FUTURISTIC INTELLIGENT TRANSPORTATION SYSTEM ARCHITECTURE FOR SUSTAINABLE ROAD TRANSPORTATION IN DEVELOPING COUNTRIES

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ABSTRACT

Sustainable road transportation has become a challenge particularly in the developing countries. Literature suggests that the ability of the transport system to respond to the mobility needs of people and goods is hampered by a continuous increase in traffic demand as a result of higher levels of urbanization, population growth, changes in population density and motorization. These factors result in traffic crashes, traffic congestion and consequent increase in travel times, fuel consumption and carbon emissions, which reduce the efficiency of mobility systems and make it unsustainable. Certain measures such as traffic control and management, congestion warning, road conditions warning, route guidance and use of eco- friendly and green vehicles are being considered to meet the challenges. Arguments have emerged that Intelligent Transportation Systems (ITS) are important to meet these challenges of achieving virtually traffic crash-free, clean and efficient mobility. This requires the development of an integrated communication architecture that provides a common frame for the road and traffic infrastructure, environment and vehicle systems to work together through Information Communication Technology (ICT) system. Therefore, this investigation explored the various ITS that are relevant to road transportation in the context of developing countries; examined the perception of road users on the use of ITS and its impacts on travel behavior; and developed a conceptual futuristic communication ITS architecture by integrating land use, road, traffic, human and environmental parameters with ICT for sustainable road transportation in developing countries. The study was conducted based on critical review of relevant literature and industrial innovations to examine the ITS system(s) applicable to developing countries. A survey was conducted in two cities of a developing country, India, to observe the perception of people, particularly road users on the use of ITS and its impacts on their travel. This was followed by development of a conceptual ITS architecture by integrating land use, activity, traffic, road infrastructure, vehicle, ICT, road user variable and indicators related to sustainable road transportation. Findings suggest that appropriate ITS with the use of ICT, can provide acceptable effective real time information regarding the road and traffic conditions, which will enable the road users in their journey planning, to avoid unwarranted incidents and moreover enhance safe and efficient mobility in the roads of developing countries.

Keywords: Intelligent Transportation System; Information Communication System, Traffic congestion, Traffic accidents; Efficient mobility

1. INTRODUCTION

The transportation sector is facing many challenges such high crash rates, traffic congestion, pollution emissions, etc. As a result, sustainable road transportation has become a challenge particularly in the urban areas of developing countries. Traffic control and management, congestion warning, intersection collision warning, road conditions warning, and route guidance are some of the measures, which are available and in some countries have been implemented to avoid traffic congestion and traffic crashes on the roads. Eco- friendly and green vehicles are also developed to make the mobility system environmentally sustainable. However, arguments have emerged that Intelligent Transportation Systems (ITS) are important to meet these challenges of achieving virtually crash-free, clean and efficient mobility. This requires development of an integrated communication architecture that provides a common frame for the road and traffic infrastructure, environment and vehicle systems to work together with the aid of Information Communication Technology (ICT) system. However, it is found that most of the research in mobility issues are directed towards implication and development of physical infrastructure or application of ITS and ICT to solve transportation problems, particularly during travel.

ITS assists in route choice; dynamic route selection, and scheduling of freight vehicles in congested urban areas using real-time traffic information systems, and operation of traffic control systems, and enable road users to receive the real time information about the incidents such as traffic accidents or congestion level through dynamic road signs or through mobile instruments like cell phones (through short message service (sms) warnings) or even through the GPS warning system. However, availability of dynamic and real time information through ITS is only available in some advanced courtiers across Europe, Asia, North America and even in developing countries such as South Africa (www.i-traffic.co.za; www.trafficsa.net). The challenge of availability of such real time information and dynamic to the road users and drivers in many developing countries such as India and South Asian nations remains same. Particularly in the Indian context while the current ITS system has the ability to provide certain information regarding the navigation and route information, it does not integrate land use and activities of the area, road parameters and traffic related parameters, and does not offer the road user to receive dynamic real time information while travelling on the road through dynamic road signs or through the mobile devices. So, there is a need for creating new and advanced systems and technologies that could alleviate these mobility related challenges currently being faced in India. However, it is also essential to find out the acceptability of the new and advanced systems and technologies as well as conceptualize a futuristic ITS architecture, which would enable creation of new and advanced systems and technologies. Therefore, the objectives of this investigation are (1) to explore the various ITS that are relevant to road transportation system in the context of developing countries such as India; (2) to examine the perception of road users on the use of ITS and its impacts on travel behavior; and (3) to develop a conceptual futuristic communication ITS architecture by integrating land use, road, traffic, human and environmental parameters with ICT for sustainable road transportation in developing countries. The study was conducted based on critical review of relevant literature and industrial innovations to examine the relevant ITS system(s) applicable to developing countries. The investigation was conducted by using a survey research method and case study of an urban region consisting of two cities of a developing country, India, to observe the perception of people particularly road users on the use of ITS and its impacts on their travel. Besides, a conceptual futuristic ITS architecture was developed with the integration land use, activity, road infrastructure, traffic, ICT, vehicles and road users and of by using algorithms sustainable road transportation related indicators. Findings suggest that appropriate ITS with the use of ICT can provide acceptable and effective real time information regarding the road and traffic conditions, which will enable all types of road users even without advanced GPS system and sophisticated cell phones in their journey planning, to avoid unwarranted incidents and moreover enhance safe and efficient mobility in the roads of developing countries.

2. UNDERSTANDING ITS FOR ROAD SUSTAINABLE TRANSPORTATION

Sustainable road transportation is found to be an integral part of sustainable development as large scale transportation and vehicular activities are increasingly contributing to the economic, mobility, living conditions and environmental challenges of regions or cities (Haghshenas, Vaziri, Gholamialam 2015; Schipper, Deakin, & McAndrews, 2009). So, it is argued that urban areas/ regions require safe, fast, energy-efficient and low carbon emission transportation system in order to contribute to the sustainability of cities or regions (Rockwood, Garmire 2015). The concept of sustainable road transportation has been adopted globally. Indicators of road transportation sustainability have been identified and discussed, policies and plans have been formulated and actions have been taken. However, according to scholars there is no single indicator that would define sustainable road transportation. Many international organizations such as (EU, Eurostat, EEA, UN and WHO) argue that indicators should be the representatives of selected geographical or political area (Dobranskyte-Niskota, Perujo and Pregl, 2007; Litman, Burwell, 2006). Accordingly, a set of indicators have been proposed and developed based on economic, social, and environmental attributes (Emberger, Pfaffenbichler, Jaensirisak, & Timms, 2008; Haghshenas, Vaziri, Gholamialam 2015; Li, Liu, Hu, Wang, & Yang, 2009; Litman, 2007; May et al., 2005; Zhao, 2009). Consequently, the various important indicators to measure sustainable road transportation envisaged include fossil fuel consumption and CO2 emissions, vehicle pollution emissions, per capita motor vehicle mileage, traffic crash injuries and deaths, transport land consumption, roadway aesthetic conditions (EC, 2005; Litman, Burwell, 2006; Sietchiping Permezel, Ngomsi, 2012; Thynell, Mohan, Tiwari 2010). However, it is also implicit that in a city urban activities, land use and road transportation system are complementary to each other. So, the concept of sustainable road transportation in an urban area is governed by different indicators which include among others; accessibility to- and quality of public transportation, level of congestion, level of carbon emissions and polluting matters, road utilization, facilities for pedestrian movement, traffic crashes, etc. (Haghshenas, Vaziri, Gholamialam 2015; Zhao, 2009). Thus, based on these indicators some scholars have advocated that the sustainable road transport policy should tackle rising levels of congestion, noise and pollution, encourage use of more environmentally-friendly modes of transport, use of higher public transportation, reduction of traffic crashes and use of Information Communication Technologies (ICT) to reduce travel needs (Dobranskyte-Niskota, Perujo and Pregl, 2007; Emuze and Das, 2015; Haghshenas, Vaziri, Gholamialam 2015; Zhao, 2009).

In this regard, arguments have emerged that effective use of ITS in road and vehicular traffic management can bring change in travel pattern and travel behaviour, consequently can reduce the need for travel, reduce congestion, traffic crashes, travel time, delay, travel cost; enhance traffic management system and improve movement manoeuvrability, which ultimately enable attainment of innovative and sustainable transportation in regions/cities (Belella et al., 2009; Emuze and Das, 2015; Fugate et al, 2009; Huschebect et al., 2009; Monni & Raes, 2008; Schipper, Deakin, & McAndrews, 2009; Sietchiping et al., 2012).

Concerted efforts have been made to meet the mobility challenges in the cities over the years. ITS remains at the core to alleviate mobility challenges and enhance travelling. It offers variety of technological solutions, but not limited to the advanced traveller information systems, advanced vehicle control systems, advanced traffic management systems, advanced rural transportation systems, advanced public transportation systems, intelligent collision warning, integrating application program interfaces (APIs) and Comprehensive Modal Emission Model (CMEM) as plug in to assess emissions, and enabling connected vehicles (Adler and Blue, 1998; Hameri and Paatela, 2005; Ng and Barfield, 1995; Olia, Abdelgawad, Abdulhai, and Razavi, 2016; Olia, Abdulhai, Abdeljawad, & Razavi, 2014; Orcan & Radoslav, 2015; Toral, Vargas, and Barrero, 2009a). As a result, road safety, reduction in congestion and increase in road capacities have been experienced.

However, Goldman and Gorham (2006) argued that ITS cannot alone solve the problems of transportation; and might exacerbate certain costs, particularly related to the environment (Goldman and Gorham, 2006) Besides, evidences from a number of empirical studies suggest that travellers make their travel decisions and route choices depending upon numerous criteria that include real time information, travel cost, travel time and its reliability, traffic safety, track comfort, roadway characteristics, utility, information supply, driver’s experience and habit, cognitive limits, socio-economic and demographic characteristics, and other behavioural considerations (Adler and Blue, 1998; Chen and Ting, 2007; Jackson, 1994; Kanninen, 1996; Martínez-Torres, Díaz-Fernández, Toral, & Barrero, 2013; Ng and Barfield,1995; Yang, 1998; Yang and Meng, 2001). But the most important criterion has been the minimisation of travel time, which rests on the traffic assignment and in effect on the traffic volume (Chen, Chang, and Tzeng, 2001; Martínez-Torres, Díaz-Fernández, Toral, & Barrero, 2013; Toral, Vargas, and Barrero, 2009a; Wardrop, 1952). Table 1 presents the various functions and services by the ITS. Some of the important functions being performed by ITS are but not limited to public transportation operation, travel management, travel demand management, emergency management, commercial vehicle management, advanced vehicle control and safety, electronics payment system and manage archive data.

Table 1 Functions and services of ITS

Functions of ITS	Services
Public transportation services	a) Public transportation management b) Information during travel
Commercial vehicle management	a) Customs clearance b) Incidence response of dangerous goods c) Freight d) Efficient Fleet management d) Security
Travel management	a) Traffic surveillance b) Route Guidance c) Rail road level crossing d) Incident Management e) Speed warnings
Travel demand management	a) Information before travel b) Pre-booking
Emergency management	a) Emergency vehicles b) Disaster response and evacuation c) Law enforcement allocation d)Emergency service allocation
Electronic payment services	a) Electronic toll payment b) Electronic parking payment c) Electronic fare collection
Advanced vehicle control and safety	a) Side collision and back collision prevention b) Security c) Automatic highway system
Integrating application program interfaces (APIs) and Comprehensive Modal Emission Model (CMEM)	a) Assess mobility, b) assess safety measures c) Assess emissions
Environmental impact	Reduce negative environmental impact
Manage archived data	

Source: (Adler and Blue, 1998; Hameri and Paatela, 2005; Ng and Barfield, 1995; Olia, Abdelgawad, Abdulhai, and Razavi, 2016; Olia, Abdulhai, Abdeljawad, & Razavi, 2014; Toral, Vargas, and Barrero, 2009a)

However, in recent times the major objective of ITS delineated to improve road safety, reduce traffic congestion, improve transportation and energy efficiency, reduce air pollution, and improve productivity.

2.1 Development of ITS

The first wave started in nineteen sixties with the development of Electronic Route Guidance System (ERGS) in United States, a system which consists of special hardware located at different road intersections, 2-way devices in vehicles to communicate between the system and the driver and a central computer system that processes the information. ERGS provide route information to the drivers based on real time traffic. ERGS paved way to the interactive digital map system called ARCS (Automatic Route Control System) (Smith, 2000). Initial stage models were primarily empirical and static. Theories were developed based on either ideal assumptions, or very limited experimental and survey data. These have helped to plan, construct, and operate the early transportation systems. Researchers and engineers during this period were motivated to study the detailed characteristics of the new transportation systems (Weiner, 2009). The Japanese Comprehensive Automobile Traffic Control (CACS) program and AutofahrerLeit and Information System (ALI) program of Germany were developed during the same period. This was followed by AMTICS and RACS projects that paved way for high tech traffic in Japan (Tokuyama, 1996).

The second wave was triggered with the development of Intelligent Vehicle Highway System (IVHS) that led to developments in ITS. PROMETHUS and DRIVE were the project undertaken by Europe during this period (Anand, Ramadurai, and Vanajakshi, 2010) .Travel demand was growing immensely during this period. The existing infrastructure was not enough to meet the travel needs. These issues were tackled to an extent by using the dynamic information of road conditions and traveller demand. Different strategies were planned to balance transportation supply and demand (Meyer, & Miller, 2001). Researchers were able to collect, analyse, model, and predict transportation methodologies more efficiently, and accurately than before using the advances in information technology. The models developed during this period were dynamic, statistical, and disaggregated models. Rigorous formulations and efficient numerical methods were used for development of these models. The current wave is driven by rapidly growing wireless communication technologies. Real time collection of data and connectivity between driver, vehicle and infrastructure are achieved. The real time capability has helped in easy coordination of vehicles. In spite of all these developments, natural flow characteristics still remain unchanged. Fully automated systems may be developed in future. Next wave may be triggered by technologies such as connected vehicles (Olia, Abdelgawad, Abdulhai, and Razavi, 2016), self regulatory traffic condition based route guidance (He, Zheng, Guan, and Mao, 2016). Internet of Things (Barjis, Bendavid, and Wamba, 2010), cloud computing (Armbrust, Fox, Griffith, Joseph, Katz, Konwinski, Lee, Patterson, Rabkin, Stoica, & Zaharia, 2009) and distributed computing (Attiya, & Welch, 2004). Future generation models are expected to be highly reliable, integrated and explore customized solutions to travel demand based on the characteristics of new data flow by data mining over the massive amount of data.

2.2 Classification of ITS

ITS system can be classified into five types. They are:

2.2.1 Advanced Traffic Management System (ATMS)

ATMS collects data on traffic conditions, transmits it to a single coherent interface and then formulates decisions by combining the real time data. Information is transmitted to drivers and concerned departments, for more efficient planning and operations. Ramp metering, speed control, freeway operations management systems, incident management, electronic toll collection are the results of this system (Meyer, & Miller, 2001).

2.2.2 Advanced Traveller Information System (ATIS)

ATIS provides travel related information to road users as the reference of choosing transportation modes, travel trips and routes. The system mainly includes dynamic road message signs, GPS, the internet connection, telephone, fax, information Kiosk and mobile etc (Meyer, & Miller, 2001).

2.2.3 Advanced Vehicle Control and Safety System (AVCSS)

AVCSS enhance driver's control of vehicles in order to reduce accidents and improve traffic safety. The AVCSS mainly includes vehicle collision warning and control, driving assistance, use of AI systems that can control internal operations, long-run plans of automatic driving. (Meyer, & Miller, 2001).

2.2.4 Advanced Public Transportation Management System (APTMS)

APTS applies the technology of ATMS, ATIS and AVCSS in public transit systems order to improve the quality of service, and increase efficiency and to improve safety. The system mainly includes real time passenger information systems, automatic vehicle location systems, VPS, computer scheduling and E –tickets (Meyer, & Miller, 2001).

2.2.5 Commercial Vehicle Operation (CVO)

CVO applies the technology of ATMS, ATIS and AVCSS. It consists of a satellite navigation system, computer and a digital radio. It's used for constant monitoring of operations in commercial vehicles such as trucks, buses, taxes and ambulances for better efficiency and safety (Meyer, & Miller, 2001).

2.3 Research gaps and future proposals

Requirements for futuristic models can emerge earlier when the limitations of the current models are identified; which led to the study of generating new models. As the technologies advanced, practical requirements started increasing. In the later years, technological side started to be in demand; as a result the modeling side slowed down. Practical demand saw varying changes in different generations (Ran, Jin, Boyce, Qiu & Cheng, 2012). The first generation models explored ways to obtain knowledge and methodologies to control the system. Data collection was done at scattered intervals and had poor communication facilities from infrastructure to the vehicles. Data collected was limited. Similarities between transportation systems and other physical or economic systems were studied. As the technology moved on to the second generation, detection grids were fixed on the road intersections to collect information. This generation saw the emergence of regional traffic management centers (TMCs) which could analyze real time data and provide guidance to the road user. Mismatches between the observations and theories suggested from the empirical models created during the first generations were discussed. Projects were undertaken to analyse the technologies used in ITS. ADVANCE project (Boyce. 2002) was such an attempt.

The current generation has seen advanced technologies in ITS. Bidirectional communication between vehicles and infrastucture and even among vehicles using the connected vehicle technologies have become possible. Real time information are processed in a more efficient manner. Understanding of the relationship between the entities in the transportation system has become more clear and precise than the previous models. Despite the advances, the real time informtion regarding the incidents on the roads through road infrastructure instruments such as dynamic road signs and information through mobile apparatuses available with the road user is not yet available, particularly in many developing countries such as India. So, in order to enable the availability of real time and dynamic information to the road users needs a system that would take the congnigence of various road infrastructure, activities in the area (locality), information and communication facilities, traffic, vehicles, and road user attributes. This needs integration of land use functions, physical road infrastructure, information, traffic, vehicles, road user such as driver, and ICT system.

Futuristic models consider data, communication, techniques/methodologies and technology as the major elements of ITS.Users are expected to receive more precise information. As an automated system is being proposed for future, cloud computing technology (where TMC becomes a node in the cloud) and distributed structures will be used. An efficient and dense detection grid can be obtained when full penetration is achieved over the prevailing system. Individual needs of the users will be fulfiiled which will result in active participation in the optimization and feedback of the system. As each component of the system has been studied intensively during the past few generations, this provides a motivation for the future models.

Model validation and verification still remains crucial . Examples of benchmark data sets include the NGSIM data set (FHWA, 2012) for research on traffic flow theory and the transportation testing problem data sets (Bar-Gera2011) for network modeling. Data sets are not easily available for traffic flow, traffic diversion, user reaction for routes etc. Models can't be applied without validating them. Efficient methods of collecting traffic data still needs to be proposed. The time to validate a model needs to be significantly reduced. Challenges that prevails for the future models may be filtering the data to fit the model, proposing efficient algorithms for caliberation and intepretation of the models.

However, in this investigation the scope of the work is limited to exploring the acceptability of new and advanced ITS by road users and developing a conceptual futuristic system architecture by integrating understanding the land use functions, physical road infrastructure information, traffic, vehicles, road user such as driver, and ICT system that would be relevant to developing countries such as India.

3. METHODS

Relevant literature review, survey and discussion with the stakeholders were conducted to investigate the availability of ITS suitable for road transportation system, to explore the perception of people towards ITS in road transportation that influences travel pattern and travel behaviour and also to develop a conceptual futuristic ITS architecture framework. Literature review was conducted from published literature available. For this purpose journal articles from different sources such as Science direct and Scopus were searched and reviewed, followed by reviewing of reports documents from different industries and projects relating to research in ITS.

A survey research method (road user perception survey) was used to collect data from the road users. A region comprising of two cities in India, such as Cuttack and Bhubaneswar (Cuttack- Bhubaneswar twin city region) was used as the case study for the purpose of the survey. The Cuttack-Bhubaneswar region is located in the Eastern parts of India. Cuttack and Bhubaneswar are two different cities located at about 21 kms apart and joined by National Highway (NH) 5. The sphere of influence of each city influences the other. The city roads and the NH5 joining the two cities are observed to be carrying heavy traffic during the major periods of the day particularly from 6.00 o'clock in morning up to 12.00 o'clock in night for about 18.00 hours. The NH5 carries a significant volume of heavy vehicles that include freight trucks and passenger buses in addition to cars and motor bikes. Both cities have experienced incorporation of a significant level of ICT. Although, the presence of ITS in road transportation is not considerable, yet efforts are being recently made to incorporate ITS in both cities.

The survey was conducted among the road users in both cities proportionately by employing a structured questionnaire through semi structured interviews. A sample size of 227 was administered of which 188 samples (0.83%) were found to be relevant and used for further analysis.

A perception index (PI) by using weighted average index method was developed to assess the perception people for the likely influence of ICT and ITS on transportation and travel aspects of people, which is presented in equation 1 (Eq.1).

$PI = \sum Ni*xi/N$…………………………………….. (Eq.1)

Where: Ni = Number of respondents assigned an index value between 0 and 1.
xi= Index value assigned by the respondents (between 0 and 1)
N = total sample size.

Besides, descriptive statistics, percentage analysis and regression analysis (significance tests) were conducted establish the relationship between use of ICT, ITS and road transportation variables.

4. RESULTS AND DISCUSSION

4.1 Relationship ICT and ITS use and travel characteristics

Table 2 depicts the current scenario and likely scenario in future and perception of people with regards to ICT, ITS and road transportation related variables in the study area. It is revealed that in the current scenario about 57% of the road users use ICT and more than two thirds of road users (69%) are willing to accept new and advanced ITS technology. However the use of ICT (23%), use of current ITS (18%) and adoption of new and advanced ITS technology (15%) in travel are very meagre. Similarly, currently, use of ICT to change in travel decision before the journey (34%), use of ITS to change travel decision before the journey (27%), use of ITS to change travel decision during the journey (19%), use of ITS to change travel behaviour during the journey (19%) and use of ITS to change travel pattern (17%) by road users are very meagre. These findings indicate that although a significant number of road users use ICT and are willing to adopt ITS, currently only a limited number of road users use and adopt these technologies in their travel needs, travel related decision making, and changes in travel pattern and travel behaviour. In other words, at the current state the use of these technologies related to travel is limited. Besides, in the current scenario, only about one third of respondents believe that ITS assists in reducing congestion, accidents and travel time.

However, in contrast the perception of road users with regard to use of ICT and ITS in future is different. It is found that majority (84%) of the road users would like to use ICT in general out of which 59% of the road users are willing use it for taking transportation related decisions. Similarly, more than 75% of the road users are willing to accept and adopt new and advanced ITS technology in future, although about two third (67%) of the road users will not have using the ITS at its current state Besides, about 60% of the road user would like to use ITS to change their travel decisions before and during the journey, and travel behaviour during the journey. However, only about 40% road users would like to change their travel pattern based on ITS use in future even if advanced ITS is available. Furthermore, more than 50% believe that use of ITS will reduce congestion and about 60% perceive that ITS will able to reduce crashes and travel time in future.

Thus, it implies that according to a significant segment of road users, ICT and ITS will have a big role to play in the road transportation in future. A large segment of road users would like to change their change their travel decisions before and during the journey and change their travel behaviour. Concurrently, a large segment of the road users perceive that ITS will able to reduce traffic congestion, travel time and traffic crashes. However, the impact of ICT and ITS despite the availability of advanced systems on travel pattern may remain limited.

Further, the analysis of PI shows that according to road users both ICT and ITS are expected to experience significant success in road transportation. While people would like to accept and adopt the current ITS technologies (PI= 0.75), they perceive to accept (PI= 0.84) and adopt (PI=0.78) new and advanced ITS technologies more in road transportation. The high perception indices of use of ITS with respect to relevant travel variables indicate that ITS is likely to influence considerably in change of travel decisions before (PI=0.72) and during the journey (PI=0.69), and change in travel behaviour during the journey (0.66). However, ITS may not able to influence largely to change travel pattern (PI=0.47). It is also indicated that the use of ITS in road transportation is likely to succeed in reducing congestions (PI=0.82), accidents (PI=0.68) and travel time (PI=0.73).

Table 2 Current scenario and likely scenario in future and perception of people with regards to ICT, ITS and road transportation related variables

Parameters	(%) of people		Perception index for likely success	Standard Deviation (SD)
	Current scenario	Likely scenario in future		
Use of ICT	57	84	0.78	0.17
Use of ICT in transportation related decisions	23	59	0.72	0.13
Use of current ITS in travel	18	67	0.75	0.13
Acceptance of new and advanced ITS Technology	69	77	0.84	0.18
Adoption of new and advanced ITS technology	15	76	0.76	0.16
Use of ICT and change in travel decision before the journey	34	56	0.77	0.18
Use of ITS change in travel decision before the journey	27	57	0.72	0.12
Use of ITS and change of travel decision during the journey	19	62	0.69	0.12
Use of ITS and change of travel behaviour during the journey	19	63	0.66	0.11
Use of ITS and change in travel pattern	17	43	0.47	0.14
Role of ITS in reduction of congestion	28	53	0.82	0.18
Role of reduction in accidents	31	61	0.68	0.11
Role of reduction in travel time	33	59	0.73	0.14

(Source: Road user survey 2015)

The significance test results are presented in Table 3. Significance test (t test) was conducted to establish the relationship between current ITS use and advanced ITS use and various travel road transportation (travel) characteristics of road users. It is revealed that with p (both one tailed and two tailed) values less than 0.05 for $\alpha \leq 0.05$, the relationship between current ITS use and acceptance and adoption of new and advanced ITS use; travel decisions before journey, travel decisions during the journey and travel behaviour during the journey under both current and advanced ITS system are significant. However, the relationship between the ITS use (with both current and advanced technology) and travel pattern is statistically insignificant ($p> 0.05$ for $\alpha \leq 0.05$). Thus, it indicates that road users are willing to accept and adopt new and advanced its technology in their transportation needs although they also would like to continue to accept and adopt the current ITS technology. Besides, while ITS under both current and advanced technology will able to influence and change the travel decisions before and during the journey and change travel behaviours during the journey based on the real time information available to the road users, it would not significantly impact the travel pattern of the road users.

Table 3 Relationship among ITS use and road transportation variables (Significance test results)

Transportation variables	t- Test results (T index values and p values at α≤0.05), *1 tailed and ** 2 tailed	
	Use of Current ITS technology	Use of advanced ITS technology
Acceptance and adoption of ITS	(15.005)	(20.63)
	0.00000019*	0.00000002*
	0.00000038**	0.00000004**
Travel decisions before journey	(9.19)	(23.4)
	0.0000079*	0.00000001*
	0.0000158**	0.00000001**
Travel decisions during the journey	(5.83)	(17.83)
	0.00019*	0.00000005*
	0.00039**	0.00000010**
Travel behaviour during the journey	(7.19)	(19.87)
	0.000047*	0.00000002*
	0.000094**	0.00000004**
Travel pattern	(1.73)	(1.79)
	0.061*	0.056*
	0.122**	0.112**

Note: Numbers in brackets indicate T index values

Thus, as travel decisions and travel behaviour of road users are expected to be influenced by ITS, there is a need for augmenting the current ITS in road transportation and development of possible new and advanced ITS to attain sustainable road transportation. Therefore, a futuristic communication ITS architecture by integrating land use, road, traffic, human and environmental parameters is envisaged in order to attain sustainable road transportation.

4.2 Futuristic communication ITS architecture by integrating land use, road, traffic, human and environmental parameters

The prevailing ITS system facilitates the delivery of a wide range of services such as safety, mobility and productivity. Nowadays, everyone travel using a GPS (Global Positioning System).This system has proved to be very useful and efficient in today's world. It helps in easy navigation and directs the driver until he/she reaches his/her destination. Its attractive feature is that it is cost efficient and it covers the entire planet. However, GPS does not cover the major issues like congestion control. It does not have information on the real time conditions and incidents that occur on the road. Measures should be taken to ensure that these services are provided in the road.

Figure 1 depicts a futuristic ITS system architecture proposed for developing countries like India. It is an ITS system architecture which is based on the integration of the human, physical (land use, activity and road related parameters), environmental parameters, ICT and ITS elements to attain sustainable road transportation. Human, land use and physical road and environmental parameters play important roles in this system. People are pivotal to the system in terms of as road users and also as transmitters of dynamic real time information through web based social media or sms. Land use and activities at different places on the road sides influence the characteristics of traffic. The speed of traffic, level of congestion, and other traffic incidents are dependent on the type of land use and the functions that are carried at different periods of the day. The road characteristics also play an integral role in deciding the traffic scenarios. In addition to this, environmental parameters such as weather conditions, slippery roads, availability of smog influence the traffic movement and road incidents. So people, land use, activities, road and environmental parameters become integral to the development of an ITS architecture. These parameters are integrated to the ICT and ITS infrastructure in this particular system architecture. From the ICT and ITS infrastructure point of view the proposed system contains motion sensors, radar guns, interactive LED light boards on the road sides, availability of ICT connectivity and cell phones with the road user. The system is envisaged to provide dynamic information to the road users in two ways- (1) displays through LED light boards located on the road sides, which will assist all the road users irrespective of having mobile ICT devices like GPS or cell phones and (2) information through web social media and / or cell phones, which required ICT connectivity and availability mobile devices such as smart phones or tablets with the road users.

The information transfer on the road incidents and vehicular and traffic parameter information will be collected and transmitted through motion sensors, radar guns and IR sensors. Motion sensor is an electronic device that contains infrared or microwave detector and a transmitter for illumination. It detects moving objects. Motion sensors fixed on either side of the road at 200-300m before the dangerous spot/curve detects the moving car. When the vehicle passes through a dangerous curve or a crash prone area, the motion sensors detect the vehicles and send Wi-Fi signals/SMS to the LED screen placed 100-200m before the curve. The radar gun is used to measure the speed of the moving vehicles. Radar gun is a Doppler radar unit which can be fixed on the roads. It consists of radio transmitter and receiver. The frequency of reflected radio waves is different from the transmitted waves. From that difference, speed of the vehicle will be calculated and sent to the microcontroller. If the speed of the vehicle is beyond the speed limit then Wi-Fi signals will be sent to the LED screen placed before the speed limit region. The screen will flash the speed limit to warn the user that he is driving beyond the speed limit. Thus, in both cases the road user without having a GPS system or ICT connected mobile device can be warned of the dangerous scenarios which can reduce the chances of occurrences of road incidents.

Besides, the architecture of the advanced ITS system envisaged that infra red (IR) sensors to be placed on roads at 5-10m apart particularly in congested roads. If the road is congestion free, the signals will be lost when for a small span the vehicles pass, but will reoccur after the car passed. On the other hand if the road is congested, the cars block the sensors and the signals of the sensors will be lost until the cars keep blocking the sensors. However, the signals will be seen when the road becomes congestion free. A motion sensor is envisaged to be placed 1km behind these sensors. When a vehicle passes them, they will send signals to the LED screen placed on the road sides, which would warn the user of the level of congestion. For example when the road is relatively free signals will be lost and reoccur intermittently, but when it is highly congested, the LED board will not display any signals. This would help the road user to have information about the congestion on the roads.

Moreover, an Android application can be installed on the driver's cell phone. The interconnectivity of the android system and the sensors on the roads would enable sending of sms to the cell phones of road users including the drivers through ICT connectivity regarding the potholes, traffic calming measures and other road environment such as slippery road conditions. For example, when the driver is expected to encounter potholes on the roads ahead, the application will be launched and GPS coordinates of that location will be reported. Motion sensors fixed before that location would send signals to the driver through sms in his/ her cell phone, and to the LED screen on the road sides which would display the potholes warning to the driver.

Furthermore, the connectivity of android application system and motion sensors will also send warnings (sms) about the real time traffic congestion levels and incidents like occurrence of crashes or road blocks on the routes ahead of the road user so that the road user can take alternate decisions or change his travel behaviour during the journey. Besides, this system would collect the location of the users from mobile devices such as cell phones and tablets with GPS activated. From this information, speed on the roads can be derived by use of applications such as Google traffic. Also, the road incidents like congestions, crashes and condition of roads can be reported in the web based social media by the road users that can be made available to the users in general. Consequently the other drivers and toad can be notified about the real time traffic and road scenario in a dynamic way. This could be a cost effective method which can be very helpful for the developing countries and is envisaged to would assist in attaining sustainable transportation in terms of reduced congestion, crashes and travel time and other road and traffic related incidents.

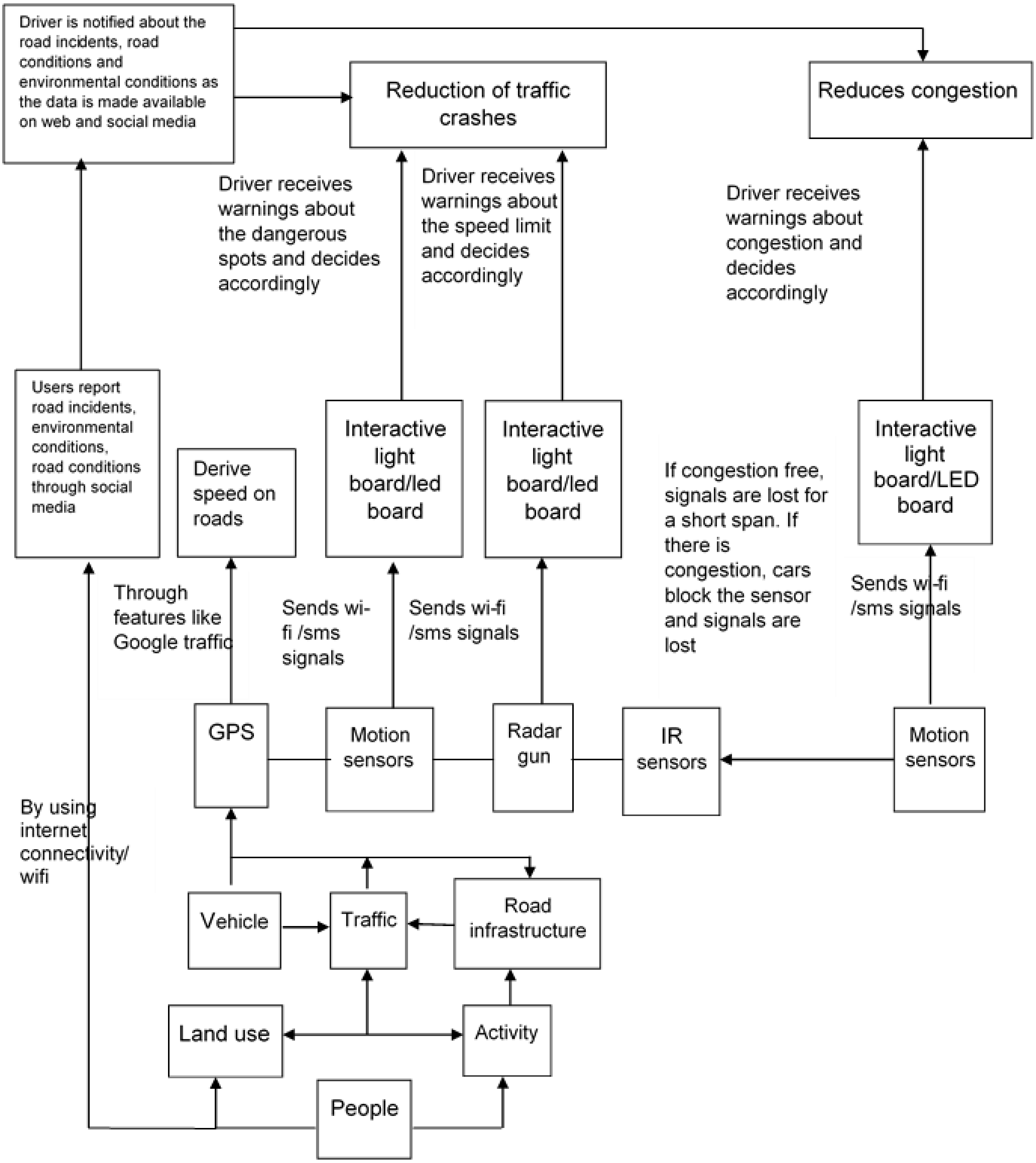

Figure 1 Futuristic ITS architecture for sustainable road transportation in developing countries.

5. CONCLUSION

The aim of the investigation was to explore the various ITS that are relevant to road transportation system in the context of developing countries; to examine the perception of road users on the use of ITS and its impacts on travel behavior; and the develop a conceptual futuristic communication ITS architecture by integrating land use, road, traffic, human and environmental parameters with ICT for sustainable road transportation in developing countries such as India. To realise the aim critical review of relevant literature and a survey research method was used. A case study was conducted by considering an urban region consisting of two cities in India where heavy vehicular traffic is experienced on their roads. It is found that a number of ITS is available and they perform numerous important road transportation functions and offer services that include but not limited to public transportation operation, travel management, travel demand management, emergency management, commercial vehicle management, advanced vehicle control and safety, electronics payment system and manage archive data. However, in developing countries like India it does not integrate land use and activities of the area, road parameters and traffic related parameters and also does not allow the road user to receive dynamic information while travelling on the road through dynamic road signs or through the mobile devices. So, a new and advanced systems and technologies are essential, which could able to meet the mobility related challenges currently being faced. Findings also suggest that the current level of use of ICT and ITS on the road transportation by road users like in their travel decisions and travel behaviour is very limited. However, majority of roads users are willing to accept and adopt advanced ITS technologies and use it before and during their travel. Road users also perceive that although currently the ITS system does not able to assist in reducing congestion, traffic crashes and travel time, yet in future advanced ITS technologies would enable alleviation of such road transportation related challenges significantly. However, the advanced ITS technology like the current ITS technology may not able to influence the travel pattern of people.

The investigation also proposed a futuristic ITS (system) architecture by integrating land use, activity, road and environmental parameters, ICT, and road users together so that by the help of radar guns, motion censors and android applications, dynamic information about the road condition and environment, traffic scenarios like congestions, incidents on roads like crashes and road blocks and warning about exceeding speed limits can be provided to road users through road traffic signs (such as LED boards) and sms to the cell phones. Besides, it will also made the information available with the road users so that they can transmit the information through use of web based social media or sms. This ITS technology is envisaged to work for all types of road users with or without advanced mobile devices such as android cell phone or tablets, and vehicles without GPS system. This system will be beneficial to developing nations particularly countries such as India where everybody can not afford to have a GPS, advanced system installed in their vehicles or mobile device. But advanced systems can be installed on the roads as envisaged in the system so that road users can access information through cost effective means such as LED information boards on the road sides, sms in their conventional cell phones or even through web based social media. It is envisaged that as the road user receives real time information, he would take appropriate and alternate decisions before and during the journey, change his travel behaviour, which would enable reduction of traffic congestions, crashes and travel time that in turn would assist in attaining sustainable road transportation in developing countries.

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