Integrating the 4th Industrial Revolution in spatial planning curricula: the case of South African tertiary institutions

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Abstract
The 4th Industrial Revolution (4IR) – the narrative of change associated with technology-related disruptions through the proliferation of cyber-physical systems – is set to have a profound impact on the built environment. Technological applications that include big data analytics, cloud computing, and machine learning will affect spatial conceptualisation and design, construction activities, building operations and management, and real estate activities. The statutory and strategic nature of spatial planning processes may be disrupted by future technological applications. Equipping current and future spatial planning practitioners with the necessary skills is essential in maintaining property sector productivity and catalysing renewed efforts toward spatial transformation in South African human settlements. The objective of this research is to evaluate current approaches in tertiary education institutions in effectively transferring knowledge regarding 4IR as it relates to the spatial planning discipline and equipping said students with the relevant skills to prolong sector competitiveness. A qualitative case study analysis is applied, which includes the assessment of the curricula of selected accredited spatial planning schools and their relevant integration of 4IR applications. Research findings highlight the limited inclusion of 4IR and related multidisciplinary, practical, and theoretical themes in spatial planning education. Recommendations include increased knowledge transfer on the theoretical synergies between 4IR and spatial planning; development of computer-based skills; and implementing existing competencies, including critical thinking and problem solving, to foster sectoral adaptability.

Keywords
4th Industrial revolution, adaptation, built environment, spatial planning, tertiary education.

1 Introduction

Profound technological advances, encapsulated by the narrative of change (Avelino *et al*. 2014) promoted as 4IR, is set to disrupt production and consumption processes across sectors and economies (NEDLAC 2019). The broad proliferation of cyber-physical systems (Baldassari & Roux, 2017), the application of which include big data analytics, cloud computing, and machine learning, will not be limited to the information technology sectors or activities, but will also affect the built environment. Associated functions, including spatial conceptualisation and design, construction activities, building operations and management, and real estate activities, are all subject to disruption on the back of advanced technological application (WEF 2017). Spatial planning, including statutory and strategic planning procedures, may also experience profound disruption. This is already apparent in the limited automation of land development application processes and the integration of sensor-based machinery in cities to allow real-time data collection and analysis of urban systems.

In South Africa, as with most countries (Bock 2015), the built environment constitutes an important arena of national investment in the form of infrastructure and property development, which includes a broad value-chain of subsectors and stakeholders. Adaptation and adaptability to the potential changes inherent to 4IR, as with other disturbances (Martin & Sunley 2015), is important to sustain sectoral productivity and wider economic growth. In addition, targeted interventions by the public sector (DHS 2021) in order to alleviate the spatial challenges and inequality as a consequence of apartheid spatial planning (Abrahams & Everatt 2019) illustrates a central dynamic of the South African built environment and the role of sectoral practitioners. Accordingly, the resilience of this sector transcends economic objectives, and is anchored in sustaining spatial reform and socio-economic upliftment.

The training and education of current and future spatial planning practitioners is essential in maintaining property sector productivity and catalysing renewed efforts toward spatial transformation in South African human settlements. Education in spatial planning, specifically on a tertiary level, ought to equip prospective planners with the required knowhow to incorporate and adapt to potential disruptions promulgated by new technological applications. The objective of this research is to evaluate current approaches in tertiary education institutions in effectively transferring knowledge regarding 4IR as it relates to the spatial planning discipline and equipping said students with the relevant skills to prolong sectoral competitiveness. To achieve this objective, a qualitative research methodology is applied, which includes the assessment of the curricula of selected accredited spatial planning institutions and their relevant integration of 4IR themes. The following section provides an overview of the relevant literature, followed by the methodology, findings and discussion, and conclusion.

2 Literature Review

The objective of the literature review is to provide an overview of 4IR, its potential impact on spatial planning, and the education of spatial planning on the tertiary level in South Africa.

2.1 Delineating 4IR

The 21st century society is currently undergoing rapid technological advancements which have been attributed to 4IR. The current revolution, unlike its predecessors, is largely influenced by "a fusion of technologies that are blurring the lines between the physical, digital and biological spheres" (Schwab 2016). 4IR is marked by technologies, devices, and processes that include the Internet of Things (IoT), Cyber-Physical Systems (CPS), autonomous robots, visualisation technologies (virtual and augmented reality), cloud computing, blockchain technology, big data analytics, additive manufacturing, and digital twins (Culot 2020; BCG 2019). All these technologies are merging with human life resulting in "a vast ecosystem of interconnected, complex and dynamic interaction between humans and the built environment, from a single space to a city scale" (Fletcher 2016 cited in Ross & Maynard 2021:p159).

While 4IR presents significant opportunities for society, Ojo-Fafore *et al*. (2021:p57) suggest that Africa's developments in 4IR are stagnant in comparison to the rest of the world, as they are limited to policy statements and challenges such as "poor physical infrastructure, low regulatory, low policy quality, the poor rule of law, high disease burden and lack of adequate skilled workers" that overburden governments and divert their attention and efforts from the realisation of 4IR. This is particularly the case in South Africa which currently ranks 75th globally on a variety of metrics termed 'Readiness for the 4th Industrial Revolution' (Sihlongonyane *et al*. 2020). This situation puts enormous pressure on areas where South Africa is currently lagging or weak. One such area is the built environment sector whereby progress on fusing technology is still in its infancy as the adoption of ICT has been largely concentrated on the use of software such as BIM Platform (Building Information Modelling), GIS (Geographic Information Systems) and Revit as opposed to innovative technologies that propel 4IR agenda (Leal *et al*. 2018).

2.2 Implications of 4IR on spatial planning

Letsoko and Pillay (2019) highlight that the impacts of 4IR have extended to the built environment industry, encompassing architecture, urban planning, and construction, and has consequently disrupted conventional approaches on how they plan and shape urban systems and cities. As a result, the urban planning environment is increasingly turning to specialised technologies to address issues related to sustainability, society, security, transportation, infrastructure, and governance (Audirac 2002). This revolution has accelerated the drive towards the realisation of the smart city concept. Vilajosana *et al*. (2013) highlight that the smart cities concept has promoted the development of Internet of Things (IoT) and through it the incorporation of sensors and big data. Yigitcanlar *et al*. (2020) indicates that IoT supports increased connectivity that leads to the generation of data and its subsequent capture, analysis, and distribution, contributing to better smart city development. This is done through the implementation of a smart environment that is interconnected and interlinked with the internet resulting in application such as e-governance, smart mobility, etc.

Furthermore, Yigitcanlar *et al*. (2020) outline that technologies such as urban artificial intelligence (AI), that is embodied in urban spaces and infrastructure, can significantly contribute to planning as data can be sourced to gain a more holistic understanding of the urban fabric. Batty (2018) explains that such technologies allows planners and policymakers to shift from closed systems (interlinked urban elements) to an open, fragmented, peri-urban fabric that has tangible impacts on density fragmentation, cohesion, and compactness. Additionally, technologies such as remote sensing which involves a technique of data collection from a distance without touching objects are also disrupting conventional urban planning decision making in the era of 4IR. Xiao and Zhan, (2009) indicate that remote sensing technologies are able to provide a spatial temporal analysis of urban expansion and land use change, among other applications.

Similarly, sensor technologies such as drone (also referred to as Unmanned Aerial Vehicles (UAVs)) technologies are useful application for mapping cities. These technologies have largely contributed to the production of 3D models and geospatial information in the depiction and evaluation of planning proposals (Bakogiannis *et al.* 2019) and to capture zoning and land use patterns (Jenkins 2013). This presents an opportunity for South African municipalities to digitize their urban planning practises. In addition, 3D printing can assist planners to better understand spatial perspectives using 3D visualisations, which can also expedite the process of discussions and negotiations and enhance a mutual understanding amongst development practitioners (Ghawana & Zlatanova 2013). Moreover, 3D printing also makes way for printing objects such as houses which will impact construction cost, regulatory frameworks, and spatial planning policy (Cameli 2019).

Technologies, such as augmented reality (AR) and virtual reality (VR), are also changing the way in which planners can shape, plan and design cities. Angelini *et al*. (2020) indicate that AR and VR can help planners receive real-time feedback from citizens and stakeholders. These tools increase public participation through providing communities insight and input into the development process (Allen *et al*. 2011). This is particularly important in the South African context where public participation processes in development projects remain a fundamental challenge.

2.3 Spatial planning education and 4IR

The rapid transformations resulting from 4IR will present different implications for many sectors. Equally, the higher education system will be impacted and needs to be responsive to these advancements. Butler-Adam (2018) indicates that one of the implications of 4IR in the education sector has to do with curricula, including teaching and learning. This revolution demands increasingly more dynamic and adaptable curricula that is connected to the demand for new skills dictated by 4IR (Coetzee *et al*. 2021). Furthermore, the successful implementation of 4IR in education will require appropriate skills. Skills are required to implement, manage, and work with new technology (Butler-Adam 2018). In the near future, it is approximated that 35% of skills currently considered important will change. Hence, new sets of skills will be required for 4IR and for the use of new technology. As such, Kamaruzaman *et al*. (2019) propose that graduates in the engineering and built environment fields would require the following skills in the 4IR era: analytical thinking and innovation; active learning and learning strategies; creativity, originality and initiative; critical thinking and analysis; complex problem solving; emotional intelligence; and system analysis and evaluation. In response, transforming the education system through curricula redesign will increasingly be measured against how educational outcomes meet the requirements of stakeholders in the workplace (Halili 2019).

2.4 Spatial planning education in South Africa

In South Africa, all public universities have to be registered and accredited by the Department of Higher Education and Training (DHET); the Higher Education Quality Committee (HEQC) under the auspices of the Council on Higher Education (CHE); as well as the South African Qualifications Authority (SAQA). Zawada (2020) explains that once programmes have been accredited by the CHE, they have to be registered on the National Qualifications Framework (NQF) which is a qualification and learner register maintained by SAQA. The NQF provides a framework for benchmarking qualifications at both national and international level in order to recognize skills and categorise them to a unified structure of recognized qualifications (Sihlongonyane 2018). In order to advance these objectives of the NQF, SAQA developed level descriptors (ranging from level one to ten) for each level of the NQF with level five to ten being focused on tertiary education qualifications.

Table 1. NQF levels (tertiary education)

NQF Level	Qualification
10	PhD
9	Master's Degree
8	Honours Degree; 4 years + Bachelor's Degree
7	3rd year of Bachelor's Degree; Advanced Diploma
6	2nd year, Advanced Certificate, Diploma
5	1st year (maximum 96 credits), Higher Certificate

Source: SACPLAN (2014a).

The South African Council of Planners (SACPLAN), the statutory council responsible for the regulation of the planning profession in terms of the Planning Professional Act 36 of 2002, aids in the accreditation and the development of the planning curricula in South African tertiary institutions (SACPLAN 2014a). SACPLAN has identified three key competencies that a planner should possess, namely generic, core and functional competencies. The table below provides a detailed outline of these competencies and their descriptions and categories.

Table 2. SACPLAN competency descriptors and categories

Competency	Description
Generic competency	Essential skills, attributes, and behaviours. Competencies common in built and natural environment disciplines. Includes critical thinking, interpersonal competencies, communications, leadership, professionalism and ethical behaviour, social responsibility
Core competency	Specific knowledge, skills, abilities, or experience required by planners to perform successfully as practitioners. Includes settlement history and theory, planning theory, planning sustainable cities and regions, urban planning and place making, regional development and planning, public policy, institutional and legal frameworks, environmental planning and management, transportation planning and systems, land use and infrastructure planning, integrated development planning, land economics, social theories related to planning and development research
Functional competency	Basic skills focusing strongly on techniques and methodologies. A combination of studio-based dexterities and in situ field work. Includes survey and analysis, strategic assessment, local area planning, layout planning, plan making and implementation, participation, and facilitation

Source: Compiled from SACPLAN (2014b).

Furthermore, SACPLAN (2014b) indicates that in order to ensure planning schools adhere to accreditation standards, each school allocates a level of competency (outlined in the table below) for their programmes determined by the number of credits that are allocated to modules.

Table 3. Competency Levels

Competency Level	Description	NQF Level
Level 1	Awareness of and basic understanding of terminology and concepts; and ability to source further information and insights when required in the work environment	6
Level 2	Have a good understanding of a field of knowledge, or an ability to apply a methodology	7
Level 3	Be able to apply or engage with the area of competency with increasing degree of mastery and sophistication	8 & 9

Source: Compiled from SACPLAN (2014b).

Currently, eleven universities in South Africa have qualifications that are accredited by SACPLAN and are related to spatial planning. This includes the Cape Peninsula University of Technology, Durban University of Technology, North-West University, University of Cape Town, University of the Free State, University of Johannesburg, University of KwaZulu-Natal, University of Pretoria, University of Venda, and University of the Witwatersrand. Among the programmes offered by these institutions, three are NQF level six, three are NQF level seven, three are NQF level eight, and six are NQF level nine (SACPLAN 2019).

3 Research Methodology

The empirical investigation employed a case study analysis to evaluate current approaches in tertiary education institutions in effectively transferring knowledge regarding 4IR as part of contemporary approaches to spatial planning education in South Africa. The analysis was completed by evaluating the yearbooks of selected planning schools. For standardisation of the analysis, planning schools were considered for inclusion and evaluation when they offered an accredited undergraduate course at NQF level eight. Three planning schools met this criterium. Note that these schools/institutions will remain anonymous. However, this, and the yearbook references utilised in the analysis, can be made available upon request.

Boud and Falchikov (1989) state that the method of assessment or evaluation, as used for this phase of the empirical investigation, is deemed justifiable providing that two critical elements are included as part thereof: (1) there is a criterion identified and used as benchmark; and (2) the determination is made based upon the extent to which the predetermined criterion is met. Based on the literature review, three themes related to the impact of 4IR on spatial planning has been identified. This includes a multidisciplinary, practical, and theoretical theme. To achieve the objectives of the study, these themes have been developed into the criteria used to evaluate the inclusion of 4IR within spatial planning curricula in South Africa.

Criterium one is the *multidisciplinary* theme. New technology and their application will have diverse impacts across all sectors. This includes spatial planning, but also all the stakeholders in the built environment. The emphasis on a multidisciplinary approach and the effective function of spatial planners within this milieu may foster knowledge transfer among stakeholders and support adaptation to potential future disruptions, including 4IR. The curricula will thus be evaluated in terms of how they foster multidisciplinarity among stakeholders in the built environment and expose spatial planning students to this context.

Criterium two is the *practical* theme. 4IR indicates the increased integration of technology in the production process, which will also be relevant to the activities of spatial planners in fulfilling their function. Accordingly, the curricula of the institutions will be evaluated based on their incorporation of computer-based applications and the exposure of students to relevant software in the design process. Knowhow on the practical application of current and emerging technology in the spatial planning context may foster ease-of-adaption to additional advances in the long term.

Criterium three is the *theoretical* theme. Based on the potential applications of 4IR relevant to spatial planning, increased emphasis has been placed in the creation of smart and sustainable cities through using new, advanced technology as part of 4IR. Broader disruptions to development facilitation, including land use management processes, has also been identified. Therefore, the curricula of the institutions will be evaluated based on their incorporation of these theoretical themes that represent the emerging relationship between the spatial planning field and potential applications of 4IR and related technology within this context.

4 Findings and Discussion

This section provides an overview of the findings of the curricula evaluation. Table 4 indicates details on the curricula of the institutions, with reference to their NQF level, number of modules, the total credits the curricula comprise of, and the inclusion of 4IR themes both in terms of the number of modules that incorporate related themes, and the percentage of credits that these modules represent in the curricula. The inclusion of 4IR is evaluated based on the identified criteria, which include references the multidisciplinary, practical, and theoretical themes inherent to 4IR.

Table 4. Inclusion of 4IR in programmes (number of modules and % of credits)

Institution	NQF level	Modules	Credits	4IR inclusion	
				Modules	Credits (%)
Institution A	8	35	544	9	26%
Institution B	8	41	480	11	30%
Institution C	8	46	497	11	25%
Average					27%

As evident in table 4, the curricula of the three institutions utilised in the analysis have 35, 41, and 46 modules, respectively. While these programmes share the same NQF level, their total credits differ. The relevant programme of institution A comprises of 544 credits, while being 480 in institution B, and 497 in C. In terms of the inclusion of themes relating to 4IR, the institutions have a similar number of modules and credits that are linked to this outcome.

Institution A has nine modules to which 4IR themes are relevant, and both institution B and C have 11 modules. Relative to the total number of credits that the identified modules represent, institution B has the highest proportion as 30% of credits are linked to modules that include themes relevant to 4IR. This percentage is lower in the remaining institutions; 26% in institution A and 25% in C. The average for this variable among the three sample institutions is 27%. Table 5 provides a further breakdown of the nature of the 4IR inclusion. This is presented as a percentage of the total credits that are linked to the delineated multidisciplinary, practical, and theoretical themes.

Table 5. Themes of 4IR inclusion (% of relevant credits)

Institution	Multidisciplinary	Practical	Theoretical
Institution A	15%	-	12%
Institution B	8%	8%	14%
Institution C	15%	4%	6%
Average	12%	4%	11%

As indicated in the table, the multidisciplinary theme is the most prominent relating to 4IR among the sample institutions, followed by theoretical and practical themes. On an institutional level, the inclusion of 4IR themes in the curriculum of institution A is limited to the multidisciplinary and theoretical. In terms of multidisciplinarity, institution A includes considerations of the future work environment of spatial planning students and the disciplines involved in designing and installing engineering services; urban design themes; multidisciplinary teams and related participatory planning; and the divergent roles of planners and other stakeholders in facilitating development. Accordingly, 15% of credits in the curriculum are linked to the multidisciplinary theme inherent to 4IR. In institution B this figure is 8%, with the identified modules incorporating architectural and engineering skills, while referencing planning design on different scales and themes relating to sense of place. This curriculum also emphasises the specific role of planners among built environment practitioners. Similar considerations are incorporated in the curriculum of institution C, which has the joint highest consideration of multidisciplinarity among the sample institutions: 15%.

Among the institutions, the practical theme of 4IR is the most limited of those identified. While not identified in institution A, this theme represents 8% of credits in the curriculum of institution B and 4% in institution C. The practical theme is incorporated through reference to automated and computer-based design approaches, integration of design software (e.g. AutoCAD and ArcGIS) in module outcomes, and the broad utilisation of relevant technological applications for academic purposes.

When analysing the theoretical theme of 4IR, it is evident that institutions A and B are placed second and first, with 12% and 14% of curriculum credits linked to this theme. Reference is made to smart cities within the context of creating sustainable and resilient human settlements; transport infrastructure and the future development of cities; analysis and evaluation of land use management systems; processes of development facilitation and administration; and applications of new urbanism and case studies of smart and sustainable cities. Institution C, where 6% of credits are applicable to the theoretical theme, references the future of land use management; processes relating to development applications and procedures; and innovative planning practices.

Accordingly, based on the analysis, there is a limited incorporation of themes relating to 4IR in spatial planning curricula in South Africa, with 27% of credits applicable to either its multidisciplinary, practical, or theoretical themes. Among these, the multidisciplinary theme is the most prominent, being applicable to 12% of curriculum credits in the sample institutions, followed by the theoretical (11%) and practical (4%) themes.

In comparison, spatial planning students in South Africa are entrusted to a greater degree with the knowhow and skills relating to their successful function as part of a broader, multidisciplinary team of professionals in the built environment. In the context of 4IR and the anticipated disruption inherent to the application of new – and as of yet unanticipated– technologies, this holistic contextualisation of the role of planners and integration with related disciplines may allow for more rapid adaptation as technological disruptions proliferate throughout the built environment. Continuous insights gained from related fields throughout the development process and cooperation among disciplines may not only optimise sector-wide adjustments and mitigate the potential effects of disturbances, but also enable the effective positioning of the sector over the long term. While this theme is the most prominent among those relevant to 4IR in current curricula, there is a need further integrate related considerations of multidisciplinarity relevant to spatial planning, including exposure to the skills, functions, and activities of other stakeholders, particularly architects and civil engineers, in the built environment as part of the curricula. An increased focus on multidisciplinary in the context of knowledge transfer in spatial planning education in South Africa, may aid sectoral adaptation.

The inclusion of theoretical themes related to 4IR are also limited in spatial planning education in South Africa. As discussed in section 2, there is significant theoretical overlap between spatial planning functions and potential applications of 4IR in the built environment. Increased knowledge transfer on the theoretical synergies between 4IR and spatial planning may not only enhance the adaptability of future spatial planning students, but also contribute to achieving broader societal objectives, including the creation of sustainable, resilient, and smart cities and human settlements. This is also specifically relevant to the South African urban spatial contexts, and policy objectives which seek to transform fragmented and unequal human settlements.

As evident from the findings of the analysis, there is a significant need for increased inclusion of the practical theme related to 4IR in spatial planning curricula, which currently constitutes 4% of credits. While the full breadth and depth of applications related to 4IR may be currently unclear, it is evident that automated and computer-based processes will grow in prominence. This is also applicable to the use of relevant software in the planning and design process relevant to the function of spatial planners. It is in this context that knowledge transfer on the practical application of current and emerging technology in the spatial planning may be beneficial to spatial planning students. The development of computer-based skills and knowhow may foster resilience to similar technological advances over the long term.

While there is potential for increased inclusion of 4IR themes in curricula, based on the regulatory landscape guided by SACPLAN, competencies inherent to spatial planning education (refer to table 2) empower students to be critical thinkers and creative problem solvers, in addition to gaining and applying the relevant knowledge in their field. The successful incorporation of these competencies in spatial planning education in South Africa may enable adaptability and resilience of planning professionals in the face of diverse external disruptions. These skills are of particular importance in the face of uncertainty regarding the long-term impact of 4IR on the built environment, where the application of new technology will require ongoing innovation, analytical thinking, active learning, creativity, and complex problem solving. While revised curricula may enable skills development relevant to the multidisciplinary, practical, and theoretical themes of 4IR in connection to spatial planning, striving toward the effective transfer to existing competencies to spatial planning students will enable adaptability within any disrupted context.

5 Conclusion

Significant disruption is expected in the built environment and spatial planning with the onset of 4IR and the related proliferation of advanced technologies. Spatial planning curricula in South Africa ought to be reviewed with the objective of increasing the inclusion of 4IR, including related multidisciplinary, practical, and theoretical themes. This will include knowledge transfer on the synergies between spatial planning and 4IR, the role and function of spatial planners within diverse teams of stakeholders, and the development of computer-based skills in the planning and design process. While this may increase sectoral adaptability in the face of the wide-spread implementation of advanced technologies that may revolutionise production processes, the empowerment of spatial planning students with existing competencies of SACPLAN, such as critical thinking and problem solving, may also foster long-term adaptability regardless of the nature of disruption. A future avenue of research include primary data collection with the objective of gaining input from current students and professionals in spatial planning and the built environment on their perceived preparedness for sectoral disruption caused by 4IR. Additional comparative research between different tertiary education contexts may augment the findings of this research, with the focus current limited to the South African milieu. A limitation to the current research is data availability, with the extent of curriculum analysis and evaluation limited to the detail provided in the programme overviews of each institution.

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