International Journal of Sustainable Land Use and Urban Planning
ISSN 1927-8845| Vol. 1 No. 2, pp. 46-61 (2013)

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# Impacting Sustainable Behaviour and Planning in Smart City

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## Abstract

In the recent literature, the concept of "smart", "intelligent", or "cognitive" cities has gained increasing attention as an approach for addressing the challenges of urban management. The premise of a smart city is that by having the right information at the right time, citizens, service providers and city government alike will be able to make better decisions that result in increased quality of life for urban residents and the overall sustainability of the city. It is, therefore, stipulated that information resulting from a smart city implementation has a two-fold impact: (1) it shifts the social behaviour of citizens towards a more efficient and sustainable utilization of city resources (bottom-up), and (2) it allows service providers (such as utilities and transit companies) and city government to provide more efficient and sustainable services (top-down). There is an explicit need to understand the impact of smart cities on urban environmental, social and economic sustainability from a holistic perspective.

**Keywords:** *Governance; Smart City; Sustainable Behaviour; Sustainable Planning, Urban Sustainability*

## Introduction

The premise of a smart city is that by having the right information at the right time, citizens, service providers, and city government alike will be able to make better decisions that result in an increased quality of life for urban residents and the overall sustainability of the city (Mostashari et al., 2011a). There is an explicit need to understand the impact of smart cities on urban environmental, social and economic sustainability from a holistic perspective.

This paper explores the influence of smart city technologies on urban sustainability. Conceptual systems' diagrams are provided, which map the relationship between smart city and different aspects of sustainability as outlined in the literature, and identify the gaps that will need to be addressed in order to robustly understand the full impact of smart city on urban sustainability. The paper also discusses the role of the smart city as a way for residents to contribute to the decision-making process, and explores the mechanisms by which information sharing changes the structure of urban governance and citizens' behaviours towards more sustainable behaviours.

The paper is organized as follows. First, Section II discusses the concept of urban sustainability and investigates its process in economic, social, and ecological contexts. In Section III, the concept of smart cities, its importance and various examples are discussed. The impact of smart cities on urban sustainability, as well as the role of information technologies in citizens' behaviour and city planning, is presented in Section IV. Section V presents a conceptual systemigram model to investigate the effects of information technologies

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on sustainable behaviour and planning. Finally, conclusions are drawn in Section VI.

## Urban Sustainability

In general, "sustainability" refers to a harmonious relationship between human and environmental systems which ensures that human needs are not only met in the short term, but continue to be met in the long term by conserving and allowing for the regeneration of the natural environment. Although the term of sustainability has different interpretations, it is generally agreed that for human activities to be sustainable, there must be a relatively constant capital stock (Alberti, 1996). In other words, sustainable development should meet the needs of all people across long time periods, including both present and future generations (Keirstead and Leach, 2007; Alberti and Susskind 1996; Curwell and Cooper, 1998). Sustainability is often described as a multi-dimensional concept that is applied not only to the natural environment, but to society and the economy (Walsh, 2011; Cutcher-Gershenfeld et al., 2004). Urban sustainability refers to those aspects that are most prominent in urban interactions and structures. To achieve its goals in areas related to environment, equity and economics requires changes in planning policies, technology and the social behaviour of citizens (Cutcher-Gershenfeld et al., 2004).

Urbanization has increased, particularly in developing countries with an average annual urban growth rate of 3.6% between 1950 and 2005. However, during the same period, industrialized countries experienced an urban growth rate of only 1.4% (Sahely et al., 2005; Aubry et al., 2011). It has been estimated that 45% of the population of developing countries (1.97 billion) and 75% of those in developed countries (945 million) were living in cities in 2000 (Aubry et al., 2011; Mega, 2010). It is expected that by 2025, the urban population will reach 5.5 billion, with an estimated 2.5% annual rate of increase. The urban population in developing countries will reach 4.3 billion; that is, more than three times that of developed countries (projected to be 1.2 billion) (Choguill, 1996). Finally, Shen has estimated that 70% of the total global population will live in urban areas in 2050 (Shen et al., 2010). Population density directly affects different aspects of sustainability such as environment, urbanization and quality of life (Prado-Lorenzo et al., 2011). In other words, urban population growth impacts the environment and is one of the most important challenges for the management of sustainability (Alberti and Susskind, 1996; Maiello et al., 2011). Urban sustainability is achieved by minimal usage of non-renewable resources, remaining within the absorptive capacity limits for local and global waste, and meeting basic human needs (Choguill, 1996). Historically, cities have given rise to many societal problems such as large-scale pollution, waste, congestion, poverty and criminality (Rotmans and Asselt, 2011; Jenks et al., 1996). Sustainable cities aim at combating such problems by achieving economic, social, cultural and ecological development (Alberti and Susskind, 1996).

Urban sustainability relies on several types of capital (and their mutual relationships), including monetary, natural resource, human, cultural and social capital (Munda, 2004). The interactions between these drive economic growth, social equity, and environmental protection (Beck and Stave, 2011). Thus, matching these dynamics to a co-evolutionary perspective is one of the most important challenges of urban sustainable development. Concentrating on one indicator may result in the neglect of others. For example, a pure focus on ecological indicators completely overlooks socio-economic issues. Similarly, purely economic considerations that focus on efficiency issues often neglect environmental, distributional and cultural dimensions. Therefore, in the context of urban sustainability, a multi-dimensional framework is necessary (Munda, 2004) that will deal with the process of urbanization in economic, social, environmental (Choguill, 1996; Huang et al., 2009; Keirstead and Leach, 2007), cultural (Mega, 2010), ecological (Choguill, 1996; Gibbs, 1997), political (Gibbs, 1997), technical (Choguill, 1996), and engineering (Sahely et al., 2005) contexts.

For cities, economic sustainability points to their ability to generate resources and wealth via improved productivity and competitiveness in the market (Castells, 2000). Countries with a higher gross domestic product (GDP) often have a higher life expectancy, lower infant and child mortality rate, higher literacy rate, and higher score on the human development index (HDI). Economic growth

also helps to improve social capital (education, worker health, etc.), which in turn results in further growth, fostering a virtuous cycle (Spangenberg, 2005; Andad and Sen, 2000).

In sum, economic sustainability relates to the achievement of new levels of socio-economic, demographic and technological output that will strengthen the foundations of the urban system in the long term (Basiago, 1999). The basic dimensions of socio-economic sustainability are population or demography, economic activity, per capita GDP or personal income, rates of change in employment and output, and community/culture. The presence of minority languages and cultures strengthens regional identity (Copust and Crabtree, 1996).

Social sustainability is the ability to acknowledge plural identities, avoid social exclusion, make co-operation and competition compatible within society, follow a deliberate policy of social mobilization against structural violence, and form sustainable (accountable) governments (Castells, 2000). The major themes of this social dimension are equity, health, education, housing, security, and population (Hutchins and Sutherland, 2008). Specifically, social sustainability responds to human needs including food, housing, clothing, sexuality, health care, healthy environment, safe drinking water and sanitary facilities, freedom from bodily harm, protection in the event of illness, old age and social hardship, and even broader needs such as education, leisure, social relationships, and self-fulfilment (Littig and Grieler, 2007). Social sustainability also refers to trans-generational well-being that encompasses current and future generations. For instance, reducing social inequality improves quality of life across a nation, provides equitable growth opportunities for future generations and harmonizes the living environment for all. Here, employment plays an essential role since sustainable income improves social relations and the emotional well-being of individuals, thereby reducing divorce, suicide, alcoholism, poverty, social exclusion, welfare dependence, and the incidence of psychological problems (Chan and Lee, 2008). In sum, from a sociological perspective, urban social sustainability has three main indicators. The first indicator refers to the urban population's basic needs and quality of life including measures of individual income, poverty, income distribution, unemployment, education and further training, housing conditions, health, security, and work satisfaction. The other two indicators, social justice and social coherence (Littig and Grieler, 2007), relate, respectively, to fairness in distribution and opportunity, and the presence of social services such as health, education, gender equity, political accountability and participation (Assefa and Frostell, 2007).

Other aspects of social sustainability would include (Dave, 2009): access to facilities and amenities, amount of living space, health of inhabitants, community spirit and degree of social interaction, sense of safety, and satisfaction with one's neighbourhood. A social sustainability framework is composed of social capital, infrastructure and justice, as well as engaged governance (Cuthill, 2010; Sharifi and Murayama, 2012). Additional components are: "(1) basic needs such as housing and sufficient income that must be met before capacity can develop; (2) individual or human capacity or opportunity for learning and self-development; and (3) social or community capacity for the development of community organizations, networks that foster interaction" (Davidson, 2010).

Ecological sustainability combats the irreversible deterioration of the environment and deals with land development and preservation (Castells, 2000; Basiago, 1999). Environmental sustainability efforts mainly focus on achieving a balance between production and consumption, as opposed to prioritizing economic growth. It thus involves a set of constraints on major activities regulating the human economic subsystem, including the use of renewable and non-renewable resources, pollution and waste assimilation. The preservation of natural capital and maintenance of resources is integral to the concept of environmental sustainability (Goodland, 1995). Urban environmental sustainability indicators include (Hilty et al., 2006):

- "Greenhouse gas emissions,
- Energy intensity of the economy,
- Volume of transport to gross domestic product,
- Modal split of transport,
- Urban air quality,
- Municipal solid waste land filled or incinerated."

Urban sustainability can be achieved when issues relating to economic, social, environmental, and cultural sustainability are all taken into consideration, both with respect to planning and citizens' daily behaviour. Achieving sustainability requires the establishment of a balance between competing social interests that alternately promote economic development, environmental protection, and social equity (Hutchins and Sutherland, 2008; Chan and Lee, 2008; Assefa and Frostell, 2007; Lan et al., 2007; Carew and Mitchell, 2008; Dempsey et al., 2011). For purposes of measuring urban sustainability, its indicators should provide (Shen and et al., 2010):

- Explanatory tools aimed at translating concepts of sustainable development into practical terms;
- Pilot tools aimed at assisting policy-making choices that promote sustainable development;
- Performance assessment tools aimed at evaluating the effectiveness of various efforts.

## Smart Cities

For many people, city life is more a mixture of alienation, isolation, fear of crime and terrorist attacks, congestion, and pollution than a feeling of community, participation, animation, beauty or pleasure (Komakech, 2005). A transition from the former to the latter may be supported by smart computing: a new generation of integrated hardware, software, and network information technology systems with real-time awareness of the surrounding world that can help citizens make more intelligent decisions. Smart computing transforms cities from their traditional forms into smart cities (Nam and Pardo, 2011). Cities require accurate and real-time information about the status of urban services in order to improve public safety and provide adequate infrastructure-based services such as safe drinking water, reliable electricity, and sustainable, safe and reliable transportation and communication. However, traditional cities cannot optimize this provision of services due to constantly changing conditions. Important officials are not able to access the requisite information for decision-making in the right form, and at the right time (IBM, 2011). In other words, a smart city provides the required infrastructure for citizens and officials to make more intelligent decisions. In doing so, it plays an essential role in dealing with challenges relating to ecological, social, cultural, and economic sustainability (Caragliu et al., 2011). This section looks at various perspectives on the smart city currently existing in the literature.

The utilization of information technology for decision-making by citizens, service providers and city government has given rise to the general notion of a smart city. There are several models for an information-centric city in the literature, which are hierarchically based upon one another. Any information-centric city features three mutually connected dimensions: technology, human, and institutional. The "technology" dimension includes digital, intelligent, ubiquitous, wired, hybrid, and information elements. On the other hand, creativity is a main driver to smart city. Human dimension factors including people, education, learning, and knowledge, have key roles in smart city. Finally, the role of government, the relationship between government agencies and non-government parties, and their governance are fundamental to the design and implementation of smart city initiatives and are considered as institutional factors of an information-centric city (Nam and Pardo, 2011).

Combining software and telecommunication networks, sensors, and identifiers creates intelligent cities (Mitchell, 2007). In a simplified scheme, the concept of the wired and digital city describes information and communication technologies (ICTs) that enable network technologies to connect many users, for example, citizens, companies and agencies (Yovanof and Hazapis, 2009). The goal of a digital city is described as "creating an environment for information sharing, collaboration, interoperability and seamless experience for all its inhabitants anywhere in the city" (Yovanof and Hazapis, 2009). This serves as the foundation of an intelligent city (Yovanof and Hazapis, 2009), which can be described a "smart space" based on embedded informational technologies and innovation systems that enhance productivity among the population (Komninos, 2006); the information provided by these technologies is used effectively to create a safe and sustainable place to live (Komakech, 2005). Intelligent cities aim to pool advanced knowledge and experience in the form of electronic government, planning systems and citizen participation. They enable citizens and stakeholders to access local services through the use of new technologies (Kingston et al., 2005). The 'smart'

attribute of an urban environment is used in many different contexts; for example, in a marketing-based (Hollands, 2009) or smart-growth (Bronstein 2009) sense. This demonstrates the broad variety of topics addressed by the smart city literature, such as, urban sprawl, increasing infrastructural costs, environmental concerns (Krueger, 2007) and health (Geller, 2003). In practice, "the concepts of 'smart' and 'intelligent' cities both describe an urban system of systems that modifies its behaviour in response to changes in the environment, monitoring its various components and acting accordingly to potential or actual changes of state in order to achieve a desired goal" (Yovanof and Hazapis, 2009).

In sum, smart cities can be defined as "territories with high capacity for learning and innovation, which is built-in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management. [And] actual smart cities can be seen to embody specific characteristics that include digital infrastructure and ICT usage, emphasis on business-led urban development, the social inclusion agenda via e-governance, concern with high-tech and creative industries in urban growth, the importance of social capital in urban development and the inclusion of environmental and social sustainability" (Tranos and Gertner, 2012). In other words, "[a] smart city is a city which functions in a sustainable and intelligent way, by integrating all its infrastructures and services into a cohesive whole and using intelligent devices for monitoring and control, to ensure sustainability and efficiency" (Hancke and Hancker, 2012). Forrester defines the smart city as the "use of Smart Computing technologies to make the critical infrastructure components and services of a city, which include city administration, education, healthcare, public safety, real estate, transportation, and utilities more intelligent, interconnected, and efficient. He defines Smart Computing as a "new generation of integrated hardware, software, and network technologies that provide IT systems with real-time awareness of the real world and advanced analytic to help people make more intelligent decisions about alternatives and actions that will optimize business processes and business balance sheet results" (Washburn and Sindhu, 2009). For instance, smartphones transmit data like ticket numbers, credit card accounts and ID information to a central server, and the SIM-cards in the phones store that data (Chen, 2012). Smartphones enable a variety of crowd sourcing applications to collaborate in data collection (Hancke and Hancker, 2012).

In a smart city, all significant infrastructures - including roads, bridges, tunnels, rail, subways, airports, seaports, communication infrastructure, water, power, and major buildings - are monitored in order to maximize the services available to residents (including security services), while optimizing the use of resources (Hall, 2000). Hence, the critical infrastructures of a city can be made more intelligent, interconnected, and efficient by employing smart computing technologies (Balaouras, 2010). Financial services, knowledge-intensive high-tech industrial enterprises, companies within the information sector, and additional creative and knowledge-intensive service enterprises compose the corporate structure of informational cities (Stock, 2011). Although wireless infrastructure is an essential component of any digital city, in a truly "smart" city it is more than just a network. A smart city is able to transform key governmental processes both internally across departments and employees, and externally to citizens and businesses, through an interoperable, Internet-based government service (Al-Hader et al., 2009). While the concept of smart cities primarily emphasizes the use of information technology (IT), social infrastructure - including intellectual and social capital - also plays a vital role for smart cities. People and their respective relationships define social infrastructure. Smart people generate and benefit from social capital. The presence of education/training, culture/arts and business/commerce, and a hybrid mix of social, cultural and economic enterprise, is also essential. A smart community composed of government, business and citizens realizes the potential of its information technology, utilizing it in ideal and positive ways in everyday life and work. Such a community not only is integrated, collaborative and inclusive, but contains multiple neighbourhoods and communities of interest. Although IT infrastructure plays a key role in a smart city, a real engagement and willingness to collaborate and cooperate on the part of public institutions, business sectors, non-governmental organizations, schools and residents is an additional component (Nam and Pardo, 2011). Smart governance (related to participation), smart human capital

(related to the workforce), smart environment (related to natural resources), smart living (related to quality of life), and smart economy (related to competitiveness) compose the major dimensions of a smart city (Lombardi, 2011). The concept of a "cognitive city" additionally implies an urban environment where citizens learn, understand, and respond to changes in environment and adapt their behaviour according to past experiences. Citizens, social institutions and IT play essential roles in making a city more "cognitive" by improving decision-making processes and resource allocation (Mostashari et al., 2011b).

Smart city architecture includes three layers (Mostashari et al., 2009):

- Human/Institutional Layer: embraces all residents, non-governmental organizations (NGOs), government regulators, and actors in the private sector involved in the creation of market dynamics. The integration of profit maximization goals into the economic utility function of these social agents determines strategies at the data network and physical network levels.
- Data Layer: includes all data gathering devices, information sensors, local wireless and cellular networks that monitor the status of various systems within the city. This layer integrates subsystems to make the overarching system more "smart."
- Physical Layer: consists of all physical objects and infrastructures and their accompanying physical properties, and provides connectivity for the city's subsystems. For instance, wireless sensors can be installed in components of the physical layer in order to collect monitored parameters and transfer this data to the data network layer. Data network agents, in turn, use those sensors/actuators located within the physical system to monitor the performance of city systems and initiate control actions based on the economic optimization scheme utilized within the social network layer.

Singapore is an example of a smart city where the quality of life for residents has been enhanced. Since 1997, Singapore's government has created an IT-based teaching and learning environment for schools in order to equip children with creative thinking methods and help them to benefit from effective communication (Mahizhnan, 1999).

Another example is Amsterdam, where technology is used to enhance the efficiency of energy and communication systems as well as human capital. This smart city has been successful in curbing $CO_2$ emissions and improving the transportation infrastructure. Amsterdam residents are able to make smart choices and have the opportunity to be smart entrepreneurs (Brinkman, 2011). In 2006, the city of Dubuque, Iowa in the USA launched the sustainable development model in the form of a triadic and reciprocal system based on the goals of environmental protection, economic prosperity, and social equity. Dubuque takes into account the importance of sensors - including smart water and electric meters, mobile phones, GPS devices, parking meters, and traffic, pipe, weather and building sensors - to optimizing resources for residents and city managers. Citizens play the core role in Dubuque's model by using smart phones as source data (Naphade and et al., 2011).

In the United Arab Emirates, in 2006, the government of Abu Dhabi initiated a project to make Masdar "one of the world's first zero car cities." To achieve this goal, the city invested in renewable energy and sustainable technologies including wind, solar, and biomass (Reiche, 2010). However, the project was not quite successful since in that project only the availability and quality of the smart infrastructures were considered, and the human dimension was ignored. As mentioned above, smart cities should aim at improving the quality of life for residents. In other words, in smart cities, governments and businesses invest in ICTs to improve sustainable development and quality of life, by providing smart urban infrastructures that will inform residents about the desired environmental agenda (Harter et al., 2010).

## Impact of the Smart City Paradigm on Urban Sustainability

To achieve multi-dimensional urban sustainability, both bottom-up citizen behaviour and top-down government decision-making must become more efficient, effective and sustainable (Cutcher-Gershenfeld et al., 2004). This section discusses the findings in the literature on how smart cities impact sustainable behaviours on the part of citizens and

sustainable planning on the part of officials. It is necessary that officials (who work based on established rules and standards) report and respond with fairness and consistency to the concerns of residents. During this process, all residents, including the poor, should be able to play an essential role in decision-making. Public employees should have access to basic entitlements necessary to make a living. All residents should have access to low-cost, understandable and relevant information, from which effective accountability and clear laws, regulations and policies can be provided (De, 2010). Meanwhile, the interconnected systems of land use, water, energy and transportation systems that comprise the urban infrastructure all affect the decision-making process. Finally, the implementation of socioeconomic and environmental policy affects the decision-making process for sustainable cities (Minne et al., 2011).

**A. Sustainable Citizen Behaviour**

Human behaviours such as overpopulation and overconsumption may cause major environmental threats, including global warming and ozone layer destruction (Oskamp, 2000; Giord, 1999).

Accordingly, behaviour change is required to achieve the goals of sustainability. In practice, psychologists can play an essential role in helping citizens to adopt sustainable patterns of living and enhance their contributions to the environmental, economic, and social aspects of sustainability (Oskamp, 2000; McKenzie-Mohr, 2000a; Vlek and Steg, 2007). Since human behaviours are rooted in social situations, institutional contexts and cultural norms (Shove, 2010), individual adaptation and change - as well as personal agency - are also embedded within those socio-structural networks. Social structures shape rules and resources to organize, guide, and regulate human actions. Meanwhile, human activities create, implement, and alter social systems. Within this dynamic, personal agency and social structure operate “as interdependent determinants in an integrated causal structure rather than as a disembodied duality” (Bandura, 2004).

Human behaviour change is necessary to achieve the goals of sustainable urban development, including political and environmental activities. Actors include officials, inhabitants, non-governmental organizations (NGO), activity groups, religious groups, community-action groups, private sector firms, women, and experts. In other words, the participation of not only government, but all segments of society - including the active participation of citizens - is necessary to achieve sustainable development through decentralization of decision-making and implementation of power (Moon, 2006). Both horizontal and vertical cooperation between governmental and non-governmental actors is necessary for establishing a new mechanism of governance, in which all groups have equal participation and no single actor can have a dominant influence. Depending upon the degree of decentralization, to maximize the local and regional participation of authorities in policy formulation and implementation, institutional bridges between these authorities and central government, social partners and NGOs should be created (Mega, 2010). In practice, in smart cities, the usage of new communication information technologies facilitates smart administration and good governance using tools such as e-governance and e-democracy. This, in turn, enhances effective political participation among residents and officials (Fertner et al., 2007).

ICTs strengthen freedom of speech and improve access to public information and services in a smart city (Partridge, 2004). Citizens prefer online participation and discussion, due to the relative lack of nonverbal politics in an online environment. Inequalities stemming from race, gender and disability are decreased in online communities. In fact, the medium of the web might serve to increase citizens' political participation and the power they can wield in their communities (Sotarauta, 2001).

In the process of developing urban sustainability, limitations in natural resources, intra- and intergenerational equity, integration of economic, social and environmental priorities, and expansion of public participation in decision-making should all be considered (While et al., 2004). Sustainability development projects accomplish this through environmental policies and resource management strategies that encourage non-profit organizations and community environmental groups to play an essential role in urban governance (Lee and Huang 2007). In practice, the role of these local communities and groups in protecting the environment is more significant than the government's role (While et al., 2004).

All residents should be aware of mechanisms for reducing energy-consumption in households.

Schools and libraries can also function to boost citizens' awareness. In addition, universities, financial institutions, telecom and ICT companies, and transport and waste management companies can play essential roles (Brinkman, 2011). In smart cities, several entities will be used interchangeably as either consuming or producing devices, for example, electric cars. In this infrastructure, such devices will no longer be considered mere "black boxes," but will be interconnected, providing more detailed information about their energy behaviour (Karnouskos and Holanda, 2009).

Smart cities may also affect the travel behaviour of citizens (Verplanken et al., 1997). Public and private advanced traveller information systems (ATIS) provide travellers with appropriate information to make better travel decisions, and therefore reduce travel time, stress and traffic congestion within transportation networks. In practice, commuting decisions can be influenced by travel information, socio-demographic characteristics, attributes of the trip and route, and situational factors (Khattak et al., 1999). The most important aspect of smart mobility is the availability of ICTs and modern, sustainable transportation systems that offer both local and international accessibility (Fertner et al., 2007). For instance, the central idea behind making Hoboken a 'smart city' is to provide improvements to all modes of transportation that might transform it into a better place for transit riders as well as pedestrians, while at the same time improving conditions for those who drive. New facilities, improvements to intersections, and other actions will make it safer to walk and bicycle in the city along with this improved access to transit. This system would ultimately connect all parts of the city (Stevens Institute of Technology 2013 and City of Hoboken, 2004).

Figure 1 summarizes the impact of the smart city on the behaviours of citizens in relation to urban infrastructures (energy, travel, and waste behaviours) and social behaviours (political activities).

### B. Sustainable Planning

New urbanism, smart growth, and the ecological city are three sustainable urban development approaches. Smart growth refers to natural resource protection, regional collaboration, and economic development based on local capacity and resident participation. New urbanism addresses itself more to" architecture of community", that is, it focuses on the structure of places and open spaces to improve the quality of life. In the eco-city, land-use policies reflect the use of renewable energy, diverse transportation options, short travel distances, and urban density (Jepson and Edwards, 2010). For planners, the city should be considered a complex system consisting of both economic and environmental subsystems. Accordingly, planners require tools to manage natural resources, pollution, information, and trade (Campbell, 1996).

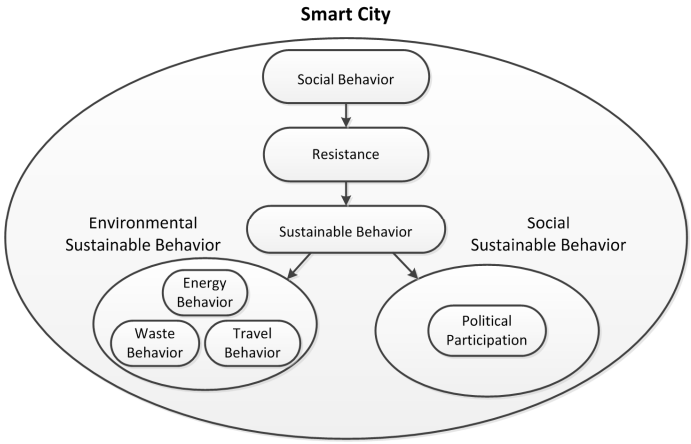



**Figure 1:** Impact of smart city on sustainable behaviour

In order to achieve urban sustainability, government employs information technologies, including internet and mobile computing, to enhance its relationship with citizens, businesses, and other governmental sectors. This enables the delivery of more services to citizens, improved interactions with businesses, and more efficient governmental management. Other benefits of e-government include less corruption and cost along with greater transparency, convenience, and revenue growth. Meanwhile, citizens themselves are empowered by this improved access to government information and services (Palvia and Sharma, 2007; Yildiz, 2007); it is important that these citizens be able to participate in decisions regarding energy infrastructures and transportation systems. In practice, the implementation of other socioeconomic and environmental policies also affects the decision-making process in sustainable cities (Minne et al., 2011).

The use of technology helps leaders inform and connect people, while giving officials the ability to make immediate and informed decisions. In this

way, a city is transformed into a connected network system, that is, a smart city (Moss, 2009). Smart cities are characterized by an increased use of knowledge networks and integrated e-services to improve the quality of life for their citizens. This occurs through the delivery of better services and goods, as well as enhanced creative relationships among local officials, professionals and residents, which enable them to come up with the right set of strategic policies (Paskaleva, 2011). This seamless experience of information-sharing, collaboration and interoperability facilitates citizens' access to commercial and governmental services and information (Yovanof and Hazapis, 2009).

The ability to produce smarter, lower-consumption energy based on renewable sources such as hydropower, solar, wind, biomass and biofuels, geothermal, and ocean and tides represents a fundamental step towards a sustainable energy future and offers special opportunities for cities (Mega, 2010). "In the future service-based Internet of Energy (IoE), several alternative energy providers, legacy providers, virtual power plants, households and so on, that are the elements of smart cities, are interconnected. Via smart meters, one is able to interact with a service based infrastructure and perform actions such as selling and buying electricity. More advanced services are envisaged that will take advantage of the near real-time information flows among all participants" (Karnouskos, 2009).

Transportation is a network for industry and services, which acts as an engine and catalyst for growth and prosperity. Several dimensions of sustainable development may benefit from an improved transportation system. Clean and highly eco-performing public transport can be the backbone of sustainable urban transport services. Public transport represents an acceptable alternative to cars, only when it is safe, clean, reliable, fast, frequent, noiseless, flexible, easily accessible, well-designed, environmentally-friendly and economically viable (Mega, 2010). This infrastructure affects people's choices when it comes to both transportation mode and energy consumption, which in turn affects air pollution (Alberti, 1996). Providing access to accurate and real-time travel information can improve transportation. This travel information may include weather conditions, traffic congestion, travel distance, time of departure for public transportation, road conditions, directions, and special problems (roads under repair or closed, accidents, potholes, etc.) (Verplanken et al., 1997). Travellers, in turn, will make better decisions that reduce travel time, stress and traffic congestion. Meanwhile, operations managers can enhance their decision-making by gaining access to the locations of automatic vehicles provided by using smart transportation system.

An intelligent transportation system allows for an integrated view of real-time traffic data through the use of devices installed on roads such as traffic signals, cameras and sensors. The provided data is processed with the purpose to establish an intelligent and adaptive traffic management system that empowers drivers through dynamic messaging and other methods, to choose optimal routes and avoid accidents or street problems, thereby increasing safety. This will also empower transit network operators to make better decisions regarding traffic signals, locations of new roadways, and problems with existing roadways (Penttinen et al., 2007). Monitoring public infrastructures such as bridges, roads, and buildings may increase the efficient use of these resources and decrease the cost of regular scheduled inspections (Hancke, 2012).

Another component of urban infrastructure is land use. To improve urban sustainability, land use strategies that rely on public transportation and compact living, and are aimed at reducing natural resource consumption, should be encouraged. Officials should, therefore, pursue a walkable, mixed-use model integrating high-performance buildings and infrastructures. Two important values of urban sustainability are compactness (density) and biophilia (human access to nature) (Minne et al., 2011). In urban sustainability process, the personal appeal and societal benefits of neighbourhood living, where daily needs can be met on foot, are greatest in those neighbourhoods that have all the necessary attributes of compactness, completeness, connectedness and biophilia (Douglas, 2008). However, not only improvements in biotic and abiotic aspects of urban life, but also in social aspects related to satisfaction, experiences and perceptions of the everyday environment, should be considered. Accordingly, urban parks and open green spaces play essential roles in accomplishing urban sustainability goals (Chiesura, 2004).

Rio de Janeiro, Brazil, presents one successful example of smart, sustainable planning. Rio uses ICT capabilities to connect multiple systems in order to manage disasters, emergencies, and planned events. For instance, in the event of a disaster, relevant agencies are coordinated to make intelligent decisions based on integrated data resources such as traffic, weather, and building sensors. Similarly, Singapore optimizes transportation operations, while Dubuque improves energy consumption through the use of ICTs (Naphade et al., 2011). Figure 2 summarizes the impact of a smart city on sustainable planning through changes in urban infrastructures (energy, land use and transportation systems) and governance structure.

## Conceptual Systems Model

Figure 3 summarizes the impact of a smart city on urban sustainability. As shown, to achieve multi-dimensional urban sustainability, both citizens' behaviour and official decision-making must become more efficient, effective, and sustainable. A smart city encourages citizens towards sustainable behaviours through change in their political, energy, travel, and waste behaviours. In addition, a smart city affects sustainable planning through changes of urban infrastructures (energy, land-use, and transportation systems), and the structure of urban governance.

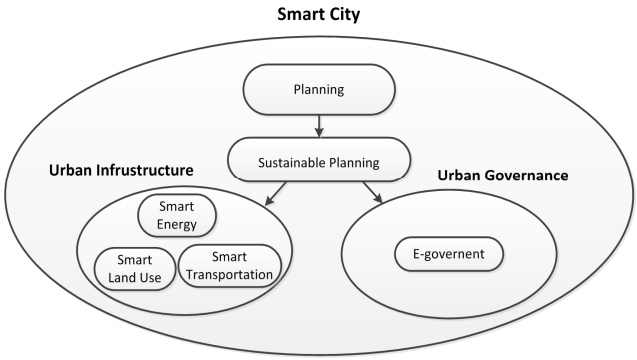



**Figure 2:** Impact of smart city on sustainable planning

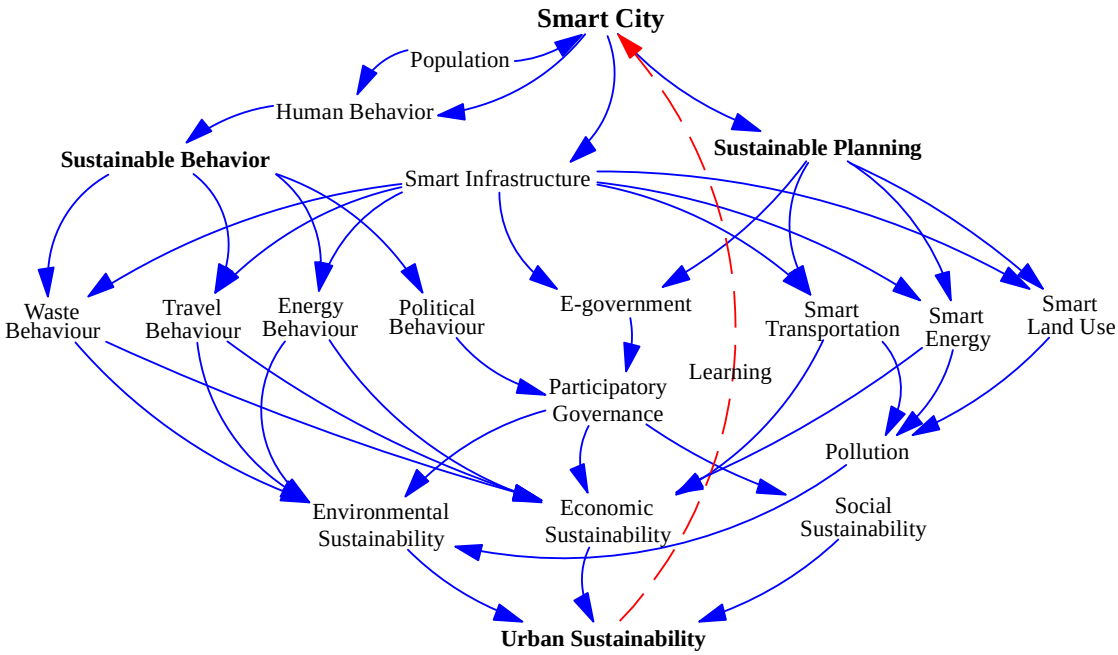



**Figure 3:** The process of achieving urban sustainability

Official policies on land use, energy and transportation impact the amount of pollution, which in turn has a pronounced effect on environmental sustainability. On the part of citizens, changes in consumption, travel and energy behaviours reduce demand which in turn positively affect environmental and economic sustainability. Both environmental and economic sustainability are also affected by changes in political behaviours and accordingly by participatory governance.

Moreover, smart planning enhances the capacity of government agencies to deliver public services while involving citizens in decision-making processes. Social sustainability will be enhanced as a result of this broad participation of citizens in their political system. Smart infrastructure plays an important role in sustainable planning and behaviours. In short, urban sustainability is realized when questions of social, economic and environmental sustainability have all been taken into consideration. On the other hand, in an urban environment, citizens can learn from and respond to environmental changes and can adapt their behaviours according to past experiences. In practice, benefiting from ICTs, citizens and social institutions can play an essential role in making a city more cognitive. The dotted line in Figure 3 shows the impact of urban sustainability policies on the infrastructure of a smart city.

## Conclusion

Access to the right information at the right time allows citizens, service providers and city government to make better decisions that result in increased quality of life for urban residents and overall sustainability of the city. To achieve multi-dimensional urban sustainability, citizens' behaviour and government decision-making must each become more efficient, effective and "sustainable". Smart cities offer a very promising solution to this need, by helping citizens and officials to develop sustainable behaviours and planning. The new information made available from such implementation can shift the social behaviour of citizens towards a more efficient and sustainable utilization of city resources, while allowing service providers and city government to provide services more efficiently and sustainably. In other words, smart cities will require innovation when it comes to planning, management and operation of their infrastructures and resources if they are to cope with the future demands of their citizens (Naphade et al., 2011).

Smart cities are thus capable of altering the environmental and social behaviours of citizens, whether this means providing information about mechanisms for reducing energy consumption, or updates on travel routes. In addition, they facilitate smart governance and political participation among citizens and officials through the use of ICTs like e-governance and e-democracy. They impact urban infrastructures such as systems of water and land use, energy, and transportation, encouraging the use of renewable energy sources as a path to sustainable development. Nevertheless, in making use of these technologies, cities must deal with challenges related to privacy, security and government surveillance. In practice, residents will live in a "surveillance society"; that is, where societies are connected but completely unknown to one another (Alusi et al., 2011). Yet another challenge facing smart cities is to properly model and understand human behaviours through psychology, user experience design and social computing (Naphade et al., 2011).

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