Study of Technological Solutions in the Analysis of Behavioral Factors for Sustainability Strategies

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Abstract  The management and consumption of resources in cities in sustainable way have been considered a relevant issue worldwide. For that reason, the New Urban Agenda defines a set of sustainable development objectives-SDG for the year 2030. On the other hand, consumerism behaviors by people have had a considerable increase since of the Second World War period. Achieving sustainability objectives requires the establishment of policies and standards as enabling elements, but they must go hand in hand with a cultural change on the people aligned with the strategies to achieve sustainability. The purpose of this study is the development of a comprehensive analysis of the cultural beliefs that influence in the behavioral aspects of people and how they could affect the achievement of the development of sustainability in cities and how some technologies like big data, IoT, and IA, can be used to analyze these behaviors and improve the decision-making processes in city managers.

Keywords  Smart city · Sustainability · Cognitive maps · Social factors · Behaviors

1 Introduction

Cities have chosen the development of smart cities as a management and operation model to achieve their sustainability and resilience goals. The smart city definition is related to a type of urban development but based on sustainability that can satisfy its citizens’ basic needs [14]. New improvements in artificial intelligence (AI), computing power, and the inclusion of emerging technologies such as IoT and
Cloud allows obtaining information from the abundance of data to make decisions in order to promote the proper use of available resources in cities transforming them into smart cities. IoT has been considered a key element to establish a sensorization of the elements that make up the city in the different domains of health, education, transport, energy, and waste management [1]. In contrast, big data techniques and cloud are complements for storing and processing data generated by IoT devices. However, this data could be useless without an appropriate smart way of extracting the knowledge. Thus, AI will play a fundamental role in the optimal management of smart cities transforming data into knowledge.

Under this premise, in recent years there has been an important development in IoT and AI solutions also called smart solutions to meet the needs of the domains of the smart city. Smart solutions allow for instance obtaining, processing, and storing data of the number of cars on a highway, the temperature of a greenhouse, or the amount of electrical energy consumed in a home [2]. According to specialized sites such as Gartner [8], the growth projections of IoT and AI solutions will exceed millions in the coming years.

But when we focus on analyzing city management from an urban planning perspective, we not only consider physical elements such as the number of cars or people, but we also consider human factors related to the pillars of the city (environment, politics, economy, and technology). Urban planning should consider as central element of the citizen, who is a social entity part of the city that has a dynamic and complex characteristic [14]. From a pragmatic point of view, urban planning is more likely to predict the number of cars that will be on a street at a given time, and it has been feasible to predict human behavior and its impact on sustainability goals.

Human behavior, especially those related to sustainability aspects (sustainable behaviors), can be affected by some social factors shown in Fig. 1.

This context motivated to plan the following research questions that mark the development of this work:

1. Are smart solutions focused on sensing the aspects that allow measuring the impact on sustainability?
2. Are smart solutions adaptable to the existing social dynamics in the city?

Fig. 1 Social factors that could affect human behavior
3. What are the behavioral aspects aligned to sustainability that need to be measured?

This study is motivated by this idea “to satisfy our current needs without compromising the capacity of future generations to satisfy theirs” (UN 1987), technological resources such as artificial intelligence and IoT can allow the analysis of the behavior of citizens to identify the dynamics of various factors that must be modified to achieve sustainability.

Understanding the problem of environmental pollution through a holistic vision that integrates artificial intelligence, big data, IoT, and sustainable behavior to identify the relationships that exist between social, economic, and psychological variables, is our main contribution.

The remainder of this paper is structured as follows. Section 2 presents an overview related to people’s behavior and sustainability. This section tries to cover the relationship between social factors and people’s behavior and how they affect the sustainability of the cities. Section 3 presents the methodology used in this study and the results obtained from the SLR to determine the main aspects of social factors that could affect the sustainability goals of cities. Then, Sect. 4 covers the aspects for modeling social factors related to sustainability. Finally, Sect. 5 shows the conclusions for this study.

2 Background

Sustainability not only has an environmental perspective and also includes economic and sociocultural perspectives. Urban sustainability situates citizens as social change agents with an ethical and self-interested [14]. Some researchers have linked the relationship between environmental values and the behavioral intention of people’s behavior [3]. Additionally, Barr mentions that people’s behavior will also depend on situational factors and psychological variables.

The strategies for sustainability consider two aspects: citizens and responsible environmental behavior. Building a new model of sustainability for the development of cities in the twenty-first century implies taking into account psychological factors such as feelings, values, motives, intentions, and deliberate, planned and systematic behaviors, influenced by the levels of needs, satisfaction, information, capabilities, and resources.

The re-establishment of the “balance” between society nature entails a whole change of mentality and, therefore, of the conception of people regarding development, consumption, progress, and environmental care. People need to face the sustainability crisis that is going through at the beginning of the twenty-first century. Even with the result of successive scientific–technological revolutions, cities have not reached equally for everyone. The actual mode of industrial production could enhance predatory behavior in people in terms of the consumption of material and
energy resources, as well as polluting by the generation of waste, which ruins the planetary nature [15].

In recent years, the new version of the city introduces the concept of urban dashboards and platforms that integrates devices, namely Internet of things (IoT). These devices can be sensors, monitoring stations, digital cameras, actuators, tracking systems, etc. IoT devices generate a large number of data. This data could be vastly, and it needs to be processed by techniques, namely big data. Big data techniques are based on gathering massive amounts of data (volume) from different sources (variety) and processing very quickly (velocity) them in order to extract values that support decisions-making, designing solutions, and modifying processes of cities to make them sustainable [16]. In order to extract all the knowledge of the processed data optimally, AI algorithms can be a significant boost. Thus, according to a report of Pricewaterhouse Coopers (PWC) related to the real value of AI for business and how to capitalize it, they estimate that the global gross domestic product (GDP) will be up to 14% higher in 2030 as a result of the accelerating development of the use of AI [17].

2.1 Social Factors That Influence Sustainability

Developmentalism as a conception of social progress, the denial of the natural, anthropocentrism and ecocentrism beliefs, frugalist, altruism, the pursuit of pleasure in the satisfaction of artificially created needs (hedonism), fatalism and utilitarian behaviors and beliefs of an abundance unlimited resources [5] could influence social behaviors. Natural processes triggered by human action and high speed of social changes need maintain an equality relationship between the availability of resources and the people’s needs.

Lifestyles are influenced by instinct and the human psyche that lead us to competence and storage of resources, from an evolutionary perspective [6].

On the other hand, the marketing models that promote greater consumption of products through cultural meanings play an important role as they provide guidelines on acceptable behaviors, marking individual decision-making and that are internalized in the self are combined with the concept as representations of success, that drive behavioral patterns of consumption [9].

2.2 Approach of an Ecological Culture

Modification of consumerism lifestyles toward ecological or sustainable styles raises the analysis of trajectories that allow understanding the relationships between behaviors, personality beliefs through intelligent technological solutions that help to minimize the waste of resources, reduce pollution, and approach the search for a community welfare. To achieve these points, the solutions must join forces to build an
ecological society that places limits on the use of natural resources, remembering
the natural balance, where the common good is above the individual good [5].

Make cities and urban spaces inclusive, safe, resilient, and sustainable, need of
an interdisciplinary work between social sciences and engineering that promotes
sustainable consumption patterns among citizens. People must be aware of their
beliefs and behaviors about the ability to renew natural resources of the planet and
the amount of waste that becomes polluting emissions. Build ecological lifestyles
to achieve the transition from the urban ecosystem toward sustainability. Ecological
footprint measurement is an important concept to identify global human activity and
sustainability at the local level. Proposals that are researched and developed globally
are framed on the following aspects:

- Environmental awareness.
- Constructive and transformative behaviors, as well as critical thinking.
- Pro-environmental competencies.
- Social representation and community feeling of human development.

Some models and concepts that have been developed:

- Social mind raised by McDougal 1974.
- The model proposed by Baron and Kenny in 1996 seeks the mediation between
  beliefs, attitudes, and motives about human behavior.
- Conservation beliefs, authenticity, and material beliefs influence recycling behav-
  iors. Obregon 1996.
- Emotional components predict pro-environmental behavior Grob 1995.
- At the personality level, Bustos in 2004 determined that the internal locus of
  control directly and positively indexes the beliefs of obligation about saving
  resources.
- Dominant social paradigm.
- Paradigm of human exception, and
- New ecological paradigm.

3 Methodology

The methodology proposal in this study is based on the literature review using the
PRISMA guideline. We select the following scientific databases: Scopus, IEEE
Xplorerer, and Science direct. Based on the three research questions, we made a
literature review of 252 articles obtained from the following search strings:

- “Citizen” AND “behavior” AND “sustainability”.
- “Citizen” AND “sustainability” AND IoT”.
- “Citizen” AND “sustainability”.
- ”Citizen” AND “sustainability” AND “artificial intelligence”.

Based on the qualitative analysis carried out using the systematic review tool
Rayyan, we identified the following relevant aspects:
The most of scientific sources that analyze aspect of sustainable citizen behaviors are journal articles, then book series and next conferences (see, Fig. 2). Based on the analysis of scientific papers, the most relevant journals focus on the following topics: production, business, psychology, environmental, sustainability, and education (see Fig. 3). We observed that exist a lack of journals specialized in technology. This finding is aligned with our first research question and expand our interest to be identified if smart solutions support the measures of sustainability.

Follow the qualitative analysis in this study, we identify the characteristics of citizens based on sustainability (see Fig. 4).

- Environmental or ecological citizen has been suggested within the field of political theory as an approach to realize personal responsibility for the environment.
- Active citizen focused on the construction of democratic values.
- Global citizen is committed to helping and cooperating with others.

### 3.1 Social Factors in Smart Home

Jagers [10] mentions that there is willingness to change behavior in citizen associated with reducing the negative effects on the environment and mentions that exists in the responders to believe that adapting social practices to nature’s limits, for instance through lifestyle changes, is available solution. If this predisposition for change
Fig. 4 Relationship between sustainability and citizen

exists, how it is coherent with the actual reality or “new normality” and with the consumer lifestyles that have been predominant for several years. Mass consumption was one of the realities that could be evidenced with the onset of the COVID-19 pandemic, which may at first glance turn out to be far from the sustainability goals sought worldwide.

As we had mentioned previously, one of the social factors that affect the development of smart cities is digital lifestyles, which one has seen a huge impact as a result of the COVID-19 pandemic. Teleworking, tele-education, and online shopping became daily activities where the use of electronic devices had a significant increase. This unexpected increase of production and buy of electronic devices could be no aligned with sustainability goals (see Fig. 5).

Fig. 5 Consumerism of electronic devices during COVID-19
3.2 Social Factors in Transportation

Urban mobility is another aspect in the urban planning of the city. A study related to New Jersey transit found the relation between time trip and stress [20], and the research also found that some routes commuter has more stress level. Another study shows that metrobus drivers in the city of Mexico are stressed by the insecurity at work [12]. On the other hand, related to passenger, a study to exploring passenger anxiety indicates that the following service items cause passenger anxiety during trains travel: crowding, delays, accessibility to a railway station, searching for the right train on a platform, and transferring trains [4]. Additionally, other study which focuses on foreign people analyzed the stress perceived by foreigners that use public transportation in Bogotá, and this study found the following control variables: lack of control, crime, accidents, cleanliness, noise, temperature, and space [13]. Moving around in public transport causes anxiety and stress in cities, which drive people to select other mobility alternatives such as Uber or Lyft. People fell that when they use these services, aspects related to well-being improve because they do not need worries about traffic or parking (see Fig. 6.

4 Cognitive Maps for Modeling Consumerism Behaviors in Smart City

So, social behavior is dynamic and has a dependency of situational factors, as Barr mentioned. Some social behaviors generate consumerism approaches, which one could affect to the sustainability goals (see Fig. 7. On the other hand, smart solutions that integrate IoT, big data, and artificial intelligence can reduce traffic jams or improve cars and citizens’ mobility. Additionally, the data collected by smartphones...
and cameras can show citizens information about the traffic situation and suggest optimal routes avoiding stressful situations. [17]. In [18], the authors show that motorized transportation is the highest in air pollution. Thus, they have designed and developed an air quality monitoring instrument (AQMI) using solid-state gas sensors and GPS module. Results can be used for patients with air pollution-related health problems to find less polluted routes. In contrast, [11] propose a study that deals with the complexity of assessing transit service quality by identifying attributes affecting passenger’s satisfaction. The authors use a fuzzy model composed of 26 variables as factors. Results can help in improving existing transit facilities and devising strategies for ensuring sustainability. In [19], a novel context air quality prediction model is presented. In this model, the authors include context-aware computing concepts to merge an accurate air pollution prediction algorithm based on artificial intelligence with information from both surrounding pollution sources and user’s health profile. Results show 90–96% of precision.

Social factors can positively or negatively affect the sustainability of cities. Table 1 shows the relation between the affectation of social factors to vertical domains in smart city which forms consumerism perspective.

| Social factors/vertical domain | Smart health | Smart transport | Smart home | Smart waste | Public safety |
|-------------------------------|--------------|----------------|------------|-------------|--------------|
| Urban migration               | X            | X              |            | X           | X            |
| Life expectancy               | X            |                | X          |             |              |
| Well-being                    | X            |                | X          | X           | X            |
| Digital lifestyles            |              |                | X          | X           |              |
| Stress                        | X            | X              |            |             |              |
Under this context, smart solutions must be able to measure these social dynamics and assess how much is its positive or negative impact on sustainability objectives. Urban planning processes require the integral vision of all components that interact in smart city. Figure 8 shows one proposal that consider the consumerism behavior how element that affects the urban planning.

Model the identifiers of people’s consumption behaviors and how much they contribute to sustainability aspects, for example how many times people take an Uber for a short distance instead of taking a bicycle. Machin [15] proposed some indicators for sustainability:

- AA; Environmental sustainability index.
- S.S; Sociological sustainability index.
- EE; Economic sustainability index.
- AS; Sociological–environmental sustainability index (Supportability).
- AE; Economic–ecological sustainability index (viability).
- SE; Economic–sociological sustainability index (Equity).

Assunção [7] mentions that new urban sustainability assessment systems based on land senses ecology are needed, which should combine natural elements, physical senses, and psychological perceptions, and assist decision-makers to develop

Fig. 8 Cognitive map for sustainability urban planning
successful management policies. Under this context, Assunção proposes a fuzzy cognitive mapping and system dynamics.

5 Discussion

Results of the study suggest that it is necessary to consider the dependence of sustainability on environmental, economic, and social factors in order to establish technological solutions at the local level that allow smart cities to develop a sustainable model of development where citizens are aware of the limits to the exploitation of natural resources and the amount of waste they generate, and there is interest in the construction of models that allow work in this line. For example, in smart transportation, analyzing data from IoT devices such as cameras, traffic sensors, signals, and emissions sensors distributed throughout the city can optimize the traffic flow smartly. As a result, citizens could also be informed of the traffic situation in real time and select the optimal alternative routes avoiding stressful situations and improving their quality of life. Additionally, optimal urban mobility can help use better energy management to save money and improve the environment. So, environmental, social, and economic sustainability can be achieved.

On the other hand, from the smart home approach, the combination of social inclusion and smart health care can underline the importance of social integration, education, and healthy lifestyle changes to bring the people and society to create a participatory and tolerant environment. As a result, sustainable behavior is reached. IoT, big data, cloud computing, and AI can contribute to making possible the transformation of cities to smart cities and sustainable environment.

Promoting equity, justice, solidarity, and respect for the ethnic and cultural aspects of the population, as well as the defense of biodiversity, are basic axes of sustainability, and technology must approach these aspects to build more effective solutions that respond to the complexity of human development problems. Engineers should also create and apply technology to minimize waste of resources, reduce pollution, and protect human health, well-being, and the ecological environment.

The goal is that smart solutions allow us to know if our behaviors are contributing to the environmental care of the planet. Cognitive maps are one interesting alternative to model social behaviors for decision-making. The inclusion of AI models could improve the effectiveness and time response to analyze huge volume of data generated for smart cities. From our literature review, the modeling of cognitive maps using fuzzy techniques could be applied. Figure 9 shows some learning techniques that could improve the accuracy of fuzzy cognitive maps.
Fig. 9 Learning techniques for fuzzy cognitive maps

6 Conclusions Limitations and Future Research

In this work, we have focused on gathering some relevant evidence about the use of IoT, artificial intelligence, big data, cloud in contrast to promoting equity, justice, solidarity, and respect for the ethnic and cultural aspects without forgetting the defense of biodiversity. All of them are primary axes of sustainability, so technology must approach these aspects to build more effective solutions that respond to the complexity of human development problems.

However, from technological point of view, the lack of politics related to public data access is a limitation for developing experimental and holistic studies. On the other hand, the behavior of citizens is very sensitive to changing their response patterns due to the influence of context variables (persuading to generate new needs or increase the search for satisfaction) and internal variables (thoughts or experiences that stimulate consumption). Uncertainty is a challenge and limitation when seeking to model social factors such as human behavior. The development of artificial cognitive networks must have permanent feedback and dynamism through inductive analysis that improves generalizations since the human experience is built from each human being’s individuality. As future research, we expect academia to create and apply technology to minimize waste of resources, reduce pollution, and protect human health, well-being, and the ecological environment. So, the goal is that smart solutions allow us to know if our behaviors contribute to the environmental care of the planet.
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