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Extending cost–benefit analysis for the sustainability impact of inter-urban Intelligent Transport Systems

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ABSTRACT

The paper reports research involving three cost–benefit analyses performed on different ITS schemes (Active Traffic Management, Intelligent Speed Adaptation and the Automated Highway System) on one of the UK's busiest highways — the M42. The environmental scope of the assets involved is widened to take into account the possibility of new technology linked by ICT and located within multiple spatial regions. The areas focused on in the study were data centre energy emissions, the embedded emissions of the road-side infrastructure, vehicle tailpipe emissions, additional hardware required by the vehicles (if applicable) and safety, and all aspects of sustainability. Dual discounting is applied which aims to provide a separate discount rate for environmental elements. For ATM, despite the energy costs of the data centre, the initial implementation costs and mitigation costs of its embedded emissions, a high cost–benefit ratio of 5.89 is achieved, although the scheme becomes less effective later on its lifecycle due to rising costs of energy. ISA and AHS generate a negative result, mainly due to the cost of getting the vehicle on the road. In order to negate these costs, the pricing of the vehicle should be scaled depending upon the technology that is outfitted. Retrofitting on vehicles without the technology should be paid for by the driver. ATM will offset greenhouse gas emissions by 99 kt of CO_2 equivalency over a 25 year lifespan. This reduction has taken into account the expected improvement in vehicle technology. AHS is anticipated to save 280 kt of CO_2 equivalency over 15 years of operational usage. However, this offset is largely dependent on assumptions such as the level of market penetration.

Introduction

CBA (and its discounting method) plays a central role in determining the feasibility of current and future road transport projects. However, for the significant *indirect* impacts on the economic, social, and environmental systems connected with the transport system, alternative approaches to the microeconomic approach become inevitable. When evaluating technologically distributed systems such as ITS, all elements of the system must be taken into account. For example, Active Traffic Management features technology on the road-side but is also connected to a regional centralised system which includes the data centre and the traffic control centre which manages all road-side technology including the message signs and speed indicators.

The environmental impacts of ITS also sit alongside the carbon offset that these technologies generate by improved management of the transport network (i.e. through smoother flowing traffic, reduced congestion overall). Using current methods, the ICT support infrastructure, physical transport infrastructure and the operational assessment of vehicle throughput have all been calculated in isolation. Without a calculation of the overall emissions generated there is the risk that some elements remain unaccounted for, for example ‘cause and effect’ chains and hidden consequences. The aim of the research in this paper is to extend the scope of the emissions accounted for within a traditional CBA to include both the potential carbon reduction from operating an ITS scheme and the embedded emissions from constructing and implementing the scheme.

The process of monetising the environmental cost savings using current CBA methodologies is inaccurate due to the use of solitary discount rates applied over long time periods. This is a general limitation of the CBA method and this paper aims to resolve this by applying dual discounting when estimating the costs and benefits of ITS.

Cost benefit analysis: methodology and associated literature

Environmental factors for CBA in Europe are calculated through climate change mitigation costs. Sentance (2009) argues that to create and maintain a low carbon policy it is necessary to implement emissions trading (ETS) and taxation where both mechanisms have individual benefits, however, not all parties may perceive the mechanisms as a positive measure. It is also recommended that they be suited to a

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particular region or sector, therefore the literature recommends a sectoral approach (Fujiwara, 2010; Millard-Ball, 2010). CBA has attracted some criticism due to its one-dimensional monetary valuation judgments, particularly the role of the discount rate or the appraisal period to be used (Simpson and Walker, 1987). The literature identifies a number of CBA studies applied to current and anticipated ITS systems (see Table 1).

According to Stevens (2004) however, CBA offers various advantages in measuring the sustainability performance of ITS. It uses established economic principles to assign values and is therefore able to reflect whether the investment is worthwhile to society from a holistic perspective. It may also be required in order to secure public or private sector funding. In the current political climate, this may result in prioritisation of environmentally sustainable ITS.

Modifications to the established CBA methodology may allow the measurement of environmental ITS performance to become a reality. Earlier notable studies took an approach based on performance indicators for ITS. These included the analysis of ITS performance in the EU FP5 funded CITY PIONEERS, which developed project guidance for local regions in implementing ITS applications (Pattinson et al., 1998). The introduction of simplistic ITS performance indicators was also the goal of the EU funded MAESTRO project (James, 1999). The Maestro guidelines focused upon assessing new technologies and services from theory to implementation. More recently, Lai et al. (2012) conducted a CBA for accident reduction and fuel consumption for Intelligent Speed Adaptation This was based on two independent market penetration scenarios: market driven and authority driven. Overall, the cost benefit ratio for the market scenario to 2070 was 3.4, whilst the corresponding figure for the authority scenario was 7.4. Stevens (2004) argues that for any measures of performance, validity, reliability and sensitivity all play a key role in the measurement of successful applications and services.

CBA, as a sole ESAT tool, has disadvantages for ITS service appraisal in line with the issues raised within the literature. Firstly, there is no reference point on which to base the initial appraisal. Traditionally, CBA is calibrated based upon past projects and due to the lack of historical data, the accuracy of the cost benefit assessment may suffer and an expert judgement given instead. Due to time, scope and budget constraints the appraisal may not be performed successfully, jeopardising historical data accuracy for future projects. These benefits (such as climate change) may not be reported satisfactorily, although Stevens (2004) argues that publicising project side effects such as pollution may compromise the readiness and support of future transport projects. The counter-argument is that environmental transparency is high on the political agenda, therefore the impact on the environment should be documented thoroughly. Valuation outcomes such as willingness to pay (or accept) are aggregated figures and based upon values such as income. The methods used to value impacts (stated preference and hedonic pricing) may not be completely adequate and the knowledge base to estimate longer-term impacts may be missing. Policy judgements are therefore required and may usher expert opinion. The valuation of environmental impacts over a long period may not be feasible using CBA alone, as qualitative aspects such as social, safety and welfare cannot be processed through this methodology without modification to the discounting method. Recent research suggests approaches such as dual and declining discounting may allow such issues to be addressed in the future.

According to Almansa and Martínez-Paz (2011), CBA is currently being modified via two different perspectives. Firstly, the development of a new toolset which aims to measure the valuation of environmental aspects which were originally rejected from the analysis due to an incompatibility with the CBA specification (aspects are rejected if they do not interface with the economic valuation). In potentially high impact environmental projects with a long term effect on future generations, assigning the discount rate to the time horizon (where emissions can span centuries) is of high importance due to the potential variance in profitability assessment. Probabilistic criteria (as opposed to exact values) are desired due to the ability to integrate uncertainty assessments, such as those arising from Monte Carlo analysis. The second approach is a longer process which deals with the constant revision of the underlying theory of the traditional approaches of discounting. Climate change features repercussions over a long period of time, whilst current discounting models are primarily focused on assessment over a couple of decades. Kula and Evans (2011) conducted a case study that involved treating environmental benefits separately within the framework of the sustainable development field and applied dual discounting to an afforestation project within the UK. The results reflected environmental benefits (such as carbon offsetting) as well as conventional benefits. This approach could therefore potentially enhance the economic viability of investment projects. As with discounting, the focus is on the present and short-term estimate. Therefore dual discounting should be applied (and sustainability should be addressed) independently from economic appraisal, although recent efforts have been taken to project discounting into the future (Almansa and Martínez-Paz, 2011; Lai et al., 2012). In this paper, a cost–benefit analysis was performed on three different types of ITS scheme: Active Traffic Management (ATM), Intelligent Speed Adaptation (ISA) and the Automated Highway System (AHS). These three technologies were chosen due to the rapid evolutions and major change they are likely to bring in the near term and long term in terms of emissions, safety and economic benefits. Some of these technologies i.e. ISA whilst technically feasible, are awaiting the right policy and practical implementation context, which understanding the impacts may help to deliver. The areas focused on in the study were: the data centre energy emissions, the embedded emissions of the road-side infrastructure, vehicle tailpipe

Table 1
Studies of CBA applied to ITS.

Review of CBA/CEA applied to ITS			
ITS technology	Country/region of study	Literature	Total number
Active Traffic Management *incl. variable message signs*	France	Motyka and James (1994)	4
	USA	Sisiopiku et al. (2009)	
	Canada	Schnarr and Kitaska (1996)	
	Finland	Nokkala (2004)	
Automated Highway System	Generalised	Ran et al. (1997)	3
	Germany/Japan	(Baum et al., 1999; Baum and Geissler, 2000)	
Advanced driver assisted systems	Norway	Shibata (1992)	5
	UK/USA	(Jeffery, 1981; Harvey, 1994)	
	UK	(Carsten and Tate, 2005; Lai and Carsten, 2012)	
Travel information system	USA	Lee (2000)	1
Combined/strategic analysis and frameworks	UK	Perrett et al. (1996)	5
	EU	(James, 1999; Psaraki et al., 2012)	
	USA	Yun and Park (2004)	
	N/A	Stevens (2004)	