**Examining the Influence of 4IR Technologies in Urban Planning: A Case of the City of Johannesburg**

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## 1 ABSTRACT

There is rapid increase of new technologies that are being implemented in many fields benefiing their operations positively, and urban and regional planning is also slowly growing in deploying various tecbnologies. The Fourth Industrial Revolution (4IR) has introduced transformative technologies such as Artificial Intelligence (AI), Big Data, the Internet of Things (IoT), and Geographic Information Systems (GIS), which are reshaping urban planning and governance. The city of Johannesburg is located in South Africa which is in the developing world. The city is working towards becoming a world class city. To achieve this, there is a need of deploying advance technological tools in urban planning learning from developed countries. The aim of the study is to explore the influence of 4IR technologies that might have in the City of Johannesburg (CoJ), focusing on how these innovations enhance decision-making, optimize resource allocation, and improve urban efficiency. By analyzing real-time data, predictive analytics, and smart infrastructure solutions, the research analysis the potential of 4IR technologies in addressing urban challenges. With the adoption of a qualitative case study approach, through the use of literature, this research evaluates existing applications and applications that could be implemented of AI and Big Data in Johannesburg's urban planning strategies, as well as the challenges related to data privacy, and infrastructure readiness, The findings highlight the benefits of technology-driven urban management while also identifying barriers to widespread adoption. Therefore, the study recommends the integration of 4IR technologies into Johannesburg's urban planning framework to foster sustainable and inclusive city development.

Keywords: Smart Cities, Big Data, Artificial Intelligence, urban planning, 4IR

## 2 INTRODUCTION

Fourth Industrial Revolution provides techonological advancements that could bring solutions to urban planning challenges and drive the City of Johannesburg towards becoming a smart city. These technologies require to be deployed correctly to be functional, and effectively. Accordingly, there is a need for them to be well-utilized by both the governmnent and the city residents. The aim of the study is to explore the influence and impact of 4IR technologies that might have in the City of Johannesburg, focusing on how these innovations enhance decision-making, optimize resource allocation, and improve urban efficiency. By analyzing real-time data, predictive analytics, and smart infrastructure solutions, the research analysis the potential of 4IR technologies in addressing urban challenges. The city has been adopting various technologies in various aspects such as the CoJ municipality integrating e-services in their operations to ensure tha the city residents can easily obtain information, communicate and other related services, there has been smart mobility developments such as the Bus Rapid Transit system (Known as Rea Vaya system), High speed rail system (known as Gautrain system which includes Bus, train and midi-buses), rising number of ride e-hailing services, Free WiFi services in various neighbourhoods and parks for city residents to connect to the internet, usage of green energy such as the adoption of solar powers, Geographic Information System services used to assist in planning and also providing the city residents with real-time navigation information, CCTV networks to prevent crime, sensored waste management, and environment sensors monitoring conditions to prevent natural disasters, and other technologies. The use of more technological innovations can enhance the urban living leading to quality of life and promote sustainable development.

## 3 BIBLOMETRIC LITERATURE REVIEW

The use of biblometric mapping of literature has been adopted for this study. This is to identify suitable literature for this study and identify most of the common themes researched on related to fourth industrial revolution, Artificial intelligence, Big data, smart cities, urban planning and South Africa. Further, the results of the mapping network indicates a summary of themes that are most studied and or that need attention.
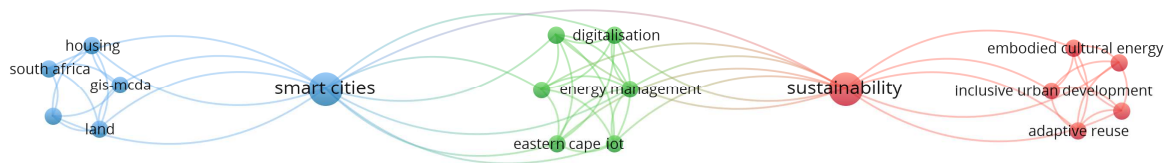
Figure 1: Keyword co-occurrence network visualisation

The above figure1 indicates a biblometric mapping of literature about authors keywords. These keywords indicate the most used keywords related to the study. There are 18 items (keywords), 3 clusters, 58 network links, 198 total link strength, and there is a total of 43 occurences. Only 18 keywords formed the network as 22 keyworkds could not connect to other keywords. Accordingly, links indicate the connection between various keywords in the biblometric mapping of literature, and the occurences shows how much a keyword has appeared in the networks. Furthermore, the total link strengths highlights that which keywords are most connected to other keywords indicating that most author's studies focuses on such themes. The authors keywords formed 3 clusters that are indicated by different colours. Each cluster has subfields that most authors work focuses on. In cluster 1, there are six keywords indicated by red node which include adaptive-reuse, cultural resilience, embodied cultural energy,inclusive urban development, sustainability, Tshwane/ Pretoria. The cluster indicate that some of the studies conducted are based on inclusive urban development with cultural resilience and embodied cultural energy. Accordingly, adaptive-reuse is a significant concept that needs to be implemnted for creating sustainabilty smart cities.

In cluster 2, there are six keywords represented by a green node which include Eastern Cape, digitization, enegry management, internet of things, urbanization, and smart municipalities. This cluster highlights that various studies conducted indicate that municipalities in the Eastern Cape are transitioning towards smart municipalities were there is deployment of internet of things and digitization for energy management and urbanization. In cluster 3 there are two keywords represented by a blue node which include gis-mcda, housing, land, smart cities, South Africa, and well-located. The cluster indicates that there are various studies conducted of identify suitable land location for housing development and smart cities development across South Africa using gis multi-criteria decision analysis. Further, there is a strong connection in the network for the keyword smart cities as it is strongly linked with cluster 2, cluster 3 and also with one keyword in cluster 1 which is sustainability. The keyword connects with Eastern Cape, digitization, enegry management, internet of things, urbanization, and smart municipalities in cluster 2 highligting that for successful smart cities development in the Eastern Cape there is a need for all the keywords in cluster 2 to be implemented or included in planning. Consequently, there is a need for gis multi-criteria decision analysis to identify suitable land location for succesful development of smart cities, which this will produce sustainable smart cities.
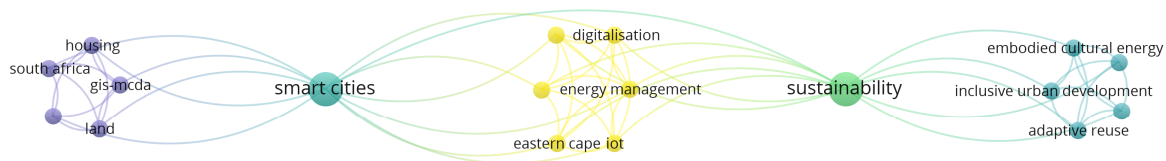


Figure 2: Keyword co-occurrence overlay visualisation

The above figure 2 highlights the publication themes that were most trending from the year 2018 to the year 2024. Consequently, this indicates that studies on smart cities, sustainability and technological innovations in urban and regional planning experience boost from late 2019 to 2024 in South Africa. However, there are very few studies conducted related to this study which highlights that there is more research that could be

done in this area. As seen on the above keyword co-occurrence overlay visualisation, there are few keywords that are creating a network of authors keywords, indicating that this research area in South Africa has not been explored sufficiently to assist provide positive impact using this approach in urban planning. During 2018, studies conducted related to the study focused on deployment of technology such as gis multi-criteria decision analysis to identify suitable locations for development of smart cities, suitable land for housing in South Africa. In 2020 to 2022, more studies were conducted on smart cities and sustainability. Accordingly, in 2023 to 2024, more studies were conducted on digitalization, internet of things, energy management, and sustainability.

## 4 APPROACH AND METHODOLOGY

The study deployed a case study research design were the City of Johannesburg was selected to explore how the 4ir technologies can influence urban planning. Accordingly, a qualitative approach is followed were variouss publications are examined related to the study through the use of biblometric mapping of literature. The use of biblometric mapping of literature assist to identify common research areas related to smart cities, urban planning, artificial intelligence, big data, digital mapping, Johannesburg and South Africa, and this allow the study to identify a literature gab. 12 publications were downloaded on scopus which included 4 conference papers, 6 journal articles and 2 book chapters. The keywords selected were urban planning, smart cities, and South Africa. Only three keywords were used to ensure that the study obtain most suitable publications and also if more keywords are added no publication is obtained. Which this indicates that there is a gab on studies conducted that include urban planning, 4IR, artificial intelligence, big data, smart cities, digital transformation, Johannesburg, and South Africa. Therefore, there is a need of more studies conducted to assist developing South African cities using advancement of technology which could assist producing smart cities where South African cities can go where they have never been.

During the data cleaning process, the abstracts of all publications generated were examined and all the publications were relevant to the study. Selected publications were exported to a excel sheet csv document to provide a suitable file that VOSviewer allow for biblometric mapping of literature. Accordingly, the excel sheet was inserted in the VOSviewer to start the process of biblometric mapping of literature. Accordingly, the type of analysis chosen is co-occurrence and the unit of analysis selected are authors keywords. Consequently, the threshold chosen is based on the number of occurrences of a keyword should appear which was once. 40 keywords were generated, and when the threshold was selected, 40 keywords meet the threshold. when the number of co-occerences were reduced to two, only three keywords meet the threshold which this will lead to poor network analysis produced. Therefore, the results produced figure 1 representing keyword of co-occurrence network visualisation and figure 2 representing keyword co-occurrence overlay visualisation.

## 5 RESULTS AND DISCUSSIONS

This section provides the results and analysis on the influences of 4ir technologies in urban planning, and how these technology could enhance the City of Johannesburg. There are various technologies that are developed in the City of Johannesburg to address urban challenges, development, governance, city operations and service delivery. Building information modelling are deployed for risk management. The technologies referred here include BIM, automatic rule checking, knowledge based systems, reactive and proactive safety systems based on information technology. There is a distinct difference between reactive and proactive safety systems for risk management. Forsythe (2014) and Teizer et al. (2010) pointed out reactive systems using information technologies such as VR, 4D CAD, and GIS seldom use real-time data and need a post data collection processing effort for analysis, while in contrast proactive technologies can collect and analyse real-time data, and provide real-time warning and immediate feedback to construction site about dangers in time. It has been found that BIM, on one hand, can be used as a systematic risk management tool in the development process and, on the other hand, can perform as a core data generator and platform to allow other BIM-related tools for further risk analysis, where most of these technologies can be used interactively in related investigations (Zou et al., 2017). The municipality of johanesburg use technology such as GIS for mapping to identifying suitable sites for development and identifying areas that need the provision of service delivery.

Accordingly, Big Data is the term being used to describe a wide spectrum of observational or "naturally-occurring" data generated through transactional, operational, planning and social activities.The major potential of big data applications is in four areas: (1) improved strategies for dynamic urban resource management, (2) theoretical insights and knowledge discovery of urban patterns and processes, (3) strategies for urban engagement and civic participation, and (4) innovations in urban management, and planning and policy analysis (Thakuriah et al., 2017). The city deploys such technology to collect real-time information to provide quality of services to the citizens. Prior to this era which we can loosely call the age of the smart city (Batty, 2020), describes that computers were mainly used to support plan-making functions, although data and information had become central to the operation of the routine planning system as well. This is best seen in planning skills which in the year 2000 were still organised around spatial representation through GIS and CAD, forecasting models from transportation to housing, the development of web pages to communicate ideas that might be organised digitally such as database access and the development of a national infrastructure for the archiving and transmission of data (Batty, 2021).

The IoT is considered the next large prospect for the world of the Internet, as it has come out of its early stages and is entering into the era of revolutionizing the traditional network infrastructure into a fully integrated future with the internet. Thus, this leads us to the concept of smart homes where different electronic appliances are interconnected with each other and achieve high-quality two-way interactive multimedia services. In such a system where a large number of devices are communicating with each other, a massive volume of data (called Big Data) is generated. To enrich smart home technology, the better analytics of Big Data could play a vital role in the advancement of Information and Communications Technologies (ICTs). This type of Big Data analysis provides a better understanding and useful information about the future as well as about planning and development, thus providing us insight into Big Data. This type of technology is used to enable a large variety of security as well as monitoring applications, and for urbanization, it is of utmost importance to comprehend the demand for service profiling to enhance efficiency and may advance city management (Rathore et al., 2016).

Smart city is a concept that encapsulates various technological innovation concepts into a single architecture (Alvi et al., 2016; Silva et al., 2018). The key concept of the smart city is to obtain the right information at the right place and on the right device to make a city-related decision with ease and to aid citizens more quickly (Rathore et al., 2016). According to Manville et al.(2014;7) 'it is in this context that smart cities emerge not just as an innovative modus operandi for future urban living, but as a key strategy to tackle poverty and inequality, unemployment and energy management'. Many cities around the world adopted smart urban technologies with an aim to become a smart city, maintain a scientific-technologic position of excellence via ensuring and expanding economic competitiveness to transforming and modernising their societies and cities, and sustain their growth and development. Examples of some the smart city initiated concepts; the Amsterdam Smart City initiative formed a collaboration between the citizens, government and businesses to develop smart projects to make a change by energy saving, which a concept more or less like this is initiated in CoJ as more solar power energy devopemnts are created such as solar power street light and more houses and companies generate electricity from solar power; the Southampton City Council utilised smart cards to stress the importance of integrated e-services, which this is similar to some of the CoJ city services of having one e-smart card for different purposes; the City of Edinburgh Council formed a smart city vision around an action plan for government transformation; the Malta Smart City formed a strategy to promote a smart business park as a way to leverage economic growth (Yigitcanlar, 2015), a similar strategy is implemented in Johannesburg were various city parks are provided with free WiFi for residents to use for various purposes such as work and entertainment.

Figure 3 indicates a concept of a technology driven City of Johannesburg supported by the 4ir technological innovations which can lead to a functional smart city. This demonstrate that 4IR technologies such as artificial intelligence, internet of things, big data, digital transformation can allow the provision of massive amount of data to provide efficient suitable response to urbanisation challenges and services delivery. Accordingly, optimization of land use zoning for areas across the city to function efficiently and sustainable. Consequently, more advance technologies could be integrated with the use of GIS to identify suitable locations that can provide affordable housing for the city residents and combat the challenge of the increasing informal settlements and optimize infrastructure planning ensuring that the city is resilient to natural disasters.
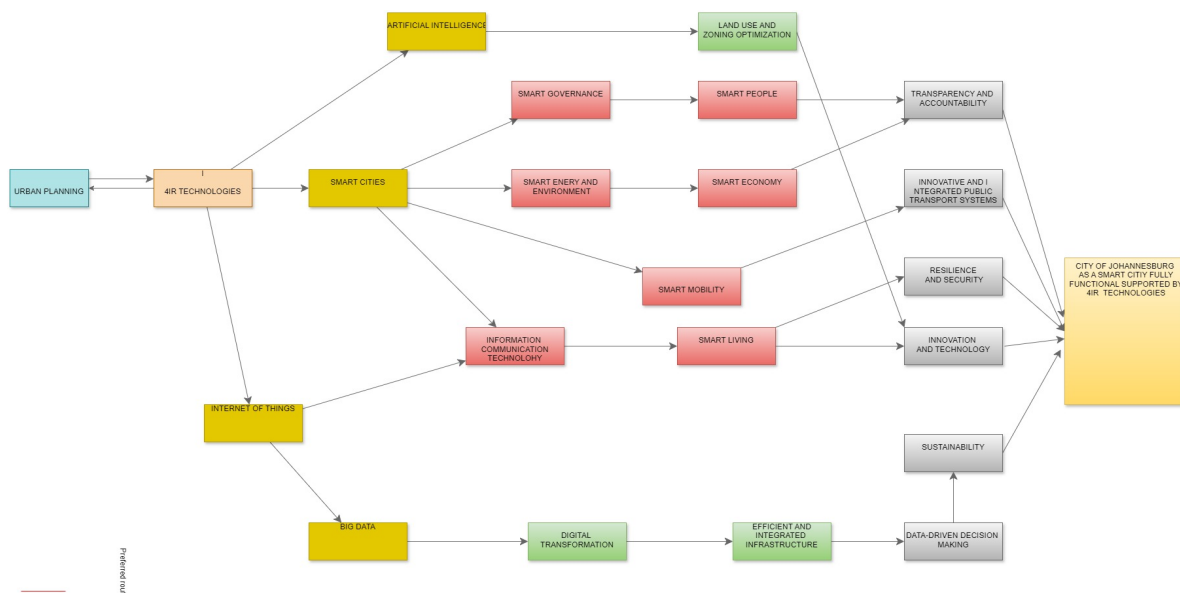
Figure 3: Concept of technology driven City of Johannesburg

Further, these technologies could assist with the vision of the city to become a world class city and becoming a smart city. This would include smart governance which will change governance and coordination processes as well as planning processes with public participation leading to transparency and accountability, smart people and smart economy were people are compatible with technology and assist in the development of the economy eradicating the levels of poverty. Accordingly, smart mobility were various innovative public transport systems such as Gautrain and bus rapid transit system (Rea Vaya system) and other modes could be integrated to ensure effective and reliable public transport systems, smart living ensuring that there is safe and security in all the neighbourhoods and 24hrs policing response services across the city. Consequently, smart energy and the environment were there could be provision of effcient solar-energy as the country is struggle with power provision and more technologies that could monitor the environment to provide in-time alert to communities and areas that are prone to disasters before hand.

In addition, innovative technologies afford opportunities for data-driven cities which is generated from various technologies that could assist with spatial transformation as informed decisions are taken and this is very important in Johannesburg neighbourhoods to transpire as there is spatial injustice and would create sustainability. All this can help transform the city and be resilience creating City of Johannesburg to be a functional smart city. However, the challenge of reaching this point lies in the tools and resources in the city and the policies and legislative frameworks to support this approach.

## 6 CONCLUSION

The City of Johannesburg is a transitional city working towards being a developed world class city. There are various types of infrastructure developed making the city functional, and with 4ir technological innovations being integrated towards enhancing the city. Enhancing the city towards being a smart city, there is a need of ensuring that the technological innovations that are deployed are functional and utilized by both the service providers and city residents. These various technologies such as internet of things, artificial intelligence, big data analytics, geographic information systems, smart infrastructure and digital twins, autonomous vehicles and smart transportation, renewable energy and smart grids, digital platforms for citizens engagement, automation, and virtual reality and augemented reality are suitable in urban planning which could enhance the city's functionality making the City of Johannesburg to go where no cities have gone before. Technological integration is critical in urban innovation to provide solutions that traditional urban planning systems struggle to provide. Lastly, technology could transform the city to be more data driven making it effective, efficient, functional , sustainable and provide a quality of life for the residents.

## 7 REFERENCES

15th International Conference on Computers in Urban Planning and Urban Management, 2017. (2017). [Conference review]. Lecture Notes in Geoinformation and Cartography, 1-503. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85056293162&partnerID=40&md5=f2893ebe0bde67189f29be3295a1146f

6th International Conference on Sustainable Development and Planning, SDP 2013. (2013). [Article]. WIT Transactions on Ecology and the Environment, 173. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84996449355&partnerID=40&md5=83a9003e05fc37725558af00310e9ef2

Alvi, A.N., Bouk, S.H., Ahmed, S.H., Yaqub, M.A., Sarkar, M. and Song, H., 2016. BEST-MAC: Bitmap-assisted efficient and scalable TDMA-based WSN MAC protocol for smart cities. IEEE Access, 4, pp.312-322.

Aswegen, M. V., & Retief, F. P. (2022). Large urban systems: Towards a sustainability framework. In The Elgar Companion to Urban Infrastructure Governance: Innovation, Concepts and Cases (pp. 284-307). Edward Elgar Publishing Ltd. https://doi.org/10.4337/9781800375611.00025

Batty, M., 2020. The smart city. In The city reader (pp. 503-515). Routledge.

Batty, M., 2021. The digital transformation of planning. Environment and Planning B: Urban Analytics and City Science, 48(4), pp.593-597.

Clarke, N. J., Kuipers, M. C., & Roos, J. (2020). Cultural resilience and the Smart and Sustainable City: Exploring changing concepts on built heritage and urban redevelopment [Article]. Smart and Sustainable Built Environment, 9(2), 144-155. https://doi.org/10.1108/SASBE-09-2017-0041

Forsythe, P., 2014. Proactive construction safety systems and the human factor. Proceedings of the Institution of Civil Engineers-Management, Procurement and Law, 167(5), pp.242-252.

Geyer, H. S. (2023). Can informality help create smart, sustainable cities? The vibrancy of self-organised informal settlements in Cape Town [Article]. GeoJournal, 88(3), 2471-2489. https://doi.org/10.1007/s10708-022-10758-6

Manville, C., Cochrane, G., Cave, J., Millard, J., Pederson, J.K., Thaarup, R.K., Liebe, A., Wissner, M., Massink, R. and Kotterink, B., 2014. Mapping smart cities in the EU [online]

Masiba, P. Z., & Mphambukeli, T. N. (2023). The Suitability of the Proposed New Coastal 'Smart City' Between Port Saint Johns and Margate on the Wild Coast in KwaZulu-Natal, South Africa. Proceedings of 2023 IEEE International Smart Cities Conference, ISC2 2023,

Mokoena, B. T., Musakwa, W., & Moyo, T. (2017). Developing the well-located land index to establish smart human settlements for the ekurhuleni municipality, South Africa. Lecture Notes in Geoinformation and Cartography,

Mukome, B., Seyam, M., & Amoo, O. (2022). Retrofitting Stormwater Harvest System in Dispersing Reliable Water Supply in a Climate-Smart City. Lecture Notes in Networks and Systems,

Musakwa, W. (2017). Perspectives on geospatial information science education: an example of urban planners in Southern Africa [Article]. Geo-Spatial Information Science, 20(2), 201-208. https://doi.org/10.1080/10095020.2017.1339403

Musakwa, W., & Gumbo, T. (2017). Impact of urban policy on public transportation in gauteng, South Africa: Smart or dumb city systems is the question. In Green Energy and Technology (Vol. 0, pp. 339-356). Springer Verlag. https://doi.org/10.1007/978-3-319-54984-2_16

Odendaal, N. (2003). Information and communication technology and local governance: Understanding the difference between cities in developed and emerging economies [Article]. Computers, Environment and Urban Systems, 27(6), 585-607. https://doi.org/10.1016/S0198-9715(03)00016-4

Rathore, M.M., Ahmad, A., Paul, A. and Rho, S., 2016. Urban planning and building smart cities based on the internet of things using big data analytics. Computer networks, 101, pp.63-80.

Silva, B.N., Khan, M. and Han, K., 2018. Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. Sustainable cities and society, 38, pp.697-713.

Teizer, J., Allread, B.S., Fullerton, C.E. and Hinze, J., 2010. Autonomous pro-active real-time construction worker and equipment operator proximity safety alert system. Automation in construction, 19(5), pp.630-640.

Thakuriah, P., Tilahun, N.Y. and Zellner, M., 2017. Big data and urban informatics: Innovations and challenges to urban planning and knowledge discovery. Seeing cities through big data: Research, methods and applications in urban informatics, pp.11-45.

van der Hoogen, A., Fashoro, I., Calitz, A. P., & Luke, L. (2024). A Digital Transformation Framework for Smart Municipalities [Article]. Sustainability (Switzerland), 16(3), Article 1320. https://doi.org/10.3390/su16031320

Yigitcanlar, T., 2015. Smart cities: An effective urban development and management model?. Australian Planner, 52(1), pp.27-34. Yigitcanlar, T., 2015. Smart cities: An effective urban development and management model?. Australian Planner, 52(1), pp.27-34.

Zou, Y., Kiviniemi, A. and Jones, S.W., 2017. A review of risk management through BIM and BIM-related technologies. Safety science, 97, pp.88-98.