Big Data and Urban Analytics: City Science in Developing Economies

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Technology as an Inseparable Element of the Cognitive Being and the Smart City as its Expression on the Territory

Technological development is a characteristic that has accompanied humanity throughout its history. Its origin could be located from the evolution of man as a cognitive being (Homo sapiens), interpreting technology in accordance with the definition of the Real Spanish Academy (Spanish: Real Academia Española or RAE), as the set of theories and techniques that allow the practical use of scientific knowledge, as well as the set of industrial instruments and procedures of a given sector or product (Royal Spanish Academy, RAE 2019).

In his transcendental work From Animals into Gods: A Brief History of Humankind, Harari (2018) distinguishes three important revolutions in the history of humanity: the cognitive revolution that marks the beginning of history approximately 70,000 years ago; this is located at the beginning of the era of the H. sapiens species, when human cultures emerged. The second is the agricultural revolution, between 12,000 and 5,000 years ago, when some authors place the origin of the first human settlements as villages and towns in Neolithic societies that lived closely with the Nature-Mother Goddess (Eisler, 1998, Mumford, 1961). And the third is the scientific revolution that began only 500 years ago, which gave rise to the Age of Enlightenment and the industrial revolutions of the 18th century to the present day.

These three revolutions have brought significant changes in the way we humans have developed as a species, and to our relationship with other organisms and the environment. From this analysis we turn out looking not so well in relation to the level of development and power that we have reached, which, according to the author, makes us akin to gods, with similar powers of creation and destruction, but with little understanding of what to do with that power, in addition to an awfully bad relationship with our habitat and natural environment. The technological advances which we are witnessing are not equally distributed, and this fact does not assert us as a better species; on the contrary, according to Harari (2018) there is great uncertainty regarding the future of the H. Sapiens, our species, since it is not clear if we will be able to evolve towards becoming gifted beings with different consciences and feelings, in comparison with the way in which we currently know and understand them or if, by contrast, the use of technology will fragment us into increasingly unequal societies, with the predominance of some groups over others.

This technological, economic, and cultural development transferred to the physical expression of the territory has generated a current growth model for the city that is one of accelerated, disconnected, and dispersed urbanization. It is a model where the use of private vehicles prevails, and where public transport expenses are high due to the great distances traveled to access sources of employment, education, and other basic and recreational services. There is a poor distribution and coverage of infrastructure and equipment services, as well as a proclivity towards a horizontal housing model which does not help to generate sustainable living conditions. This translates into a state of inequality, as there is a lack of access to opportunities; a situation whose underlying problem is on the rise and that mainly affects the lower-income population, who are typically excluded and pushed towards the outskirts of the cities where land for housing is affordable.

Castells (2010) establishes among the characteristics that delineate the causes of spatial dynamics and, therefore, the urban form of the global network society, the close interaction between the technological transformation of society and the evolution of its spatial form. In other words, technology not as a determining factor, but rather as a facilitator of new social structures. So, what should be the form in the future? One that reflects a more democratic society, in Scott's terms (2014).

Mostly in the last decade, the rise of information and communication technologies (ICTs) has permeated all the scenarios of daily life in order to make the city more efficient, to the point that now there is an “abuse” of the term ‘Smart City’.

The connotation of the intelligent city is not new. In the past, there have been different approaches that address the study of the city as an organic entity, which is structured from networks and flows (Batty, 2013). According to Mitchell (2007), at the beginning of the 21st century and derived from a series of technological and communication advances, cities have been made up of a series of subsystems similar to living organisms that allow them to respond as such, in an intelligently coordinated manner. According to the author, the intelligence in the cities resides in the effective combination of digital telecommunications and transport infrastructure (nervous system), the embedded intelligence which is present everywhere (brains), the sensors (sensory organs), and the software (knowledge and cognitive competence).

However, the concept of the smart city surfaced just at the beginning of the millennium as a merging of ideas about how information and communication technologies could improve the functioning of cities, to make them more efficient and competitive, and to provide new ways to address the issues of poverty, social deprivation and polluted environments as premises of care to improve the quality of life (Batty et.al, 2012, p. 483).

Smart cities are typically defined as those which rely on the use of information tools and communication technologies (ICTs) for smarter, and therefore, more efficient performance of resources, which translates into energy savings, and improvements in services and in the overall quality of life, while reducing adverse impacts on the environment (Shaheen & Cohen, 2017).

Albino, Berardi and Dangelico (2015) trace the use of the term smart city for the first time in the 90s, related to the employment of new ICTs. This concept has become popular in scientific literature and in international politics, where it is recognized that cities are key elements for the future, due to their role in social and economic aspects, but the serious impact that they have generated on the environment is also acknowledged. This poor environmental performance is one of the pillars that support the arguments for smart growth, so that cities develop new ways to meet these challenges. In this sense, the concept of smart city is not limited only to the application of technologies in the cities, but it takes it to other areas, which has created confusion among public policy makers seeking to make their cities smarter.

According to Peter Hall and Kathy Pain (cited in Castells, 2010), in the knowledge economy “advanced or specialized” services are the dynamo of urban growth, wealth and power, and it is one of the reasons that explain the phenomenon of metropolitan concentration. These types of services are mainly concentrated in the urban centrality and in well-connected areas. In other words, the phenomenon of intra-urban inequality is present in both developed and developing economies, this regarding who can take advantage of the services and the knowledge economy.

A New Transdisciplinary Urban Science

After a literature review on smart cities, other apparently related concepts and disciplines appear, such as city science, urban science, computer science or urban analytics, among others. This is noteworthy, as it indicates that there is no consensus in the definition of smart cities, and neither is there a conceptual framework for these new meanings. However, the following examination will attempt to make an initial approach and to establish distinctions with respect to what is referred to as the smart city.

In the City Science perspective, cities are considered as complex systems of systems which are not predictable and which are based on the understanding of these systems of networks and flows that interact with the objects within them (Siller, 2015). To study the city, other sciences are required, such as social physics, urban economics, transport theory, and urban geography. Additionally, the analysis relies on technological tools such as simulation methods to predict interactions between variables and flows, and thereby help in future decision-making concerning the cities (Batty, 2013).

One of the distinctions made by the proponents of city science with respect to the conceptualization of the smart city, is that in the use of technological and information tools it is attempted to understand the needs and habitual dynamics of the population, thereby identifying urban issues to generate impact simulation instruments that help consensus decision-making, involving more actors (e.g., citizens), and contributing to achieve more humane cities.

The science of the city is proposed as a structural construction towards the transdisciplinary vision to understand urban phenomena as a complex object, as is the case of the city (Gómez et.al, 2019). It is about shifting from an interdisciplinary quality, in which a group of disciplines or disciplinary approaches participate, towards a trans-disciplinary fusion, due to the hybrid character of the disciplinary framework that makes up the science of cities (Wilson 2012, Batty, 2013, cited in Gómez et.al, 2019). This encompasses from the theories that build the complexity paradigm (chaos theory, systems theory, among others) to recognized disciplines such as social physics, urban economics, urban sociology, among others (Batty, 2013).

This conception of the city as a complex system is consistent with the interdisciplinary approach of the socio-eco-technological systems (SETs) (McPhearson et al, 2016; Van der Leer et al, 2019, cited in Gómez et.al, 2019). In this approach, the social subsystem encompasses the economic, political, cultural, and biosocial socio-systems, whose components are fundamentally individuals or human organizations related to each other and to the other subsystems through actions, interactions, and transactions. The ecological-territorial subsystem, in turn, includes natural systems that act in two ways, since they function as a territorial support or hinterland of the other subsystems, enabling conditions for their production and reproduction, and at the same time they are intervened by social agents. And the third, the techno-infrastructural subsystem, or the collection of systems made up of human agents and devices (transport systems, energy generation and distribution, urban management and governance, equipment, etc.) that mediates between the previous subsystems in terms of transformation (production, manufacturing or execution of processes) or control, such as organization, management and regulation of processes and systems.

Consequently, the city science promotes the scientific interdisciplinarity destined to the generation and application of knowledge along with the technological interdisciplinarity destined for cognitive interventions; that is, it involves both the hybridization of disciplines directed to basic and applied research, and the fusion of technological disciplines oriented to the design of systems and processes, among which urban administration stands out (Gómez, et al. 2019).

Although some similarities and differences are perceived in the different definitions of concepts, the proponents of the new city science make some distinctions with respect to smart cities, to direct this approach towards the study of urban issues as network systems and interconnected flows (Batty, 2013). However, what the proponents of smart cities and the city science agree on, is that both approaches seek to improve the conditions of habitability in the city in a more efficient way. That is, improvements in infrastructure, provision of services, mobility, even the production of more inclusive societies.

Among the applied research centers in the city science field (also called urban science or smart city science) where new technologies for spatial and urban analysis are being developed, the following stand out:

- The City Science research group of the Massachusetts Institute of Technology (City Science-MIT Media Lab, formerly called Changing Places Group and successor to the extinct Smart Cities group that operated from 2003-2010). This center is geared towards the research of new models of urban architecture (flexible spaces to live and work) along with the design of personal and autonomous vehicles that better respond to unique individual needs through intelligent personalization. They develop technology intended to understand and respond to human, environmental, and market dynamics. They also work on the development of autonomous and real-time information systems for personal decision-making, as well as interfaces to persuade people to adopt sustainable behaviors. The lines of research address three areas: places to live and work (Changing Places), urban modeling, simulation, and prediction (City Scope) and mobility on demand (PEV-Persuasive Electric Vehicle). This research group has created an international network of collaborations with cities where City Science laboratories have been installed, including, but not limited to: Andorra, Toronto, Hamburg, Shanghai, Taipei, and Aalto. The perspective of this group is to develop collaborations in rapidly growing cities in Latin America, Africa and India in the coming years, where the greatest challenges and impacts of urbanization are expected to occur in the future (City Science, Media Lab, 2019).
- New York University's Center for Urban Science and Progress (CUSP). Established in 2012, CUSP is an interdisciplinary research center which applies the STEM approach in the service of urban communities by employing data-driven solutions and technology for complex urban problems. It is an academic collaboration with New York City that seeks to improve urban services, optimize local government decision-making processes, create smart urban infrastructures, as well as address challenges such as crime, environmental pollution, and public health. The center collects, integrates, and analyzes information (data) from different agencies to understand and improve urban systems and quality of life. CUSP asserts the objective of helping the cities of the world to be more productive, more livable, more equitable and resilient; it also states to oversee the research agenda for the science of cities. The center combines specialists from various disciplines in the areas of physics and natural sciences; computing and data science; social sciences, engineering, and other professional fields such as politics, design, and finance (Center for Urban Science and Progress, 2019).
- The Bartlett Centre for Advanced Spatial Analysis (CASA) of the University College of London. Established in 1995 to lead the development of smart city science, it focuses on the application of computational models, data visualization techniques, innovative sensor technologies, mobile applications, and urban theory linked to urban systems. The researchers of the center carry out spatial analysis, using geographic information systems and other forms of representation of space and time data. They employ a wide range of methods: from social physics to econometrics; along with statistical

models, which go from augmented reality and hyper-local sensing, to crowdsourced data collection. The approach is multidisciplinary, applied to create constructive models, visualize big data, and develop new methods for collecting, analyzing, and communicating information. At CASA, systems theory and complexity sciences constitute the theoretical framework for their investigations; visualization technologies, computational human interaction and data analysis are employed for the development of projects. This center offers solutions to the problems of resource efficiency, planning and effective governance in cities to make them better places to live. CASA involves researchers from different training backgrounds such as architects, geographers, mathematicians, physicists, archaeologists, and computer scientists (The Bartlett Center for Advanced Spatial Analysis, CASA, 2019).

- The Urban Informatics group in the Queensland University of Technology was founded in 2006. In their work they apply various established and novel methods of research with the purpose of identifying challenges and opportunities in urban environments. They are based on sociocultural, economic, ecological, and technological spheres. The group collaborates with different individual actors, communities and organizations from the public, private and social sectors. The objective of their research projects is to study and co-create urban futures that are more livable and equitable, ensuring that the results have an impact on the community. The researchers of the group come from different areas: humanities and social sciences; design, planning and architecture; human-computer interaction, information technology and computer science.
- The Urban Analytics Lab at the National University of Singapore is an interdepartmental and multidisciplinary research group that was established in 2019. They focus on urban analytics, geographic data science, and 3D city modeling. Their projects are linked to the disciplines of architecture, urban planning, and real estate development. For the development of their studies they use infrastructure, geospatial and urban computing technology (geomatics, data standardization, data quality, machine learning and geographic information systems) (Urban Analytics Lab, 2019).
- The Center for Spatial Planning Analytics and Visualization of the Georgia Institute of Technology. This Center, previously called the Center for Geographic Information Systems, has been dedicated to the development of geospatial technologies for nearly 20 years. In it, the researchers seek to create a symbiosis between technology and data management so that public policies build arguments in the decision-making phase to carry it out in an informed way. Their work revolves around various disciplines such as: transportation, urban planning, conservation (land and animals), renewable energy, green areas, and the environment.
- The UN Technology Innovation Labs (UNTILs). They focus on the use of innovative technology to solve some of humanity's most pressing needs, and because they belong to the United Nations, their analyzes are always aligned with the Sustainable Development Goals (SDGs). Each laboratory is based on different humanitarian themes that are central according to the specific location. Currently there are four: Egypt, India, Finland, and Malaysia. Unlike the other research centers of academic constitution listed in this section, these laboratories have been created with the auspices of the

> national governments of each headquarters, which must regulate the participation and collaboration of other actors, such as research centers and private sector entities (some are located in technology and / or business hubs) or startups (United Nations Technology Innovation labs, 2019).

These research centers have in common, to a greater or lesser degree, the development of basic and applied science to urban problems; synergy with other sectors or local actors such as governments, civil society, and industry; as well as interdisciplinarity. Among their objectives is the search for efficiency and equity in cities. However, except for the recent UN laboratories (UNTILs), most of them are located in cities of developed economies where these issues are not comparable to those of the Global South and Latin America in particular.

A Science for Rich Cities or to Alleviate Poverty and Inequality?

One of the arguments that the city science promoters establish is that not only do new technologies and applications revolutionize the way of doing things, facilitate activities and improve the productivity of companies, but they also provide greater social inclusion (Prince & Jolías, 2017). However, are these advantages possible for emerging economies in contexts of scarcity of resources, low educational level of the population, unmet basic needs, insecurity, lack of information, among other concerns?

There is a great digital divide in Mexico, and to bridge it not only are economic resources required, but changes in our institutions are also necessary. These changes seem particularly out of date with the rapid technological transformations taking place worldwide.

In the Mexican Constitution, internet access is established as a right so that all citizens are well informed. In 2013, during the last federal administration, the Connected Mexico government project (in Spanish: México Conectado) was launched specifically to address this constitutional right and guarantee access to broadband internet service. For this purpose, telecommunication networks were established in public places and spaces such as schools, health centers, libraries, community centers or parks at the federal state and municipal levels. In that administration, 101 thousand sites were connected, and in the current government the name of the program is expected to be Internet for All (Government of Mexico, 2019).

Nevertheless, the right of access to the internet is not exercised in an equitable way; access inequality responds to issues of education, income, age, and gender, with these differences being more accentuated in marginalized groups (Merino, 2017). Although there are no data or studies that allow evaluating the strategy of Connected Mexico that sought to reduce the digital divide, the National Survey on Availability and Use of Information Technologies in Households (INEGI, 2019) provides certain guidelines which indicate that these digital inequalities are still considerable, although progress has been made towards reducing them.

In recent years, the world average of people with internet access went from 10% in 2000 to 50% in 2015, and Mexico was below the world average until 2013, when it reached a 43.5% user penetration rate. Merino (2017) concludes that between 2010 and 2015 there was an increase in users and connected homes; however, places with less internet access have yet to see this situation improved. There continues to be great inequity in internet access and therefore knowledge, reflecting the country's economic inequality (Merino, 2017).

This condition of inequality is related to the urban change that is intertwined with neoliberal, cognitive, and cultural change (Scott, 2011). In the global, neoliberal city, there is a re-stratification of the working classes: on the one hand, a pole integrated by the analytical and creative class, and on the other, a pole made up of a subclass of low-wage service workers who perform informal and often undervalued activities, such as maintenance and housework; the number of the latter is increasing. Therefore, there is a contradiction in what the creative city theory pursues: tolerance and redistribution of income, which in practice does not occur (Scott, 2014). On the contrary, there are authors who affirm that there is a risk that, since there are no mechanisms for governments to invest in advanced technology that meets the needs of urban growth and its socioeconomic aspects at the city scale, then technology would be a intensifier of social inequalities, remaining accessible only to the most advantaged sectors of the population (Thakuriah et al. 2017: 7).

Technological Tools for Urban Analysis

As mentioned before, ICT and the Internet of Things (IoT) have been incorporated in all areas of daily life in recent decades, and they are present in a large part of economic and social activities. In some contexts, not only have processes or user experience been improved, but activities themselves have been completely modified. Artificial intelligence, robotics and big data also have several applications in the areas of medicine, mobility (e.g., electric and autonomous vehicles), education, agriculture, and 3D printing. This has been called the 4th Revolution or the Exponential Era, and many industries are expected to be transformed or to disappear in the next 5-10 years, due to the speed and magnitude of the changes generated and to come -among the dissolved companies is Kodak, as a consequence of the emergence of digital cameras. Furthermore, new business models have appeared, such as Uber and Airbnb, which are developed from a software which unites all the processes of the activity, but the company that controls them does not invest in vehicles or properties (Gollub, 2016).

In the area of mobility and transportation, research on human behavior, and the relationship between these behaviors or patterns are affected by individual conditions. This research has been carried out in the last four decades, due to the interest in predicting the future demand of large investment projects in transportation. For that purpose, instruments have been used to collect information, such as travel surveys (Origin-Destination surveys or O-D) that can be accompanied by GPS applications. These types of surveys depend on active user participation, and therefore are limited, expensive, and with relatively small samples (Chen, et al. 2016). The rapid development of mobility technologies and mobile devices has generated a large amount of ‘passive’ information, since the user generates it involuntarily, simply by means of their cell phone, or without intending to use it for utilitarian purposes of inquiry. This information called big data is collected through social networks input (Facebook, Twitter, WhatsApp); cell phones; smart cards for public transportation; route planners, and traffic data such as Google Maps, TomTom, My Drive or Waze. These applications allow users to calculate travel times and routes through a Global Positioning System. Often, to describe mobility, data from bank cards and other sensors and devices are also employed. There are some applications with greater contribution potential due to the type of information they collect; for example, the information from taxis show patterns of drivers, rather than of users; smart cards yield data on the use of transport modes, and the use of cell phones provides greater precision of spatial and temporal information than that of the social networks (Chen, et al, 2016; IDB, 2019).

Big data provides information for better planning, and therefore represents a particularly important input to improve transportation infrastructure and services. It can help analyze different travel behaviors, among which gender issues stand out (e.g., how women move in transport, issues of insecurity, harassment, lack of access) which are identified and can be improved. The availability of the data helps understand how users move and thus assists in making conscious decisions on more efficient mobility systems (IDB, 2019).

Digital intelligence provides real-time information for decision-making, which saves time and costs. It has recently started to be applied to informal settlements, where official institutions do not collect information. Consequently, digital intelligence is an innovative tool of which users are a central part of the system, as they are the generators of information inputs (IDB, 2019). The lack of data on informal settlements has been a problem in Mexico for many years, since the Institute of Statistics, Geography and Informatics (INEGI, in its Spanish acronym) does not record the housing and land uses that take place on uneven ground, which is incomprehensible for a country in which it is considered that about 50% of the urban area of the country has been developed from irregular settlements.

Hence, technological trends focus on the use of artificial intelligence; robotics is used in manufacturing processes and other activities such as agriculture or housework; big data allows to assume trends, make decisions or develop policies in the public and private sectors; the IoT is present in everything we do, because objects can be interconnected with each other through sensors and machines that generate all kinds of information to measure, monitor or operate devices remotely, as it is happening with autonomous vehicles, which will play a leading role in the transport of individuals and goods, as well as in the occupation of public space. Among the expected impacts of their use is the decrease in accidents and the consequent transformation of insurance businesses. Another substantial change is taking place in energy systems, which will allow, for example, the desalination of water at significantly low costs and the virtualization of many services such as education, commerce and even currency. These technological changes can transform the economic and social models of today (Prince and Jolías, 2017).

The evolution of technology is manifested in the activities of people's daily lives, with alterations that generate welfare. However, these changes -certainly increasingly rapid, are not assimilated by vulnerable groups because, since they have limited resources, they cannot adapt to and benefit from them; which means that far from improving the comprehensive situation of a community, they intensify existing inequalities. Consequently, it is necessary to build public policies that allow these vulnerable groups to improve their conditions and thus move to the next phases, reducing the prevailing inequality gaps.

Concluding remarks

City science as a new discipline needs to establish a common theoretical framework at an international level which avoids generating different interpretations and misunderstandings in its conception as a socio-ecological-technological transdiscipline. It must be distinguished from other concepts and fields with which it is related: smart cities, urban science, urban analytics, and urban computing.

The most influential schools of thought are situated in cities of developed countries, and although they have produced studies about their developing counterparts, their work is focused on their countries of origin. The MIT City Science research group and CASA stand out for their achievements, under the leadership of Kent Larson (formerly of William Mitchell) and of Michael Batty, respectively.

In the research centers reviewed in this study, the discourse on the use of technology to achieve more equitable cities is observed as a constant. Nevertheless, there is scarce evidence on concrete applications to address the most pressing problems of urbanization in Mexican cities, this, in part, because these centers are located in countries with developed economies which feature different issues from the ones afflicting cities of emerging economies.

In Latin America and the Global South in general, there are still few examples of public policy programs that apply technology for the analysis and resolution of population issues; for the most part they focus on surveillance (cameras in public spaces) and on obtaining biometric data for the registration of people (e.g., voter credentials from the National Electoral Institute in Mexico), but there are few palpable efforts to improve the quality of life of the communities. The latter should be the orientation of city science research projects in the region.

In summary, the challenge of technological change in the context of developing economies is linked to regulatory and institutional transformations. It involves new business models and public policies that generate incentives for technological development and its equitable access by the different population groups. In this regard, three challenges are presented for the development of a city science in Latin American cities: to generate a theoretical framework of reference for city science in the region, to utilize the limited resources existing in the cities in an efficient manner, and to dedicate technology to a different use from that which the state has destined it to: surveillance and control of the citizens.

The current pandemic caused by COVID-19 is demonstrating how adaptation to new ways of life and work through the use of technology is relatively easier for certain socioeconomic groups in the population, and how, in contrast, it is affecting more vulnerable groups that are intrinsically more at risk in health and financial matters (Bergamini, 2020).

We have approximately 70 thousand years of inhabiting the earth and of conceiving ourselves as cognitive beings, but this quality does not make us better than our primate ancestors; we have reached exponential degrees of technological development, which leave us one step away from creating beings that are potentially more intelligent than us; however, we have not helped ourselves towards achieving a society that is more equitable and more respectful of our environment. It is time that we accomplish it through technology, through the science of the city.

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