components are supposed to be linked to one another to achieve larger aims and the analyst has to take care to consider the results of these linkages as well as the components in isolation.

This article came early on the scene when there was relatively little actual ITS being implemented (though, of course, plenty of technology was being used). Brand et. al. (2002) had an opportunity to consider an actual example, namely the Commercial Vehicle Information Systems and Networks (CVISN) program used in the US, which provides electronic credentialing and electronic screening of heavy trucks to improve road transport performance. The analysis used traditional measures of benefit, such as safety and reduced travel time. The results indicated that the pilot system was worth rolling out given its positive benefit-cost ratio under most scenarios. More will be said about this particular analysis, actually a rarity, later on.

A critical issue in ITS evaluation is the notion of ‘benefit’. Economists consider benefit as a net gain to society. But many in the ITS field focus on much more narrow technological outcomes, such as improvements in crash rates, ‘customer satisfaction’ or throughput on a particular segment where a particular technology is deployed (e.g. variable speed limits on motorways). A 2005 literature survey of benefits evaluations for ITS consists almost entirely of such measures (Koonce 2005).

These measures are not invalid per se and many times their measurements are carefully done. But they remain only part of the story. Machines can improve performance of a task they are designed for but are they worth their costs? And is the task they perform more efficiently ultimately improving society? These are key questions often easier to answer in theory than in practice.

Indeed the literature thus far tends to have a distinct split between conceptual and methodological exercises on notional projects and 'case studies' or 'evaluations' that are more partial and limited in nature (Gough 2001, Maccubin et. al. 2003, Bekiaris et. al. 2004). Leviäkangas et. al. (2002) have conducted a profitability analysis of an ITS system; Juan et. al. (2006) have reviewed various attempts to measure its socio-economic impacts; and Chowdury and Sadek (2003) have considered planning ITS planning principles. But ITS benefit-cost analyses, at least as represented in the literature, are few and far-between.

3.2 The policy and planning literature on ITS benefit-cost analysis

While academic study of ITS benefit-cost analysis remains fairly thin, more and more professional and governmental attention have been paid to the problems of ITS cost and benefit, particularly in the last decade as ITS expenditures rise and systems, as opposed to technical components, take shape.

The European Union in particular has been a leader in adopting an ITS action plan promulgated in detail by the European Commission in 2011 and building upon a legal framework approved by the European Parliament in 2010. This action plan has 6 elements, two of which have a benefit-cost flavor to them: Action Area 1 which calls for optimal use of road traffic and travel data and Action Area 4 which focuses on integration of vehicle data with infrastructure systems (European Commission 2011).

The Commission document focuses especially on road safety as a key benefit and detailed benefit-cost guidance has recently been developed in a Commission staff working document, dated 15-5-2013. Entitled 'Cost-Benefit Analysis", this paper supplements Directive 2010/40/EU regarding data and procedures and their relation to road safety and presents a template of benefit and cost categories for ITS in the EU with detailed descriptions of issues surrounding these categories. More detail of this template are provided below in Box 1 (European Commission 2013).

Looking at broader issues of implementation and impact, Austroads has recently issued a report on cooperative ITS. The report describes some substantial efforts at understanding broader benefits and costs of ITS underway in the EU, Japan, the US and in various parts of Australia. Some of the Australian studies are described in more detail and put in a conceptual model in Box 2 in Section 4 of this paper (Austroads 2011).

Perhaps not surprisingly, the academic literature is a little behind the applied policy analysis on ITS since governments and other institutions are at the coalface grappling with these issues directly. The trend is clearly towards benefit-cost assessment of these systems and viable frameworks for this task are being developed. But there is still more to do.

BOX 1: THE EUROPEAN COMMISSION'S 2013 INITIAL BENEFIT ANALYSIS OF ITS ROAD SAFETY INVESTMENTS (SOURCE: EUROPEAN COMMISSION 2013, PP. 12-21.
Project/Program being analysed: traffic information services along the trans-European road network of almost 100000 km across Europe (59201 km of motorways, 25 683 km of high-quality roads, and 15 007 km of ordinary roads) Cost categories (both capital and maintenance): (1) data collection costs

- Inductive loops
- MIDAS loops
- Camera (CCTV)
- Road weather stations
- Radar sensors
- Reception of PSAP data
- one-off software cost

(2) data sharing costs

refer to the costs associated with the formatting and availability of the data needed for providing road safety-related traffic information to end users. Mainly:

• Setting up a national DATEX II node (i.e. publisher of standardised traffic data); or

• Amending/updating an existing DATEX II node.

(3) Operating costs

refer to the costs of collating and maintaining the traffic/weather data, processing the information and information reports, staff training and expertise outsourcing, etc.

Benefit categories:

(1) Reduction of fatalities and injuries

(2) Reduction in delays

BCR Results

Considering both low and high cost baseline assumptions and differing implementation scenarios, BCRs were notionally calculated based on rough estimates for the different benefit and cost categories above. All the high-cost estimates had BCRs of less than 1 (0.27 to 0.20 depending upon implementation scenarios). All the low-cost estimates had BCRs above 1 (1.09 to 2.58).

Broader Impacts

A broader social externality analysis was not completed. However Economic, Social and Environmental impact categories were defined and rankings for each of these were assigned to implementation options considered by the BCR with initial rankings summed to provide illustrative results. The highest ranking here was consistent with the highest BCR ranking obtained above.

3.3 Why so little ITS benefit-cost analysis thus far?

Benefit-cost analysis is critical to ensuring ultimate success in ITS design and deployment. ITS application on a systematic basis is still relatively new (i.e. around three decades old) and so both academics and authorities are still only part way up the learning curve. As the EU policy in particular shows there have been some significant BCA conceptual advances. But the gap in more specific implementation has occurred in part because, as already mentioned, 'ITS' as a generic term must be more clearly specified before such analysis is possible. This is probably especially true for academic analysts where initial conceptual and philosophical grounding is especially valued.

Several possible definitions have already been considered and it is not necessarily clear that one is always preferred to another when one is defining the limits of a ‘project’ (the typical basic unit of analysis).

From an analytical standpoint it is clear that ITS can be judged either from both a component-wide perspective -- how cost-effectively and economically efficiently does each separate ITS component operate? -- and from a system-wide perspective -- do the components, viewed together, yield synergistic outcomes which provide additional bang for the buck above and beyond the yields of each individual component? – and there is a strong argument for doing both.

However, the analytical task in such a case is often large and difficult to undertake which may scare away the faint-hearted analyst or outrun the budgets of most Treasury departments. Additionally the mere uncertainty about the definition of ‘ITS’ does hobble the key requirement of benefit-cost analysis for a well-defined intervention with a well-defined ‘with’ and ‘without’ baseline.

Not that this should be an insurmountable obstacle. After all, benefit-cost has been applied to many unusual things, including entire railway systems, slavery and war. But ITS itself has, for the most part, not been widely implemented in the fullest sense yet so there is limited actual experience with its potential performance and is ‘causal chain’, to borrow Brand’s phrase. The combination of fluidity in definition and relative lack of experience on the ground have probably been the main reasons that so few examples of ITS benefit-cost are available.

3.3 The system dimension

This returns to a basic question surrounding ITS: how much does the S really stand for "system"? If it was really intended to operate as a system -- and the framers of it certainly talked that way -- then we have to ask whether it really does operate this way? To the extent that it does operate that way, can we then reasonably analyze it as a separate investment unto itself, with, however, some large and complicated interrelated parts or are there ‘synergies’ to be considered? And even to the extent that is doesn't operate that way, can or should we perhaps still analyze it from the perspective of a system?

The Brand et. al. (2002) exemplar is worth returning to at this point. This analysis examined a discrete and sharply defined system with specific objectives, namely the Commercial Vehicle Information Systems and Networks (CVISN) program, a US Federal pilot initiative to examine and facilitate the use of various information systems and communication technologies to improve commercial vehicle operations. More specifically the authors studied the Model Deployment Initiative (MDI) that commenced in 1996 in the US States of Maryland and Virginia and later extended to eight additional states. The MDI’s purpose was to explicitly demonstrate the technical and institutional feasibility, costs, and benefits of intelligent transportation system (ITS) programs aimed more generally at improving the safety and technical efficiency of commercial vehicle operation. From a benefit-cost standpoint this is a key starting point. It is not easy to define the proper scope of a ‘system’ and to properly delineate its complete objectives but such a step is key. So in a sense Brand and his co-authors had a complex but clearly delineated ‘project’ to look at and one whose main value lay in its technological aspects.

However the clear delineation of the components that make up that system and the identification and allocation of costs and benefit categories those components specifically generate, separately and together, is equally critical to allowing an analysis to proceed at all. Table 1 summarizes the categorization used by Brand and co-authors.

TABLE 1: BRAND ET. AL. (2002) SYSTEM COMPONENTS AND BENEFIT CATEGORIES

(adapted from page 36)
Component 1: Roadside enforcement including safety information exchange and electronic screening
Component 2: Electronic credentialing of vehicles
Component 1 BENEFITS -- Truck crashes avoided, – Transit time savings, and – Air and noise pollution reductions Component 1 COSTS – One-time startup cost to state, – Replacement capital costs to states – Increased operating costs to states – Increased operating costs to carriers – Increased out-of-service costs to carriers
Component 2 BENEFITS – Operating cost savings to states, – Operating cost savings to carriers, and – Inventory cost savings to carriers Component 2 COSTS – One-time startup cost to states, and – Replacement capital costs to states in future years

Following this template, the authors estimate benefits and costs generated by each technology separately and jointly, monetize the impacts and then calculate benefit-cost ratio scenarios given differing assumptions about operations (e.g. compliance) along with sensitivity analysis of key parameters such as discount rate. Under most of the scenarios, except for one, the benefit-cost ratio is greater than one and the Net Present Value (NPV) is positive.

There is nothing remarkable per se in the mechanics of the actual analysis. Its key value is its specificity about (a) clear definition of an ‘ITS’ project; (2) specific delineation of the project’s components, in isolation and as a ‘system’; (3) and concrete linking of project components and system to definite and measurable outcomes.

The old saying ‘it’s not rocket science’ certainly applies. But when confronted with ITS systems benefit-cost analysts seem to think that rocket science is called for and either go off into theoretical outer space or get lost in more narrow details. Good ITS benefit-cost analysis is clearly possible but requires a clear head from start to finish, especially with regards to project definition, scope and components.

4. The Australian context

4.1 Is there ITS in Australia?

There is, of course, widespread use of technology in transport in Australia. Road pricing, for example, is widely used, as are, increasingly, electronic transit ticketing systems, to name but just two examples.

Given that ITS has both system and component aspects to it, one could say that Australia tends to invest in transport technology but not ITS. Much, though not all, major urban transport facility investment is done by private operators in specific projects rather than for overall networks, or network subsystems. In addition for private firms benefit-cost analysis in the fullest sense of including all social and environmental externalities may not be the relevant benchmark for the in any case (though it would be for the public sector in deciding to let the contract, of course). Of course a private operator does need financial feasibility and such operators routinely do this sort of assessment, at least for the components they are responsible for.

4.2 ITS project analysis in Australia thus far

The 2002 Australian Parliamentary inquiry into ITS did note that the use of technology in transport and its academic and professional study was long-standing, particularly into technological aspects. But it also noted that "Intelligent transport systems are often little noticed elements in Australia's complex and diverse transport system. ITS is so much a part of the accepted background of Australia's transport infrastructure that many users of transport systems are not aware of the contribution ITS makes to the efficient and economic movement of people, produce and products." (Australian Parliament 2002, p. 3)

There are plenty of projects noted in the inquiry report and also a very long citation of benefits. But, here too, the benefits noted tend to be either very narrow and put in terms of technological process improvements or are blanket estimates taken from biased sources. For example, "the committee was advised by ITS - Australia that ITS is estimated to provide a benefit/cost return of 10:1, while Mr Colin Jensen advised the committee the benefit to cost ratio was in the range 4.8:1 to 19.0:1, with the lower estimations being 'considered conservative" (Australian Parliament 2002, p. 17). (Author's note: this report actually has a typographical error stating cost to benefits when the context clearly indicates that the intent was to say the opposite. The author has adjusted this in the cited BCRs just given). An entire section on benefits is not even countered by a similar section on costs, to say nothing of presenting a true benefit-cost analysis.

Ten years later the Standing Council on Transport and Infrastructure, part of the Australian Department of Infrastructure and Transport, has issued a "Policy Framework for Intelligent Transport Systems in Australia" (DiT, 2012). That report does address some important points, and mentions the need for technology investments to have identifiable benefits for users. It does also mention a project on "Economic Analysis of Smart Infrastructure" whose goal is to incorporate results of the economic analysis by BITRE of Smart Infrastructure/ITS, in order to ensure the policy framework is consistent with the goals of government in enhancing asset productivity. (DiT, 2012, p. 16)"

A more comprehensive view, however, is already emerging in Australia, at least for roads. The previously cited Austroads (2011) is a clear example of this. The study's stated purpose is to identify policy issues of cross-jurisdictional scope involved under two theoretical scenarios – a market-driven and a policy- driven approach – with respect to ITS introduction and rollout nationally, ending with an identification of potential policy actions that could maximise benefits to Australia from cooperative ITS and manage any risks effectively. International benchmarks are identified as a starting point. Box 2 below contains some of the key findings of this report that are most pertinent to BCA of ITS in Australia.

BOX 2: AUSTROADS BENEFIT AND COSTS CONSIDERATIONS FOR COOPERATIVE

ITS INTRODUCTION AND IMPLEMENTATION IN AUSTRALIA
Development of National ITS systems, especially in federal systems, requires cooperative effort. Benefits and costs of such cooperative action (as opposed to individual interventions, which the report notes still are sometimes needed) must be considered. The Austroads report considers the drivers of both of these and presents the following findings (in paraphrase summary) (1) Benefit Drivers • Expansion of the range around a vehicle within which real-time information is gathered. • Associated expansion of the time horizon to anticipate/mitigate/avoid problems to improve safety and network management. • Two-way communication and data exchange, so vehicles and network operators can both be suppliers and users of data, expanding real-time understanding of the transport system and its users. • High speed real-time gathering, coordination and manipulation of data into personalised information and 'building block' services. • Open technical architecture and open interfaces that support applications and services from many providers (2) Issues relating to cost minimization and efficiency • Dynamic and Uncertain Environment: bring together stakeholders early in the development process. • Interoperability: The ability of applications to communicate and work with each other provides the foundation to gaining maximum net benefits. • Functions, Responsibilities, Liabilities and Governance: Identify agreed upon functional responsibilities for cooperating entities. • Privacy and Security: need to be addressed from an early stage in the design, development and regulation of cooperative ITS applications. • Human-Machine Interface (HMI): balance retro-fit and new system benefits and costs in choosing the best options. • Digital Mapping and Positioning: it may not be prudent to rely solely on one approach. • Communications: choice of standard and management of licences, access rules and potential interference with other uses. • Aftermarket Applications: leveraging of applications for post-implementation settings and uses. • Potential for Conflict Between Public and Private Objectives: ensure that applications do not run counter to public objectives but uphold good practice. • Roadworthiness: issues of ongoing maintenance and roadworthiness of applications. • Consumer Confidence and Market Penetration: regulation of operators, applications, equipment, software, etc to provide confidence to consumers that required standards of performance will be met. (3) Key Lessons for Australia

Early structured engagement of key stakeholders backed by government and private sector leadership.

Foundation investment to achieve long-term interoperability and avoid ad hoc development.

Usefulness of test sites and pilots before major commitments.

Based on a scenario analysis a market-driven approach would likely focus on the delivery of private benefits and support innovation in market niches; but the small size of Australia's market presents some impediments to interoperability and attainment of a 'critical mass' of enabled vehicles.

5. Conclusions

The discussion up to this point has both ex-post and ex-ante implications. Almost all of the transport technology implemented in Australia has not really been conceived of, or implemented as, a system to begin with. But it is probably useful to re-examine some of these collections of investments to see if they did, in fact, achieve some systematic impact, whether that impact was a net positive or negative, and if the result was in fact just a series of local impact programs, not functioning as a system, whether that made any difference.

The ex-ante dimension is that it is probably useful to consider whether a technology investment is just a single project or perhaps a phase of a larger system. Benefit-cost analysis should be done in both cases, but a system analysis of the sort undertaken by Brand and colleagues would be recommended in the latter case. The protocol could run something like this:

(1) ITS as a series of local transportation investments, some of which involve common technologies. In this case the analysis could focus on, for example, urban roadway segments for Sydney, Melbourne, Brisbane, etc., with just the incremental benefits and costs considered. This may be especially apt if, in fact, network building proceeds in just this way.

(2) ITS as a series of system component investments. In this case, the system has to be defined properly, both in terms of service/impact area and true techno-economic linkages (or 'causal chain'). So perhaps Perth's multimodal transport system could be defined as the system. In that case the components could be organised along (a) specific policy or program objectives such as Freeway, Incident, and Emergency Management, and Electronic Toll Collection; arterial management; traveller information systems; advanced public transportation systems; commercial vehicle operations; and system inter-operability. Or (b) these could be functionally based, such as sensing, e.g. the position and velocity of vehicles on the infrastructure; communicating, e.g. from vehicle to vehicle, between vehicle and infrastructure, and between infrastructure and centralized transportation operations and management centres; and computing, e.g. processing of the large amounts of data collected and communicated during transportation operations;

(3) ITS as a national system. Building on (1) and (2), ITS investments can be evaluated from both a component-wide perspective -- how cost-effectively and efficiently does each separate ITS component operate -- and from a system-wide perspective -- do the components, viewed together, yield synergistic national outcomes which provide additional bang for the buck above and beyond the yields of each individual component? Much of the policy discussion seems to revolve around this premise, but little of the implementation, or analysis does, at least currently. But should this change?

Finally, there is a critical public-private dimension. If the ITS project is purely privately provided, planned and financed, profitability analysis will be sufficient. If it is a PPP, then the government needs to take a broad system view and conduct benefit-cost analysis as to whether the project should be put out to tender at all, with the private provider doing its assessment of whether there will be a profitable market. And with sole public provision, the problem collapses down into proper design of the analysis, along the lines suggested already.

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