Industrial Revolution 4.0: Reconnaissance of Opportunities and Challenges for Smart Sustainable Cities

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Abstract

New technologies usually replace many of the technologies known to humankind. Today, humanity is experiencing the fourth industrial revolution, i.e., 4IR, where the boundaries between biological, digital, and physical technologies are blurring. The previous industrial revolutions brought opportunities and costs. The paper examines the expected outcomes of 4IR on the city and the means to benefit from 4IR technologies in city planning. The research methodology is mixed, using the symphony metaphor and conducting bibliometric analysis. The researchers interrogated the literature landscape about 4IR to outline the substantial opportunities and potential impacts. They conducted a bibliometric analysis of the contemporary academic discourse linking 4IR to metropolitan areas. Preliminary synthesis shows a growing trend in the total number of documents per year since 2016—the connection between 4IR and the city focus on the smart city. The 4IR technologies could help make smart sustainable cities a reality and avert any harmful outcomes. Planning and architectural education must align their curricula to use these novel technologies by equipping graduates with the competencies to face a changing world and capitalize on opportunities.

Keywords: Bibliometric analysis; Innovation, Urban planning; Smart city.

Introduction

In his book titled *Future Shock*, published in 1970, the futurist Alvin Toffler projected that those new technologies would replace many of the technologies known to humankind. He predicted that Information and Communication Technologies (ICT) would transform the ‘Ad-hocracy’ globe into a ‘free-form world’ characterized by a dynamic organization (Toffler, 1970). A decade later, Toffler published his second book titled *The Third Wave*. He analyzed a wide range of issues, including the whirling economy, the electronic cottage, the break of the state, and the shift from the outdated politics to contemporary democracy of the twenty-first century—it is the third wave of changing the history of humanity (Toffler, 1980).

The first industrial revolution began with the discovery of the steam engine in 1760. Coal was the primary energy source; textile and steel were the dominant industries and trains for transportation. The second industrial revolution continued until 1990. The significant characteristic of the second industrial revolution was inventing the internal combustion engine. Petroleum and electricity dominated energy sources, and vehicles and trains emerged as the principal modes of transportation. The third industrial revolution began in 1960 using nuclear energy and natural gas. The most notable advances were in computers and robots, while aircraft and automobiles dominated the mode of transportation. In 2016, Klaus Schwab noticed a fourth new wave, which he coined the Fourth Industrial Revolution (4IR). It synthesizes technologies and their interaction, thus blurring the boundaries between the biological, digital, and physical domains (Schwab, 2016a, 2016b). In 2000, 4IR appeared to associate with new technologies, such as Big Data, the Internet of Things (IoT), 3D printing machines, and genetic engineering. The development of green energies became a priority to face environmental crises, and electric along with bullet trains complement other transport modes (Xu et al., 2018). Figure 1 portrays the timeline and characteristics of the 4IR that humanity experienced in the past centuries.

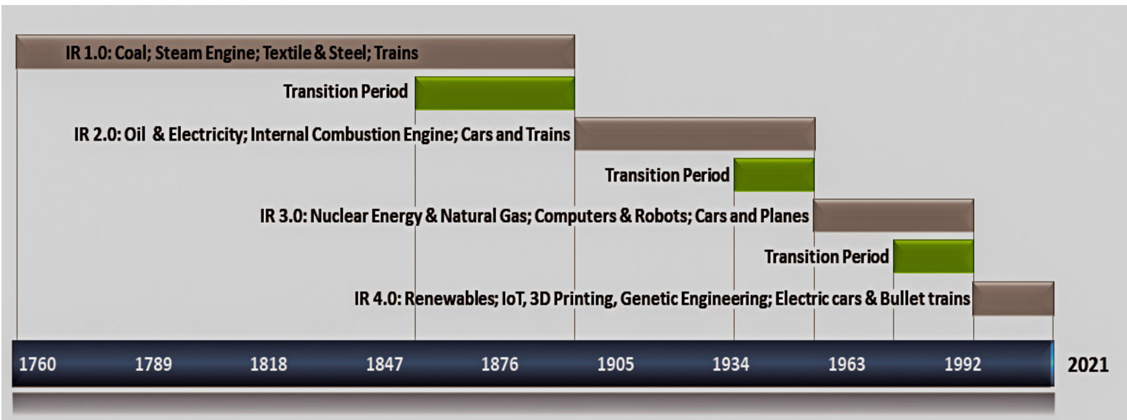

Figure 1. Timeline representing the characteristics of the four industrial revolutions (Source: The Authors)

The interplay of political, economic, social, and institutional forces results in the built environment, requiring new urban planning and architectural theories. Each wave produces a new civilization accompanied by economic structures, ethics, political mindsets, and lifestyles. The 4IR, also known as Industry 4.0, is changing almost every aspect of life differently (Skilton and Hovsepian 2017). With the first industrial revolution, new building materials, such as steel, were available to architects and engineers to construct monumental buildings, such as skyscrapers. However, the first industrial revolution came with social and urban ills that led to the garden city movement in Britain (Howard, 1902) and the city beautiful in the USA (Foglesong, 2016). The second industrial revolution sped up the modernization of the capitalist society, thus leading to suburbanization, social injustice, and the city center's decay (Dear & Scott, 1981; Harvey, 1973). With the third industrial revolution, cities of the post-industrial period lost their manufacturing bases as production plants moved to cities of the developing countries (Scott, 2011). The decay of downtown, environmental crises as degraded air quality, and the outbreak of crime are among the outcomes of the third industrial revolution (Adesina, 2005; Lake, 1999).

Planning theory is integrally a component of the community's collective thinking regarding public matters. "Without theory, good planning is simply a random occurrence"

(Beauregard, 1995). The past three industrial revolutions had both positive and negative impacts on the city. Looking ahead is amongst the roles of scientific research; thus, the paper attempts to shed light on the consequences of 4IR on metropolitan areas; and how can 4IR technologies be of use for urban planning and sustainable urban development.

The authors examined the contemporary literature to answer these questions, mainly that most of the population lives in urban areas. The city is at the center of two crises: the COVID-19 pandemic and the quest for social justice. It was, therefore, crucial to respond to these questions. Scholars must think proactively and investigate recent developments in the planning theory.

Popkova et al. (2019) classified contemporary literature on 4IR into four groups. The first is the socio-oriented cluster, and it addresses the positive and negative manifestations of 4IR in modern society. For example, the newly provided goods will enhance people's living standards and lead to unemployment. The competency-based group of literature is the second, and it envisages the need for a specialist with new competencies, knowledge, and capability to use new information and technologies. Automation of processes is the third cluster known as the production process group. The behaviorist cluster stresses the transition from a human-object relation into an object-object interaction. In our opinion, these four groups of literature are not in competition; instead, they are complements. 4IR, as a phenomenon, cannot be viewed from a single perspective. An integrated, holistic view is a necessity, which the authors attempt to offer, to capture the opportunities that 4IR avails and avoid negative impacts.

The 4IR technologies offer substantial opportunities that encompass a wide range of fields. Technology can increase productivity from five to eight percent in the next five to ten years, generate new jobs, and replace manual work with robots. 4IR technologies can improve social media platforms to learn, connect, and exchange information. Competition and easy access to digital marketing platforms will improve the quality and price of services and goods, and consumers will be more engaged in production and distribution chains. The challenges that require attention include (a) income inequality and disruption of labor markets; (b) reshaping industries, business, and service sectors; (c) privacy issues; (d) cybersecurity; and (e) ethical predicaments (Dimitrieska et al., 2018; Xu et al., 2018).

The 4IR can exacerbate existing environmental threats or create unknown risks related to climate and environment, people and society, economy, and governance. However, the technological innovations, such as 3D printing, advanced materials, artificial intelligence (AI), biotechnology, blockchain, drones and autonomous vehicles, energy capture, IoT, robots, virtual, augmented, and mixed realities, can deliver sustainability in emerging cities (World Economic Forum, 2017).

The effects of 4IR on cultural heritage are double-edged. The positive effects include the production of virtual tours, enabling the broad public to access the cultural heritage of specific sites and museum exhibitions. The 4IR provides digital archives useful for remodeling, conserving, enhaning, and other various purposes (Balletti & Ballarin, 2019). For example, following the devastating fire that damaged Notre-Dame Cathedral in April 2019, a construction company specialized in 3D printing proposed rebuilding the cathedral by scanning stone vaults already available on the Internet and print replacements to restore the famous building (Gorman, 2019).

Most scholars and specialists who elaborated most of the literature on 4IR technologies in urban settings are in the fields of management, communications, information, and computers. They offer the 'smart city' solution to contemporary urban problems (Kim, 2018). There is no common description of what makes up a smart city (El-Kholei & Yassine, 2019). For some scholars, it is a digital city. To others, it is a city "whose economy and governance is being driven by innovation, creativity, and entrepreneurship, enacted by smart people" (Kitchin, 2014). In another instance, some researchers focus on the possibility of using these new technologies to solve an urban issue, such as crime and efficient provision of municipal services, using 4IR technologies, for instance, Big Data and IoT (Batty, 2012, 2013; Borins, 2006; Brech et al., 2011; Kourtit & Nijkamp, 2018; Siano et al., 2018; Suma et al., 2018).

The rise of new technologies might enable scholars and practitioners to address contemporary developments, such as a pandemic. It is crucial to interrogate the landscape of literature about 4IR to enhance the ability of design professionals to cope with new realities. These novel theories must address the use of the 4IR technologies in the planning process and avert any harmful outcomes.

MATERIAL AND METHODS

1. Data source

The authors chose Scopus as the database for bibliometric data. They selected query wordings, Boolean operators, and the year range of publications to enter the analysis. The authors searched for all publications with the 'industry 4.0' 'OR' 'fourth industrial revolution' OR 'I4.0' OR 4IR' OR 'I4' in titles, abstracts, or keywords. They checked the titles, abstracts, and keywords to include 297,188 publications in the Scopus database in the analysis. They then limited the previous document results to the publications with city/cities in their titles, abstracts, or keywords. In September 2019, the authors found and retrieved 92 publications. that Annex 1 exhibits.

2. Research strategy

The present research is a mixed study using the symphony metaphor that Seidel (1998) developed for qualitative data analysis, including Noticing things, Collecting things, and Thinking about things (NCT). For quantitative analysis, the authors used VOSviewer, a specialized bibliometric analysis application that van Eck and Waltman (2014, 2020) developed.

2.1. Used software

The application generates the co-occurrence networks using natural language processing. It refers to multiple phrasing occurrences or information described in document attributes such as the title, abstract, or author keywords. To illustrate bibliometric linkages among authors, documents, and cited references, VOSviewer may also generate co-authorship, bibliographic coupling, and co-citation networks. The foundation of VOS mapping is the generation of association normalization similarity matrices. For a network of n nodes, $s_{ij} \in S$ signifies the similarity or association strength of nodes i and j in a network of n nodes using Equation 1 (van Eck & Waltman, 2014, 2020; Yan et al., 2021).

Equation 1

$$S_{ij} = \frac{2mc_{ij}}{S_i S_j}, \forall\, i, j - 1, 2, \ldots, n$$

where m is the total number of links in the network, $c_j \in C$ is the number of links, such as co-occurrence links or co-citation links between nodes i and j, and s_i is the total number of links to node i. After constructing the similarity matrix, VOS mapping uses distance-based mappings to locate node i in a p-dimensional map (typically p = 2), Equation 2. On the other hand, VOS clustering conducts clustering analysis by a maximizing method comparable to modularity-based clustering (van Eck & Waltman, 2014, 2020; Yan et al., 2021).

Equation 2

$$V(c1, \dots, c_n) = \frac{1}{2m} \sum_{i<j} \delta(c_{,} c_j)\, w_{ij} \left(c_{ij} - \gamma \frac{c_i c_j}{2m}\right)$$

where c_i is the cluster of the i^{th} node, the result of $\delta(c_i, c_j)$ is a perfect one if $c_i = c_j$ or zero otherwise, and γ is the clustering resolution (van Eck & Waltman, 2014, 2020; Yan et al., 2021).

2.2. Conducting the analysis

After running the application on the data, the authors applied the NCT framework for interrogating qualitative data that Seidel (1998) recommended. To notice things, the authors examined the documents and wrote their observations in notes, plus coding the data. They used two counting methods according to the occurrences attribute. The first is the full counting method, i.e., the number of occurrences of each term in all documents. The second is a binary counting method, where the occurrences attribute is several documents in which a term occurs at least once. In the full counting method, setting the threshold minimum number of occurrences was ten times. We aimed to notice the research areas in 4IR relevant to city planning. The analysis shows that the term “smart city” is a specific topic per se based on its relatively high relevance score. The term/noun phrase with a high relevance score means more specialized, whereas the term/noun phrase with a low relevance value is quite general (van Eck & Waltman, 2014).

Next is to collect things by sorting the bits and pieces of information. The step was possible by interpreting the results of the bibliometric analysis of the contemporary academic discourse associating 4IR to the city, in other words, interpreting the results of the cluster analysis mentioned earlier. The bibliometric analysis is “a statistical evaluation of published scientific articles, books, or the chapters of a book. It is an effectual way to measure the influence of publication in the scientific community” (Iftikhar et al., 2019) research funding institutions, and practitioners. It shows the scholar’s research areas, the citation network, and the paper content, amongst other matters (Lim & Buntine, 2016).

Thinking about things is the third stage. The objectives of this step are to (a) make sense of each collection, (b) explore patterns and relationships both within and between the clusters, and (c) make general findings of the literature the authors examined. The authors performed a holistic investigation to summarize the research outputs in 4IR and smart city published in Scopus.

Results

1. Trend and type of publications

Preliminary synthesis suggests a growing trend in the total number of documents per year since 2016. In the past four years, there have been two publications in 2016, eleven in 2017, twenty-eight in 2018, and forty publications in 2019, Figure 2. The main three document types are articles (44.6 percent), conference papers (34.8 percent), and book chapters (10.9 percent), Figure 3.

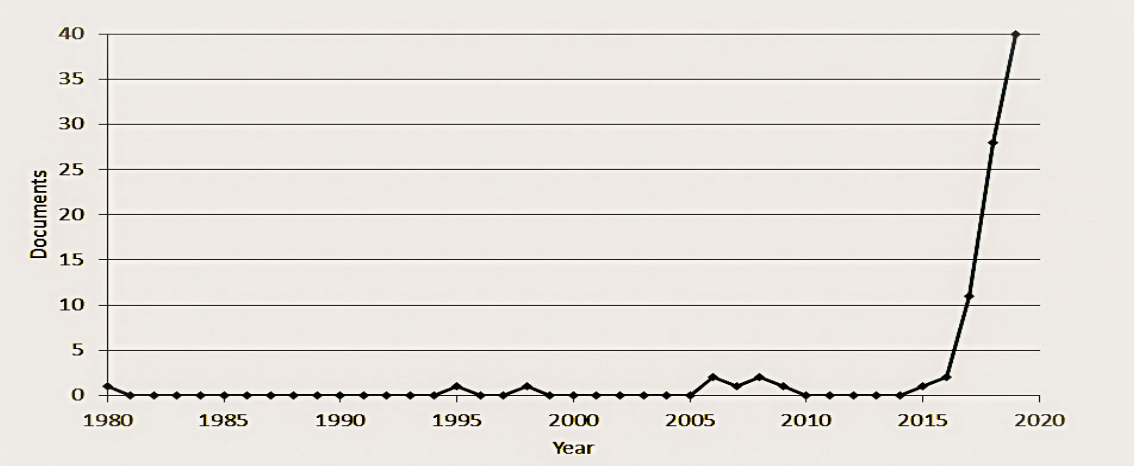

Figure 2 Trend analysis of documents examining 4IR development, 1980-2019, (Source: The Authors).

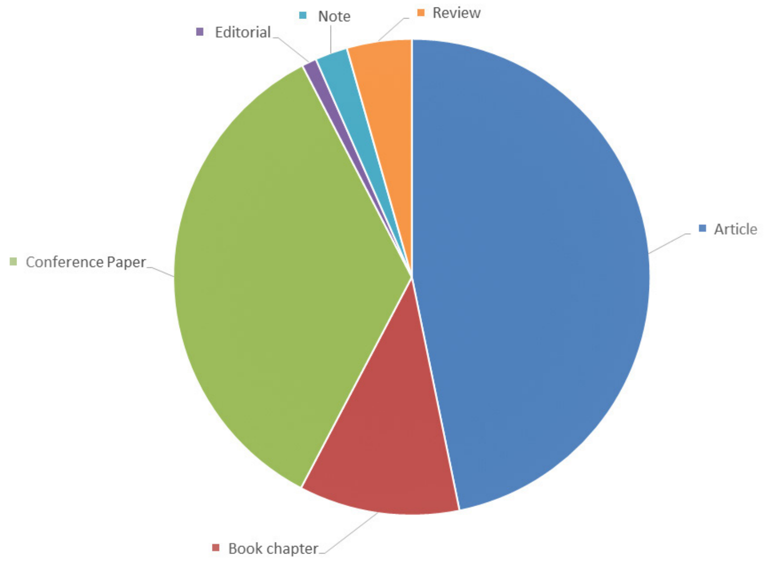

Figure 3. Documents examining 4IR development, 1980-2019, indexed in Scopus classified by publication type (Source: The Authors).

VOSviewer identified 74 terms out of 3,654 terms. It calculated the Relevance Score for the 74 terms and selected 60 percent of the most relevant terms. The total number of verified items was 44 representing the most common terms used in the literature. VOSviewer Network Visualization technique classified the 44 terms into four clusters, as shown in Figure 4.

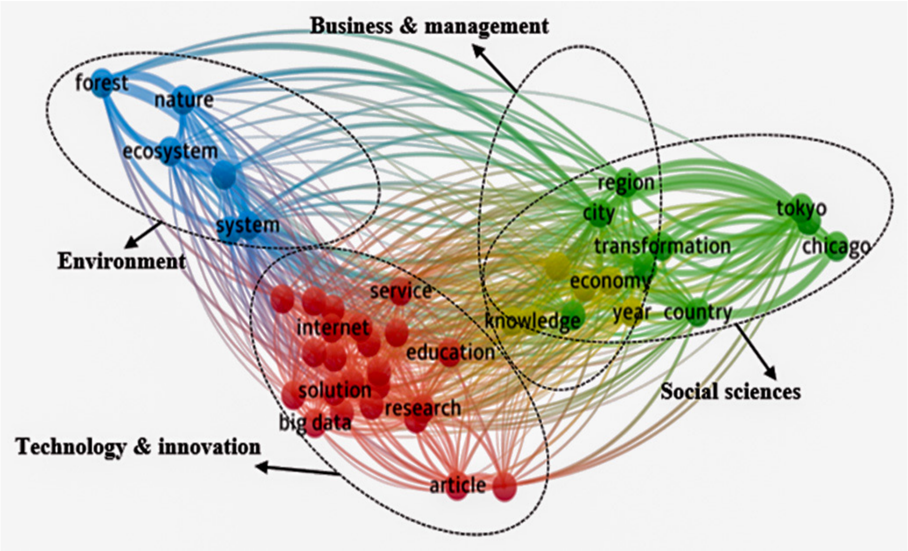

Figure 4. Network visualization of most frequent terms using full counting method constructed via VOSviewer, N = 92, f (frequency) ≥ 10).

The first cluster (in red) in the lower-left area includes 23 items. They represent literature on technology and innovation. Nine items constitute the second cluster, which is in green, representing social sciences. On the upper left corner, i.e., the blue cluster is the third group of documents. They represent environmental sciences. Finally, the yellow cluster (cluster 4) focuses on business and management (six items).

The visualization shows an association between social sciences on the one hand, and business and management, and technology and innovation on the other. It also shows distant linkages between environmental sciences and the other three clusters, suggesting the need to pay attention to the environmental dimension and use 4IR technologies to resolve environmental issues, which could be possible once the circular economy concepts gain acceptance and momentum.

2. Binary counting

The binary counting method identified 38 out of 3,654 keywords, selecting 60 percent of the most relevant keywords. The authors discarded two irrelative keywords, i.e., paper and era. Table 1 presents the remaining 21 relevant terms in the domain of interest.

Table 1. Frequently used terms in the 4IR literature using the binary counting method.

Keywords	(Occ)	(RS)	Cluster
Fourth Industrial Revolution	67	0.3563	1
Issue	14	0.4650	1
Data	25	0.5083	1
Concept	12	0.5391	1
Business	10	0.6426	1
Internet	21	0.7504	1
Smart City	19	0.8084	1
Thing	17	0.9715	1
IoT	16	1.0496	1

Keywords	(Occ)	(RS)	Cluster
Information	15	1.1692	1
Application	15	1.8490	1
City	25	0.3989	2
Innovation	14	0.5542	2
Challenge	20	0.8013	2
Time	12	0.8610	2
World	20	0.9309	2
Economy	18	1.2108	2
Person	15	1.4558	2
Role	20	1.5888	2
Industrial Revolution	20	2.0168	2
Country	17	2.0722	2

Note : (Occ) = Occurrence, (RS) = Relevance Score

Source: The Authors

The Network Visualization technique produced a keyword map, Figure 5. The nodes are the 21 terms harvested from titles and abstracts of the publications. Their size signifies the frequency of occurrence, and the distance between them indicates their relatedness. The application assigned the relatively close terms into two clusters. The red cluster, i.e., cluster 1, includes 11 items, while the green cluster, i.e., cluster 2, includes ten items.

The result suggests that the 4IR in cluster 1 is the most frequent term, with 64 occurrences at the center of the map. However, its low relevance score (RS=0.36) reveals a moderate relationship to various topics. Similarly, the term city has the highest number of occurrences in cluster 2, reaching 25; the word city is broad and has a modest association with other topics. The relevance score mounted to 0.40. Finally, smart city has a high relevance score reaching 0.8, indicating that smart city is a specific topic that the examined literature covers. The visualization map exhibits the association between smart city and 4IR, primarily with more minor terms set.

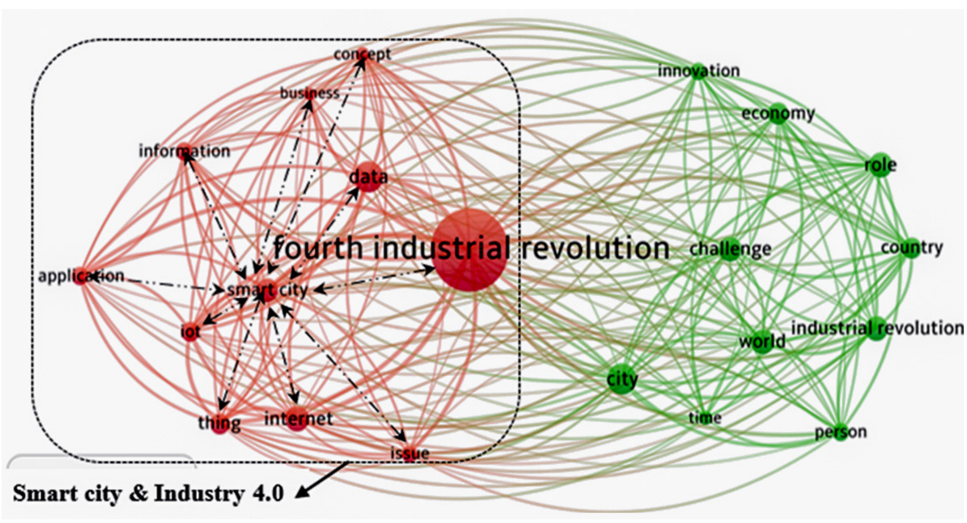

Figure 5. Network visualization of most frequent terms using binary counting method constructed via VOSviewer, N = 92, f (frequency) ≥ 10).

The bibliometric analysis reveals a growing interest in the field of 4IR. There is little attention to the connection between 4IR and the city at large. Out of 297,188 publications indexed in Scopus, only 92 publications address city/cities in their title, abstracts, or keywords, of which 61 were published between 2016 and 2019. Most of them were articles and conference papers representing 44.6 and 34.8 percent, respectively. The remaining are books and book sections. Using two counting methods and setting the threshold to ten times depict terms related to subject areas (i.e., technology and innovation, social sciences, environment, and business and management). The 4IR is a general topic, and its co-occurrence with other terms/noun phrases follows a random pattern. A smart city is a more specific topic that co-occurs primarily with more minor terms set. The finding also points to the lack of research addressing the effects of 4IR on city planning while highlighting its relatedness to smart cities.

Discussion

The results from the bibliometric analysis signify an increased number of publications examining 4IR in the past five years. There is little participation from Arab scholars, and most of the published research focuses on technology and innovation. Results suggest four clusters of concepts: (a) technology and innovation; (b) social sciences; (c) environment; and (d) business and management.

Few researchers examined the linkages between 4IR and city planning. The 4IR research related to the built environment focuses on smart cities, including blockchain technology, Big Data, and AI. Blockchain helps generate data regarding land uses, ownership, and subdivision, providing planners with up-to-date and timely information needed for decision-making. Blockchain is essential for buyers and sellers in real estate markets, as it is an assurance against informality and fraud. The information the blockchain technology generates will enhance levels of providing social services and physical infrastructures.

Big data are exceptionally sizeable data sets that, once examined computationally, uncover forms, trends, and relationships, particularly concerning human conduct and communications. Coupled with spatial information that remote sensing technologies, such as data cube, provide planners with time-series multi-dimensional that enables detecting land uses and land changes, Big Data can revolutionize the sphere of urban planning methods and models. Big data will minimize the time needed for problem definition and enhance scenario building.

Machines programmed to think like humans in action, i.e., AI, are essential in managing the city. AI applies in transportation, managing water resources, managing wastes, and other physical infrastructures, and AI applications are in education and health care services. Both Big Data and AI will improve planners' capacities to reduce disaster risk through improved Early Warning Systems. The 4IR technologies enable planners to elaborate and implement procedures for prevention, thus minimizing risks that emerge because of the susceptibility and exposure of the city (El-Kholei, 2019).

Undoubtedly, the 4IR technologies will change the geography of production and patterns of consumption. However, 4IR technologies will not solve social, spatial, and environmental injustice, and technology cannot solve racism, for example. Surveillance of public spaces could change the function of these urban areas as venues for demonstrations where protesters can express their demands.

As former industrial revolutions, 4IR technologies also bring issues about ethics. Peters

(2017) provided a genealogy of the concept of technological determinism besides a meta critique of how academic accusations of fallacy risk putting difficult but necessary types of inquiry on hold. To consider someone as a technological determinist is to claim all moral authority on your side while failing to address the question of what we should do with these devices that infest our lives.

Our analysis shows that scholars regard theories of the social construction of technology (SCOT) and the theory of technological paradigms (TTP) as opposing, if not incompatible, perspectives on technological change. However, when scholars use SCOT and TTP as complementary analytical tools, it is easier for them to understand and design innovation processes in which different stakeholders contribute most productively (Olsen & Engen, 2007) to producing a sustainable urban settlement.

The growing use of 4IR technologies will affect both planning and architectural education. 4IR technologies are drivers remaking how design professionals think, work, learn, and organize in society. These technologies will completely transform how they live and work, directly affecting how they build the contemporary city and the entire urban system.

4IR technologies depend on the exhaustive usage of cyber-physical solutions and internet-based technologies. Architectural and planning education in the coming years must align with these exponential technologies bearing in mind social and environmental realities because technologies transform social, economic, ecological, and cultural settings. Architects and planners of the future depend today on the quality of education to equip them with the skills and competencies to face a changing world, where skills are more important than a certificate.

Architectural and planning education must include elements of transition in their curricula. Learning traditions are valuable for understanding learning in sustainable transitions, and they are relevant for facilitating learning. The chosen learning traditions from various disciplinary backgrounds provide insightful information, but very few of them do an excellent job of addressing the complexities of transitions. They do, however, encompass a wide range of essential learning settings. These traditions help investigate new areas, such as learning in socio-technical regimes (van Mierlo & Beers, 2020).

Conclusion

The rise of 4IR technologies provides opportunities for better urban planning. The 4IR technologies are especially relevant to the development of sustainable cities. Many technologies are already showing promise in reshaping urban sectors, such as transportation, energy, waste, water, and buildings, and the pace of change will only pick up. When combined with new business models, cities can use these cutting-edge technologies to boost urban economic productivity, reduce environmental impact, and enhance well-being. The 4IR, on the other hand, poses its own set of risks. Cities must invest in enabling technological infrastructure and skills to avoid falling behind, thus mitigating the 4IR's unintended negative consequences.

Today, the contemporary city faces several challenges, notably the COVID-19 pandemic. It has had devastating impacts on our world, but they are not all negative. When confronted with the reality of everything being remote, from work to entertainment to education to connecting with friends and more, the technologies driving the 4IR provided solutions to maintain some semblance of normalcy in business and life.

The 4IR brings its own set of challenges, particularly in terms of social justice and legal protection for people.It necessitates that we be human and humane, knowledgeable and adept at seeking new knowledge, capable of making connections and seeing them within a complex network of digital sources. The 4IR entails new labor risks, such as the remake of existing jobs, the destruction of many of them, and the relocation of countless others. We expect it to cause fundamental socioeconomic transformations all over the world. The 4IR can cause extensive social challenges, tensions, and the erosion of specific values. The intense exposure to mass communications integrated knowledge systems, and digital marketing is likely to obliterate any sense of personal or communal privacy. The greatest social challenge is the elevated risk of cybercrime as a consequence of enhanced connectivity.

Another negative impact of the 4IR is climate change. Massive industrialization, rapid technological development, increased urbanization, deforestation, resource depletion, desertification, rapid population growth, water scarcity, and food insecurity are among the negative impacts of the 4IR. The 4IR technologies, however, might enable energy monitoring applications, which improve energy efficiency and reduce carbon emissions. Energy savings positively impact firm productivity and will curb the harmful GreenHouse Gases that contribute to climate change.

The literature falls into four distinct clusters. The first focuses on the positive and negative signs of 4IR technologies. The second foresees the necessity for an expert who has new competencies, knowledge, and the ability to use new information and technologies. The third represents the automation of procedures in the production of goods and services. The last group focuses on replacing the human-object interrelation with an object-object interaction system.

Results from the bibliometric analysis show a growing trend in 4IR in 2016. Most of the published research focuses on technology and innovation; however, there is little attention to the connection between 4IR and the city. The few 4IR research related to the built environment focuses on smart cities, such as AI and Big Data.

Indeed, the 4IR technologies will change the geography of production and patterns of consumption. 4IR technologies will transform the planning process, enabling the generation and dissemination of information, thus providing planners with tools for better problem definition, alternative valuation, monitoring, verification, and evaluation. These technologies will not resolve forms of social and environmental injustices that result from imperfect institutional frameworks. In fact, within imperfect institutional frameworks, technologies might complicate issues regarding social and environmental injustice.

4IR technologies are transforming the way people live. Both architectural and planning education must respond and prepare students to be ready for the change in the job market that requires skills and competencies on the extensive use of cyber-physical solutions and internet-based technologies.

Endnotes

[1]The qualitative data collection procedure is not a straight line. It possesses the properties listed below. (a) Iterative and progressive because it is a continuous cycle. In theory, the procedure is an endless spiral. (b) The procedure is recursive because one part may prompt the researcher to return to a prior step. (c) The process is holographic, which means that each stage contains the entire process.

[2]VOSviewer is a bibliometric network visualization tool that employs advanced scientometric techniques for layout and grouping, natural language processing, and the generation of bibliometric networks based on Web of Science or other worldwide citation datasets.

[3]The number of edges in a cluster is compared to the predicted number of edges in the cluster if the network were a random network with the same number of nodes and where each node retains its degree, but edges are otherwise randomly coupled.

Annex 1

The 92 documents indexed in Scopus about the 4IR and the city retrieved for the analysis

No	Author	Title	Year	Document Type
1	Abdurrahman, Abdurrahman	Developing STEM Learning Makerspace for Fostering Student's 21st Century Skills in the Fourth Industrial Revolution Era	2019	Conference Paper
2	Adam et al.	Review on manufacturing for advancement of industrial revolution 4.0	2018	Article
3	Alias et al.	Big data, modeling, simulation, computational platform and holistic approaches for the fourth industrial revolution	2018	Article
4	Aliour, Moradi and Ghaffari	The meta-analysis of smart data international research	2019	Article
5	Alkahtani, A.	Major challenges and obstacles facing the Arabic learning process in globalisation era	2018	Article
6	Al-Sayed and Yang	Towards Chinese smart manufacturing ecosystem in the context of the one belt one road initiative	2018	Article in Press
7	Amekudzi-Kennedy, Labi and Singh	Transportation Asset Valuation: Pre-, Peri- and Post-Fourth Industrial Revolution	2019	Article
8	Andersson and Andersson	Creative Cities and the New Global Hierarchy	2015	Article
9	Anon	Book Reviews	1980	Article
10	Antoniuk et al.	Barriers and opportunities for hi-tech innovative small and medium enterprises development in the 4th industrial revolution era	2017	Review
11	Arranz, Blanco and Miguel	Digital skills before the advent of the fourth industrial revolution [Competencias digitales ante la irrupci³n de la Cuarta Revoluci[³n Industrial	2017	Review
12	Ayentimi and Burgess	Is the fourth industrial revolution relevant to sub-?Sahara Africa	2019	Article
13	Baines et al	The Fourth Industrial Revolution: Will it change ?pharmacy practice	2019	Note
14	Beno, M.	Robot rights in the era of robolution and the acceptance of robots from the Slovak citizen's perspective	2019	Conference Paper
15	Botha, Deonie	Knowledge management and the future of work	2018	Conference Paper
16	Bush and Dailami	A critique of solutions and research to the challenges of adopting metallic additive-layer manufacture in full-scale production	2019	Conference Paper
17	Butera, Federico	Technology, organisation and work in the Fourth Industrial Revolution: The renaissance of socio-technical design [Lavoro e organizzazione	2017	Article

No	Author	Title	Year	Document Type
18	Campo et al.	IoT Solution for energy optimisation in industry 4.0: Issues of a real-life implementation	2018	Conference Paper
19	Carlucci et al.	Review on research studies and monitoring system applied to cetaceans in the Gulf of Taranto (Northern Ionian Sea, central-eastern (mediterranean sea	2017	Conference Paper
20	Chan, Johannes	Immigration policies and human resources planning	2008	Book Chapter
21	Chelyshkov, P.	Computer-aided design of cyber-physical building systems	2019	Conference Paper
22	Chong et al.	Digital literacies and sustainable development: Narratives from yet another tale of two cities	2016	Conference Paper
23	Cinque et al.	Cloud Reliability: Possible Sources of Security ?and Legal Issues	2018	Article
24	Colombo et al.	Industrial Cyberphysical Systems: A Backbone of the Fourth Industrial Revolution	2017	Article
25	de Amorim et al.	Urban challenges and opportunities to promote sustainable food security through smart cities and the 4th industrial revolution	2019	Article
26	de Vries, Jan	Literature of the enlightenment, 1700-1800	2007	Book Chapter
27	Ding and Zawawi	Automated workflow for unstructured grid	2019	Review
28	Diño and Ong	Research, technology, education & scholarship in the fourth industrial revolution [4IR]: Influences in nursing and the health sciences	2019	Review
29	Douglass, Mike	The “new” Tokyo story: Restructuring space and the struggle for place in a world city	2009	Book Chapter
30	Ferrero, Beattie and Phoenix	Sensor city-A global innovation hub for sensor technology	2018	Article
31	Fomunyam, K.	Decolonising the mind in engineering education in south African higher education	2018	Article
32	Fukuoka, K ukuoka	Management of Regional Ecosystem for Environmental Conservation	1995	Article
33	Gooneratne et al.	Outlook and perspectives	2019	Book Chapter
34	Hassan Onik, Miraz and Kim	A recruitment and human resource management technique using blockchain technology for industry 4.0	2018	Conference Paper
35	Hatuka, Ben-Joseph and Peterson	Facing forward: Trends and Challenges in the development of industry in cities	2017	Article
36	Healy, J. C.	The global impact of telematics for health-care professionals	1998	Article
37	Horažďovský, Novotný and Svítek	Data-driven management of dynamic public transport	2018	Conference Paper
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46	Lee et al..	Is the Fourth Industrial Revolution a window of opportunity for upgrading or reinforcing the	2019	Article
47	Lee, Kim and Seo	Cyber-attack scenarios on smart city and their ripple effects	2019	Conference Paper
48	Lieu Tran et al..	Trends in preparing cyber-physical systems engineers	2019	Article
49	Liu, Chen	International competitiveness and the fourth industrial revolution	2017	Article
50	Malapane	An application of data mining in the fourth industrial revolution- A case of South Africa	2019	Conference Paper
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54	Mokoena et al.	Spatio-temporal modelling & the new urban agenda in post-apartheid South Africa	2019	Conference Paper
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الثورة الصناعية 4.0: استطلاع الفرص والتحديات أمام المدن الذكية المستدامة

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المُستَخلَص

عادة ما تحل التكنولوجيات الجديدة محل العديد من التكنولوجيات المعروفة للبشرية؛ واليوم تشهد البشرية الثورة الصناعية الرابعة، حيث أصبحت الحدود بين التكنولوجيا البيولوجية، والرقمية، والفيزيائية غير واضحة. جلبت الثورات الصناعية السابقة منافع وأضرار، لذلك تبحث الورقة في النتائج المتوقعة من الثورة الصناعية الرابعة على المستقرات الحضرية، وسبل الاستفادة من تكنولوجيات الثورة الصناعية الرابعة في تخطيط المدن. قام الباحثان بمسح الأدبيات والأبحاث المعاصرة لتحديد الفرص المتاحة والآثار المحتملة للثورة الصناعية الرابعة. ثم قاما بتحليل ببليومتري للأدبيات الأكاديمية المعاصرة التي تربط بين الثورة الصناعية الرابعة والمدن. أظهرت النتائج اتجاهاً متزايداً في عدد الأبحاث المنشورة منذ عام 2016، والتي تركز على إمكانية جعل المدن الذكية مستدامة وحقيقة واقعة مع تجنب الكثير من النتائج السلبية، لذلك يجب أن توائم مدراس تعليم التخطيط والعمارة مناهجهما الدراسية لاستخدام هذه التكنولوجيات الجديدة عن طريق تزويد الخريجين بالمهارات اللازمة لمواجهة عالم متغير والاستفادة من الفرص المتاحة.

مفاتيح الكلمات: التحليل الببليومتري، الابتكار، التخطيط الحضري، مدينة ذكية مستدامة.