Transport Reviews

A Transnational Transdisciplinary Journal

ISSN: 0144-1647 (Print) 1464-5327 (Online) Journal homepage: https://www.tandfonline.com/loi/ttrv20

Making a Business Case for Intelligent Transport Systems: A Holistic Business Model Framework

Konstantinos N. Giannoutakis & Feng Li

To cite this article: Konstantinos N. Giannoutakis & Feng Li (2012) Making a Business Case for Intelligent Transport Systems: A Holistic Business Model Framework, Transport Reviews, 32:6, 781-804, DOI: 10.1080/01441647.2012.740096

To link to this article: https://doi.org/10.1080/01441647.2012.740096

Published online: 19 Nov 2012.

Transport Reviews, Vol. 32, No. 6, 781–804, November 2012

Making a Business Case for Intelligent Transport Systems: A Holistic Business Model Framework

KONSTANTINOS N. GIANNOUTAKIS AND FENG LI

Cass Business School, City University London, 106 Bunhill Row, London, EC1Y 8TZ, UK

(*Received 11 January 2012; revised 4 July 2012; accepted 11 October 2012*)

ABSTRACT *Intelligent transport systems (ITS) are technologies, applications and systems for accident warnings, reduction of driving workload, congestion avoidance and traffic management. The infrastructure also opens up opportunities for new digital services to users and for new ways of managing and maintaining transport infrastructure. Despite the significant potential benefits identified by previous research since the 1980s, the market for ITS has so far failed to take off, and a robust business case for the full-scale development of ITS remains absent. This is important because the potential benefits of ITS can only be realized if the technologies and services are widely used. Today, many ITS are still too expensive to purchase and install, often requiring substantial upfront investment, but the returns could take many years to materialize. This paper will provide a systematic overview of previous research on ITS and propose a holistic business model framework to help make a business case. This is still a rapidly evolving area, and a new research agenda will be discussed.*

Keywords: intelligent transport systems; business models; technological innovation; innovative business models; sustainability

Introduction

Intelligent transport systems (ITS), also known as intelligent transportation systems or advanced transport telematics (ATT), are systems, technologies and services aimed at providing safer and more efficient transport services, by increasing productivity, improving safety, reducing travel time, reducing costs and saving energy (Miles & Chen, 2004). Such systems also open up significant opportunities for new services for drivers, travellers and infrastructure providers. Examples of ITS include in-vehicle information systems (Kantowitz, 2000; Wiese & Lee, 2007) and advanced driver assistance systems (Amditis et al., 2010; Man Ho, Yong Tae, & Joonwoo, 2010), such as in-vehicle navigation, intelligent speed adaptation (ISA) (Larsson, 2012; Vlassenroot, Brookhuis, Marchau, & Witlox, 2010; Young, Regan, Triggs, Jontof-Hutter, & Newstead, 2010), forward collision warning (Braitman, McCartt, Zuby, & Singer, 2010; Sengupta et al., 2007) and

Correspondence Address: Konstantinos N. Giannoutakis, Cass Business School, City University London, 106 Bunhill Row, London EC1Y 8TZ, UK. Email: kostas.giannoutakis.1@city.ac.uk

0144-1647 print/1464-5327 Online/12/060781-24

http://dx.doi.org/10.1080/01441647.2012.740096

several others collision warning systems (Jenkins, Stanton, Walker, & Young, 2007; Piao & McDonald, 2008; Trivedi, Gandhi, & McCall, 2007). Many ITS applications, such as inter-vehicle communication, are still under development, while some others are still at the experimental or conceptual stage, such as 'car platooning' (Clement & Taylor, 2006).

Although the earliest attempt for the development of ITS applications was found in Japan in the 1970s, with the CACS project (Comprehensive Automobile Traffic Control System), the first systematic step was taken in the late 1980s in the USA (Catling, 1994). The birth of the term ITS occurred in the early 1990s, with the adoption of the Intelligent Vehicle Highway Systems Act of 1991 by the US Department for Transportation (Wootton, Garcia-Ortiz, & Amin, 1995). The new concept was about solving traffic-related problems, not only by opening new roads but also by making the existing transport infrastructure more efficient. The ITS programme was launched. Garcia-Ortiz, Amin, and Wootton (1995) list six thrust of the ITS programme of the early 1990s, covering both intelligent infrastructure and intelligent vehicles: (a) advanced traffic management systems, (b) advanced traveller information systems, (c) advanced vehicle control systems, (d) commercial vehicle operations, (e) advanced public transportation systems and (f) advanced rural transportation systems.

Although the term ITS was born in America, Europe is considered to be the first to launch integrated research projects, such as the PROMETHEUS project (PROgraMme for a European Traffic of Highest Efficiency and Unprecedented Safety) since 1986 (Catling, 1994). It was a Pan-European project experimenting on the design and implementation of driverless vehicles and autonomous driving algorithms, with the participation of the European Commission, more than 13 vehicle manufacturers, universities and research centres from 19 European countries (Bertozzi, Broggi, & Fascioli, 2000). Other European projects of the 1980s and early 1990s were DRIVE I (1988–1991) and DRIVE II (1992–1994), aimed at promoting Road Transport Informatics and ATT, respectively. BMW, Opel, Daimler Benz, Jaguar and LUCAS have been some of the automobile industries involved in several of these projects (Brackstone & McDonald, 2000).

Japan was involved in ITS developments since the 1970s, with projects such as the CACS programme in 1976, or the Vehicle Information and Communication Systems (VICS) programme in 1991 (Wootton et al., 1995). The CACS project was led by the National Police agency of Japan and the Ministry of Construction, aimed at introducing a system able to provide dynamic information by performing route calculation and using on-board digital maps (Catling, 1994). Of similar nature was the VICS project, with the participation of the Ministry of International Trade & Industry, Ministry of Infrastructure and Transport, Ministry of Construction, the National Police Agency and several automobile and electronics industries (VICS, 2012).

Despite the significant potential benefits from ITS and the heavy investments by the public and private sectors in R&D projects and pilot studies since the 1980s, the market for ITS has so far failed to develop as predicted. This research will systematically review previous studies in ITS and, then, using a holistic business model framework will explain how some of the key barriers could be overcome. This paper will contribute to our understanding on why rapid technological developments in ITS have failed to translate into large-scale, sustainable developments.

In the next section, the methodology we followed for this paper will be described. The third section presents the key findings of our systematic review process and highlights the absence of systematic business analysis in the ITS literature. The fourth section presents a holistic business model framework. This is then followed by discussions about adapting the proposed business model framework to the ITS of the future, using examples from the ongoing trend of ITS research on vehicular communication and connectivity. Finally, some key conclusions are summarized and a future research agenda will be discussed.

Research Methodology

This paper is based on a systematic review of previous studies on ITS. The difference between a systematic review and the traditional narrative reviews is that the former follows exhaustive search and gives collective insights through theoretical grouping of topics, procedures aimed at minimizing bias and error and providing 'high-quality' evidence (Tranfield, Denyer, & Smart, 2003). Snaddon (2001) reviewed general competition-related issues in transportation, but no systematic review of previous studies on ITS could be identified.

Our review spans a range of disciplines, from engineering and transport science to business studies and social sciences. Figure 1 illustrates the most popular subject areas for ITS studies after a preliminary search of the Web of Knowledge (WoK) database. ITS have been studied mainly from the engineering perspective. In contrast, business and economics constitute only a very small part to the past research (1.79%).

The research methodology we followed in this paper was a modification of the one proposed by R. Lee (2009), who adopted a step-by-step algorithmic selection of papers to review the literature on social capital (Table 1). We started by selecting bibliographic databases, namely The WoK—All databases (WoK), EBSCOhost—Business Source Premier (BSP) and the Web of Science—Social Sciences Citations Index (SSCI). WoK includes databases from many different disciplines, which serves our multidisciplinary search scope. BSP is much more concentrated on business-related journals. SSCI, on the other hand, was used to fill the gap in business-related journals the previous two databases failed to identify. In the second step, we filtered the references by using keywords, in 'topic' (WoK/SSCI) and 'SU-Subject Terms' (BSP). It is interesting to note that the terms

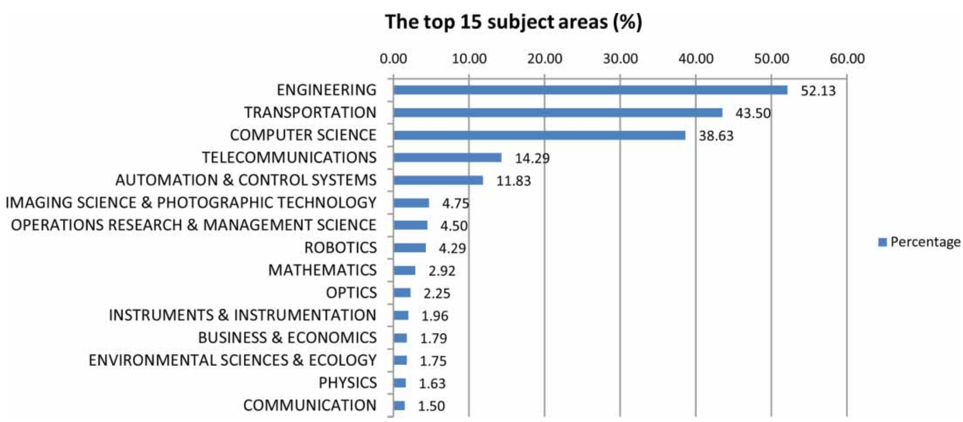

Figure 1. WoK search results, the top 15 subject areas by percentage (2400 hits).

Table 1. The systematic literature review process

Step 1: Selecting databases	WoK BSP SSCI
Step 2: Keyword search	WoK/BSP: ('Intelligent Transportation Systems' OR 'Intelligent Transport Systems' OR 'Intelligent Transportation' OR 'Intelligent Transport') AND ('Business') Subject areas: All SSCI: (Transportation OR Transport) AND Business Subject areas: Management, Business, Transportation, Social Sciences—Interdisciplinary
Step 3: Selecting document types	Articles, academic journals, magazines Reviews Editorials
Step 4: Labelling by abstract	*Label A*: All papers directly relevant to the literature review, i.e. papers that address business, socioeconomic, political, legal and environmental issues *Label B*: All papers with mainly technical focus, but indirectly related to the issues considered by Label A All other papers are discarded
Step 5: Revisiting papers	More careful read of Label A papers Second read through Label B abstracts, conclusions and main findings
Step 6: Extra additions	Key references cited by selected publications Ad hoc search and online sources Experts' recommendations
Step 7: Database grouping	Putting databases together Removing duplicates Grouping

'business' and 'e-business' could be used interchangeably as they both returned the same number of hits. Our search covered all periods for WoK and BSP and the latest five years for SSCI in order to enhance the bibliography with the most recent economic and business studies.

Selecting 'articles, editorials and reviews' (WoK) or 'academic journals and magazines' (BSP), the hits were reduced to 792 for WoK and 151 for BSP. For SSCI, our search was restricted to full articles and to the subject areas of management, business, transportation and social sciences (interdisciplinary); thus, we reduced the search results to 182. In step 4, the second filtering included reading of abstracts and labelling of results in two categories, A and B. Label A was articles that explicitly addressed business and socioeconomic issues, referred to e-business matters, discussed about policies and regulations, general topics directly related to our research for a sustainable business case. Label B was technology-oriented articles, written by and referring to engineers. The vast majority were IEEE publications in journals with the top 5-year impact factors and were given a label B if they could implicitly inform our analysis, according to the issues examined by Label A articles. We discarded all other articles.

In the next step, we performed a second review over Label B articles. This time, we looked into more details, such as introduction and main findings. We also added references from ad hoc search, key references cited by selected publications and recommendations from experts. By putting the databases together, removing duplicates and grouping the studies, we arrived at the final reference list.

We reviewed these references mostly based on their abstracts, introductions and key findings. We avoided researching too much detail about purely technical descriptions. References highly related to economics and business issues were prioritized and followed up with reading of the full articles.

Understanding ITS: A Systematic Review of Previous Studies

Intelligent Infrastructure

Our systematic review identified six key topics by previous studies concerning intelligent infrastructure. As outlined in Table 2, previous studies have researched data collection for proactive traffic management infrastructure, such as analysis of crashes using data from loop detectors (Abdel-Aty, Pande, Lee, Gayah, & Santos, 2007; Pande & Abdel-Aty, 2005). Data mining and manipulation of this type provide useful information on traffic conditions and reveal patterns of traffic flow and the most likely areas of the road network for accidents to occur. The handling of such traffic information passes through several stages. W.-H. Lee, Tseng, and Shieh (2010) divide the applications of traffic information into three

Table 2. Intelligent infrastructure references by authors and topic

Intelligent infrastructure	
Topic	References
Data collection for proactive traffic management infrastructure	Abdel-Aty et al. (2007), Pande and Abdel-Aty (2005), Barrero, Toral, Vargas, Cortes, and Milla (2010), Tubaishat, Zhuang, Qi, and Shang (2009)
Wireless networks for road–vehicle and vehicle–vehicle communication	Ding, Wang, Meng, and Wu (2010), Milanes, Perez, Onieva, and Gonzalez (2010), Seii et al. (2009), Sisiopiku and Elliott (2005), Wang (2007), Yongchang, Yan, Chowdhury, Kuang-Ching, and Fries (2009)
Traffic data management algorithms and techniques	J. Lee, Veloso, Hounshell, and Rubin (2010), Ni, Leonard, Guin, and Feng (2005), Trullols, Fiore, Casetti, Chiasserini, and Ordinas (2010), Velaga, Quddus, and Bristow (2009)
Systems and applications for travel time, air quality management, data archiving, etc.	Haghani, Hamedi, Sadabadi, Young, and Tarnoff (2010), Hounsell, Shrestha, Piao, and McDonald (2009), Velastin, Boghossian, Lo, Sun, and Vicencio-Silva (2005), Li et al. (2009), Rabie, Abdulhai, Shalaby, and El-Rabbany (2005), Smith and Venkatanarayana (2005), Vanajakshi, Subramanian, and Sivanandan (2009), Venigalla and Ali (2005), Zhu, Li, Zhu, and Ni (2009)
Congestion charging and economic models	Albalate and Bel (2009), Bureau and Glachant (2008), Guo and Yang (2010), Holguin-Veras, Cetin, and Xia (2006), Kottenhoff and Brundell Freij (2009), de Bok (2009), De Borger and Van Dender (2003), Guo and Yang (2010), Han and Yang (2009), Hamdouch, Florian, Hearn, and Lawphongpanich (2007)
ETC	Chen, Fan, and Farn (2007), W. H. Lee, Tseng, and Wang (2008), Lu, Ye, Ding, and Xiang (2004), Odeck and Welde (2010), Ogden (2001)

stages: data collection and cleansing, data fusion and integration, and data distribution. The collected data coming from the data collection and cleansing are integrated with geographic information systems and other traffic information and finally, they are distributed to the users through several interfaces (e.g. web, radio and mobile phones). The last feature could open up opportunities for new services through the existing infrastructure and lead to the next level of more connected and integrated vehicles. Using the Internet as part of the ITS architecture is gaining momentum and studies on the implications of this already exist (Barrero et al., 2010). Although vehicular communications are not a reality yet, prototype communication protocols have already been tested. Handling of communication information and reliable infrastructure is a key to vehicular networks. Some authors have worked on techniques for data transmission to vehicles through infrastructure nodes (Trullols et al., 2010), studied the topological characteristics of such networks to develop map-matching algorithms (Velaga et al., 2009), while others have proposed techniques on manipulating datasets with missing data through imputations (Ni et al., 2005).

Infrastructure for the management of traffic data constitutes the first step towards wireless networks and global positioning systems (GPS), another popular topic among transportation researchers. Ding et al. (2010) propose a platform-free algorithm for route guidance systems that takes into consideration real-time traffic information, while Milanes et al. (2010) propose vehicle-to-vehicle (V2V) communication systems for traffic management at intersections using fuzzy logic. Other authors suggest larger engagement of the road infrastructure in vehicular communications, such as combining V2V with roadside-to-vehicle communication systems (Seii et al., 2009), further enhancements or improvement of active warning systems, which detect not only vehicles but also pedestrians and wild animals on the roadside and warn drivers (Sisiopiku & Elliott, 2005). However, the reality behind vehicular communications requires further and more combined efforts. Although the necessary technology exists and various research projects have been dedicated to this, vehicular communications require large investments from the public sector, as well as, adequate entrepreneurial incentive for private companies to participate. Within this context, several alternative architectures, either distributed or centralized, or a combination of them have been considered (Yongchang et al., 2009).

The ultimate target of vehicular communication infrastructure is road safety and reduction of road fatalities. The eSafety initiative put emphasis on the human factor and the European Commission, by fitting eSafety within the Information Society Technologies thematic area of Framework Programme 6 and funded a series of integrated projects aimed at counteracting the effects of wrong driving practices with the use of technologies. The European Commission launched the eSafety initiative in April 2002, with the main target of reducing the number of people killed in roads by half by 2010 (Jarasuniene & Jakubauskas, 2007). It consists of a group of experts such as the European Commission, road and safety authorities, automobile manufacturers, research organizations and road operators, co-chaired by ERTICO, ITS Europe and Association of European Car Manufacturers, working together in order to promote ITS for better road safety across Europe. The eSafety Working Group (WG), which was established for setting up targets and standards throughout the initiative, came up with 28 recommendation covering a broad range of road safety aspects and 16 target areas. The most notable was the eCall target. It included adjustment of E-112 (the EU

Health Service Executive Treatment Abroad Scheme) to European transport and establishment of data transfer protocols for in-vehicle emergency calls. However, experience of the past decade showed that the target of halving road fatalities by 2010 was not feasible. That still maintains European roads as dangerous areas with heavy death toll especially among young drivers, and prompts for a more systematic implementation of ITS (Jarasuniene & Jakubauskas, 2007). More about safety systems will be discussed in the section about intelligent vehicles.

Research has also focused on congestion charging. As Holguin-Veras et al. (2006) and Albalate and Bel (2009) show, as congestion is characterized by many economic externalities, they find that toll increases seem to affect mostly owners of large vehicles, such as trucks, instead of having a proportional impact on all user groups. Disproportional effects of tolls against lower income people have also been observed in a study in Paris (Bureau & Glachant, 2008), while in Stockholm, congestion charging witnessed increased acceptability when it was combined with expansion of the public transport system (Kottenhoff & Brundell Freij, 2009). Several authors have proposed alternative solutions to deal with congestion, either with the use of ITS, or through other economic measures, including tax reforms or new ways of congestion pricing (De Borger & Van Dender, 2003; Guo & Yang, 2010; Hamdouch et al., 2007; Han & Yang, 2009). Congestion charging has always been a matter of friction among road users, authorities and toll collectors. The establishment of ITS with nationwide projects could improve the road conditions and driving assistance making road tolling not necessary or replace it with other more socially accepted taxes. However, large public spending on ITS infrastructure, given the current economic situation in the developed world, seems highly unlikely for the years to come. New business models for companies wishing to operate in this field will be required and several alternatives must be examined, such as deployment of more efficient and cost-effective technological solutions. A worth mentioning technology on congestion management and charging is electronic toll collection (ETC). ETC also known as electronic payment and pricing system is a fast growing technology for dealing with congestion charging. New technologies have enabled the collection of congestion charging automatically, for example by recognizing the vehicle's registration number, without the need for cashiers at toll plazas, or the need for the drivers to stop there. Most of the studies regard ETC as revolutionary in the field of ITS; however, concerns about the safety of the system (Lu et al., 2004) and breaching of privacy (Ogden, 2001) have also been addressed.

Intelligent Vehicles

We identified seven key issues from previous studies on intelligent vehicles. As speed is one of the major contributors to accidents, most research has been on speed adaptation under changing driving conditions (Fries, Chowdhury, & Ma, 2007; Zhang, Suto, & Fujiwara, 2009) and especially on using adaptive cruise control (ACC) or ISA. ACC/ISA is a system able to control the accelerator, the engine and the brakes, so that the driver keeps a safe distance from the vehicle in front. It has been tested both in practice as a widely used embedded system in modern vehicles and through simulations for further improvement (Jianqiang, Shengbo, Xiaoyu, & Keqiang, 2010). There have also been studies on enhancements with other features, such as lane detection (Jung, Lee, Kang, & Kim, 2009; Pauwelussen & Feenstra, 2010), wireless connection of ACC-enabled vehicles

(Naus, Vugts, Ploeg, van de Molengraft, & Steinbuch, 2010), efficient fuel consumption through assessment of the wind speed (Khayyam, Nahavandi, & Davis, 2012), and generally less manual control and more automation (Zheng & McDonald, 2005). It has also been tested against pedestrian safety indicating that it reduces the risk of collisions with pedestrians and the risk of death by mitigating collisions (Ma & Andreasson, 2005). However, concerns exist about the imperfections and safety of the system (Larsson, 2012), especially during overtaking where acceleration is necessary, despite that simulations have shown that the acceleration rate and traffic flow are not affected by its use (Tapani, 2012).

Lane departure warning (LDW) is another crash avoidance system alerting the driver if the vehicle moves out of its lane with a switched off turn signal. It operates with cameras and sensors mounted on the vehicle able to detect the road markings (Braitman et al., 2010; Cheng, Jeng, Tseng, & Fan, 2006; Clanton, Bevly, & Hodel, 2009; Glaser, Mammar, & Sentouh, 2010). Unlike other vision-based systems that detect the surrounding environment (e.g. see Sivaraman & Trivedi, 2010; Wu, Decker, Chang, Camus, & Eledath, 2009), LDW functions are based on sensing the location of lanes on the road. There is also ongoing research to improve the warning system, as it is quite susceptible to failure in roadways without markings (Clanton et al., 2009) or it can disseminate false warnings (Braitman et al., 2010).

Pedestrian detection system (PDS) is also based on artificial vision. It recognizes human bodies from video segments that it records with its cameras and warns the driver about the danger of collisions with pedestrians. One of the main difficulties in implementing reliable PDS is the ability to detect and track successfully human figures among other objects in the images (e.g. moving or stationary vehicles, signs, trees and buildings). It is not an easy task to classify a human image, as Pai, Tyan, Liang, Liao, and Chen (2004) explain, due to 'the articulated nature of the human body', and they propose a method of tracking humans by the walking rhythm. They also discuss the problem of occlusion, i.e. human bodies emerging behind objects such as stationary vehicles (Table 3).

A topic that is gaining popularity is human–machine interface (HMI) and the drivers' distraction by system errors and unnecessary warnings or information (Baldwin, 2002; Glaser et al., 2010; Ioannou & Stefanovic, 2005; Lansdown, 2000; Rajaonah, Tricot, Anceaux, & Millot, 2008; Stevens, 2000). The interest in ITS is being shifted from installing and optimizing technology to HMI and safety (Stevens, 2000). Lansdown (2000) shows that the driver's performance may be affected by ITS as it can distract their attention from the roadway, stressing the importance to evaluate these systems to ensure that they do not add unnecessary tasks to the driver or cause any distraction. Trivedi et al. (2007) are working on 'driver monitoring', i.e. recording real-time information about the driver's mental state, driving style, etc. They propose a system that uses in-vehicle cameras, sensors and machine-learning techniques to record information from the environment, the vehicle and the driver themselves. Similar work is presented by Perez et al. (2010) about 'Argos', a sensor-based computerized car with an in-vehicle data recorder that records information about the driver's speed, point of gaze and also data from the surrounding environment.

Regarding ITS for public use, some literature has also focused on ITS for public transport, with emphasis on bus services. Some authors studied the bus operations in the UK with regard to public appeal, traffic congestion and quality of services. Hounsell (2004) proposes a series of ITS applications to improve the service,

Table 3. Intelligent vehicles references by authors and topic

Intelligent vehicles	
Topic	References
ACC/ISA	Jianqiang et al. (2010), Jung et al. (2009), Naus et al. (2010), Pauwelussen and Feenstra (2010), Zheng and McDonald (2005), Agusdinata, van der Pas, Walker, and Marchau (2009), Vlassenroot et al. (2007), Vlassenroot et al. (2010), K.L. Young et al. (2007), K.L. Young et al. (2010)
LDW	Bertozzi et al. (2002), Braitman et al. (2010), Cheng et al. (2006), Clanton et al. (2009), Glaser et al. (2010), Hsiao, Yeh, Huang, and Fu (2009), Jenkins et al. (2007), Suzuki and Jansson (2003), Wang et al. (2005)
PDS	Bertozzi et al. (2002), Broggi, Cerri, Ghidoni, Grisleri, and Jung (2009), Cao, Qiao, and Keane (2008), Ge, Luo, and Tei (2009), Pai et al. (2004), Trivedi et al. (2007)
Response and assistance in hazardous situations	Mitchell and Suen (1998), Hamza-Lup, Hua, and Peng (2007), Jagtman, Hale, and Heijer (2006), Kulmala (2010), Man Ho et al. (2010), Vashitz, Shinar, and Blum (2008), K.L. Young et al. (2008)
HMI	Baldwin (2002), Glaser et al. (2010), Ioannou and Stefanovic (2005), Lansdown (2000), Perez et al. (2010), Rajaonah et al. (2008), Stevens (2000), Maciej and Vollrath (2009), Trivedi et al. (2007)
Safety evaluation of ITS	Fries et al. (2007), Jenkins et al. (2007), Jung, Kwak, Shim, Yoon, and Kim (2008), Ma and Andreasson (2005), Pai et al. (2004), Spyropoulou, Penttinen, Karlaftis, Vaa, and Golias (2008), Young et al. (2008), Young et al. (2010), Zhang et al. (2009)
Public transport: bus operations	Albalate and Bel (2010), Brake, Mulley, Nelson, and Wright (2007), Brake and Nelson (2007), Cebollada (2009), Davison and Knowles (2006), Hounsell (2004)

including automatic vehicle location (AVL), a system of real-time monitoring of bus fleets, bus priority with AVL at traffic signals, urban traffic management and control systems with detectors, as well as enforcement measures (e.g. bus lane cameras, CCTV). Vanajakshi et al. (2009), for example propose data collection about real-time traffic conditions in order to calculate expected travel time and disseminate more accurate information to passengers waiting at bus stops, such as GPS data collected from bus-mounted cameras. They tested the proposed system in India and found promising results in terms of accuracy in the expected time of arrival. Earlier studies have done reviews on bus-mounted machine vision systems (Rabie et al., 2005). Regarding the UK, Davison and Knowles (2006) review the UK policy for bus operations through Bus Quality Partnerships. The problem of lacking co-operation and disjoint services is also addressed by Brake et al. (2007) and Brake and Nelson (2007), who stress the importance of adopting the appropriate technology by the partnerships, considering political, legal, geographical and communication restrictions.

Despite the ongoing research and development of embedded ITS for intelligent vehicles, manufacturing firms seem to follow their own strategies and the market is being flooded with separate systems and devices, quite often incompatible with each other or with the road infrastructure. They also give rise to the problem of information overloading and unnecessary warnings to the driver. Traditional business models consider the actions and strategies a company should follow to remain sustainable by creating value. In the case of ITS, however, especially with intelligent vehicles, our literature research has shown a plethora of systems and applications, many of which remain at the experimental level, or follow different trajectories in market penetration. This initiates the discussion of reconsidering traditional business models, putting ITS within the context of more connected applications, perhaps through common platform strategies for ITS firms. This topic is gaining momentum in the twenty-first century. There have already been examples of fully autonomous vehicles, such as the Google car (Brown, 2011; O'Rourke, 2010), car platooning, i.e. arrays of electronically connected vehicles that drive without human intervention for a particular part of the road (Clement & Taylor, 2006; Rajamani & Zhu, 2002) and cybercars (Awasthi, Chauhan, Parent, & Proth, 2011), centralized fleet management systems for passengers in public transport, amusement parks or shopping centres. The future of ITS lies within deeper integration of systems and services and new business models should move in this direction. However, the ITS literature, as this section showed, focused mainly on the technological aspects without much analysis on the business and economic and societal issues.

Economic and Business Studies on ITS

The only recent work on business models in ITS and transport we identified is the paper by Zografos, Androutsopoulos, and Sihvola (2008), which presents business models for flexible passenger transport services (FPTS). FPTS provide customized transport services to special groups of travellers (e.g. elderly or disabled), offering options on type of vehicle to use and online booking selection of routes. The authors present a methodology for ranking and selecting the most appropriate business model, based on specific criteria, such as legal and regulatory framework, market opportunities, business vision and business mission.

Most of the business-related studies on transport and ITS do not discuss business models, but they focus on ITS projects and their economic evaluations. Cost–benefit analysis (CBA) is the most popular methodology. At the international level, the most notable organization is the International Benefits, Evaluations and Costs (IBEC) WG (IBEC, 2012), a UK-based WG of ITS experts which collectively develop methods and techniques on evaluating ITS on a global scale. The IBEC group sponsors and participates in international discussions on ITS project evaluations, ITS world congresses, exchange of ideas with academics and practitioners, and provides training and knowledge on ITS across the world.

In terms of selected past studies in the academic literature, Odeck and Welde (2010) discuss the importance of assessing ITS projects, especially with CBA, and give the fully automatic Oslo toll collection system as an example, where traditional tollbooths are replaced by ETC and road users pay tolls by using on-board devices. The main goals of most ITS projects can be classified in four categories: safety, efficiency, energy and the environment and security. The costs of the project include components such as equipment, construction cost and operating cost, whereas the benefits include less travel time for road users, fewer emissions, less accident risk and better streetscape by removal of tollbooths. Naniopoulos, Bekiaris, and Panou (2004) use CBA to evaluate the results of the TRAVEL-GUIDE project, an EU project on providing guidance in the implementation of ITS by evaluating combinations of existing and emerging technologies, and also, estimating the users' willingness to pay for such systems. Melkert and Van Wee, 2009 use CBA for the 'Superbus', a conceptual high-speed vehicle for public transport running from Amsterdam to Groningen. One of the main challenges is the futuristic nature of the project, which makes the quantification of costs and benefits difficult. Leviakangas and Lahesmaa (2002) also highlight the deficiencies of CBA in evaluating and selecting ITS investments, mainly due to the fundamental differences between ITS and physical investments. They support multicriteria analysis (MCA), which takes into account more factors than CBA, such as experts' preferences and goal settings. MCA is also favoured by Tsamboulas (2007), especially for international transport projects, where reaching an agreement among different countries is usually more difficult.

Another study on ITS and transport involves the use of Leontief's Input–Output (I–O) table for studying the effects of ITS adoption on Michigan's economy (Farooq, Hardy, Gao, & Siddiqui, 2008). The results indicate positive effects for the local economy and suggest promotion of ITS to a national level. Studying the macroeconomic features of the US transport, Lahiri and Yao (2006) show the links between the business cycles of transport and the business cycles of the US economy to find evidence of recession in the transport sector, and how the recession in transport can be forecast by signs of upcoming recessions of the aggregate economy. As transport is one of the driving forces of the US economy, demand in transport usually is an indicator of the producers' expectation about future profits. In addition, transport can be easily affected by oil price shocks and austerity measures. As a result, recessions in transport are usually longer than the ones of the aggregate economy; they start earlier and end later. Regarding the UK recession, S. Lee (2010) examines how travel behaviour is affected and what opportunities might arise for sustainable transport, and calls for more sustainable and environment-friendly modes of transport. This is not new, the environmental side of ITS and transport has been studied in the past, but mostly from the perspective of congestion and its consequences (e.g. see Kanninen, 1996).

Despite their significant potential, the full benefits of ITS cannot be realized unless they can be provided in sustainable and scalable fashions. Most previous studies have so far focused on the technical opportunities and challenges. Although a few studies have addressed the issue of sustainability in the broad transport sector (Cohen, 2010; van den Bergh, van Leeuwen, Oosterhuis, Rietveld, & Verhoef, 2007), very few research exists on the financial sustainability of ITS. The business and the wider social issues have not been adequately investigated so far.

Making a Business Case for ITS

About Business Models

Most previous studies have failed to address the issues of sustainability and scalability for ITS, which call for the development of sustainable business models. Previous studies have identified a wide range of specific business models, both from the empirically based approach to develop taxonomy; and the theoretically inspired approach to develop business model typology (Baden-Fuller & Morgan, 2010; F. Li, 2007a). Business models define how a business works and the logic that creates its value (Afuah & Tucci, 2003; Rappa, 2011; Zott, Amit, & Massa, 2010). It provides the vital link between an organization's vision and strategy with its operations (F. Li, 2007b; van der Heijden, 1996). Business models have been studied from multiple perspectives via different approaches and used in a variety of different ways (Baden-Fuller & Morgan, 2010). On the one hand, business models can be regarded as representations of a class of organizations in the way similar to scale models or schemas that they can be presented, illustrated and manipulated. On the other hand, they can be regarded as ideal types that organizations should aspire to become, which can be used to guide strategic transformation in real organizations.

The notion of business models became prevalent in the mid-1990s, with the rapid development of the Internet (Zott, Amit, & Massa, 2011). The fast pace of developments of the Internet provides fertile soil for the birth and evolution of business models (Teece, 2010; Wirtz, Schilke, & Ullrich, 2010). Despite the increasing attention to business model theory and the vast number of publications, scholars have not agreed on a common definition for business model and the theory expansions have followed specific examples of firms or products (Zott et al., 2011). An example is the study of Koen, Bertels, and Elsum (2011), who speak of Intel Celeron processor to describe a low-cost business model and of Mercedes A-Class as a business model for the middle-class market. This lack of a common definition is partially due to the conceptual characteristics of business model concept, its intangible nature as a firm's blueprint for its actions and reactions in the market. Another reason is that business model is a new concept, with the vast majority of relevant literature published only in the last decade. The academic literature has provided a plethora of definitions, each one stemming from a different perspective. Some of them are as follows: 'articulation between different areas of a firm's activity' (Demil & Lecocq, 2010), the way a business 'articulates the logic and provides data' (Teece, 2010), 'an organization's approach to generating revenue at a reasonable cost' (Gambardella & McGahan, 2010) or the mechanism that 'explains how the important non-financial and financial variables in the performance measurement system are related to each other' (Huelsbeck, Merchant, & Sandino, 2011). Although diverse and derived from different points of view, most definitions include or refer to a common keyword: value.

Several authors describe business models in relation to value creation, capture and distribution (Gambardella & McGahan, 2010; McGrath, 2010; Teece, 2010; Zott et al., 2011), not only referring to value in financial turnovers for the firm, but also to the broader sense of value as a positive outcome that passes on to the customer base. Customer satisfaction, in other words, value for the customer, has been the ultimate target of value generation within a business model and the determining factor for its success (McGrath, 2010).

The concept of business model is also intertwined with innovation both in its Schumpeterian sense, as the process of combining technology with resources and producing products and services (Amit & Zott, 2001), and in the sense of business model innovation, i.e. creating innovative business models (Raphael Amit & Zott, 2012). A business model can be characterized not only as a transformational approach to change and innovation (Demil & Lecocq, 2010), but also an explanation why firms innovate differently in different environments (Koen et al., 2011). Although it is associated with modern technologies, it still touches upon the first-generation innovation models, i.e. technology push models, as described by Rothwell (1992): technology is still the driving force of innovation in ITS research and development. There have been significant advancements in primary research, engineering and manufacturing, but not enough in terms of marketing, the last step in completing successfully technology push models. It is the most crucial aspect of capitalizing on technological innovation at a firm level. According to

Chesbrough (2010), "a mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model" (p. 355).

Business models are essential for translating commercial opportunities into revenue-generating activities, but despite the apparent focus on commercial sustainability, any sustainable business models in ITS need to take into account the divergent nature and unique characteristics of the sector. In particular, the business models need to effectively address the tensions between creating commercial value and generating wide social and economic values and the fair distribution of the benefits amongst different stakeholders. Commercial value is often associated with technological innovation, but to translate such innovations into sustainable revenue streams and profit, sustainable and innovative business models are necessary (Raphael Amit & Zott, 2012; Pries & Guild, 2011).

A Business Model Framework for ITS

Our review highlighted that most previous studies are for specific applications or specific economic analysis by transport economics. So far, previous studies have failed to make a business case for ITS, either systematically for each of the key components or at the ITS domain level. ITS developments have been haphazard. The complexity of the market, the vested interests of key stakeholders and in addition, the growing austerity of national economies, set barriers to widespread implementation of ITS at national or international levels. It is hard to imagine a top-down approach towards making a holistic business case for ITS through some central coordination and strategic planning. Lack of funding and conflicting interests (e.g. government, transport authorities and unions) have focused on ITS discussions for policy issues, overlooking the business essential aspects. On the other hand, the majority of business models literature, as described above, seems inadequate to describe the value creation or capturing of ITS. Production processes are costly and soon render obsolete because of technological advancements. Hence, they force firms to introduce new ones, cancelling out value and profits that may have existed before.

Given the absence of adequate public spending and lack of systematic research on ITS, it is more realistic to expect not top-down, but bottom-up business case developments, driven by leading firms which have a true understanding of the innovative nature of ITS. To help make a business case, the first step is to articulate the key components and relationships of ITS business models, using a business model framework. The framework we propose is the one described by Amit and Zott (2012), which is about business model innovation. We researched literature on business models and for this research we selected the framework by Amit and Zott, which is based on an extensive review of previous studies. We use this framework to analyse ITS and make a business case for it. We also draw examples from ITS and transport to demonstrate the relevance and applicability of the business model framework.

The authors discuss on the importance of creating innovative business models, compared to introducing innovation in production process, and explain the superiority of the former as less time-consuming and more cost-effective. To illustrate this, their paper compares Apple and HTC and highlights the differences in outcomes by innovative business models and innovations in production processes: by adopting a more innovative business model that allowed the company to switch from hardware to customer relationships, Apple achieved a sharp increase in net income and share prices in the last 12 years. On the other hand, HTC followed a business model for innovative hardware devices and its share price remained almost stagnant for the same period. In other words, Apple is more dynamic, i.e. making profits by maintaining customer relationships and adapting to their needs, but HTC is following a more static approach and receives a smaller share of the market by investing in innovative smart phones and tablets. As the authors put it, drawing parallelism with the 'razors and blades' business model (selling cheap razors, but locking-in customers and selling them expensive blades), "HTC sells great razors, but no razor blades".

Amit and Zott (2012) identify three main elements for successful business model innovation, namely

- *Content*: it refers to the line of business the firm undertakes.
- *Structure*: it refers to the interoperability among the various business activities, how they are related, how they are executed and how they complement each other.
- *Governance*: it refers to the delegation of the line of business, the division of labour and who is in charge of each activity in general.

A big change in any of these elements, changes the business model itself. By changing the content, i.e. the line of business, a company may enter new markets or alter the products and services it already offers. One example of the automobile industry is Mercedes-Benz's plans on introducing a new vehicle, more compact and more economical, which will also enable the drivers to get connected to the Internet (Simonite, 2012). By this change in content, Mercedes-Benz is targeting the so-called, Generation Y, a group of younger drivers who are highly attached to smart phones and the social networking technologies. This way, the firm is changing (or supplementing) its traditional image of a manufacturer for drivers who want a vehicle relevant to their social status, to a manufacturer who also satisfies the younger generation of drivers, more interested in having a smart phone and stay connected with others always and everywhere.

Structure is about synchronizing several activities together. To use another example from the automobile industry we refer to General Motors's (GM) OnStar system, which offers driving assistance, integration with smart phones, communication and car diagnostics. OnStar has become an innovative system for on-road support (Barabba et al., 2002; Welch, 2011). Instead of receiving services from several contractors, an OnStar subscriber uses GM's subscription for route guidance, technical support, anti-theft tracking and blocking of the vehicle, live on-road communication and many other functions. By introducing this novel way of service providing and customer care, GM changed its business model and re-organized its network of partners by including various service providers, such as technical support crews, car insurance companies or even the police. It has also brought all the related activities under centralized control systems.

Finally, changes in governance might trigger changes in outsourcing or even the beginning of new collaborations with other partners. The Niches+ project is a good example of change of governance in transport (Niches+, 2012), similar to the consortium of magazine publishers described by Amit and Zott (2012). A consortium of European partners, such as Polis (European Cities and Regions

Networking for Innovative Transport Solutions), Eurocities (the network of major European cities), Newcastle University, Southampton University and others, ran the project aimed at promoting innovation for more efficient and sustainable urban transport (moving urban transport from its niches positions to some improved niches+ positions). It constitutes a good example of change in governance by bringing policy-makers together and deciding on adopting common innovative measures for urban transport. Four thematic areas were examined:

(a) Innovative concepts to enhance accessibility (e.g. public transport planning, neighbourhood accessibility planning, traveller information for people with disabilities).
(b) Concepts for efficient planning and use of infrastructure and interchanges (intermodal interchanges with cycling facilities, innovative bus systems, etc.).
(c) Traffic management centres (financing, mobile travel information, environmental pollution collection and management).
(d) Automated and space-efficient transport systems (rapid transits, electric vehicles, car sharing, etc.).

The project was funded by the EU 7th Framework Programme and finalized in April 2011 in London with guidelines for future implementation of the proposed innovative measures.

Discussions: Adapting the Business Model Framework to Future ITS

In the age of innovation, adopting an innovative business model is a vital ingredient for the sustainability of any firm. However, the crucial question remains: how could such a framework based on innovative business models be adapted to ITS?

The exact adaptation of the framework will depend on the very nature of each ITS firm. Nevertheless, regardless the firm's characteristics, one must consider the fundamental pillars of the model framework, content, structure and governance, as essential parts of the models foundations. Examples of how these three can be applied to ITS are as follows:

- *Content*: the content of many ITS firms is in a constant flux. With the current developments in new ITS applications about vehicular communications and more connected vehicles (Awasthi et al., 2011; Katsaros, Kernchen, Dianati, Rieck, & Zinoviou, 2011; Sotelo, van Lint, Nunes, Vlacic, & Chowdhury, 2012), the pillar of content of innovative business models becomes more important. New research sheds light on the prospects of vehicles as spaces offering the facilities to stay connected with peers and friends. Vehicles of the future are going to be something more than just private spaces, extensions of one's character that take them from A to B. According to a survey (Mai & Schlesinger, 2011), 'the new generation of drivers cherish social media and technology more than a car'. This new generation is already here and shall be the target of automotive manufacturers. Making vehicles more connected, or, 'putting more Internet in vehicles' is going to be a significant change in content for ITS firms and a central topic of our future research.
- *Structure*: it is about harmonically coordinating activities of ITS firms. Considering the future trends of ITS and the high possibility of taking intelligent

transport to the level of vehicular communication and connectivity, this calls for changes in the ITS firms' structure. Platform strategies for ITS is one example. The vision for the future is platform strategies for automotive and ITS services, which changes the focus from developing products to developing and distributing services, from building services on platforms to using a Platform-as-a-Service (Beimborn, Miletzki, & Wenzel, 2011; Rodero-Merino, Vaquero, Caron, Muresan, & Desprez, 2012) to induce technological innovations. The integration of ITS with online web-services could bring major changes in the car industry and to traffic management. It will also create new platforms for the existing services (e.g. insurance and rescue), by making the vehicles multitasking machines, just like mobile phones and personal computers are nowadays. This will create new innovative solutions and business opportunities. Such a vision can be achieved with virtually zero marginal cost, as the main technological components already exist (Briscoe, Sadedin, & De Wilde, 2011). This can also bring changes to the third main component, governance.

- *Governance*: with platform strategies and novel applications of ITS supplementing the existing services, or, creating new ones, change in governance of ITS firms will be inevitable. Who will be in charge of each activity shall be a major aspect in the years to come and will require closer collaboration among ITS stakeholders. It will also involve discussions on market shares and stakeholders' interactions, aspects that our future research is going to investigate.

Conclusions and Future Research

Intelligent transport is a fast growing discipline, spanning several domains, from design and engineering to technological innovation and social implications of transport. Business studies have so far neglected ITS, judging from the fact that the vast majority of publications are from a transport or engineering, rather than from a business perspective. The market of ITS has not taken off yet, despite the rapid technological innovations and developments and the significant potential benefits identified by previous research. This research discussed the underlying reasons for this market failure and then used the business model theory to help make a business case for the sustainable development of ITS. The procedure we followed in this paper was a systematic review of previous research, which identified and discussed the main streams of research, the most popular topics and the less-explored areas. By reviewing the most influential ITS developments, we provided a systematic view of the ITS evolution and highlighted the main areas where this evolution took place.

Although ITS is a broad area, and classifications of the key technologies are difficult, the systematic literature review identified two main areas of development: intelligent vehicles and intelligent transport. Hundreds of systems and devices exist and many prototypes are tested as well. New research is investigating vehicular communications and more automated systems, where the drivers' workload will be less and the vehicles would operate in the 'auto-pilot' mode. However, research in the business aspects of ITS has so far remained stagnant, with only recently gaining momentum and exploring the possibilities of connecting vehicles. The proposed business model framework can offer valuable help towards in this direction. Since breakthrough advances will probably occur through bottom-up research and development, the ITS industry will be faced with numerous problems of coordination. As Surowiecki (2004) suggests, problems of coordination need bottom-up approaches, it is about fitness, getting various stakeholders to work together in harmony without anyone telling them what to do.

Empirical research is necessary in order to gather primary data from businesses and social groups through surveys, case studies and simulations. Survey of users will provide first-hand information of the people's opinion on specific ITS and their perception of value by using them. This in turn can offer valuable knowledge to companies that operate in this field or wish to enter the ITS industry. Case studies of companies will help us to map the stakeholders and understand their investment decision-making processes. Simulations will allow us to perform experiments of hypothetical situations, explore systems of players or agents under controlled conditions and infer about their future behaviour in the real world.

Further research is required to explore the wider social, economic and business implications of ITS. The regulatory and policy environment will determine the distribution of costs and benefits amongst key stakeholders and ITS implementation. These issues must be investigated from the perspectives of multiple stakeholders.

Acknowledgements

We acknowledge the financial support by the Social Inclusion through the Digital Economy (SiDE) project at the Newcastle Digital Economy Hub, funded by Research Councils UK (RCUK) under its Digital Economy Research Programme. We also thank Prof Eric Sampson from Newcastle University for his help and advice on the selection of bibliography, the editor of Transport Reviews and three anonymous reviewers for their valuable comments.

References

Abdel-Aty, M., Pande, A., Lee, C., Gayah, V., & Santos, C.D. (2007). Crash risk assessment using intelligent transportation systems data and real-time intervention strategies to improve safety on freeways. *Journal of Intelligent Transportation Systems*, *11*(3), 107–120. doi: 10.1080/15472450701410395

Afuah, A., & Tucci, C.L. (2003). A model of the Internet as creative destroyer. *IEEE Transactions on Engineering Management*, *50*(4), 395–402. doi: 10.1109/tem.2003.819651

Agusdinata, D.B., van der Pas, J., Walker, W.E., & Marchau, V. (2009). Multi-criteria analysis for evaluating the impacts of intelligent speed adaptation. *Journal of Advanced Transportation*, *43*(4), 413–454.

Albalate, D., & Bel, G. (2009). What local policy makers should know about urban road charging: Lessons from worldwide experience. *Public Administration Review*, *69*(5), 962–975.

Albalate, D., & Bel, G. (2010). What shapes local public transport in Europe? Economics, mobility, institutions, and geography. *Transportation Research Part E*, *46*(5), 775–790.

Amditis, A., Bertolazzi, E., Bimpas, M., Biral, F., Bosetti, P., Da Lio, M., & Sjogren, A. (2010). A holistic approach to the integration of safety applications: The INSAFES subproject within the European Framework Programme 6 Integrating Project PReVENT. *IEEE Transactions on Intelligent Transportation Systems*, *11*(3), 554–566. doi: 10.1109/tits.2009.2036736

Amit, R., & Zott, C. (2001). Value creation in e-business. *Strategic Management Journal*, *22*(6–7), 493–520. doi: 10.1002/smj.187

Amit, R., & Zott, C. (2012). Creating value through business model innovation. *MIT Sloan Management Review*, *53*(3), 41–49.

Awasthi, A., Chauhan, S.S., Parent, M., & Proth, J.M. (2011). Centralized fleet management system for cybernetic transportation. *Expert Systems with Applications*, *38*(4), 3710–3717. doi: 10.1016/j.eswa.2010.09.029

Baden-Fuller, C., & Morgan, M.S. (2010). Business models as models. *Long Range Planning*, *43*(2–3), 156–171. doi: 10.1016/j.lrp.2010.02.005

Baldwin, C.L. (2002). Designing in-vehicle technologies for older drivers: Application of sensory-cognitive interaction theory. *Theoretical Issues in Ergonomics Science*, *3*(4), 307–329. doi: 10.1080/1463922021000009029

Barabba, V., Huber, C., Cooke, F., Pudar, N., Smith, J., & Paich, M. (2002). A multimethod approach for creating new business models: The General Motors OnStar Project. *Interfaces*, *32*(1), 20–34.

Barrero, F., Toral, S., Vargas, M., Cortes, F., & Milla, J.M. (2010). Internet in the development of future road-traffic control systems. *Internet Research*, *20*(2), 154–168. doi: 10.1108/10662241011032227

Beimborn, D., Miletzki, T., & Wenzel, S. (2011). Platform as a Service (PaaS). *Business & Information Systems Engineering*, *3*(6), 381–384. doi: 10.1007/s12599-011-0183-3

van den Bergh, J., van Leeuwen, E.S., Oosterhuis, F.H., Rietveld, P., & Verhoef, E.T. (2007). Social learning by doing in sustainable transport innovations: Ex-post analysis of common factors behind successes and failures. *Research Policy*, *36*(2), 247–259. doi: 10.1016/j.respol.2006.11.001

Bertozzi, M., Broggi, A., Cellario, M., Fascioli, A., Lombardi, P., & Porta, M. (2002). Artificial vision in road vehicles. *Proceedings of the IEEE*, *90*(7), 1258–1271. doi: 10.1109/jproc.2002.801444

Bertozzi, M., Broggi, A., & Fascioli, A. (2000). Vision-based intelligent vehicles: State of the art and perspectives. *Robotics and Autonomous Systems*, *32*(1), 1–16.

de Bok, M. (2009). Estimation and validation of a microscopic model for spatial economic effects of transport infrastructure. *Transportation Research Part A: Policy and Practice*, *43*(1), 44–59. doi: 10.1016/j.tra.2008.06.002

Brackstone, M., & McDonald, M. (2000). A comparison of EU and US progress in the development of longitudinal advanced vehicle control and safety systems (AVCSS). *Transport Reviews*, *20*(2), 173–190. doi: 10.1080/014416400295239

Braitman, K.A., McCartt, A.T., Zuby, D.S., & Singer, J. (2010). Volvo and infiniti drivers' experiences with select crash avoidance technologies. *Traffic Injury Prevention*, *11*(3), 270–278. doi: 10.1080/15389581003735600

Brake, J., Mulley, C., Nelson, J.D., & Wright, S. (2007). Key lessons learned from recent experience with flexible transport services. *Transport Policy*, *14*(6), 458–466. doi: 10.1016/j.tranpol.2007.09.001

Brake, J., & Nelson, J.D. (2007). A case study of flexible solutions to transport demand in a deregulated environment. *Journal of Transport Geography*, *15*(4), 262–273. doi: 10.1016/j.jtrangeo.2006.08.006

Briscoe, G., Sadedin, S., & De Wilde, P. (2011). Digital ecosystems: Ecosystem-oriented architectures. *Natural Computing*, *10*(3), 1143–1194.

Broggi, A., Cerri, P., Ghidoni, S., Grisleri, P., & Jung, H.G. (2009). A new approach to urban pedestrian detection for automatic braking. *IEEE Transactions on Intelligent Transportation Systems*, *10*(4), 594–605. doi: 10.1109/tits.2009.2032770

Brown, A.S. (2011). Google's autonomous car applies lessons learned from driverless races. *Mechanical Engineering*, *133*(2), 31.

Bureau, B., & Glachant, M. (2008). Distributional effects of road pricing: Assessment of nine scenarios for Paris. *Transportation Research Part A: Policy and Practice*, *42*(7), 994–1007.

Cao, X.B., Qiao, H., & Keane, J. (2008). A low-cost pedestrian-detection system with a single optical camera. *IEEE Transactions on Intelligent Transportation Systems*, *9*(1), 58–67. doi: 10.1109/tits.2007.909239

Catling, I. (Ed.). (1994). *Advanced technology for road transport: IVHS and ATT*. Boston, MA: Artech House, Inc.

Cebollada, A. (2009). Mobility and labour market exclusion in the Barcelona metropolitan region. *Journal of Transport Geography*, *17*(3), 226–233. doi: 10.1016/j.jtrangeo.2008.07.009

Chen, C.D., Fan, Y.W., & Farn, C.K. (2007). Predicting electronic toll collection service adoption: An integration of the technology acceptance model and the theory of planned behavior. *Transportation Research Part C: Emerging Technologies*, *15*, 300–311. doi: 10.1016/j.trc.2007.04.004

Cheng, H.Y., Jeng, B.S., Tseng, P.T., & Fan, K.C. (2006). Lane detection with moving vehicles in the traffic scenes. *IEEE Transactions on Intelligent Transportation Systems*, *7*(4), 571–582. doi: 10.1109/tits.2006.883940

Chesbrough, H. (2010). Business model innovation: Opportunities and barriers. *Long Range Planning*, *43*(2–3), 354–363. doi: 10.1016/j.lrp.2009.07.010

Clanton, J.M., Bevly, D.M., & Hodel, A.S. (2009). A low-cost solution for an integrated multisensor lane departure warning system. *IEEE Transactions on Intelligent Transportation Systems*, *10*(1), 47–59. doi: 10.1109/tits.2008.2011690

Clement, S., & Taylor, M. (2006). The simple platoon advancement model of ITS technologies applied to vehicle control at signalised intersections. *Journal of Advanced Transportation*, *40*(1), 1–21.

Cohen, M.J. (2010). Destination unknown: Pursuing sustainable mobility in the face of rival societal aspirations. *Research Policy, 39*(4), 459–470. doi: 10.1016/j.respol.2010.01.018

Davison, L.J., & Knowles, R.D. (2006). Bus quality partnerships, modal shift and traffic decongestion. *Journal of Transport Geography, 14*(3), 177–194. doi: 10.1016/j.jtrangeo.2005.06.008

De Borger, B., & Van Dender, K. (2003). Transport tax reform, commuting, and endogenous values of time. *Journal of Urban Economics*, *53*(3), 510–530. doi: 10.1016/s0094-1190(03)00024-x

Demil, B., & Lecocq, X. (2010). Business model evolution: In search of dynamic consistency. *Long Range Planning*, *43*(2–3), 227–246. doi: 10.1016/j.lrp.2010.02.004

Ding, J.W., Wang, C.F., Meng, F.H., & Wu, T.Y. (2010). Real-time vehicle route guidance using vehicle-to-vehicle communication. *IET Communications*, *4*(7), 870–883. doi: 10.1049/iet-com.2009.0163

Farooq, U., Hardy, J.L., Gao, L., & Siddiqui, M.A. (2008). Economic impact/forecast model of intelligent transportation systems in Michigan: An input output analysis. *Journal of Intelligent Transportation Systems*, *12*(2), 86–95. doi: 10.1080/15472450802023352

Fries, R., Chowdhury, M., & Ma, Y. (2007). Accelerated incident detection and verification: A benefit to cost analysis of traffic cameras. *Journal of Intelligent Transportation Systems*, *11*(4), 191–203. doi: 10.1080/15472450701653499

Gambardella, A., & McGahan, A.M. (2010). Business-model innovation: General purpose technologies and their implications for industry structure. *Long Range Planning*, *43*(2–3), 262–271. doi: 10.1016/j.lrp.2009.07.009

Garcia-Ortiz, A., Amin, S.M., & Wootton, J.R. (1995). Intelligent transportation systems—enabling technologies. *Mathematical and Computer Modelling*, *22*(4–7), 11–81.

Ge, J.F., Luo, Y.P., & Tei, G.M. (2009). Real-time pedestrian detection and tracking at nighttime for driver-assistance systems. *IEEE Transactions on Intelligent Transportation Systems*, *10*(2), 283–298. doi: 10.1109/tits.2009.2018961

Glaser, S., Mammar, S., & Sentouh, C. (2010). Integrated driver–vehicle-infrastructure road departure warning unit. *IEEE Transactions on Vehicular Technology*, *59*(6), 2757–2771. doi: 10.1109/tvt.2010.2049670

Guo, X., & Yang, H. (2010). Patero-improving congestion pricing and revenue refunding with multiple user classes. *Transportation Research Part B: Methodological*, *44*(8–9), 972–982.

Haghani, A., Hamedi, M., Sadabadi, K.F., Young, S., & Tarnoff, P. (2010). Data collection of freeway travel time ground truth with bluetooth sensors. *Transportation Research Record*, 2160, 60–68. doi: 10.3141/2160-07

Hamdouch, Y., Florian, M., Hearn, D.W., & Lawphongpanich, S. (2007). Congestion pricing for multimodal transportation systems. *Transportation Research Part B: Methodological*, *41*(3), 275–291.

Hamza-Lup, G.L., Hua, K.A., & Peng, R. (2007). Leveraging e-transportation in real-time traffic evacuation management. *Electronic Commerce Research and Applications*, *6*(4), 413–424. doi: 10.1016/j.elerap.2006.12.002

Han, D., & Yang, H. (2009). Congestion pricing in the absence of demand functions. *Transportation Research Part E: Logistics and Transportation Review*, *45*(1), 159–171.

van der Heijden, K. (1996). *Scenarios: The art of strategic conversation*. Chichester: John Wiley & Son.

Holguin-Veras, J., Cetin, M., & Xia, S. (2006). A comparative analysis of US toll policy. *Transportation Research Part A: Policy and Practice*, *40*(10), 852–871.

Hounsell, N.B. (2004). Keeping buses moving: Role of intelligent transport systems. *Proceedings of the Institution of Civil Engineers: Municipal Engineer*, *157*(1), 55–60.

Hounsell, N.B., Shrestha, B.P., Piao, J., & McDonald, M. (2009). Review of urban traffic management and the impacts of new vehicle technologies. *Intelligent Transport Systems, IET*, *3*(4), 419–428.

Hsiao, P.Y., Yeh, C.W., Huang, S.S., & Fu, L.C. (2009). A portable vision-based real-time lane departure warning system: Day and night. *IEEE Transactions on Vehicular Technology*, *58*(4), 2089–2094. doi: 10.1109/tvt.2008.2006618

Huelsbeck, D.P., Merchant, K.A., & Sandino, T. (2011). On testing business models. *Accounting Review*, *86*(5), 1631–1654. doi: 10.2308/accr-10096

IBEC. (2012). *International Benefits, Evaluation and Costs (IBEC) Working Group*. Retrieved June 10, 2012, from http://www.ibec-its.co.uk/

Ioannou, P.A., & Stefanovic, M. (2005). Evaluation of ACC vehicles in mixed traffic: Lane change effects and sensitivity analysis. *IEEE Transactions on Intelligent Transportation Systems*, *6*(1), 79–89. doi: 10.1109/tits.2005.844226

Jagtman, H.M., Hale, A.R., & Heijer, T. (2006). Ex ante assessment of safety issues of new technologies in transport. *Transportation Research Part A: Policy and Practice*, *40*(6), 459–474. doi: 10.1016/j.tra.2005.08.007

Jarasuniene, A., & Jakubauskas, G. (2007). Improvement of road safety using passive and active intelligent vehicle safety systems. *Transport*, *22*(4), 284–289.

Jenkins, D.P., Stanton, N.A., Walker, G.H., & Young, M.S. (2007). A new approach to designing lateral collision warning systems. *International Journal of Vehicle Design*, *45,* 379–396.

Jianqiang, W., Shengbo, L., Xiaoyu, H., & Keqiang, L. (2010). Driving simulation platform applied to develop driving assistance systems. *IET Intelligent Transport Systems*, *4*(2), 121–127. doi: 10.1049/iet-its.2009.0041

Jung, H.G., Kwak, B.M., Shim, J.S., Yoon, P.J., & Kim, J. (2008). Precrash dipping nose (PCDN) needs pedestrian recognition. *IEEE Transactions on Intelligent Transportation Systems*, *9*(4), 678–687. doi: 10.1109/tits.2008.2006789

Jung, H.G., Lee, Y.H., Kang, H.J., & Kim, J. (2009). Sensor fusion-based lane detection for LKS pluc ACC system. *International Journal of Automotive Technology*, *10*(2), 219–228. doi: 10.1007/s12239-009-0026-0

Kanninen, B.J. (1996). Intelligent transportation systems: An economic and environmental policy assessment. *Transportation Research Part A: Policy and Practice*, *30*(1), 1–10.

Kantowitz, B.H. (2000). In-vehicle information systems: Premises, promises, and pitfalls. *Transportation Human Factors*, *2*(4), 359.

Katsaros, K., Kernchen, R., Dianati, M., Rieck, D., & Zinoviou, C. (2011). Application of vehicular communications for improving the efficiency of traffic in urban areas. *Wireless Communications & Mobile Computing*, *11*(12), 1657–1667. doi: 10.1002/wcm.1233

Khayyam, H., Nahavandi, S., & Davis, S. (2012). Adaptive cruise control look-ahead system for energy management of vehicles. *Expert Systems with Applications*, *39*(3), 3874–3885. doi: 10.1016/j.eswa.2011.08.169

Koen, P.A., Bertels, H.M.J., & Elsum, I.R. (2011). The three faces of business model innovation: Challenges for establishing firms. *Research-Technology Management*, *54*(3), 52–59. doi: 10.5437/08953608x5403009

Kottenhoff, K., & Brundell Freij, K. (2009). The role of public transport for feasibility and acceptability of congestion charging—the case of Stockholm. *Transportation Research Part A: Policy and Practice*, *43*(3), 297–305.

Kulmala, R. (2010). Ex-ante assessment of the safety effects of intelligent transport systems. *Accident Analysis & Prevention*, *42*(4), 1359–1369. doi: :10.1016/j.aap.2010.03.001

Lahiri, K., & Yao, V.W. (2006). Economic indicators for the US transportation sector. *Transportation Research Part A: Policy and Practice*, *40*(10), 872–887. doi: 10.1016/j.tra.2006.02.006

Lansdown, T.C. (2000). Driver visual allocation and the introduction of intelligent transport systems. *Proceedings of the Institution of Mechanical Engineers—Part D—Journal of Automobile Engineering*, *214*(6), 645–652.

Larsson, A.F.L. (2012). Driver usage and understanding of adaptive cruise control. *Applied Ergonomics*, *43*(3), 501–506. doi: 10.1016/j.apergo.2011.08.005

Lee, J., Veloso, F.M., Hounshell, D.A., & Rubin, E.S. (2010). Forcing technological change: A case of automobile emissions control technology development in the US. *Technovation*, *30*(4), 249–264. doi: 10.1016/j.technovation.2009.12.003

Lee, R. (2009). Social capital and business and management: Setting a research agenda. *International Journal of Management Reviews*, *11*(3), 247–273.

Lee, S. (2010). Transport and the recession: An opportunity to promote sustainable transport. *International Planning Studies*, *15*(3), 213–226. doi: 10.1080/13563475.2010.509475

Lee, W.-H., Tseng, S.-S., & Shieh, W.-Y. (2010). Collaborative real-time traffic information generation and sharing framework for the intelligent transportation system. *Information Sciences*, *180*(1), 62–70. doi: 10.1016/j.ins.2009.09.004

Lee, W.H., Tseng, S.S., & Wang, C.H. (2008). Design and implementation of electronic toll collection system based on vehicle positioning system techniques. *Computer Communications*, *31*(12), 2925–2933. doi: 10.1016/j.comcom.2008.05.014

Leviakangas, P., & Lahesmaa, J. (2002). Profitability evaluation of intelligent transport system investments. *Journal of Transportation Engineering-ASCE*, *128*(3), 276–286. doi: 10.1061/(asce)0733-947x(2002)128:3(276)

Li, F. (2007a). What is e-business and does it still matter? *International Journal of Information Technology and Management*, *6*(2–4), 125–137.

Li, F. (2007b). *What is e-business? How the internet transforms organizations*. Oxford: Blackwell Publishing.

Li, X., Shu, W., Li, M.L., Huang, H.Y., Luo, P.E., & Wu, M.Y. (2009). Performance evaluation of vehicle-based mobile sensor networks for traffic monitoring. *IEEE Transactions on Vehicular Technology*, *58*(4), 1647–1653. doi: 10.1109/tvt.2008.2005775

Lu, J., Ye, F., Ding, J.P., & Xiang, Q.J. (2004). The impact of ETC systems on the safety performance of toll collection plazas, in: *Proceedings of the 4th International Conference on Traffic and Transportation Studies*, 235–241, Dalian, China.

Ma, X.L., & Andreasson, I. (2005). Predicting the effect of various ISA penetration grades on pedestrian safety by simulation. *Accident Analysis and Prevention*, *37*(6), 1162–1169. doi: 10.1016/j.aap.2005.06.017

Maciej, J., & Vollrath, M. (2009). Comparison of manual vs. speech-based interaction with in-vehicle information systems. *Accident Analysis & Prevention*, *41*(5), 924–930. doi: 10.1016/j.aap.2009.05.007

Mai, A., & Schlesinger, D. (2011). A Business case for connecting vehicles: Executive summary. *CISCO Point of View*. Retrieved from http://www.cisco.com/web/about/ac79/docs/mfg/Connected-Vehicles_Exec_Summary.pdf

Man Ho, K., Yong Tae, L., & Joonwoo, S. (2010). Age-related physical and emotional characteristics to safety warning sounds: Design guidelines for intelligent vehicles. *IEEE Transactions on Systems, Man & Cybernetics: Part C—Applications & Reviews*, *40*(5), 592–598. doi: 10.1109/tsmcc.2010.2041926

McGrath, R.G. (2010). Business models: A discovery driven approach. *Long Range Planning*, *43*(2–3), 247–261. doi: 10.1016/j.lrp.2009.07.005

Melkert, J., & Van Wee, B. (2009). Assessment of innovative transport concepts using cost-benefit analysis. *Transportation Planning and Technology*, *32*(6), 545–571. doi: 10.1080/03081060903374767

Milanes, V., Perez, J., Onieva, E., & Gonzalez, C. (2010). Controller for urban intersections based on wireless communications and fuzzy logic. *IEEE Transactions on Intelligent Transportation Systems*, *11*(1), 243–248. doi: 10.1109/tits.2009.2036595

Miles, J., & Chen, K. (Eds.). (2004). *The intelligent transport systems handbook* (2nd ed.). Swanley, UK: The World Road Association (PIARC).

Mitchell, C.G.B., & Suen, S.L. (1998). Urban travel, intelligent transportation systems, and the safety of elderly and disabled travelers. *Journal of Urban Technology*, *5*(1), 17–43.

Naniopoulos, A., Bekiaris, E., & Panou, M. (2004). Cost and benefits of information technology systems and their application in the infomobility services: The TRAVEL-GUIDE approach. *Economic Impacts of Intelligent Transport Systems: Innovations and Case Studies*, *8*, 463–480.

Naus, G.J.L., Vugts, R.P.A., Ploeg, J., van de Molengraft, M.J.G., & Steinbuch, M. (2010). String-stable CACC design and experimental validation: A frequency-domain approach. *IEEE Transactions on Vehicular Technology*, *59*(9), 4268–4279. doi: 10.1109/tvt.2010.2076320

Ni, D.H., Leonard, J.D., Guin, A., & Feng, C.X. (2005). Multiple imputation scheme for overcoming the missing values and variability issues in ITS data. *Journal of Transportation Engineering-ASCE*, *131*(12), 931–938. doi: 10.1061/(asce)0733-947x(2005)131:12(931)

Niches+. (2012). *Niches+ Project Website*. Retrieved June 25, 2012, from http://www.niches-transport.org/

Odeck, J., & Welde, M. (2010). Economic evaluation of intelligent transportation systems strategies: The case of the Oslo toll cordon. *IET Intelligent Transport Systems*, *4*(3), 221–228. doi: 10.1049/iet-its.2010.0027

Ogden, K.W. (2001). Privacy issues in electronic toll collection. *Transportation Research Part C: Emerging Technologies*, *9*(2), 123–134.

O'Rourke, M. (2010). My other ride is a robot. *Risk Management (00355593)*, *57*(10, 48).

Pai, C.J., Tyan, H.R., Liang, Y.M., Liao, H.Y.M., & Chen, S.W. (2004). Pedestrian detection and tracking at crossroads. *Pattern Recognition*, *37*(5), 1025–1034. doi: 10.1016/j.patcog.2003.10.005

Pande, A., & Abdel-Aty, A. (2005). Identification of rear-end crash patterns on instrumented freeways: A data mining approach, in: *Proceedings of the 2005 IEEE intelligent transportation systems conference (ITSC)*, 819–824, Vienna, Austria.

Pauwelussen, J., & Feenstra, P.J. (2010). Driver behavior analysis during ACC activation and deactivation in a real traffic environment. *IEEE Transactions on Intelligent Transportation Systems*, *11*(2), 329–338. doi: 10.1109/tits.2010.2043099

Perez, A., Garcia, M.I., Nieto, M., Pedraza, J.L., Rodriguez, S., & Zamorano, J. (2010). Argos: An advanced in-vehicle data recorder on a massively sensorized vehicle for car driver behavior experimentation. *IEEE Transactions on Intelligent Transportation Systems*, *11*(2), 463–473. doi: 10.1109/tits.2010.2046323

Piao, J., & McDonald, M. (2008). Advanced driver assistance systems from autonomous to cooperative approach. *Transport Reviews*, *28*(5), 659–684.

Pries, F., & Guild, P. (2011). Commercializing inventions resulting from university research: Analyzing the impact of technology characteristics on subsequent business models. *Technovation*, *31*(4), 151–160. doi: 10.1016/j.technovation.2010.05.002

Rabie, T., Abdulhai, B., Shalaby, A., & El-Rabbany, A. (2005). Mobile active-vision traffic surveillance system for urban networks. *Computer-Aided Civil and Infrastructure Engineering*, *20*(4), 231–241.

Rajamani, R., & Zhu, C. (2002). Semi-autonomous adaptive cruise control systems. *IEEE Transactions on Vehicular Technology*, *51*(5), 1186–1192. doi: 10.1109/tvt.2002.800617

Rajaonah, B., Tricot, N., Anceaux, F., & Millot, P. (2008). The role of intervening variables in driver-ACC cooperation. *International Journal of Human-Computer Studies*, *66*(3), 185–197. doi: 10.1016/j.ijhcs.2007.09.002

Rappa, M. (2011). *Business models on the web*. Retrieved from http://ecommerce.ncsu.edu/business_models.html

Rodero-Merino, L., Vaquero, L.M., Caron, E., Muresan, A., & Desprez, F. (2012). Building safe PaaS clouds: A survey on security in multitenant software platforms. *Computers & Security*, *31*(1), 96–108. doi: 10.1016/j.cose.2011.10.006

Rothwell, R. (1992). Successful industrial innovation—critical factors for the 1990s. *R & D Management*, *22*(3), 221–239. doi: 10.1111/j.1467-9310.1992.tb00812.x

Seii, S., Niwa, E., Mase, K., Nishibori, M., Inoue, J., Obuchi, M., & Kizu, M. (2009). Field evaluation of UHF radio propagation for an ITS safety system in an urban environment. *IEEE Communications Magazine*, *47*(11), 120–127.

Sengupta, R., Rezaei, S., Shladover, S.E., Cody, D., Dickey, S., & Krishnan, H. (2007). Cooperative collision warning systems: Concept definition and experimental implementation. *Journal of Intelligent Transportation Systems*, *11*(3), 143–155. doi: 10.1080/15472450701410452

Simonite, T. (2012, January). Mercedes announces plans to pursue Generation Y. *Business Impact—The Connected Vehicle* MIT, pp. 14–15.

Sisiopiku, V.P., & Elliott, J.R. (2005). Active warning systems: Synthesis. *Journal of Transportation Engineering-ASCE*, *131*(3), 205–210. doi: 10.1061/(asce)0733-947x(2005)131:3(205)

Sivaraman, S., & Trivedi, M.M. (2010). A general active-learning framework for on-road vehicle recognition and tracking. *IEEE Transactions on Intelligent Transportation Systems*, *11*(2), 267–276. doi: 10.1109/tits.2010.2040177

Smith, B., & Venkatanarayana, R. (2005). Realizing the promise of intelligent transportation systems (ITS) data archives. *Journal of Intelligent Transportation Systems*, *9*(4), 175–185.

Snaddon, D.R. (2001). Competition in transportation—a literature analysis. *Technovation*, *21*(6), 373–381.

Sotelo, M.A., van Lint, J.W.C., Nunes, U., Vlacic, L.B., & Chowdhury, M. (2012). Introduction to the special issue on emergent cooperative technologies in intelligent transportation systems. *IEEE Transactions on Intelligent Transportation Systems*, *13*(1), 1–5. doi: 10.1109/tits.2012.2184645

Spyropoulou, I., Penttinen, M., Karlaftis, M., Vaa, T., & Golias, J. (2008). ITS solutions and accident risks: Prospective and limitations. *Transport Reviews*, *28*(5), 549–572. doi: 10.1080/01441640801886605

Stevens, A. (2000). Safety of driver interaction with in-vehicle information systems. *Proceedings of the Institution of Mechanical Engineers—Part D—Journal of Automobile Engineering*, *214*(6), 639–644.

Surowiecki, J. (2004). *The wisdom of crowds*. London, UK: Abacus.

Suzuki, K., & Jansson, H. (2003). An analysis of driver's steering behaviour during auditory or haptic warnings for the designing of lane departure warning system. *JSAE Review*, *24*(1), 65–70.

Tapani, A. (2012). Vehicle trajectory effects of adaptive cruise control. *Journal of Intelligent Transportation Systems*, *16*(1), 36–44. doi: 10.1080/15472450.2012.639641

Teece, D.J. (2010). Business models, business strategy and innovation. *Long Range Planning*, *43*(2–3), 172–194. doi: 10.1016/j.lrp.2009.07.003

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, *14*(3), 207–222.

Trivedi, M.M., Gandhi, T., & McCall, J. (2007). Looking-in and looking-out of a vehicle: Computer-vision-based enhanced vehicle safety. *IEEE Transactions on Intelligent Transportation Systems*, *8*(1), 108–120. doi: 10.1109/tits.2006.889442

Trullols, O., Fiore, M., Casetti, C., Chiasserini, C.F., & Ordinas, J.M.B. (2010). Planning roadside infrastructure for information dissemination in intelligent transportation systems. *Computer Communications*, *33*(4), 432–442. doi: 10.1016/j.comcom.2009.11.021

Tsamboulas, D.A. (2007). A tool for prioritizing multinational transport infrastructure investments. *Transport Policy*, *14*(1), 11–26. doi: 10.1016/j.tranpol.2006.06.001

Tubaishat, M., Zhuang, P., Qi, Q., & Shang, Y. (2009). Wireless sensor networks in intelligent transportation systems. *Wireless Communications & Mobile Computing*, *9*(3), 287–302. doi: 10.1002/wcm.616

Vanajakshi, L., Subramanian, S.C., & Sivanandan, R. (2009). Travel time prediction under heterogeneous traffic conditions using global positioning system data from buses. *IET Intelligent Transport Systems*, *3*(1), 1–9. doi: 10.1049/iet-its:20080013

Vashitz, G., Shinar, D., & Blum, Y. (2008). In-vehicle information systems to improve traffic safety in road tunnels. *Transportation Research Part F: Traffic Psychology and Behaviour*, *11*(1), 61–74. doi: 10.1016/j.trf.2007.07.001

Velaga, N.R., Quddus, M.A., & Bristow, A.L. (2009). Developing an enhanced weight-based topological map-matching algorithm for intelligent transport systems. *Transportation Research Part C: Emerging Technologies*, *17*(6), 672–683. doi: 10.1016/j.trc.2009.05.008

Velastin, S.A., Boghossian, B.A., Lo, B.P.L., Sun, J., & Vicencio-Silva, M.A. (2005). PRISMATICA: Toward ambient intelligence in public transport environments. *IEEE Transactions on Systems Man and Cybernetics Part A—Systems and Humans*, *35*(1), 164–182. doi: 10.1109/tsmca.2004.838461

Venigalla, M., & Ali, A. (2005). Deriving performance measures for transportation planning using ITS archived data. *Civil Engineering and Environmental Systems*, *22*(3), 171–188. doi: 10.1080/10286600500279998

VICS. (2012). *Vehicle Information and Communication Systems Website*. Retrieved June 15, 2012, from http://www.vics.or.jp/english/vics/index.html

Vlassenroot, S., Broekx, S., De Mol, J., Panis, L.I., Brijs, T., & Wets, G. (2007). Driving with intelligent speed adaptation: Final results of the Belgian ISA-trial. *Transportation Research Part A: Policy and Practice*, *41*(3), 267–279. doi: 10.1016/j.tra.2006.05.009

Vlassenroot, S., Brookhuis, K., Marchau, V., & Witlox, F. (2010). Towards defining a unified concept for the acceptability of intelligent transport systems (ITS): A conceptual analysis based on the case of intelligent speed adaptation (ISA). *Transportation Research Part F: Traffic Psychology and Behaviour*, *13*(3), 164–178. doi: 10.1016/j.trf.2010.02.001

Wang, J., Schroedl, S., Mezger, K., Ortloff, R., Joos, A., & Passegger, T. (2005). Lane keeping based on location technology. *IEEE Transactions on Intelligent Transportation Systems*, *6*(3), 351–356. doi: 10.1109/tits.2005.853701

Wang, X.B. (2007). Modeling the process of information relay through inter-vehicle communication. *Transportation Research Part B: Methodological*, *41*(6), 684–700. doi: 10.1016/j.trb.2006.11.002

Welch, D. (2011). OnStar wants to turn your car into a smartphone. *Bloomberg Businessweek*, (4220), 19–20.

Wiese, E.E., & Lee, J.D. (2007). Attention grounding: A new approach to in-vehicle information system implementation. *Theoretical Issues in Ergonomics Science*, *8*(3), 255–276. doi: 10.1080/14639220601129269

Wirtz, B.W., Schilke, O., & Ullrich, S. (2010). Strategic development of business models implications of the Web 2.0 for creating value on the Internet. *Long Range Planning*, *43*(2–3), 272–290. doi: 10.1016/j.lrp.2010.01.005

Wootton, J.R., Garcia-Ortiz, A., & Amin, S.M. (1995). Intelligent transportation systems—a global perspective. *Mathematical and Computer Modelling*, *22*(4–7), 259–268.

Wu, S.G., Decker, S., Chang, P., Camus, T., & Eledath, J. (2009). Collision sensing by stereo vision and radar sensor fusion. *IEEE Transactions on Intelligent Transportation Systems*, *10*(4), 606–614. doi: 10.1109/tits.2009.2032769

Yongchang, M.A., Yan, Z., Chowdhury, M., Kuang-Ching, W., & Fries, R.N. (2009). A framework for performance evaluation of communication alternatives for intelligent transportation systems. *Journal of Intelligent Transportation Systems*, *13*(3), 111–126. doi: 10.1080/15472450903084212

Young, K.L., Regan, M.A., Triggs, T.J., Jontof-Hutter, K., & Newstead, S. (2010). Intelligent speed adaptation-effects and acceptance by young inexperienced drivers. *Accident Analysis and Prevention*, *42*(3), 935–943. doi: 10.1016/j.aap.2009.10.013

Young, K.L., Regan, M.A., Triggs, T.J., Stephan, K., Mitsopoulos-Rubens, E., & Tomasevic, N. (2008). Field operational test of a seatbelt reminder system: Effects on driver behaviour and acceptance. *Transportation Research: Part F*, *11*(6), 434–444. doi: 10.1016/j.trf.2008.04.004

Young, K.L., Regan, M.A., Triggs, T.J., Tomasevic, N., Stephan, K., & Mitsopoulos, E. (2007). Impact on car driving performance of a following distance warning system: Findings from the Australian transport accident commission SafeCar Project. *Journal of Intelligent Transportation Systems*, *11*(3), 121–131. doi: 10.1080/15472450701410411

Zhang, J., Suto, K., & Fujiwara, A. (2009). Effects of in-vehicle warning information on drivers' decelerating and accelerating behaviors near an arch-shaped intersection. *Accident Analysis & Prevention*, *41*(5), 948–958. doi: 10.1016/j.aap.2009.05.010

Zheng, P.J., & McDonald, M. (2005). Manual vs. adaptive cruise control—can driver's expectation be matched? *Transportation Research Part C: Emerging Technologies*, *13*(5–6), 421–431. doi: 10.1016/j.trc.2005.05.001

Zhu, H.Z., Li, M.L., Zhu, Y.M., & Ni, L.M. (2009). HERO: Online real-time vehicle tracking. *IEEE Transactions on Parallel and Distributed Systems*, *20*(5), 740–752. doi: 10.1109/tpds.2008.147

Zografos, K.G., Androutsopoulos, K.N., & Sihvola, T. (2008). A methodological approach for developing and assessing business models for flexible transport systems. *Transportation*, *35*(6), 777–795. doi: 10.1007/s11116-008-9176-6

Zott, C., Amit, R., & Massa, L. (2010). *The business model: Theoretical roots, recent developments, and future research*. Retrieved from http://www.iese.edu/research/pdfs/DI-0862-E.pdf

Zott, C., Amit, R., & Massa, L. (2011). The business model: Recent developments and future research. *Journal of Management*, *37*(4), 1019–1042. doi: 10.1177/0149206311406265