INTELLIGENT TRANSPORT SYSTEMS EVALUATION: FROM THEORY TO PRACTICE

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ABSTRACT

The nature and extent of impacts of ITS projects is fundamentally different from those of conventional road projects. Evaluation of ITS projects is complicated by the presence of the unique variables affecting the outcomes of projects, which include driver behavioural response and market penetration issues. ITS project evaluation methods must be developed to the same standard as evaluation procedures for conventional transport investment. It is important that the costs and benefits of both ITS and conventional projects are evaluated comprehensively in order to ensure efficient and cost-effective project selection and prioritisation.

There is little historical data available to quantify most ITS impacts and some ITS impacts, such as increased comfort or travel time reliability, are qualitative or difficult to measure or value. There is presently little understanding of the causal relationships between ITS projects and their impacts and often it may not be appropriate to transfer results in space and time.

This paper provides a state-of-practice summary of ITS evaluation methods and impact measurement efforts, by drawing on a comprehensive survey of available literature. The results of a survey of practitioners and stakeholders designed to address the main issues are also reported on.

INTRODUCTION

Intelligent transport systems (ITS) are applications of advanced communications, electronics, navigation and information processing technologies that are designed to improve the performance of the existing transport system, specifically by improving safety, efficiency, comfort and reducing adverse environmental effects. ITS applications include advanced traffic management systems, advanced traveller information systems, electronic payment systems, advanced vehicle control systems, advanced commercial vehicle operations and advanced public transport systems. Applications of ITS now regularly deployed include variable message signs, electronic toll collection, incident management systems, closed circuit television surveillance and in-car navigation equipment.

Intelligent transport systems are increasing in popularity as a method of improving the safety and efficiency of the transport system. In most cities congestion is increasing, the public demand for mobility and improved safety is increasing and construction of new roads is constrained by increasingly limited public funds and environmental issues. In order to increase the level of service on roads without constructing additional capacity, traffic management and traveller services are required to optimise the productivity of existing road capacity.
Despite the widely espoused anecdotal evidence of the benefits of ITS, ITS projects must compete with conventional road projects for funding at the local, regional and national levels of government. It is therefore important that the costs and benefits of both ITS and conventional projects are evaluated comprehensively in order to have efficient and cost-effective project selection and prioritisation. Kulmala and Pajunen-Muhonen (1999) suggest that ITS planning has been inadequate due to the lack of a comprehensive evaluation technique and empirical ITS impact data. In order to effectively plan and implement ITS projects, road authorities need tools to assist in the evaluation and comparison of ITS alternatives and conventional road projects. As ITS is now a recognised form of transport system improvement, project evaluation methods must be developed to the same standard as evaluation procedures for conventional transport investment.

The aim of this research project is to “fill the gap” in existing evaluation processes to allow for comprehensive evaluation of ITS projects. The objective of the research project is to develop a method for evaluating ITS projects that will allow comparison of the costs and benefits of such projects with those of conventional road projects. Specifically, this will involve developing a spreadsheet tool comprising a method for evaluating ITS projects and investigating the impacts of specific ITS applications for inclusion in the evaluation tool. Due to the limited time available, the research scope is limited to road based ITS applications.

This paper presents the findings of the literature review and the results of comprehensive consultation of stakeholders and evaluation experts.

HOW DOES ITS EVALUATION DIFFER FROM CONVENTIONAL ROAD PROJECT EVALUATION?

The nature of some ITS impacts is fundamentally different from those of conventional road projects and this naturally leads to significantly different requirements of project evaluation. ITS projects have potential impacts that are additional to those impacts caused by traditional road projects. ITS evaluation is also complicated by the presence of the unique variables affecting the outcomes of projects, which include driver behavioural response and market penetration of ITS. Market penetration is the degree to which the ITS equipment is purchased or utilised by travellers.

To add further complexity, the same impacts generated by ITS and conventional road projects may be generated by different mechanisms. Vehicle operating costs (VOC), for example, are calculated in existing evaluation methodologies as a function of the average traffic speed, road roughness, terrain and vehicle type whereas an ITS project may reduce vehicle operating costs by smoothing traffic flow and reducing the number of vehicle stops. To evaluate ITS with existing road project evaluation processes that exclude or undervalue these impacts would severely understate total project benefits.

There is little historical data available for most ITS impacts, while other ITS impacts such as increased comfort are qualitative or difficult to measure. As ITS is an emerging technology, there is little understanding of the causal relationships between projects and impacts and often it will not be appropriate to extrapolate measured impacts from an existing site to a proposed site.

The review of the literature highlighted two significantly different views of how ITS projects should be evaluated. One opinion is that a completely new framework should be developed to evaluate ITS; while the other is that the existing road project evaluation procedures should be used by adapting the methods of measuring and valuing the impacts of ITS. Some authors agree that there is little difference between ITS and conventional road projects and that it is sufficient in most cases to apply existing evaluation methods to assess ITS projects (Underwood and Gehring 1994). Gillen and Li (1999) recognise that the problem lies in the measurement and
valuation of cost and benefits with the lack of historical data. On the other hand, Bristow et al. (1997) suggest that current evaluation procedures are not suited to measuring or valuing many of the impacts that form the rationale for some ITS projects.

Consequently there are two distinct parts to the research problem. The first part is generally agreed upon – that ITS impacts require innovative methods of measurement or prediction. The second is more contentious and is encapsulated by the question – “should an entirely new evaluation procedure to evaluate ITS be developed or should the new ITS impact measurement procedures be incorporated into existing evaluation methodologies?” Hence this section presents the two issues separately – how the impacts of ITS projects differ from the impacts of conventional road infrastructure projects and how applicable the available evaluation procedures are to ITS project evaluation.

Impacts of ITS

The main impacts of ITS projects that are not generally considered in the evaluation of traditional road infrastructure projects include:

- travel time reliability improvements
- improved control over travel choices
- environmental benefits due to smoother traffic flow (less stops)
- privacy compromise due to data/surveillance nature of some ITS applications
- higher risk of implementation due to high technological content and hence higher uncertainty attached to impact predictions.

Travel time reliability can be improved by smoothing the traffic flow, reducing the frequency and duration of incidents and by providing information on travel times and delays to the traveller. With improved information and assurance of travel times, routes and modes, travellers have greater control over their travel choices. A potential negative impact of ITS is that with the intensive surveillance and data collection nature of some ITS applications, travellers may become more concerned about their privacy. ITS projects also have a greater technical risk due to the technical component – the equipment used must be effective and remain flexible to future advances in technology (Brand 1993).

Some of the benefits of ITS, such as increased user satisfaction and comfort, improved availability or quality of information, or reduced accident risk, are difficult to quantify and measure. Harris et al (1996) provide an example of an emergency vehicle locator device that may never be used but is an important safety feature. This example indicates the difficulty of valuing qualitative impacts, which are generally measured by user willingness-to-pay surveys. Without historical impact data it is difficult to estimate or model the impacts of ITS.

As well as the difficulty of measuring the benefits of ITS, the value of some benefits, for example travel time, may vary with ITS (Gillen et al. 1999). In conventional road project evaluation, capacity improvements typically decrease the amount of pure travel time. With ITS, however, a traveller information system may simply reduce the amount of time that the traveller spends planning their trip or searching for a parking space at the end of their trip. Thus the amount of pure travel time is not reduced but the duration of related essential activities at either trip end is reduced. Trip planning time, for example, may be conducted in conjunction with another activity (such as a coffee break) and hence have a lesser value than pure travel time which is conducted exclusively.

ITS evaluation process

Many authors state that the evaluation process for ITS projects should be different from the evaluation processes used for traditional road projects. Zhang et al (1998) reason that, as there
is little understanding of the mechanisms with which ITS impacts are generated, existing evaluation methodologies may not be appropriate. This implies that measured impacts from one site may not be transferable to other potential applications, as we have no statistical confidence of how the parameters of each scenario and the ITS application may interact to produce the project impacts.

It has been stated that the relationships between cause and effect in ITS projects are more complex than conventional road projects. The impacts of the interactions and synergy between components are often more significant than the effects of any individual component (Harris et al. 1996). To account for this complexity, an ITS evaluation methodology must be capable of evaluating the impacts of individual components of the project, as well as the resultant impacts of various combinations of components. In addition, some ITS projects achieve a very small improvement in capacity compared to conventional road projects (Underwood and Gehring 1994). Consequently, the ITS evaluation methodology must be more sensitive and detailed than existing evaluation models and ensure that ITS impacts are not obscured by the temporal fluctuations of traffic impacts.

As ITS generally has a high electronics and communications content, there is a large amount of technological risk. The application may be subject to technical failure and must remain flexible to future innovations in technology. As a result of the lack of experience with ITS projects and knowledge of costs and benefits, there are potential variances in the projected benefits and costs of the project. Due to the greater risk and shorter life of ITS projects, the evaluation process must incorporate extensive risk and sensitivity analysis.

The success of some ITS applications is dependent on the behavioural response of travellers (Bristow et al. 1997). For example, an alternative route recommendation displayed on a variable message sign will have no effect of alleviating congestion if travellers do not comprehend and act upon the message. Traveller behaviour is influenced by previous experience, knowledge of the network and the behaviour of other drivers, as well as the availability of the ITS equipment (Underwood and Gehring 1994). The evaluation process must incorporate driver behavioural factors, a variable that is much less prevalent in conventional road project evaluation.

**CHOICE OF EVALUATION METHODOLOGY**

When choosing a method of evaluation for ITS projects it is important that there is a balance between the complexity and cost of the evaluation and the cost of the potential project. The required complexity of the evaluation depends on the purpose of the evaluation results – the degree of complexity required for determining the net worth of the project to society is much higher than for performance measurement (Turner and Stockton 1999). The main problem with ITS evaluation is that all evaluation methods require significant data, which is presently sparse due to the evolving nature of ITS projects. Gillen et al. (1999) suggest that as ITS projects are usually enhancements to the existing transport system, they are not large enough projects to cause a significant change in the economy and consequently, a full economic impact analysis is rarely required. It is usually adequate to consider the distributional effects of ITS projects in a socio-economic analysis such as cost-benefit analysis or multi-criteria analysis.

Although benefit cost analysis is the most commonly used method of evaluation for ITS projects, the single output benefit-cost ratio is based on many assumptions about the monetary values of benefits. This problem could be overcome by incorporating a benefit-cost ratio as one of many evaluation indicators into a goals based evaluation framework such as multi-criteria analysis (Turner et al. 1998). While this solution will avoid exclusion of project impacts, it may lead to double counting of certain impacts that are included in both the cost benefit ratio and the multi-criteria analysis.
Baum and Schultz (1997) recommend the use of either benefit cost analysis or cost effectiveness analysis in ITS project evaluation. Similarly, Bristow et al. (1997) recommend that cost-effectiveness analysis be used when benefits are difficult to measure or in addition to cost-benefit analysis as a means of sensitivity analysis. Cost-effectiveness analysis compares alternative projects on the basis of the project cost and a single measurable project impact. The European Union EVA ITS evaluation manual recommends the use of cost benefit analysis where standard monetary values are available, multi-criteria analysis where monetary values are not available for major impacts and cost effectiveness analysis where monetary values are available only for costs and a specified impact is achieved (Bristow et al. 1997).

Many previous ITS evaluations have involved capacity analysis based on traffic volumes, road geometry and signal parameters to calculate a level of service (Turner et al. 1998). Turner states that these capacity analyses do not include the full benefits of ITS and recommends that cost effectiveness analysis should be used instead, incorporating measures of effectiveness such as reduction in congestion, safety improvements or fuel consumption (Turner et al. 1998). Gillen and Li (1999) state that rather than including social costs in a cost-effectiveness analysis it is more sensible to conduct a complete cost-benefit analysis with risk and sensitivity analysis.

Criteria for an effective ITS evaluation methodology

The most important criteria for an effective ITS evaluation methodology are listed below and detailed in the following paragraphs.

- The evaluation should be transparent and allow for simple updating of impact parameters.
- The methodology should provide an accurate output, as well as being objective without any positive or negative bias.
- The methodology should allow comparison of results of evaluation of ITS and conventional transport projects.
- The evaluation should include rigorous sensitivity testing and not apply false precision to the estimated impacts.
- The methodology should consider the combined effect of implementing various combinations of ITS.
- The methodology must be developed to avoid double counting of benefits.
- The base and project cases studied in the evaluation must be based on the same operational conditions.

There was a consensus among the reviewed literature that the evaluation methodology should provide an output that allows comparison of evaluation results between ITS and conventional transport projects (Underwood and Gehring 1994; Rathi and Harding 1997; Peng et al. 2000). An example of such a comparison would be a traditional investment such as added lanes to a freeway and ramp metering. It is reasonable that the evaluation output be consistent between ITS and non-ITS projects to allow comparison as all projects will generally be competing for funding and prioritisation. Further, some authors believe that an ITS evaluation methodology should be completely compatible with existing road infrastructure project evaluation methodologies (Rathi and Harding 1997). While full compatibility of the two methods would provide advantages in terms of staff training and database or software requirements, such a constraint could severely limit the flexibility of an early ITS evaluation method to emerging knowledge and growing data on ITS impacts.

Due to the relative lack of empirical impact data there will be a degree of uncertainty in estimating the impacts of ITS project. It is imperative, therefore, that the evaluation methodology includes rigorous sensitivity testing and does not apply false precision to the estimated impacts. Most authors highlighted the need for extensive sensitivity analysis, whereas only a minority (Turner et al. 1998) discussed the misuse of false precision in estimating ITS impacts.
Two reports stated that the evaluation methodology should evaluate the synergy of various combinations of ITS projects (Rathi and Harding 1997; Harris et al. 1996). The authors explain that the resultant effect of the interactions of various combinations of ITS components is often more significant than the sum of the effects of individual implementation of the ITS components. It would be more effective, for example, to implement a combination of ITS applications using the same infrastructure than implementing each application with separate infrastructure but providing the same output. A more complex synergy results from the occurrence of behavioural responses that may be stimulated by a combination of ITS applications.

An economic evaluation methodology must be structured so as to avoid double counting of benefits (Brand 1994). Double counting occurs when multiple performance measures actually measure the same benefit but over a different period of time. For example, the inclusion of long-term changes in land use that result from short-term impacts such as travel time improvements would be double counting. While these long-term impacts should not be included in an economic analysis, they could be included in an impact assessment so that stakeholders are aware of the longer-term implications of the project. Brand (1994) provides another common example of double counting in the economic evaluation of ITS projects in which the possible savings from avoiding constructing additional capacity are included as a benefit. Although savings from avoided infrastructure costs are a major advantage of ITS projects, to include such costs in an economic evaluation is unreasonable: if the additional infrastructure were constructed it is likely that the capacity increases would be greater than those arising from the ITS project. To include both the benefits of the ITS project and the avoided infrastructure costs, the original benefits that result from the infrastructure cost saving would be double counted.

It is important that the base and project case be selected so that a true evaluation of the ITS application can be completed. The base case is typically the existing or do-minimum situation with traffic growth and without the ITS project while the project case is the base case situation with the ITS project. The base and project cases must contain the same operational conditions. Tarnoff (1999) presents an example of this problem where a new signal timing system replaces an original timing system in which the timings had not been modified for, say, 10 years. It would be inaccurate to compare the original system with the ten-year-old timings and the new system with new timings – this would be a combined evaluation of the new system as well as the new timings. To accurately evaluate the new system, the comparison of old and new systems must be completed with identical signal timings.

The ITS evaluation methodology that will be developed as part of this research will attempt to meet all of the abovementioned criteria, as well as information obtained during the consultation phase.

**CONSULTATION PHASE**

This section presents the findings of the consultation phase of the research project, which was conducted in order to identify any significant ITS evaluation issues prior to developing the ITS evaluation methodology. The consultation comprised a half-day Queensland Transport and Main Roads workshop and a survey of ITS and project evaluation experts and stakeholders, which was designed and conducted by the author. The results of both stages of consultation informed the development of the evaluation methodology.

**ITS evaluation workshop**

The ITS evaluation workshop was conducted as part of the consultation for the ITS Strategy that is being developed by Queensland Transport and the Queensland Department of Main Roads.
The purpose of the workshop was to provide the strategy development team with a list of issues and actions with regard to ITS evaluation to be included in the strategy document. Furthermore, the workshop provided a timely opportunity to gain feedback about ITS issues from industry and government personnel for the purpose of this research project. The half-day workshop commenced with a presentation by the author, which set the scene for the workshop by highlighting some of the significant issues related to ITS evaluation that were distilled from the literature review. The first workshop task required the participants to identify the issues that should be considered in the development of an ITS evaluation methodology. The second task was to develop a list of actions that would be required to resolve the issues that were identified in the preceding session.

The workshop participants came from a variety of employment sources - figure 1 indicates the relative proportions of participant interest. The participants distributed themselves into three groups of approximately 13 people per group with a fairly equal range of participant experience between the three groups. As the ITS strategy is being jointly developed by Queensland Transport and Main Roads, the participation from each department is appropriately equal. The proportion of attendance of academia, private industry and local government are considered to be appropriate.

The participants of the ITS evaluation workshop attended voluntarily based on their personal or professional interest in ITS evaluation and awareness of the workshop, which was internally advertised in both Queensland Transport and Main Roads, in major professional organisation magazines and by email invitation to external ITS practitioners. Consequently, the level of ITS and project evaluation experience and knowledge of the workshop participants varied considerably. Most of the workshop participants, however, came from an ITS background so there may have been some bias towards promoting the benefits of ITS rather than maintaining an objective, project evaluation perspective. The sample size of 40 people was reasonable, especially considering the time commitment (half day) of the workshop.

**ITS evaluation issues**

The first session of the workshop involved group discussion about the issues involved in ITS evaluation. The significant issues that were identified by the workshop participants are listed below.

- The evaluation method should be designed according to the requirements of the decision makers who will use the output of the evaluation methodology and the purpose of the evaluation may affect the requirements of the evaluation design.
- The evaluation framework should provide analysts the freedom to select the most appropriate analysis technique for each project. It was suggested that different approaches might be required to evaluate private (in car) and public (road/infrastructure) applications.
- The ITS evaluation framework should provide guidelines to assist in determining when to consider installing ITS.
- The ITS evaluation methodology must allow comparison of ITS projects with non-ITS projects.
- ITS evaluation practitioners should be aware of and incorporate external research into their evaluations but must consider the suitability of adapting such research to local conditions.
- Any risk assessment included as part of the evaluation must reflect the political risk of an under-performing system. The workshop participants acknowledged a risk of institutional impediments if ITS solutions challenge existing treatment.
- There is a need for accepted benefit valuation techniques and a method to promote the benefits of ITS while reducing any unwarranted hype and maintaining credibility, which could be achieved by ensuring that valuation parameters are valid and transparent.
The challenge of measuring and costing the social, environmental and equity impacts of ITS was identified by most discussion groups.

**ITS evaluation actions**

The second session of the ITS evaluation workshop required participant groups to identify the actions that are required to resolve the issues that they identified in the preceding session. The most significant actions are listed below.

**General evaluation methodology requirements**

- An ITS evaluation guideline be produced, incorporating the results of demonstration and pilot projects with a revised guideline be produced once a number of ITS projects are implemented to strengthen variables and refine the original evaluation model.
- An ITS evaluation tool/model should be developed and it should contain a reasonable degree of flexibility to allow for integration of the emergent understanding of ITS impacts.
- The methodology should contain risk profiles or risk analysis tools.

**Type of evaluation**

- Evaluation methodology should include an array of evaluation methods such as multi-criteria analysis, as well as cost-benefit analysis, to broaden the scope of the evaluation.
- Review existing evaluation methods, such as cost-benefit analysis and multi-criteria analysis, for their suitability to ITS evaluation.
- Study the evaluation methods or processes used in other agencies, for example, Queensland Health, that also provide non-quantifiable benefits, as well as researching the evaluation processes used by other transport organisations.

**ITS impacts**

- Identify the impact measures that should be included in the evaluation.
- The ITS evaluation methodology should identify first order potential benefits, include social, equity and environmental benefits, evaluate synergies of ITS components and provide credibility to claims of ITS benefits.
- Identify the relationships between ITS projects and their impacts.

**Implementation of ITS evaluation methodology**

- Gain agreement with decision makers for a modified evaluation methodology.
- Identify and understand existing data sources, their detail and reliability, as well as identifying areas in which better data is required (for example, new types of data required and areas of non-coverage).

The findings of the workshop emphasised the importance of applying the experience of other organisations in measuring qualitative benefits and in designing a methodology that will be most appropriate for evaluation of ITS, rather than conventional road projects. The findings with regard to implementing the evaluation methodology are beyond the scope of this project. The workshop findings reiterate the importance of understanding the cause and effect relationships between ITS projects and their impacts and imply that this is the most difficult task in developing an ITS evaluation methodology.

**Survey of ITS and project evaluation practitioners**
The survey of ITS and project evaluation stakeholders and practitioners was conducted for the purpose of identifying any major issues or perceptions about ITS evaluation prior to developing the methodology. Participants were initially emailed an introductory letter, a copy of the survey questionnaire and a draft executive summary of the literature review. The respondents were then contacted by phone to arrange an appropriate time for the telephone interview. The survey was conducted as a telephone interview of duration of between 5 and 30 minutes, depending on the knowledge and availability of the survey respondent.

**Figure 2** indicates the proportion of respondents from various organisations or industry sectors. Survey respondents were specifically selected based on their knowledge of project evaluation or ITS, or their role as stakeholders of these processes.

Compared to the distribution of the ITS evaluation workshop participants, the survey included a greater proportion of officers from the Queensland Department of Main Roads than Queensland Transport, mainly due to the fact that the emphasis of this research project is road-based ITS. The proportion of Brisbane City Council participants is roughly equivalent to that of the ITS evaluation workshop. Approximately half of the respondents have no involvement with ITS projects and consequently the responses from the survey would be anticipated to contain less bias towards promoting ITS than those of the workshop. Due to time constraints and time availability of targeted respondents, the sample size was quite small and the results should not be considered as representative of the relevant population. The significant findings of the survey are presented below.

### Previous evaluations

Out of the eighteen people surveyed, ten of them have evaluated an ITS project or program. The evaluation methods used by these ten people are presented in Table 1.

<table>
<thead>
<tr>
<th>Method</th>
<th>Respondents who have used this method to evaluate ITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost benefit analysis</td>
<td>7</td>
</tr>
<tr>
<td>Commercial analysis</td>
<td>2</td>
</tr>
<tr>
<td>Multi-criteria analysis</td>
<td>1</td>
</tr>
<tr>
<td>Cost-effectiveness analysis</td>
<td>1</td>
</tr>
<tr>
<td>Business case</td>
<td>1</td>
</tr>
<tr>
<td>Before-and-after comparison</td>
<td>1</td>
</tr>
<tr>
<td>Traffic simulation</td>
<td>1</td>
</tr>
<tr>
<td>Engineering judgement</td>
<td>1</td>
</tr>
<tr>
<td>Program level analysis</td>
<td>1</td>
</tr>
<tr>
<td>Political judgement</td>
<td>1</td>
</tr>
</tbody>
</table>

In one case, an external consultant had completed the evaluation so the respondent was unfamiliar with the method of evaluation. One respondent had completed cost benefit analysis, cost effectiveness analysis and commercial analysis in conjunction. Another had completed traffic simulation and cost benefit analysis. Another respondent had completed cost benefit analysis, multi-criteria analysis and developed a business case for ITS applications. One respondent used CBA to evaluate a ramp metering project by adapting the impacts estimated by the California PATH project to local conditions. CBA was used in another evaluation where international ITS impact data for ten roads with similar characteristics to the local road was averaged over three impact types and applied to the proposed site. A floating car was used to measure the impact of signal coordination on bus-lane utilisation in a before-and-after study.
The impacts that were most frequently included in evaluations of ITS by survey respondents are travel time costs, vehicle operating costs and safety costs. Other impacts that were specified by only one respondent included such impacts as productivity, user comprehension, user acceptance, maintainability, noise and emissions.

The respondents were asked if they would take corrective action in a future evaluation of ITS projects. Of the ten respondents who have evaluated ITS previously, four replied that they would not do anything differently in a future evaluation of ITS. The responses, however, may have contained some bias due to the fact that people are unlikely to be completely open when identifying deficiencies in their own work. The most significant activity that respondents would do differently in a future evaluation would be to improve the integrity of the data used to estimate the project impacts.

**Key criteria for an effective ITS evaluation**

This section of the survey identified any key attributes of an evaluation method that would be required in order to successfully evaluate ITS projects. Four respondents did not specify any specific criteria while one respondent stated that there is no difference between ITS projects and conventional road projects that would normally be evaluated.

Most responses related to general criteria for an evaluation method, such as robustness, relevance and objectivity. The most significant responses were that the ITS evaluation methodology should:

- allow macro and micro levels of analysis
- allow comparison of ITS and non-ITS projects
- be objective rather than subjective
- incorporate knowledge from existing projects
- include cost-benefit analysis
- include multi-criteria analysis.

Other noteworthy responses indicated that the methodology should:

- consider the elasticities of impacts
- consider market size and economies of scale
- consist of a checklist of when ITS solutions are appropriate
- align with government and Treasury objectives
- include a commercial analysis
- include a test for alignment of project with policy.

**Impediments to developing an ITS evaluation methodology**

The impediments to developing an ITS evaluation methodology that were most frequently predicted by the survey respondents included:

- inadequate knowledge of ITS impacts
- inadequate knowledge or skills of staff using the methodology
- suspicion about the integrity of the estimated ITS benefits
- organisational risk and reluctance of practitioners to change
- overriding of evaluation method by political pressure
- limited budgets available for evaluation
- evaluation method that is too technical.

**Impacts which should be included in ITS evaluation**

The most frequently cited impacts that should be included in an ITS evaluation included:
• safety impacts (accidents)
• journey time
• delay time
• emissions and noise
• technical risk
• vehicle operating costs.

Other less frequent responses included travel time reliability; driver distraction; network effects; and route diversion. Other significant, but infrequently reported, impacts included personal and community security, modal impacts, liability and privacy issues, reliability and possible obsolescence of technology, interoperability and relationships between different applications of ITS.

Data used for measuring ITS impacts

Respondents were asked what type of data should be collected to measure ITS impacts. Their responses are listed in Table 2.

<table>
<thead>
<tr>
<th>Data that should be collected</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depends on project type</td>
<td>2</td>
</tr>
<tr>
<td>To measure impacts</td>
<td>3</td>
</tr>
<tr>
<td>To provide trends of performance</td>
<td>1</td>
</tr>
<tr>
<td>User acceptance or perception</td>
<td>3</td>
</tr>
<tr>
<td>User response</td>
<td>1</td>
</tr>
<tr>
<td>Queue lengths</td>
<td>1</td>
</tr>
<tr>
<td>Route journey times</td>
<td>1</td>
</tr>
<tr>
<td>Improved emission evaluation methods</td>
<td>1</td>
</tr>
<tr>
<td>Improved accident evaluation methods</td>
<td>1</td>
</tr>
<tr>
<td>Improved vehicle operating cost estimation methods</td>
<td>1</td>
</tr>
<tr>
<td>Improved data on cause of fatalities</td>
<td>1</td>
</tr>
</tbody>
</table>

The specific data sources that were suggested included: user acceptance or perception; user response; and traffic data such as queue lengths and journey times. It was also stated that more comprehensive methods should be developed to predict the impact of ITS on accidents, vehicle operating costs and emissions. The current models available that were developed for traditional road infrastructure projects are generally based on average speed, road length and capacity and road roughness – factors which are unlikely to change significantly with implementation of ITS (Queensland Department of Main Roads 1999).

Integration of ITS evaluation method with existing evaluation processes

Respondents were asked if they believed that an ITS evaluation methodology should be integrated with existing road project evaluation processes. Fifteen participants gave a positive response, one answered “probably” and two responded negatively. Corresponding justification for responses was obtained but, to maintain brevity, is not listed in this paper.

The survey respondents were then asked how the evaluation methods should be integrated. The responses are shown in Table 3 but the most significant finding was that three respondents suggested that the ITS evaluation methodology be added on as a module to the existing road infrastructure CBA software package. Conversely, one participant stated that ITS evaluation should not be added on as a module as the current CBA methodology is project oriented whereas ITS evaluation would be incremental or operational.
Table 3: How should the evaluation methods be integrated?

<table>
<thead>
<tr>
<th>Method of integrating evaluation methods</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add on as a module to CBA software</td>
<td>3</td>
</tr>
<tr>
<td>Consultation and involvement with key personnel</td>
<td>2</td>
</tr>
<tr>
<td>Rigorous method</td>
<td>1</td>
</tr>
<tr>
<td>Incremental process</td>
<td>1</td>
</tr>
<tr>
<td>Include costs and benefits to users and transport outcomes</td>
<td>1</td>
</tr>
<tr>
<td>Guidance notes on appropriateness of evaluation</td>
<td>1</td>
</tr>
<tr>
<td>Add on other parameters</td>
<td>1</td>
</tr>
</tbody>
</table>

Respondents were asked to list any potential barriers to integrating the ITS evaluation methodology and conventional road project evaluation procedures. The results are shown in Table 4.

Table 4: Barriers to integrating ITS evaluation with current road project evaluation

<table>
<thead>
<tr>
<th>Barriers to integrating two methods</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of understanding by users</td>
<td>1</td>
</tr>
<tr>
<td>Skills of staff using the evaluation methodology</td>
<td>1</td>
</tr>
<tr>
<td>Complexity of evaluation methodology</td>
<td>1</td>
</tr>
<tr>
<td>Difficulty in developing methodology</td>
<td>1</td>
</tr>
<tr>
<td>Inability to include non-quantifiable benefits</td>
<td>1</td>
</tr>
<tr>
<td>Difficulty in separating link and network</td>
<td>1</td>
</tr>
<tr>
<td>Ensuring standards and compatibility between applications</td>
<td>1</td>
</tr>
<tr>
<td>Cultural resistance to new evaluation process</td>
<td>5</td>
</tr>
<tr>
<td>Lack of district/regional interest</td>
<td>1</td>
</tr>
<tr>
<td>Reluctance to use new technology</td>
<td>1</td>
</tr>
<tr>
<td>Multi-agency function of ITS vs single agency evaluation</td>
<td>1</td>
</tr>
<tr>
<td>Installation cost of ITS infrastructure</td>
<td>1</td>
</tr>
</tbody>
</table>

The most significant anticipated barrier to integrating an ITS evaluation methodology with a conventional road project evaluation is a resistance of users to utilising a new evaluation process. In addition, there were concerns that the evaluation methodology may become too complex and that there may be a lack of user understanding of the evaluation process.

FUTURE WORK

With the assistance of the Main Roads’ Traffic Management Centre at Nerang, a study to measure the impact of diversion advice displayed on variable message signs was conducted at a major intersection on the Gold Coast. There are VMS signs on all approaches to the intersection and it is possible to measure the flows travelling in all directions at the intersection. Alternate route advice was displayed during congestion conditions and the measured turning movement flows are to be compared to the turning movement flows for situations where the alternate route advice message was not displayed in similar congested conditions. Although a large traffic volume travels along this route, the sample size is relatively small. Only four runs could be conducted as an excessive manipulation of the signs may result in decreased user confidence in the signs. The results will indicate the degree to which vehicles alter their travel route as a result of the congestion warning and alternate route advice. The results of this study will be compared to similar studies and used in the evaluation methodology.

The evaluation methodology is to be developed in an Excel spreadsheet, primarily providing a framework for the evaluation of ITS. The methodology will use similar algorithms to those used in the CBA4 software of the Queensland Department of Main Roads in order to allow comparison with projects evaluated in CBA4. Finally the evaluation methodology will link to a detailed table of reported ITS impacts, used as the basis for the impact estimation in the
evaluation based on similarity of road and traffic conditions and statistical confidence in the
reported impacts.

CONCLUSIONS

The primary benefit of conducting the consultation was to inform the development of the ITS
evaluation methodology. The secondary benefit of the consultation phase was the increased
awareness of this research project and the need to develop an ITS evaluation methodology. In
addition, the goodwill created by the consultation phase will enhance the implementation of the
developed evaluation methodology.

More specifically, the feedback obtained during consultation regarding the difficulty of
measuring the actual impacts of ITS and the scepticism that an evaluation methodology could be
developed without thorough knowledge of the impacts of ITS have steered the project
significantly. While the research project aim remained unchanged, it was determined that
impact estimation for a variety of ITS impacts would not be included. Instead, it was
established that a methodology for the evaluation of an array of ITS projects would be
developed but that the bulk of the research effort would be directed at studying the impacts of
one specific ITS application and developing a comprehensive evaluation methodology for that
selected application.

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BIOGRAPHIES

Jonathan Bunker

Jon completed his Bachelor of Engineering (Civil) (Hons) in 1991, and Doctor of Philosophy on Microscopic Modelling of Freeway Operations in 1995, both at QUT. For five years he practiced as a consulting transport engineer with Kittelson & Associates, Inc. in Portland, Oregon, and sister firm Eppell Olsen & Partners in Brisbane, undertaking development transport planning, urban and regional integrated transport planning, road hierarchy and network analysis studies, design of transport facilities, and public engagement activities. He contributed with Kittelson & Associates to the development of Roundabouts, An Information Guide for the US FHWA. Jon is now Lecturer in Transport Engineering in the School of Civil Engineering, QUT. He teaches and coordinates transport engineering/planning and professional studies courses at undergraduate and postgraduate levels. Jon is currently active on numerous research projects including pavement asset management, heavy vehicle management, freeway operation, freight logistics, transport project evaluation, and in-vehicle technologies.
Figure 1: Relative proportion of workshop participant representation
Figure 2: Relative background of survey respondents