Broadband Applications for Digitally Based Public Transportation in the Smart City

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Innevitably, cities are becoming more interconnected and dependent on smart wireless computer systems and networks. In this paper, Evandro Santos discusses broadband applications in generating Big Data, and the role of technology and communication in the efficiency of urban functions and services. He argues that digital and mobile technologies are making the connections between transportation service providers and users tighter, faster, and more personal to greater collective and individual benefits.

Emerging issues and future challenges in the field of transportation planning unveil new possibilities for smart transportation through Broadband Wireless Internet Access in Public Transportation technologies for personal and mobile devices. Broadband infrastructure plays a fundamental role in modernizing transportation systems by making them safer, cleaner and more efficient. Furthermore, smart devices and innovative applications have fundamentally improved the use of broadband for transportation planning and operation purposes.

Through broadband deployment and the use of Intelligent Transportation Systems (ITS), it is possible to collect, streamline and integrate data from multiple sources. Such technologies provide an advanced planning tool for smart city governance – providing cities with creative solutions for daily tasks and emerging challenges dealing with public transportation, infrastructure efficiency, and environmental sustainability.

This paper reviews broadband applications to generate Big Data from the built environment, aiming to explore the role of technology and communication in finding more practical and efficient ways to improve essential urban functions and daily services such as mobility, public transportation, and infrastructure. This research has direct implications to enhance innovation and economic growth, urban and regional development, global competitiveness, and quality of life.

Introduction

The world has become increasingly urban. According to the United Nations (2014), 54 percent of the world's population lives in urban areas, a proportion that is expected to increase to 66 percent by 2050. In America, the vast majority of the national population is urban with an 80.7% urbanization rate, according to the United States Census Bureau (2010), with the majority of the population residing in metropolitan areas – characterized by large central cities and suburban areas. Throughout these areas, issues of poverty and technology challenges prevail.

Information and Communication Technology (ICT) has evolved quickly bringing to life new horizons and possibilities to a vast array of human needs from health care to innovations and challenges in urban management. Technology and communication have fundamental roles in finding more practical and efficient ways to improve urban quality of life, essential urban functions, and daily services such as mobility, public transportation, and infrastructure.

Big Data and the Internet of Things are the technology backbone for transportation planning and infrastructure management in the smart city context and the catalyst for a better, more efficient and sustainable public transportation.

> "*Like railroads and highways, broadband accelerates the velocity of commerce, reducing the costs of distance. Like electricity, it creates a platform for America's creativity to lead in developing better ways to solve old problems. Like telephony and broadcasting, it expands our ability to communicate, inform and entertain. Broadband is the great infrastructure challenge of the early 21st. century. But as with electricity and telephony, ubiquitous connections are means, not ends.* ***It is what those connections enable that matters.***"
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> *Federal Communications Commission – U.S. National Broadband Plan, 2010.*

This paper addresses theories, methods and tools in E-Planning (an essential part of E-Government or digital government); principles and concepts in Urban Planning, Transportation Planning and Urban Design; and ICT developments, especially the Internet. It is worth noting that technology evolves at a fast pace, and what is a breakthrough technology today, perhaps will be the foundation of ground-breaking technology tomorrow, in a continuous and most probably endless process.

Silva (2010) notes that broadband and mobile communication technology lead to a new transportation planning paradigm. They must be seen as more than a simple transfer from analogic to digital for daily routine transportation information and data, requiring the re-structuring of steps and re-engineering of procedures, development of full ICT integration, and changes in the nature and purpose of transportation planning.

Speed and reliability for communication purposes only can happen with connections established over a high-bandwidth broadband infrastructure network, enabling information to be utilized in the most efficient and effective ways. Broadband is the communication and data technology required for Geographic Information Systems (GIS), virtual reality, real-time monitoring, wireless networks, Big Data collection and management, and related applications as Intelligent Transportation Systems (ITS).

Fast broadband and wireless connections enable the use of sensors in vehicles and the human connections for "crowd-sourcing" information that can be applied to make service requests, report issues, and respond to crime, traffic jams, severe weather, and other urban and transportation related problems. According to US Telecom Broadband Association (2017), the broadband industry plays a vital role in the U.S. economy as a key resource which:

- Facilitates employment;
- Drives innovation;
- Provides a virtually unlimited forum for information exchange;
- Serves as a critical platform for consumer well-being and international competitiveness, among other direct benefits.

Smart cities are utilizing multi-sourced information flows as Big Data to improve services and develop indicators to evaluate the socioeconomic and environmental health of entire communities such as public transportation reliability, quality and efficiency as important test beds for physical improvements, social innovation and economic growth, further exploring the issues of density, diversity, innovation and inequalities set out in the National Broadband Plan. The deployment of broadband infrastructure in low population density areas, demographically diverse regions, within different state and local communications policies are examples of important barriers to overcome, resulting in more competition, better innovation policies and less inequalities, such as the 'digital divide', an economic and social inequality with regard to access to, use of, or impact of information and communication technologies (ICT).

Thanks to broadband availability and dissemination, and the Web 2.0 platform for user-generated content, usability, and interoperability, software applications can be applied elsewhere worldwide with urban neighborhoods as the locus for community organization and political participation. That's the way of using technology to foster civic engagement, social development and economic growth based on transportation, mobility and environment protection.

US Cities and National Broadband Plan

The Federal Communications Commission, an independent agency of the United States Government, has the mission to "make available so far as possible, to all the people of the United States, without discrimination on the basis of race, color, religion, national origin, or sex, rapid, efficient, Nationwide, and world-wide wire and radio communication services with adequate facilities at reasonable charges." On March 17th, 2010, FCC released the Connecting America: The United States National Broadband Plan with a goal of universal broadband access and creating a more productive, creative, efficient America in which affordable broadband is available everywhere, and everyone has the means and skills to use valuable broadband applications.

According to Mossberger (2013), cities were eligible to apply for infrastructure and other grants to assist 'underserved areas' with a broadband adoption of 40% or less. Urban areas are of pivotal importance for a national broadband policy due to their density and diversity characteristics leading to positive impacts on economic development, productivity growth, innovation opportunities and social gains. Cities, in general, have experienced direct benefits in a series of political areas such as health and education, energy, environment, safety, and transportation, among others, thanks to the advanced support of high-speed networks, especially true for densely populated cities and metropolitan areas, where the benefits for technology use are highest.

Segregation and concentrated poverty increase the digital divide in America as a gap between demographics and regions that have access to modern information and communications technology, and those that don't or have restricted access.

Although other factors play a role as obstacles to overcome for the Connecting America Plan, such as the general English language literacy, computer competence, disposable time and income, and a value on access to information as prerequisites to a reasonable utilization of the Internet.

Urban transportation and economic growth, among several other political areas, can directly benefit from investments in broadband – especially in places with limited or no connectivity. According to Qiang (2009), United States, Britain, Canada, Germany, Portugal and Finland have all included measures to expand broadband access and to bolster connection speeds in their planned economic stimulus packages. Australia, France, Ireland, Japan, Singapore and the Republic of Korea have announced separate broadband plans.

The need for an urban broadband policy is due not only because much of the national population resides in urban areas, but because of the concentration of infrastructure and technology innovation in places where government services, civic engagement and community organizing seem to be more expressive, or where technology inequalities limit the ability of local governments to realize potential cost savings, service improvements, and online communication with citizens.

Broadband initiatives Worldwide

Worldwide initiatives provide the context of what different societies are doing and how these initiatives impact different places. According to Philbeck (2016), there is a significant amount of investment allocated for broadband access throughout the world, and even so, there are still 1.5 billion individuals -urban and rural populations-- currently without access to basic broadband mostly in regions such as Asia & Pacific, Africa, The Americas, and Arab States, with required investments in an order of US$ 450 Billion, representing not only a great social development potential but also an impact on the economy mainly due to the relationship between broadband and economic growth.

Despite the amount, place and pace of investments, a certainty remains that the world is going inexorably to broadband infrastructure deployment. Just 10% increase in broadband penetration is likely to have a positive impact and could raise economic growth by between 0.25% and 1.4%. If broadband speed is doubled, GDP may increase, potentially by up to 0.3%, as demonstrated by Philbeck (2016, p. 3). Recognizing the importance of this issue, during the January 2016 Davos World Economic Forum, the UN Broadband Commission hosted a special session to facilitate alignment and collaboration among established initiatives, foster joint investments, promote partnership, and maximize the impact of the various efforts to extend the benefits of connectivity worldwide.

Smart transportation applications

Broadband and advanced communications infrastructure play an important role in modernizing various transportation systems by making them safer, cleaner and more efficient. Broadband can also encourage the use of alternatives to automobile transportation. Route-planning applications make public transportation easier to use, and in-vehicle broadband can make mass transit more attractive. Furthermore, Geographic Information System (GIS), and Global Positioning System (GPS) based applications have been created, developed, improved and applied to streamline data collection and processing for urban mobility purposes, namely for public transportation modes with a direct contribution on urban mobility parameters.

The ITS, which adds information technology to the transportation infrastructure, is the technology tool to benefit the most from worldwide broadband dissemination with developments on components of intelligent infrastructure such as transit management, freeway management, crash prevention and safety, traveller information, emergency management, intermodal freight, among several others. For the purpose of this paper, three ITS applications will be highlighted: Real-Time Monitoring, Information Management, and Instant Mapping, as features to allow portability, accuracy, and intercommunication for different devices from different technology platforms.

Advanced Metering Infrastructure (AMI) technologies is an integrated system of smart meters, communication networks, and data management systems that enable a two-way communication between utilities and customers/devices (gadgets) and users, requiring large bandwidth, and reliable dedicated speed to accomplish their tasks successfully and in a timely manner.

ITS applications together with AMI technologies can provide cities, government agencies and research institutes, as well as firms and data companies, among others involved with urban mobility, transportation data and communication, with a large amount of data from several and different networked sources, according to Santos (2012). Available intelligent transportation infrastructure as shown in Figure 1 are tools for city management through ICT and can support smart city initiatives for social, economic and environmental sustainability aims.

Big Data & Internet of Things

Big Data is a United States White House's priority directing government and the nation to improve society's technological capabilities by using vast and rich data resources. For urban transportation purposes, Big Data represents the next-level technologic tool for gathering information precisely, when and where it is needed the most.

Big Data is being used for a vast array of needs, from monitoring extreme weather and urban disasters, development in the medical field, engineering, and transportation planning. A good example was in Japan, when a 5.0 scale earthquake shook Tokyo on March 11, 2011 as an aftermath of a 9.0 magnitude earthquake at 231 miles from the East Coast of Honshu. On that day, a massive amount of data sets were collected, and authorities in Japan are now using Big Data intensively to improve preparedness and mitigation for future disasters. According to NHK Japan (2015), GPS data from more than 10 million cell phones, thousands of videos shared on sites, travel records from more than 1.5 million cars' navigation systems, and more than 35 million tweeter comments were put together that day to extract invaluable information. For transportation purposes, in the same day, public officials and authorities gathered and analysed three kinds of Big Data: Data from sensors set up by the Police Department at major roads, Route information from taxi companies, and Location information from cars' navigation systems.

A similar procedure, utilizing a plethora of travel data from new mobility services --such as Uber, Lyft, Via, Bridj, Cabify, Spli, from drivers, utilities and emergency vehicles, for instance, can be successfully applied as Big Data to monitor conditions for man made emergencies, extreme weather, natural disasters such as flash flooding, wild fires and blizzards, among several types of events. The efficiency, accuracy, and quick response of the procedure can even lead to protocols to be used during emergencies and catastrophes.

Big Data means data and information from multiple and different data sources to be systematized and processed to identify an issue or problem, and an efficient and practical way to get such data is through the Internet of Things (IoT). IoT is an open platform and a network of physical objects, devices, vehicles, buildings and other items which are embedded with electronics, software, sensors, and connectivity, which enables these objects to collect and exchange data, only possible using the NGA – Next Generation Access through optical connections in a Ultra High Speed between 100 Mbps – 1 Gbps (Wi-Fi Alliance, 2016). According to Barret (2016), "it's (IoT) Wi-Fi for smartwatches and Internet-enabled coffee makers and whatever other connected appliance might suit deranged fancies, certified by the Wi-Fi HaLow, from Wi-Fi Alliance". Wi-Fi Halow is a long range, low power, low frequency 900 MHz, 802.11ah Wi-Fi standard.

In this perspective, it is possible to identify the Internet of Moving Things (IoMT), an evolution of the IoT, as the ability to connect anything that moves and monitor, analyse, and deliver real-time insights from the resulting data. Because motion sensors provide an intuitive way for consumers to interact with their electronic devices, the market applications are endless and can include: Smartphones, Tablets, Automobiles, Wearable devices, Health and fitness monitors, Gaming consoles, Smart clothes, Smart watches, Shipment tracking, and Remote controls.

The goal is to have several applications working in just one gadget, such as a smart phone or tablet, for instance. Regardless the gaps on accuracy and reliability compared with specific devices for specific tasks (i.e. camera for HD photo, specific sensors for detection, etc.), and for the purpose of this

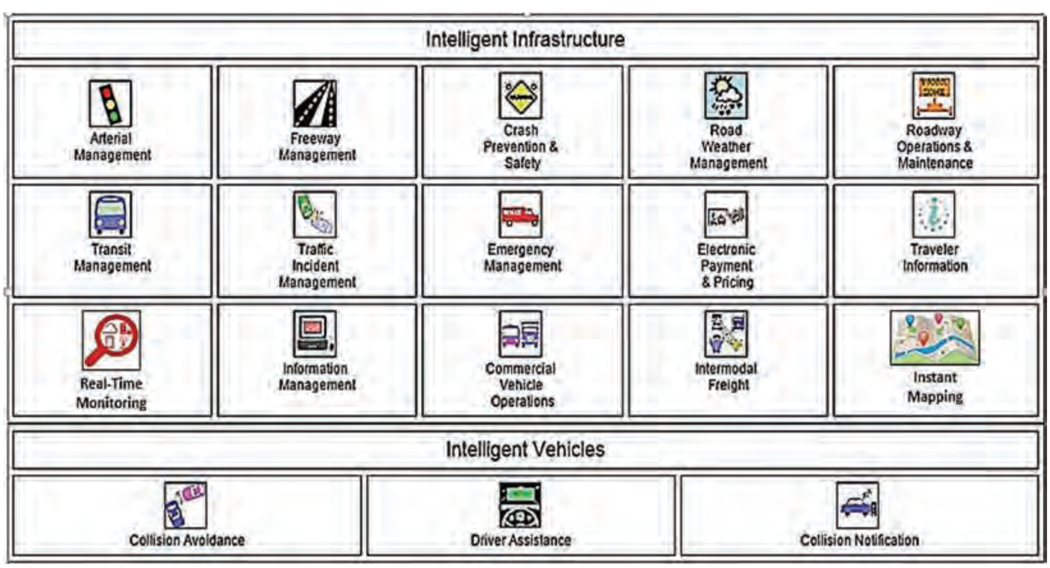

Figure 1: ITS - Intelligent Infrastructure. (Adapted from the US Department of Transportation, 2009).

paper, smart phones and applications can be considered an inexorable trend due to their increasing popularity, low cost, and their practicality and convenience.

Broadband Applications

ICT (Information and Communications Technology) has proven to be a pivotal condition and a challenge for most cities to reach economic growth and to manage most aspects of urban life. For such, digitally-based start-up enterprises play an important role for municipalities by offering data driven co-productivity, co-efficiency and open, adaptive and contextually relevant solutions, handling the exponential surge in demand for data-based urban services that just can't be met by municipalities alone, especially when dealing with Big Data.

As a technology concept, broadband applications respond to a new dynamics between cities and researchers, ICT developers, designers and management experts, providing invaluable tools related to public transportation and urban infrastructure. Cities have come to realize that offering broadband "open access" environment can support private players in the innovation sector to find novel and highly efficient ways to tackle important urban issues.

Broadband applications collect and process Big Data from its own devices and sensors, 'importing' and 'incorporating' cloud-based data from external sources. This is done through applications and platforms, such as Internet of Moving Things, mapping, visualization, reporting, and analytics specifically developed to provide actionable insights from the increasing amounts of data generated every day. Most importantly, they provide users and managers with a real-time information for planning and responding to major issues and concerns, helping to improve inter-agency coordination, systems efficiencies, emergency responses, and users' experience.

Public Transportation Connectivity

It is on public transportation where the most advanced features of ICT have been implemented. Offering onboard entertainment, positive vehicle control, passenger connectivity, surveillance and security, fleet management, onboard advertising, as well as data generation for quality service improvement, delivering on-the-go Wi-Fi with the same speed and reliability as home or office network became paramount and the flagship for public transportation agencies.

By land, water and air, in passenger mode vehicles such as trains, subways, buses, taxis, ferryboats, airplanes, and so on, the accessibility to high-speed Internet is helping transit authorities and transportation departments to quickly download travel schedules or passenger information, allowing for traffic management with intersection-place units, or by increasing security and surveillance at crossings, stations, and depots, for instance. Sensors, cameras, meters, analysers, detectors, and a plethora of devices components and accessories are set to collect, store and deliver accurate information regarding the complete trip experience, from origin to destination, including terminals, vehicles, and intermediate stops and terminuses.

Passengers can access the Internet through laptops, smart phones, PDAs and other communication devices transforming their travel experience by extending access to information and office connectivity, entertainment, and/or Voice over Internet Protocol (VoIP) applications. Moreover, with private vehicles offering broadband access and Wi-Fi connection and the advent of driverless cars, private and public transportation will be totally interconnected in a smart system through broadband and Big Data.

Broadband and Wi-Fi

According to the Broadband Commission for Sustainable Development (2015), broadband may support another dimension of connectivity that consists entirely of machine to machine communications, called M2M. Smart sensors and Radio Frequency Identification - RFID chips are increasingly becoming part of the IoT network. Underlying both acronyms is a basic concept of using the Internet to transpose the physical world onto the networked one. IoT/M2M makes everyday objects 'smart' and context-aware. In doing so, it offers significant economic benefits and a huge range of new possibilities, because smart objects can sense their surroundings and respond to them without the need for human intervention.

Broadband applications translate this concept of IoT/M2M applications for NGA supported by a major Smart Grid development. IoT/M2M has big implications for network architectures, protocols and management, which may be quite different to networks 'powered by humans'. Getting there will require the development, standardization and deployment of many technologies, from smart sensors and actuators to new broadband protocols.

The deployment of the 5G, the next generation of communication networks for the 26 billion connected devices, is expected by 2020. The 5G International Cooperation and Next Generation Mobile Networks Alliance predict that 5G networks will need to meet the needs of new usages, such as the Internet of Things as well as broadcast-like services and lifeline communication in times of natural disasters.

Conclusions

Modern, networked, and proactive cities, known as smart cities, learn faster and generate more business opportunities per geographical area than ordinary cities. According to Campbell (2012) they have a much thicker and better-connected institutional character with technology and mobility playing a key role in such development.

Entrepreneurship in ICT has become highly dependent on cities' growth patterns and expansion of data-based urban services. Broadband, ICT, ITS, NGA, IoT, IoMT, GIS, GPS, Big Data, and Smart Transportation applications are essential components of an engaged, competitive and dynamic city. As transportation planning and related infrastructure are pivotal components of how cities network, learn, and innovate, there is a promise of competitiveness, economic development, social gains and environmental protection in the so-called smart city, and ICT is the essential condition for such an achievement.

For transportation, infrastructure and mobility, cities can benefit greatly from the state-of-the-art of ICT: from the growth of wireless broadband in mobile connectivity, the broadband applications for third-generation (3G) wireless network services, the development of smartphones and other mobile devices, the emergence of new types of connected devices, and the rollout of fourth-generation (4G) wireless technologies. The availability of 5G wireless network services by 2020 will consolidate the Internet of Things and Digital Innovation as the technology avenues for cities development.

In the era of digital cities, the Internet is shaping the geography of opportunity and improvement, and reducing social and economic inequalities in urban areas, particularly through the Web 2.0 platform and the technologies for mobile devices. Broadband applications are therefore technology development for improving urban mobility and public transportation, filling a niche for transportation planning, infrastructure and operation evaluations, a leap forward for urban development based on broadband deployment and communications evolution.

As stated in the White House's report to the President (2016), technology has a structural importance in the future of cities with transportation playing a special role in three key dimensions: Energy-Efficient Districts, Accessible Mobile Districts, and Connected "Inclusive" Districts. Technologies influence patterns of behavior, and digital and mobile technologies are making the connections between transportation service providers and users tighter, faster, more personal, and more comprehensive to greater collective and individual benefits. They save time, improve comfort and productivity, lower costs for mobility and universal access, and increase safety, among several other direct and indirect benefits.

Acronyms used in this article

AMI - Advanced Metering Infrastructure
DSS - Decision Support Systems
FCC – Federal Communications Commission
GIS - Geographic Information System
GBPS – Gigabits per Second
GNSS – Global Navigation Satellite Systems
GPS - Global Positioning System
ICT – Information and Communications Technology
IoT- Internet of Things
IoMT – Internet of Moving Things
ITS - Intelligent Transportation Systems
KBPS – Kilobits per Second
LTE – Long Term Evolution
MBPS – Megabits per Second
M2M – Machine to Machine
NGA – Next Generation Access
OBI – Omnibus Broadband Initiative
OSM – Open Street Map
RFID - Radio Frequency Identification
WiMAX - Worldwide Interoperability for Microwave Access
Wi-Fi HaLow - Low power, long range 802.11ah 900 MHz Wi-Fi

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