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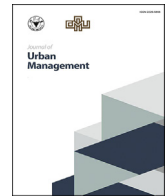
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Research Article

Modeling the smartness or smart development levels of developing countries' cities

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ABSTRACT

The race towards smart city status, influenced by the perceived benefits of innovation and sustainability in smart city concepts, has engendered the need to measure the smartness/smart development levels of developing countries' cities to improve upon urban infrastructures. However, various strategies for determining cities' smartness/smart development levels are mostly inconclusive by not considering all the dimensions in urban space in their assessments. This study adopted a fuzzy synthetic evaluation (FSE) technique to model the smartness/smart development levels of a developing country city using a six-dimensional framework which provides a comprehensive perspective on the characterization of urban frameworks of cities. A positivism research philosophy using deductive approach and purposive sampling technique was adopted. Quantitative data were collected from experts using a close-ended questionnaire in which 76 responses were retrieved. The study modeled eight indicators for each of the six dimensions using FSE to determine the smartness/smart development level index of each dimension towards the determination of the overall smartness/smart development level index of the developing country city. After analysis, the developing country city and each of the six dimensions used to characterize the city were determined as fairly developed. The implications of such level of ranking meant that the city is below the acceptable smart city status, and hence, improvement should be made in policy applications along the 48 identified indicators such as empowering human resources, sustainable resource consumption, etc., to propel the six dimensions towards smart city. This study could also serve as a theoretical model for determining the smartness/smart development levels of developing countries' cities. The study also reveals aspects in the urban framework where policy makers and urban developers could target to improve the smartness/smart development levels of cities towards the smart city status.

1. Introduction

Urbanization is defined as the process of growth or increment in the number of people in localities being classified as urban, or it could be regarded as the growing concentration of population and activities in urban and metropolitan areas, or the rapid growth and

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movement of people into urban areas (Ghana statistical service (GSS), 2014; Weeks, 2015). As urbans grow naturally through birth and/or migration, facilities and structures in urban areas become stressed and insufficient (Aghimien et al., 2020; Chatterjee & Kar, 2018). Government and city officials are entreated to identify new ways of providing for the overpopulated cities by strategically using the available limited resources without inflicting further harm on the natural environment (United Nations, Department of Economic and Social Affairs (UNDESA), 2014; Aghimien et al., 2020; Ng et al., 2021). However, cities of today must not only take into consideration the advent use of technology in urban space and the influx escalation of data to enhance urban structures towards smartness, but also appreciate requisite guidelines needed to enhance resilience, longevity, inclusiveness, and sustainability (Antwi-Afari et al., 2021; Ma & Lam, 2019).

The creation of smart cities has been achieved in its real sense in some places such as Songdo in South Korea, Kerala in India, and Masdar city in Abu Dhabi; with several pilot projects ongoing around the world (Davis, 2010; Lam & Yang, 2020). However, ever since the concept gained actuation in the scientific community in the late 20th century, the idea of smart cities, its definition and conceptualization have faced several contradicting but illuminating opinions in explicating the concept to a wide array of audience (Aghimien et al., 2020; Caragliu et al., 2011; Hollands, 2008). Gibson et al. (1992) coined the term development of urban regions towards innovation, globalization and technology to mean smart cities. However, the smart city concepts have transcended beyond the initial perception to solve urbanization problems through the usage of technology and innovation to the integration of sustainable development policies and practices to proactively counter the effects of urbanization (Antwi-Afari et al., 2021; Madakam et al., 2018; Ng et al., 2021).

The perceived benefits of adopting the smart city concepts are urging several cities in the world to improve urban structures to attain the smart city status (Lam & Yang, 2020). Yet, the question remains, how do cities identify their current level of smart development and improve urban structures through the limelight of the smart city concepts? Adopting lessons learned approach where cities implement policies from so well-doing cities or smart cities could help in improving the performance of poor cities, but cities are about people, culture, politics, environment, climate and nature, and this differ from one locality to another (Antwi-Afari et al., 2021; Martin et al., 2018). Hence, lesson learned from other smart cities could be a starting point. Nonetheless, to find the solutions to become a smart city, these poor cities must develop their own best-point solutions (Chatterjee & Kar, 2018; Chourabi et al., 2012).

In modeling the smartness or smart development levels of cities, several agencies, independent and government bodies have derived criteria or indices. For example, the Economist Intelligence Unit (EIU) in the year 2000 used digital economy ranking to assess the infrastructure quality of countries in terms of preparedness to adopt information and communication technologies (ICTs); World Economic Forum (WEF) in 2005 also used the Global Competitiveness Index (GCI), and World Intellectual Property Organization (WIPO) adopted a Global Innovation Index (GII) to rank cities in the world (Akande et al., 2019; Albino et al., 2015). But irrespective of the availability of these indices and rankings, none of them captures the entire facets of the dimensions in urban space such as mobility, economy, environment, living, governance and people (Antwi-Afari, 2019; Giffinger et al., 2007). Besides, the goal for developing countries' cities burdened with several challenges of urbanization such as traffic congestion, urban sprawl, air pollution and degradation of ecosystems is to be able to identify key problems within the cities structures and propose tailored solutions to the identified problems to improve the city's general prospects (Antwi-Afari et al., 2021; Webb et al., 2016). Therefore, the aim of this study is to model the smartness/smart development level of a developing country city (Kumasi city, Ghana) using a six-dimensional framework used for classifying medium-sized cities in a conventional study in Europe and exposing structures within the urban framework of the city which needs improvement to enhance its general ubiquitous development, resiliency, smartness and sustainability.

2. Literature review

2.1. *The changing phase of cities: The race to smart city status*

Cities have changed over the years. Previously known to be the hub for hosting the central power of governance and administrative control, cities of today have transcended beyond political ties to becoming the focal axis of living, economy, production, consumption and creativity (Aghimien et al., 2020; Bawa et al., 2016). Kroes (2010) assayed that cities of today are the drivers of innovation, inclusion, health, environment and businesses. Goodall (1987) and Kuper and Kuper (1996) defined cities as complex systems, comparatively large with stable settlements comprising of land usage, housing, transportation, utilities and sanitation. Dahiya (2012) opined that cities are the highest forms of human dwelling, the barest ground for secondary economic activities, the center for producing goods and services and the hub for entrepreneurship and social inclusion which is spearheaded by the advent of modern ICTs infrastructure linking one city to another in real time. Cities make up 2% of the earth land mass currently, but accounts for more than 50% of the world population and uses close to 75% of all the energy generated and are responsible for approximately 80% of greenhouse gas emissions while consuming up to 85% of world resources (Lee et al., 2013; United Nations Environment Programme (UNEP), 2013; UNDESA, 2014).

Notwithstanding, the number of cities in countries are in upward spiral due to urbanization and unplanned growth particularly for most developing countries (UNDESA, 2014). Therefore, Africa and Asia have been projected to increase in urbanization rate by almost 90% as compared to other continents by 2050 (United Nations, 2015). The challenges which could be faced by cities in developing countries are eminent even in current discourse (Antwi-Afari et al., 2021). For instance, in Nigeria, the current increase in population has caused people to move to cities to seek greener pastures, which is rather putting pressure on the available limited resources in the cities and as a result creating an inadequate and unhealthy environment, poor living conditions and worsen infrastructure (Aghimien et al., 2020). China, having experience a rapid 30-year economic growth and urbanization is now facing challenges such as land degradation, air pollution, social and economic disparities, unemployment, and inferior public services (Yu & Xu, 2018). In Ghana, the

rapid population growth and urban sprawl have resulted in traffic thronging, high energy consumption, poor waste management and pressure on housing (GSS, 2014).

To improve cities in developing countries towards smart city status, initiatives have been put in place to react to these challenges of urbanization. For example, current initiatives by the government of Ghana such as railway redevelopment project, free senior high schools' program, and one district one factory initiative are being implemented to revamp mobility, economy and general well-being of citizens in the country (Government of Ghana, 2019). India's government has initiated a 100 smart city development across the nation since 2015 to help create clean transportation, renewable energy supply, excellent healthcare, and affordable housing for its increasing population (Yadav et al., 2019). In South Africa, initiatives have been put in place to enhance cities in the country to accommodate smart machines, smart mobility and latest communication technologies to enhance connectivity and safety of citizens (Musakwa & Mokoena, 2017).

Irrespective of these various ambitious projects put in place to enhance cities' development towards smartness and sustainability, most developing countries are applying initiatives to city development too general and off the requisite key areas which need major focus to spur various cities to overcome their unique urbanization challenges and reach the smart city status (Aghimien et al., 2020; Ng et al., 2021). Hence, there is still the need to capture the requisite areas based on each city's status and citizens' needs to propel the development of policies to targeted aspects of cities structures such as environment, mobility, governance, living, economy and people (Antwi-Afari et al., 2021).

2.2. Modeling the smartness/smart development level of built-up cities

The determination of city smartness, or the understanding of the constructs that constitutes a smart city has been proposed and developed over the years. For example, Giffinger et al. (2007) strategically came out with a comprehensive way of defining cities, by using six-dimensional framework in urban space which comprises of mobility, economy, environment, governance, living and people. Lombardi et al. (2012) adopted Giffinger et al.'s six-dimensional framework to create a triple helix model, adding a fourth paradigm to the model. Lazaroiu and Roscia (2012) also devised a smart city index which was used in the distribution of funds for the European 2020 strategic plan. Zygiaris (2013) developed a comprehensive measurement system using six layers in defining smart cities, namely: the city layer, green city layer, instrumentation layer, open integration layer, application layer and innovation layer.

The intelligent community forum as well as other independent and government bodies have also created other assessment criterion and indices for ranking cities. For example, the global power city index was developed by the Japanese Institute for Urban Strategies; smarter cities ranking was formulated by the United States Natural Resources Defense Council for measuring cities on environmental specific performances. Scientist Joel Kotkin in collaboration with Forbes also have published the world smartest cities which mostly encourages economic hub of cities; argued to be very efficient and integrative (Akande et al., 2019; Albino et al., 2015). EIU in the year 2000 used the digital economy ranking in assessing the infrastructure quality of countries in terms of their incorporation and readiness to adopt ICTs (Al-Nasrawi et al., 2015). Other indexes used for measuring city performance includes: Global Competitiveness Index (GCI) used by the World Economic Forum since 2005; Network Readiness Index (NRI) also managed by WEF; Global Innovation Index used by WIPO and Green City Index used by EIU since 2009 under the sponsorship of Siemens.

Notwithstanding the influx of indices and methods of measurement available in determining the smartness/smart development level of a city, none captures all the dimensions of a smart city (Giffinger et al., 2007). For instance, the Green City Index mostly harnesses on environmental issues while giving little or no consideration to economic factors. The Global Competitiveness Index also focuses on the economic indicators of cities without considering other aspects of the urban framework (Antwi-Afari, 2019). Hence, using any of the indices to determine the smartness/smart development level of built-up cities could lead to limited and misleading findings (Giffinger et al., 2007). Al-Nasrawi et al. (2015) purported that the inability of the indices capturing all the dimensional-framework of cities render them inappropriate for modeling the smartness/smart development levels of any city fully.

Akande et al. (2019) enounced that the formulation of an index requires the creation of an appropriate weighting for variables. Most studies and indices used are also opaque in their methodology for weighting (Al-Nasrawi et al., 2015; Albino et al., 2015). There are two main methodologies for weighting, viz. the equal weighting method and the participatory methods. The equal weighting method is when each indicator is given the same weighting irrespective of their contribution to the measured dimension while participatory methods is when an indicator's weighting depends on its contributions. Kahn (2007) used the equal weighting method by assuming all indicators contribute the same under a particular dimension. However, the participatory method is preferred and used in this study in establishing the measurement of cities as also seen in works of Kahn (2007), Mayer (2008), and Giffinger and Gudrun (2010).

2.3. The six-dimensional framework for smart city formation

Giffinger et al. (2007) formulated a six-dimensional framework which was used to rank medium-sized cities in Europe viz people, economy, governance, living, environment and mobility. These six dimensions were formulated because existing indices and method appears unreliable for modeling the smartness/smart development levels of medium sized cities. UNDESA (2014) defines a medium size city as a city with population between one to five million people. Kumasi city, which is the largest city in Ghana in terms of population (3.49 million) makes it qualified to be classified as a medium-sized city (UNDESA, 2021). The six-dimensional framework was expatiated with a comprehensive catalogue of indicators to ensure that key areas within the urban structure were considered in analysis. Therefore, adopting these dimensions from Giffinger et al. (2007)'s studies and inferring from systematic review of literature of developing country context, further indicators were added to the list of indicators under each dimension to fit within the cultural and contextually context of Kumasi city.

Kumasi city is the industrial, administrative and cultural capital for the Ashanti region of Ghana; located approximately 500 km north of the Equator (Britannica, 2013). The city boasts of good roads linking its several business districts such as Bantama, Bompata and Adum together. The Sekondi-Takoradi to Accra railway line passes through Kumasi, but due to poor maintenance of rail tracks and trains the railway line has ceased operation. However, the incumbent government policy of railway redevelopment is said to operationalize the railway line soon (Government of Ghana, 2019). Also, since 2011, an attempt to build an inland port for Kumasi has not seen completion yet. The city has an international airport which is currently under expansion (Government of Ghana, 2019). It, however, boast of the largest open-air market in the West-Africa which serves as one of the main centers for trading of goods in the city (Emmanuel, 2018). The main occupation of most people in the city are services and manufacturing. The city has several manufacturing companies such as the Guinness Ghana Breweries, Coca-Cola company, metal engineering shops, printing shops as well as several banks, telecommunications and administrative heads of several other services companies. It is the hub of the timber industry in Ghana, and it is popularly called the ‘Garden City’ for its numerous trees and flowers (Arku, 2013). The city has four open and functional recreational parks. It also has several cultural and heritage buildings and sites which makes it a place for tourism. The city also has an official sport stadium with several mini parks for soccer and other games. The city also has good educational facilities with numerous primary, secondary and tertiary schools either privately or government owned providing education for the inhabitants of the city. The city mainly relies on hydro-electric power, but the usage of solar panels for generating electricity is growing rampantly (Vaughan, 2012). Kumasi city also has several hospitals and clinics such as the Komfo Anokye Teaching hospital, West End Hospital and Kumasi Rabito Clinic.

People: The people dimension in urban space is regarded as the most important among all the dimensions. This is because cities revolve around people and all the other dimensions link towards ensuring that the people in cities enjoy a safe, inclusive, healthy and resourceful living (Caragliu et al., 2011). To model the smartness/smart development level of cities, the people in the cities must be educated with the availability of excellent schools and training institutes in the city to enhance people understanding of basic knowledge, the use of software and the interpretation of data (Giffinger et al., 2007; Rana et al., 2019). Hollands (2008) postulated that policies in developing countries should be targeted to intentionally improve the educational lag in cities by incorporating the usage of ICT, digital and technological skills within the everyday lives of citizens. Vanolo (2014) expounded that the people dimension deals with creativity, tolerance, cosmopolitanism and the level of qualification of the people in terms of social and human capital. Giffinger et al. (2007) catalogue of indicators for the people dimension consists of flexibility, creativity, social and ethnic plurality, level of qualification, open-mindedness, affinity to lifelong learning and participation in public life.

Economy: The economic dimension of city structures is concerned with the existence of characteristics such as the ability to innovate, the spirit of entrepreneurialism, flexibility of the labor market, and the ability for cities to transform and integrate into international markets (Giffinger et al., 2007; Lombardi et al., 2012). Bakici et al. (2013), Bakıcı et al. (2013) opined that the economic dimension is also about establishing stakeholders’ cooperation through the integration of knowledge and innovation. It also encompasses the combination of the enterprise economy and innovation or ideas economy to create a green economy which could foster sustainability, cost reduction and nurturing business growth through innovative approaches (Schaffers, 2011; Zygiaris, 2013). The economic dimension considers aspects of the city that engenders and enhances business formation, sustainable management of resources, high quality of living, flexible and sustained economic growth (Caragliu et al., 2011; Renukappa & Suresh, 2018).

Governance: Rana et al. (2019) opined that the backbone of smart city formation is the governance dimension. Key indicators of this dimension consist of decision-making, transparency, enhancing public and social services and political strategies and perceptions (Giffinger et al., 2007). Meijer and Bolívar (2016) stated that transparency in governance could be enhanced through the adoption of ICTs to obtain better outcomes, new forms of human and urban collaborations and more open governance processes. Vanolo (2014) expatiated that the governance dimension of a city could be understood through the existence of a pellucid government system which is constantly innovating towards electronic governance concerning issues such as voting, taxes, health, safety and development. The city should also adopt spatial decision support systems and put in place measures to protect citizens privacy towards the rapid growth of big data which is regarded as a resource for smart city development (Lam & Yang, 2020; Schiavone et al., 2019).

Living: A city could be defined by the overall well-being of people living there. Well-being then consists of both external and internal factors which influences the satisfaction that one feels regarding where one lives (Fahey et al., 2003). Giffinger et al. (2007) expounded that the living dimension of smart city consists of the availability of cultural facilities, tourist sites, quality houses, excellent health conditions, safety, educational facilities and social cohesion. Macke et al. (2018) examined the quality of life of citizens in a Brazilian city in which it was identified that the conditions necessary to ensure quality of life emanates from the existence of indicators which promotes socio-structural relations, community integration, environmental well-being and material well-being. The living dimension could also be appreciated in terms of safety and security of food, health and social considerations and the availability of requisite facilities which promotes togetherness, love and inclusion (Giffinger & Gudrun, 2010; Lombardi et al., 2012).

Environment: Giffinger et al. (2007) stipulated that the indicators which could be considered when looking at the environmental dimension of cities are pollution, environmental protection strategies, sustainable resource management and the beauty of natural conditions. The environmental dimension indicators should consider the availability of warning system facilities for natural disasters in cities, the existence of smart grids to reduce the effects of high energy consumption and strategies to efficiently manage life on land and on water while promoting greenness and maintenance of natural resources and heritage (Lee et al., 2013; Ng et al., 2021). Strategies should be in place to also promote biodiversity in the city while promoting outdoor living and green spaces (Allam & Dhunny, 2019; Macke et al., 2018).

Mobility: The mobility dimension deals with improvement in transportation systems, reducing traffic accidents, traffic congestion and ensuring rapid movement of people around cities (Antwi-Afari, 2019). It consists of the availability of modern, sustainable and safe systems to track traffic movement, alternate traffic flows at peak moments and safeguard citizens’ safety during daily commutes through the city (Bury, 2020; Silva et al., 2018). This dimension also measures the local and international accessibility of the city, the availability

of ICT-infrastructure incorporated into transportation systems and seamless mobility accessibility for different abled people (Antwi-Afari et al., 2021; Giffinger et al., 2007). The mobility dimension should consider the existence of good road network linking various important areas in the city together with high-speed transit system to reduce traffic (Allam & Dhunny, 2019). Transport should also be easily accessible with reduced energy cost, and there should be improved walkability or cycling tracks in the region (Aletà et al., 2017).

3. Research methodology

The study adopted a positivism research philosophy using deductive approach (Antwi-Afari et al., 2021; Ng et al., 2021). To achieve the objective of the study, survey research strategy was conducted using a structured questionnaire (Collis & Hussey, 2013). The questionnaire was developed based on the six-dimensional framework of smart cities in which through a literature review and considering the context of the study, eight catalogues of indicators were obtained to measure each dimension. Questionnaire was used because of the quantitative evaluation of the indicators for each dimension in determining the smartness/smart development level of Kumasi city. The adoption of structured questionnaires to collect quantitative data using close-ended questions have been used in several studies (Ng et al., 2021; Owusu-Manu et al., 2018; Wuni et al., 2020). Also, questionnaires can generate an adequate amount of data within a short period of time, and it is reliable and accepted by industrial practitioners (Antwi-Afari, 2017; Wuni et al., 2019).

The study targeted experts in academia and industry who understand urban development or the dimensions which makes up a smart city. Since there were no central data of such experts in the city, the purposive sampling technique was used. According to Babbie (2013), the purposive sampling technique should be used when one wants to study a particular cultural setting with specific knowledgeable experts within the study domain. Notwithstanding, the experts were selected for the study when they met all these criteria. (i) A respondent should be working in an organization which has a link of influence in the urbanization of cities. (ii) The respondent should have expertise and be performing daily duties in any of the dimensions of smart city (iii) The respondent should understand smart city formation and be knowledgeable about the development status of Kumasi city. This was held firmly to enable the study obtain data from only experts who understand the six-dimensional framework and the catalogue of indicators in classifying smart cities (Kumar & Dahiya, 2017). Therefore, after purposively targeting 95 respondents, 76 (80%) responses were retrieved. The response rate was considered appropriate according to the affirmation of Moser and Kalton (1979) that the results of a survey could be considered as insufficient and biased if the return rate is lower than 30–40% of the totals sampled or distributed.

The questionnaire had two sections. The first section covered the background information of the respondents which consisted of questions such as the respondents' area of expertise and number of years of working in current positions. A nominal scale was used to analyze this section of the questionnaire. The second section of the questionnaire considered the six-dimensional framework and eight catalogue of indicators which were used to measure each dimension. A five-point Likert scale was used to gauge the respondents understanding of the smartness/smart development level of Kumasi city in the limelight of the catalogue of indicators of the six-dimensional framework. An appropriate rating was adopted from '1' – not developed to '5' – very developed.

Cronbach's alpha co-efficient test was adopted to check the internal consistency of the variables and reliability of the scale. The background information of the questionnaire was analyzed using descriptive statistics. The second section of the questionnaire was also analyzed using the fuzzy set theory via fuzzy synthetic evaluation (FSE). Fuzzy sets use linguistic variables to model the characteristics imprecision in the human cognitive process (Wuni et al., 2020). Arithmetically, a fuzzy set takes the form of membership functions which allocate grades of membership to define the rate of association of each indicator in the dimensions explained by the fuzzy set (Ameyaw & Chan, 2015). Preferences for individual or group decision-making could be achieved using this method. Hence, FSE has been accepted as one of the approaches to assess multi-criteria decision-making (cf: Ma & Kremer, 2015; Aghimien et al., 2020; Wuni et al., 2020).

4. Results and discussions

The background information of the respondents revealed that the area of expertise of the respondents was mainly in the field of governance (7.9% of the 76 responses retrieved), environment (27.6%), infrastructure and planning (43.4%), business and finance (11.3%) and education (27.6%). These areas of expertise could be seen within the six-dimensional framework adopted for this study viz economy, governance, living, people, mobility and environment. The study also identified that 76.3% of the respondents had worked in their current position for at most 10 years while 23.7% had worked for at least 11 years with 5.3% of these 23.7% having worked over 20 years in their current position.

4.1. Analytical tests

Howland and Wedman (2004) avowed that Cronbach's alpha co-efficiencies of 0.700 or more are those with very high reliable scale. The Cronbach's alpha co-efficient value of the constructs used in developing the questionnaire was 0.978 for 48 number of items, thus, showing that the scale for the study was very reliable. Also, when two or more indicators have the same mean, the one with the lowest standard deviation is given the highest priority in terms of ranking. This is because standard deviation measures the consistency of agreement between the respondents' interpretation, and hence, the lower the standard deviation, the better (Antwi-Afari et al., 2018). Yi (2011) was of the view that a standard deviation which is less than 2.000 is considered as the best because it shows a small degree of variation but a high level of agreement between how the respondents interprets the indicators. Inspecting Table 1, it could be concluded that all the indicators had a standard deviation less than 2.000, hence depicting and confirming that the respondents of this survey clearly interpreted all the indicators analogously. This study also adopted a strategic decision-making approach using fuzzy sets. For FSE,

Table 1
Weightings of dimensions and indicators of smart cities

S.N.	Dimensions and Indicators	Mean for indicators	Std. Dev. for indicators	Weightings for each indicator	Total Mean for each Dimension	Weighting for each Dimension
PD	People Dimension				23.94	0.166
PD1	Excellent schools and training institutes in the city	3.29	1.056	0.137		
PD2	Level of creativity in the urban sector	3.13	1.063	0.131		
PD3	Willingness to learn and dedication to education	3.13	1.075	0.131		
PD4	Better understanding and usage of computers	2.95	1.106	0.123		
PD5	Ability to manipulate and utilize data	2.93	1.075	0.122		
PD6	Availability of soft skills in the region	2.91	1.073	0.122		
PD7	Good reporting, reading and writing skills	2.84	1.007	0.119		
PD8	Good language skills of the citizens (English, Twi, French etc.)	2.76	0.964	0.115		
EcD	Economy Dimension				24.27	0.168
EcD1	The ability to innovate and the spirit of entrepreneurialism	3.36	1.055	0.138		
EcD2	Flexibility of the labor market and high productivity	3.29	0.977	0.136		
EcD3	Ability to transform into the international market	3.16	1.046	0.130		
EcD4	Resourceful in making most of its assets while finding solutions to problems	3.11	1.027	0.128		
EcD5	Transformation from an urban economy to a smart economy	3.04	1.012	0.125		
EcD6	Foreign/Domestic direct investment in the region	2.84	1.046	0.117		
EcD7	Destination that people want to visit (tourism)	2.83	1.051	0.117		
EcD8	High standard of living	2.64	0.962	0.109		
MD	Mobility Dimension				24.3	0.168
MD1	Strategies promoting high-speed mobility	3.09	1.073	0.127		
MD2	Integrated mobility, linking areas together (residential to workplaces to recreational, to transport nodes e.g., bus/railway stations and airports)	3.08	1.105	0.127		
MD3	Improved walkability or cycling in the region	3.05	1.142	0.126		
MD4	Seamless mobility for different abled people	3.04	1.16	0.125		
MD5	Reduced or no traffic thronging	3.04	1.194	0.125		
MD6	Sustainable transport systems (for people and goods)	3	1.108	0.123		
MD7	Mass rapid transit system (locally and internationally accessible)	3	1.131	0.123		
MD8	Accident reduction on roads in the sector	3	1.189	0.123		
EnD	Environment Dimension				23.72	0.164
EnD1	Upholding natural heritage and a strong sense of place rooted in a natural setting	3.3	1.143	0.139		
EnD2	Greenness and vegetation concerns of the place (practice afforestation and restrict deforestation)	3.12	1.222	0.132		
EnD3	Energy usage and controls in the city region	3.11	1.26	0.131		
EnD4	Efficiently manages its natural resource base (water, land, and other resources)	3.01	1.311	0.127		
EnD5	Strategies to preserve the ecological system and sustaining biodiversity in the city region	2.95	1.295	0.124		
EnD6	Promoting outdoor living and green spaces	2.83	1.37	0.119		
EnD7	Practicing good sewage and waste disposal systems	2.82	1.363	0.119		
EnD8	Warning system for natural disasters e.g., Earthquakes, Flooding etc.	2.58	1.319	0.109		
GD	Governance Dimension				22.43	0.156
GD1	Practicing urban and regional planning and integration	2.92	1.163	0.130		
GD2	Incorporating citizens in its operations	2.87	1.063	0.128		
GD3	Smart Urban Collaborations	2.86	1.174	0.128		
GD4	Smart Governance and management policies	2.83	1.204	0.126		
GD5	Smart Decision Making (Adopting spatial decision support systems, big data and geospatial technologies)	2.79	1.135	0.124		
GD6	Smart Administration (focusing on sustainable urban development)	2.76	1.199	0.123		
GD7	Openness to the public (accountability, responsiveness and transparency)	2.74	1.215	0.122		
GD8	Constantly innovating practicing e-governance to achieve better development outcomes	2.66	1.362	0.119		
LD	Living Dimension				25.57	0.177
LD1	Celebrating local history, festivals, promotes art, culture and has a ritual event	3.29	0.921	0.129		
LD2	Promoting a strong and shared values	3.29	0.977	0.129		
LD3	Plenty and healthy foods	3.28	1.028	0.128		
LD4	Personal safety and security of the place	3.26	1.147	0.127		

(continued on next page)

Table 1 (continued)

S.N.	Dimensions and Indicators	Mean for indicators	Std. Dev. for indicators	Weightings for each indicator	Total Mean for each Dimension	Weighting for each Dimension
LD5	Availability of public amenities and a vibrant downtown 24/7	3.22	1.218	0.126		
LD6	Good and satisfying social services	3.14	1.174	0.123		
LD7	Good health system	3.05	1.082	0.119		
LD8	Promotes quality living	3.04	1.064	0.119		
	Total Mean for all Dimensions				144.23	

Table 2

Membership functions (MF) of all dimensions and indicators of smart cities

S.N.	Weightings	Membership functions for each indicator (Level 3)	Membership function for each dimension (Level 2)
PD			(0.021, 0.387, 0.269, 0.212, 0.110)
PD1	0.137	(0.013, 0.263, 0.289, 0.289, 0.145)	
PD2	0.131	(0.013, 0.329, 0.303, 0.224, 0.132)	
PD3	0.131	(0.026, 0.303, 0.316, 0.224, 0.132)	
PD4	0.123	(0.026, 0.434, 0.224, 0.197, 0.118)	
PD5	0.122	(0.013, 0.461, 0.211, 0.211, 0.105)	
PD6	0.122	(0.039, 0.382, 0.329, 0.132, 0.118)	
PD7	0.119	(0.026, 0.447, 0.250, 0.211, 0.066)	
PD8	0.115	(0.013, 0.513, 0.224, 0.197, 0.053)	
EcD			(0.045, 0.304, 0.284, 0.289, 0.078)
EcD1	0.138	(0.013, 0.263, 0.211, 0.382, 0.132)	
EcD2	0.136	(0.000, 0.250, 0.329, 0.303, 0.118)	
EcD3	0.130	(0.039, 0.276, 0.250, 0.355, 0.079)	
EcD4	0.128	(0.026, 0.316, 0.263, 0.316, 0.079)	
EcD5	0.125	(0.053, 0.263, 0.342, 0.276, 0.066)	
EcD6	0.117	(0.066, 0.382, 0.250, 0.250, 0.053)	
EcD7	0.117	(0.105, 0.276, 0.355, 0.211, 0.053)	
EcD8	0.109	(0.079, 0.434, 0.276, 0.184, 0.026)	
MD			(0.072, 0.290, 0.281, 0.242, 0.115)
MD1	0.127	(0.039, 0.316, 0.250, 0.303, 0.092)	
MD2	0.127	(0.053, 0.316, 0.224, 0.316, 0.092)	
MD3	0.126	(0.092, 0.224, 0.342, 0.224, 0.118)	
MD4	0.125	(0.079, 0.276, 0.303, 0.211, 0.132)	
MD5	0.125	(0.092, 0.303, 0.184, 0.316, 0.105)	
MD6	0.123	(0.079, 0.263, 0.342, 0.211, 0.105)	
MD7	0.123	(0.079, 0.289, 0.289, 0.237, 0.105)	
MD8	0.123	(0.066, 0.329, 0.316, 0.118, 0.171)	
EnD			(0.122, 0.321, 0.169, 0.231, 0.157)
EnD1	0.139	(0.000, 0.342, 0.211, 0.250, 0.197)	
EnD2	0.132	(0.092, 0.250, 0.263, 0.237, 0.158)	
EnD3	0.131	(0.053, 0.395, 0.132, 0.237, 0.184)	
EnD4	0.127	(0.105, 0.355, 0.132, 0.237, 0.171)	
EnD5	0.124	(0.118, 0.342, 0.171, 0.211, 0.158)	
EnD6	0.119	(0.184, 0.316, 0.145, 0.197, 0.158)	
EnD7	0.119	(0.184, 0.329, 0.118, 0.224, 0.145)	
EnD8	0.109	(0.289, 0.224, 0.171, 0.250, 0.066)	
GD			(0.125, 0.351, 0.209, 0.223, 0.092)
GD1	0.130	(0.053, 0.461, 0.092, 0.303, 0.092)	
GD2	0.128	(0.066, 0.342, 0.342, 0.158, 0.092)	
GD3	0.128	(0.132, 0.289, 0.250, 0.250, 0.079)	
GD4	0.126	(0.105, 0.395, 0.171, 0.224, 0.105)	
GD5	0.124	(0.105, 0.368, 0.237, 0.211, 0.079)	
GD6	0.123	(0.132, 0.382, 0.158, 0.250, 0.079)	
GD7	0.122	(0.158, 0.329, 0.224, 0.197, 0.092)	
GD8	0.119	(0.263, 0.237, 0.197, 0.184, 0.118)	
LD			(0.024, 0.292, 0.278, 0.270, 0.135)
LD1	0.129	(0.000, 0.211, 0.395, 0.289, 0.105)	
LD2	0.129	(0.000, 0.250, 0.329, 0.303, 0.118)	
LD3	0.128	(0.000, 0.289, 0.276, 0.303, 0.132)	
LD4	0.127	(0.000, 0.355, 0.224, 0.224, 0.197)	
LD5	0.126	(0.026, 0.368, 0.158, 0.250, 0.197)	
LD6	0.123	(0.092, 0.224, 0.250, 0.316, 0.118)	
LD7	0.119	(0.053, 0.303, 0.276, 0.276, 0.092)	
LD8	0.119	(0.026, 0.342, 0.316, 0.197, 0.118)	

the evaluation of the different indicators is estimated at the level three of the membership functions (MF) while the smart development level indices of the six-dimensions are determined at the second level. The first level of the MF provides the overall smartness/smart development level index of Kumasi city.

4.2. Determination of suitable weightings for dimensions and indicators of Kumasi city

The normalized mean method was used to compute the weightings of each indicator and dimension. The weighting function of each indicator and dimension were derived using Equation (1).

$$W_i = \frac{M_j}{\sum_{i=1}^5 M_j}, \quad 0 < W_i < 1, \quad \text{and} \quad \sum_{i=1}^n W_i = 1 \tag{1}$$

Where W_i is the weightings of each indicator or dimension; M_j is the mean score of each indicator or dimension; i refers to the 5-point rating scale from 1 to 5; $\sum M_j$ is the summation of the means of all the indicators under each dimension. For example, PD1 with a mean of 3.29, and a total mean score of PD as 23.94 was calculated as:

$$W_{PD1} = \frac{3.29}{3.29 + 3.13 + 3.13 + 2.95 + 2.93 + 2.91 + 2.84 + 2.76} = \frac{3.29}{23.94} = 0.137$$

Likewise, the other indicators in the PD and those in other dimensions were all calculated using the same procedure. Also, the normalized weighting function sets satisfy the condition in Equation (1) for each dimension (Table 1). For example, the normalized weighting for PD is given by:

$$\sum_{i=1}^8 w_i = 0.137 + 0.131 + 0.131 + 0.123 + 0.122 + 0.122 + 0.119 + 0.115 = 1.000$$

Also, considering the total mean for the six dimensions (PD = 23.94, EcD = 24.27, MD = 24.30, EnD = 23.72, GD = 22.43 and LD = 25.57) as 144.23, the mean scores of the dimensions could be normalized to obtain their respective weightings using equation one as shown for PD as:

$$W_{PD} = \frac{23.94}{23.94 + 24.27 + 24.30 + 23.72 + 22.43 + 25.57} = \frac{23.94}{144.23} = 0.166$$

Also, as a check, the sum of the normalized weightings of all the six dimensions is equal to one, satisfying the Equation (1). The weightings of all the indicators and the dimensions forms the basis for calculating the membership function in Table 2.

4.3. Determining the membership functions of each dimension and indicators of Kumasi city

Based on Xu et al. (2010), the MF of each indicator could be computed from the percentage responses from the experts based on the five-point grading scale (1 – not developed (ND), 2 – least developed (LD), 3 – fairly developed (FD), 4 – developed (D) and 5 – very developed (VD)). The MF of each dimension is also created from the MF of each indicator within that dimension. The MF of each indicator is computed from Equation (2) as seen in the example for PD1. For PD1, 1.32% of the experts were of the view that “excellent schools and training institutes in the city” was not developed. However, 26.32% of the experts assessed PD1 as least developed, while 28.95%, 28.95% and 14.47% assessed PD1 as fairly developed, developed and very developed respectively. This could be represented on Equation (2) to compute the MF of PD1 as:

$$PD1 = \frac{0.013}{ND} + \frac{0.263}{LD} + \frac{0.289}{FD} + \frac{0.289}{D} + \frac{0.145}{VD} = \frac{0.013}{1} + \frac{0.263}{2} + \frac{0.289}{3} + \frac{0.289}{4} + \frac{0.145}{5} \tag{2}$$

According to Wuni et al. (2020), the MF of each indicator could be expressed otherwise as $X = \{X_1, X_2, X_3, \dots, \dots, X_n\}$. Hence, the MF of PD1 could be expressed as (0.013, 0.263, 0.289, 0.289, 0.145), and the rest of the MF for all the indicators were computed using the same procedure (Table 2).

The MF for each dimension was computed using fuzzy matrix. The fuzzy matrix equation is given in Equation (3)

$$Y_i = \begin{bmatrix} MF_{u1} \\ MF_{u2} \\ MF_{u3} \\ \dots \\ MF_{un} \end{bmatrix} = \begin{bmatrix} C1_{u1} & C2_{u1} & C3_{u1} & C4_{u1} & C5_{u1} \\ C1_{u2} & C2_{u2} & C3_{u2} & C4_{u2} & C5_{u2} \\ C1_{u3} & C2_{u3} & C3_{u3} & C4_{u3} & C5_{u3} \\ \dots & \dots & \dots & \dots & \dots \\ C1_{un} & C2_{un} & C3_{un} & C4_{un} & C5_{un} \end{bmatrix} \tag{3}$$

where Y_i is the fuzzy MF for the indicators within each dimension and MF_{u1} to MF_{un} denotes the MF of n indicators in a given dimension.

The values for C_1 to C_5 in Equation (3) are the MF level three of each indicator as shown in Table 2. Given the fuzzy matrix Y_i and the weightings W_i of each indicator (Table 1), the fuzzy evaluation matrix (Z_i) could be calculated using Equation (4).

$$Z_i = W_i \otimes Y_i = \{w_1, w_2, w_3, \dots, w_n\} * \begin{bmatrix} C1_{ui1} & C2_{ui1} & C3_{ui1} & C4_{ui1} & C5_{ui1} \\ C1_{ui2} & C2_{ui2} & C3_{ui2} & C4_{ui2} & C5_{ui2} \\ C1_{ui3} & C2_{ui3} & C3_{ui3} & C4_{ui3} & C5_{ui3} \\ \dots & \dots & \dots & \dots & \dots \\ C1_{uin} & C2_{uin} & C3_{uin} & C4_{uin} & C5_{uin} \end{bmatrix} = (z_{i1}, z_{i2}, \dots, z_{in}) \tag{4}$$

Where z_{in} is the degree of membership function of the grade alternative for a given dimension and ‘ \otimes ’ is the fuzzy composite operator. For instance, as shown in Table 2, LD contains eight indicators which has weightings of $W_{LD} = \{0.129, 0.129, 0.128, 0.127, 0.126, 0.123, 0.119, 0.119\}$, considering the MF of the indicators in this dimension from LD1 to LD8 (Table 2), the fuzzy evaluation matrix using Equation (3) could be seen as:

$$Y_{LD} = \begin{bmatrix} MF_{LD1} \\ MF_{LD2} \\ MF_{LD3} \\ MF_{LD4} \\ MF_{LD5} \\ MF_{LD6} \\ MF_{LD7} \\ MF_{LD8} \end{bmatrix} = \begin{bmatrix} 0.000 & 0.211 & 0.395 & 0.289 & 0.105 \\ 0.000 & 0.250 & 0.329 & 0.303 & 0.118 \\ 0.000 & 0.289 & 0.276 & 0.303 & 0.132 \\ 0.000 & 0.355 & 0.224 & 0.224 & 0.197 \\ 0.026 & 0.368 & 0.158 & 0.250 & 0.197 \\ 0.092 & 0.224 & 0.250 & 0.316 & 0.118 \\ 0.053 & 0.303 & 0.276 & 0.276 & 0.092 \\ 0.026 & 0.342 & 0.316 & 0.197 & 0.118 \end{bmatrix}$$

Hence, the fuzzy evaluation matrix for LD using Equation (4) is given as

$$Z_{LD} = W_{LD} \otimes Y_{LD} = \{0.129, 0.129, 0.128, 0.127, 0.126, 0.123, 0.119, 0.119\} * \begin{bmatrix} 0.000 & 0.211 & 0.395 & 0.289 & 0.105 \\ 0.000 & 0.250 & 0.329 & 0.303 & 0.118 \\ 0.000 & 0.289 & 0.276 & 0.303 & 0.132 \\ 0.000 & 0.355 & 0.224 & 0.224 & 0.197 \\ 0.026 & 0.368 & 0.158 & 0.250 & 0.197 \\ 0.092 & 0.224 & 0.250 & 0.316 & 0.118 \\ 0.053 & 0.303 & 0.276 & 0.276 & 0.092 \\ 0.026 & 0.342 & 0.316 & 0.197 & 0.118 \end{bmatrix}$$

$$= (0.024, 0.292, 0.278, 0.270, 0.135)$$

Analogously, the other dimensions’ fuzzy evaluation matrices as shown in Table 2 were calculated following these same procedures.

4.4. Computing the development indices and the overall smart development index of Kumasi city

The indices of the six-dimensions could be computed as a product of the fuzzy evaluation matrix of each dimension and the five-point grade Likert scale used for the study. The development level index is given mathematically by:

$$D_{index} = \sum_{i=1}^5 (Z_i \times E_i) \tag{5}$$

Where E_i is the five-point Likert scale (1, 2, 3, 4, 5); Z_i is the fuzzy evaluation matrix of a given dimension and D_{index} is the smartness/smart development level index of a given dimension of smart cities. Hence adopting Equation (5), the smartness/smart development level index of the six-dimensions of smart cities could be computed as:

$$\begin{aligned} PD &= (0.021, 0.387, 0.269, 0.212, 0.110) \times (1, 2, 3, 4, 5) = (0.021*1 + 0.387*2 + 0.269*3 + 0.212*4 + 0.110*5) = 3.000 \\ EcD &= (0.045, 0.304, 0.284, 0.289, 0.078) \times (1, 2, 3, 4, 5) = (0.045*1 + 0.304*2 + 0.284*3 + 0.289*4 + 0.078*5) = 3.051 \\ MD &= (0.072, 0.290, 0.281, 0.242, 0.115) \times (1, 2, 3, 4, 5) = (0.072*1 + 0.290*2 + 0.281*3 + 0.242*4 + 0.115*5) = 3.038 \\ EnD &= (0.122, 0.321, 0.169, 0.231, 0.157) \times (1, 2, 3, 4, 5) = (0.122*1 + 0.321*2 + 0.169*3 + 0.231*4 + 0.157*5) = 2.980 \\ GD &= (0.125, 0.351, 0.209, 0.223, 0.092) \times (1, 2, 3, 4, 5) = (0.125*1 + 0.351*2 + 0.209*3 + 0.223*4 + 0.092*5) = 2.806 \\ LD &= (0.024, 0.292, 0.278, 0.270, 0.135) \times (1, 2, 3, 4, 5) = (0.024*1 + 0.292*2 + 0.278*3 + 0.270*4 + 0.135*5) = 3.197 \end{aligned}$$

The above smartness/smart development level indices for the six-dimensions are considered as the second level of FSE analysis. The overall smartness/smart development level index of Kumasi city could be computed using the fuzzy evaluation matrices of the six-dimensions of smart cities and their corresponding weightings in Equations (3) and (4). The weightings of the six dimensions from Table 1 are (PD = 0.166; EcD = 0.168; MD = 0.168; EnD = 0.164; GD = 0.156; LD = 0.177). Hence, $W_{Overall}$ could be written as (0.166, 0.168, 0.168, 0.164, 0.156, 0.177). Also, considering the fuzzy evaluation matrices of the six dimensions from Table 2 and inputting them in Equation (3) the fuzzy MF of the dimensions could be written as:

$$Y_{Overall} = \begin{bmatrix} MF_{PD} \\ MF_{EcD} \\ MF_{MD} \\ MF_{EnD} \\ MF_{GD} \\ MF_{LD} \end{bmatrix} = \begin{bmatrix} 0.021 & 0.387 & 0.269 & 0.212 & 0.110 \\ 0.045 & 0.304 & 0.284 & 0.289 & 0.078 \\ 0.072 & 0.290 & 0.281 & 0.242 & 0.115 \\ 0.122 & 0.321 & 0.169 & 0.231 & 0.157 \\ 0.125 & 0.351 & 0.209 & 0.223 & 0.092 \\ 0.024 & 0.292 & 0.278 & 0.270 & 0.135 \end{bmatrix}$$

The fuzzy evaluation matrix for the overall dimensions using Equation (4) is given as

$$Z_{Overall} = W_{Overall} \otimes Y_{Overall} = \{0.166, 0.168, 0.168, 0.164, 0.156, 0.177\} * \begin{bmatrix} 0.021 & 0.387 & 0.269 & 0.212 & 0.110 \\ 0.045 & 0.304 & 0.284 & 0.289 & 0.078 \\ 0.072 & 0.290 & 0.281 & 0.242 & 0.115 \\ 0.122 & 0.321 & 0.169 & 0.231 & 0.157 \\ 0.125 & 0.351 & 0.209 & 0.223 & 0.092 \\ 0.024 & 0.292 & 0.278 & 0.270 & 0.135 \end{bmatrix}$$

$$= (0.067, 0.323, 0.249, 0.245, 0.115)$$

The overall smartness/smart development level index of Kumasi city could be calculated using Equation (5) as

$$\text{Overall level of smartness/smart development} = (0.067, 0.323, 0.249, 0.245, 0.115) \times (1, 2, 3, 4, 5) = (0.067*1 + 0.323*2 + 0.249*3 + 0.245*4 + 0.115*5) = 3.015$$

4.5. Discussions

The findings from the analysis revealed the smartness/smart development level indices of all the six dimensions of smart cities for Kumasi city to be around the 3-point Likert grade scale. Also, the overall smartness/smart development level index of Kumasi city after the FSE analysis was 3.015. Based on the 5-point Likert scale adopted for this study, it could be concluded that Kumasi city is fairly developed. Likewise, the smart development level indices of all the six dimensions of Kumasi city could also be said to be fairly developed. The implications of these levels of indices for each dimension is further elaborated as follows:

People Dimension (PD): The people dimension of Kumasi city is currently at a smartness/smart development level index of 3.000 which is the fourth highest among the six dimensions. In order to improve the smartness/smart development level of Kumasi city, the indicators in the people dimension should be considered seriously by policy makers and urban developers. This is because the people dimension is a very keen part of the smart city framework which needs to be considered in order to offshoot the other dimension into action (Antwi-Afari, 2019). Caragliu et al. (2011) opined that people make up the city, and therefore all the other dimensions should be implemented to ensure that the people in the city can enjoy a safe, inclusive, resourceful and sustainable city. Hence, the people dimension is a true measure of how smart any city could be. This means that the smart development of cities should incorporate excellent schools and training institutes towards improving the level of creativity and soft skills in the city (Hollands, 2008; Vanolo, 2014). The focus of the people dimension is about empowering the human resources in the city, and hence, initiatives should be put in place during smart city formation to enhance people's communication skills, technology usage and their adroitness in utilizing data (Giffinger et al., 2007; Rana et al., 2019).

Economy Dimension (EcD): This was the second developed dimension among the six dimensions which was used to determine the smartness/smart development level index of Kumasi city (3.051). The economy dimension consists of indicators such as “the ability to innovate and the spirit of entrepreneurialism”; “flexibility of the labor market and high production” as well as the “ability to transform into the international market”. Caragliu et al. (2011) and Renukappa and Suresh (2018) assessed that the economic dimensions should measure the ability of the city to give rise to business creation, high quality living and a sustained economic growth. It could be inferred from the smartness/smart development level index of this dimension that Kumasi city is fairly developed in this dimension. This could be attributed to the recent opening of its largest open-air market in West-Africa which serves as one of the main centers for trading goods and services in the city (Emmanuel, 2018). Also, the city has a chain of manufacturing and services companies which provides a boosting economy for its citizens. Notwithstanding, the current smart development level index of this dimension still needs improvement and policy makers should consider enhancing the indicators in this dimension such as standard of living, sustainable resource consumption and foreign/domestic direct investment towards smart city development (Schaffers, 2011; Zygiaris, 2013).

Mobility Dimension (MD): This dimension was the third developed dimension for Kumasi city. The city has currently seen a boost on its road networks through the formation of several interchanges and repair of old roads to improve the general accessibility of its business districts (Government of Ghana, 2019). Notwithstanding, since this dimension deals with other indicators such as “accident reduction on roads”, “mass rapid transit system”, and “sustainable transport systems” which experts ranked poorly. Policy makers should consider improving these indicators and their derivatives and by adopting the usage of renewable energy vehicles and incorporating emerging technologies such as computer vision and light detection and ranging to improve the overall travelling efficiency and reduce accident on roads (Silva et al., 2018). Also, the accessibility of the city to differently abled persons is a very keen indicator which exhibits city's smartness or smart development level and should be improved for Kumasi city drastically (Danso et al., 2017, pp. 535–547).

Environment Dimension (EnD): Kumasi city environment dimension was the fifth developed index among the six-dimensions which were used to classify the city's smartness/smart development status. Though the city was previously known as the ‘Garden City’ of Ghana, many green vegetation, parks and trees have now been levelled to the ground to make way for the growing population, mobility, markets and housing in the city (Arku, 2013). This could be attributed to why experts ranked this dimension very low for a previous

environmental hub city. To improve this dimension, urban planners and developers should sought to plan the city in symphony with the environment where infrastructures and ecological systems are sustainably integrated and maintained (Allam & Dhunny, 2019; Macke et al., 2018). Other indicators in this dimension which ranked very low such as “the availability of warning systems for natural disasters”, “practicing good sewage and waste disposal systems” and “promoting outdoor living and green spaces” should be incorporated into the city’s smart development to proactively enhance the safety, greenness and livelihood of Kumasi city (Antwi-Afari et al., 2021).

Governance Dimension (GD): The governance dimension is the backbone of smart city creation (Rana et al., 2019). But this dimension was the lowest ranked for Kumasi city with all the indicators of this dimension below 3.000 (fairly developed). Hence, it could be inferred that the city’s urban collaboration, e-governance, decision making, and integration all fall below acceptable levels to be classified as smart or developed in the smart city sense. To improve this dimension, Meijer and Bolívar (2016) opined that city officials should enhance the adoption and usage of ICTs infrastructure to promote transparent governance, openness and enhance human urban collaborations. Lam and Yang (2020) expatiated that as urban grows, big data becomes a resource for cities smart development, and thus, initiatives should be put in place to monitor and protects citizens privacy. Vanolo (2014) was of the view that the governance dimension could be achieved when a transparent governance system is adopted for the city with enabled technologies which could promote e-voting, e-taxes, e-health and crime reporting to enhance the safety and well-being of citizens in the city.

Living Dimension (LD): This dimension has been regarded by researchers as a key dimension which could be assessed to understand the overall smartness or smart development level of cities (Antwi-Afari et al., 2021; Giffinger et al., 2007). This is because the living dimension seeks to measure the well-being of citizens in the city (Fahey et al., 2003). The living dimension was the highest ranked dimension (3.197), but it is below the acceptable threshold limit of a 5-point Likert scale of 3.5 (Wuni et al., 2020), and therefore this dimension is still fairly developed. Policy makers and urban planners could enhance this dimension by improving the identified indicators and its derivatives through enrichment of the health system and social services in the city, encouraging more healthy agricultural yields for the city and promoting a city of inclusion, love, cultural integration, environmental and material well-being and a sense of shared value among the citizens (Giffinger et al., 2007; Macke et al., 2018).

5. Conclusions

This study was conducted to model the smartness or smart development level of a developing country city (Kumasi city in Ghana). The study adopted a six-dimensional framework *viz* economy, living, governance, environment, mobility and people to classify and understand the urban framework of Kumasi city. The use of the six-dimensions provides an inclusive synthesis view which could reveal key areas within the urban framework of cities which needs to be considered to generally enhance the smartness/smart development levels of cities towards smart city status. Through a systematic review of literature and based on already established indicators from a conventional study, eight indicators were created to gauge the smartness/smart development level of each dimension using the participatory weighting method. The smartness/smart development level of each dimension and Kumasi city was then modeled using fuzzy synthetic evaluation (FSE) technique.

The findings from the analysis revealed that Kumasi city is a fairly developed city with a smartness/smart development level index of 3.015 below the acceptable threshold of 3.5 for a city ranked on a 5-point Likert scale to be dubbed as developed. Additionally, none of the six-dimensions which were used to classify the city’s urban framework retained a score above the acceptable threshold after the FSE analysis, and hence, they were all fairly developed. The implications from the analysis exhibited key indicators within each dimension which needs improvement to enhance the city’s smartness/smart development level such as (i) empowering the human resources in the city to become more digital and educated to enhance the people dimension (ii) enhancing the standard of living, resource consumption and investments in the city to improve the economy dimension (iii) improving the accessibility of the city for different abled persons and adopting the use of renewable energy vehicles and emerging technologies to augment the mobility dimension (iv) proactively enhancing the city’s greenness, safety and livelihood by building infrastructures in symphony with the environment to boost the environment dimension (v) developing a transparent governance system which supports electronic means for assessing issues in the cities such as taxes, health, crime reporting and voting to enrich the governance dimensions and (vi) upgrading the health and social services systems in cities, and encouraging social inclusion and food security to enhance the living dimension of the city.

Consequently, this study could serve as a theoretical model for determining the smartness/smart development level of developing countries’ cities. To the world of practice, the identified indicators and dimensions could assist policy makers and urban development planners to be abreast with the requisite areas within the urban framework which needs to be improved to drastically spur the smartness/smart development level of developing countries’ cities.

Irrespective of the contribution of the study to theory and practice, there are some key limitations which needs to be considered when interpreting the results of the study. For instance, the study was conducted for only one city in a developing country, and this may not be representative for all cities in developing countries. Hence, understanding the parameters and context of individual cities could enhance making well-informed decisions and adjustable results from this study. Also, the study could not provide much detail into the various indicators of each dimension to enrich policy makers to know which indicators are more important and could be applied immediately to drastically improve the smartness/smart development levels of cities. Although the people and the living dimensions are proclaimed as important, further study is needed to provide substantive result to support this assertion scientifically. Moreover, the use of quantitative analysis only is a limitation to this study. Hence, further study could adopt a mixed approach, determine the roles of the respondents, and screen the identified indicators with the experts in the city qualitatively before gauging the indicators to measure each dimension quantitatively.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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