Environment and Ecology Research 11(2): 328-339, 2023 http://www.hrpub.org
DOI: 10.13189/eer.2023.110208

Instrumenting GIS as Smart City Tools to Identify the Impact of Tidal Flood Threat in the Coastal Zone of Pekalongan City

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Received January 1, 2023; Revised March 1, 2023; Accepted March 19, 2023

Cite This Paper in the Following Citation Styles

(a): *[1] Yasser Wahyuddin, Akhmad Rizky Fernanda, L.M. Sabri, Fauzi Janu Ammarohman, "Instrumenting GIS as Smart City Tools to Identify the Impact of Tidal Flood Threat in the Coastal Zone of Pekalongan City," Environment and Ecology Research, Vol. 11, No. 2, pp. 328 - 339, 2023. DOI: 10.13189/eer.2023.110208.*

(b): *Yasser Wahyuddin, Akhmad Rizky Fernanda, L.M. Sabri, Fauzi Janu Ammarohman (2023). Instrumenting GIS as Smart City Tools to Identify the Impact of Tidal Flood Threat in the Coastal Zone of Pekalongan City. Environment and Ecology Research, 11(2), 328 - 339. DOI: 10.13189/eer.2023.110208.*

Abstract Pekalongan City, Central Java, Indonesia, is an urban area that often experiences floods and tidal hazards. The topography of Pekalongan City is lower than the sea, resulting in frequent tidal surges. The existence of the Smart City concept encourages the use of digital instruments to identify the extent of built areas that have a threat of tidal floods. Enhanced Built-Up and Bareness Index (EBBI) were used to map built-up areas. At the same time, the GIS method is considered a digital instrumental tool to identify and obtain flood and tidal hazard classes. Results of this study demonstrate three categories of flood and tidal hazards: a low threat of 305,79 hectares or 6.67%, a moderate danger of 1897,94 hectares or 41.94%, and a high threat of 2321,25 hectares or 51,3%. The total area of built areas that fall into the low classification is 22.25 hectares or 1.58%, the medium threat is 784,54 hectares or 55.5%, and the great danger is 606,62 hectares or 42.8%. From this case, the study also stressed that the circumstances of the Smart City concept had brought more and more exposure to digital instruments employed by local government.

Keywords GIS, Smart City, Coastal Zones, Mapping, Hazard

1. Introduction

Pekalongan City is a city in the Province of Central Java, located on the north coast of Java Island, with a height of approximately one meter above sea level. Pekalongan City has an area of 45.25 km² divided into 4 sub-districts: West Pekalongan District, North Pekalongan District, East Pekalongan District, and South Pekalongan District. The North Pekalongan District is the widest sub-district, with an area of 1488 ha of Pekalongan City. The smallest subdistrict is the Pekalongan Timur Subdistrict, namely 355,14 hectares.

The topography of Pekalongan City can be said to be low. Pekalongan City is geographically located between 0 and 6 meters above sea level, with slopes ranging from 0 to 8% meters. This condition indicates that the area of Pekalongan City is lowland coupled with soil types, primarily alluvial, and various alluvial types cover Pekalongan City.

Geographically, the location of Pekalongan City is right in the coastal area, which is vulnerable to disasters such as floods and tidal waves. Apart from being caused by the topographical conditions, Pekalongan is surrounded by 3 rivers, the leading cause of flooding: the Loji River, Banger River, and Pekalongan River. The existence of floods and tidal disasters in Pekalongan City has become a common occurrence. The Pekalongan City Government is trying to anticipate disasters, such as training programs for the community and physical prevention by installing flood and tidal barriers on the Loji and Banger rivers.

On the other side, the attraction of a Smart city has provided a new dimension in hazard mitigation. To integrate the Smart City concept, the Pekalongan City Government

2021 has begun integrating all IT approaches, including GIS software technology.

Since Smart City came and resonated as a new grand urban vision in almost all parts of the world, urban practitioners, businesses, politicians, academics, communities, and NGOs have taken turns giving views that have enriched the repertoire of the Smart city itself. In the end, many argue that Smart City will remain a fragmented topic without a single form that can be followed uniformly. But not a few have also contributed to providing extraordinary inputs so that Smart cities can move out of their technology-driven framework and include sustainability, inclusive development, ecology, and green cities frameworks that lead to one ultimate concept.

Therefore, objectively, this study examines the implementation of the Smart city of the City of Pekalongan in a grounded manner, the extent to which the Smart city concept applied provides a transformative portrait of urban environment measurement from traditional to technology-driven. Some researchers have shown social adaptation and community ecological communication development [1]. Pekalongan City, Central Java, is an urban area that often experiences floods and tidal disasters. The research predicted the increase of flood in this area could attain 36 cm in 2025 and 132 cm in 2050 [2], [3]. The latest study also identified that tidal flooding had enlarged yearly. In 2020 alone, the tidal flood coverage area was 783.99 hectares [4], while other research asserted that tidal floods had affected 50% of Pekalongan city[3].

Floods and tidal floods in Pekalongan City often occur during the rainy season and high tides. In 2021, there are recorded cases of flooding occurring almost every day. The rise of sea levels and land subsidence have contributed mainly to the exposure of Pekalongan City prone to flooding and tidal disasters.

Figure 1 demonstrates the geographical position of Pekalongan City as a coastal city which exposes its vulnerability to floods and tidal hazards. Most of its area along the coastline has a high-risk threat. The event is coupled with the absence of planned mitigation efforts since the disaster was identified, so the population and settlements in the zone are still very high. It cannot be denied that the average surviving population has low economic capacity.

Built-up areas are objects affected by floods and tidal disasters. It is essential to understand, map and identify their total area in the disaster-prone zone and whereabouts to estimate the impact and losses. Reporting to the existing Pekalongan City data for 2021, the built-up area in Pekalongan City is around 51% of the area of Pekalongan City. In bearing so, it strengthens the urgency to map the built-up areas affected by floods and tidal disasters into several threat classes.

Determination of areas that have the potential to be affected by floods is a reference zone in managing flood disasters in Pekalongan City since generally Indonesia applied the priority scale methods to its urban planning due to the lack of funding. Analysis of the threat of floods and tidal disasters is carried out using the principles of Geographic Information Systems. Processing of several parameters is carried out by scoring, including rainfall data, soil type, land use, slope, distance from the river, distance from the coastline, topography, and density of the river then each parameter is overlaid.

This research uses the Analytical Hierarchy Process method in preparing the threat parameter weighting. This study resulted in the hazard map for floods and tidal disasters in built-up areas in Pekalongan City, which has the urgency to present numbers of built-up regions threatened by floods and tidal disasters in several classes and the population density affected in flood and tidal disaster classes. From another perspective, the Smart City concept encourages using digital instruments to identify the extent of built areas that threaten flooding and the number of people affected. The Enhanced Built-Up and Bareness Index (EBBI) is used to map built-up areas, while the GIS method is used to obtain flood and tidal hazard classes.

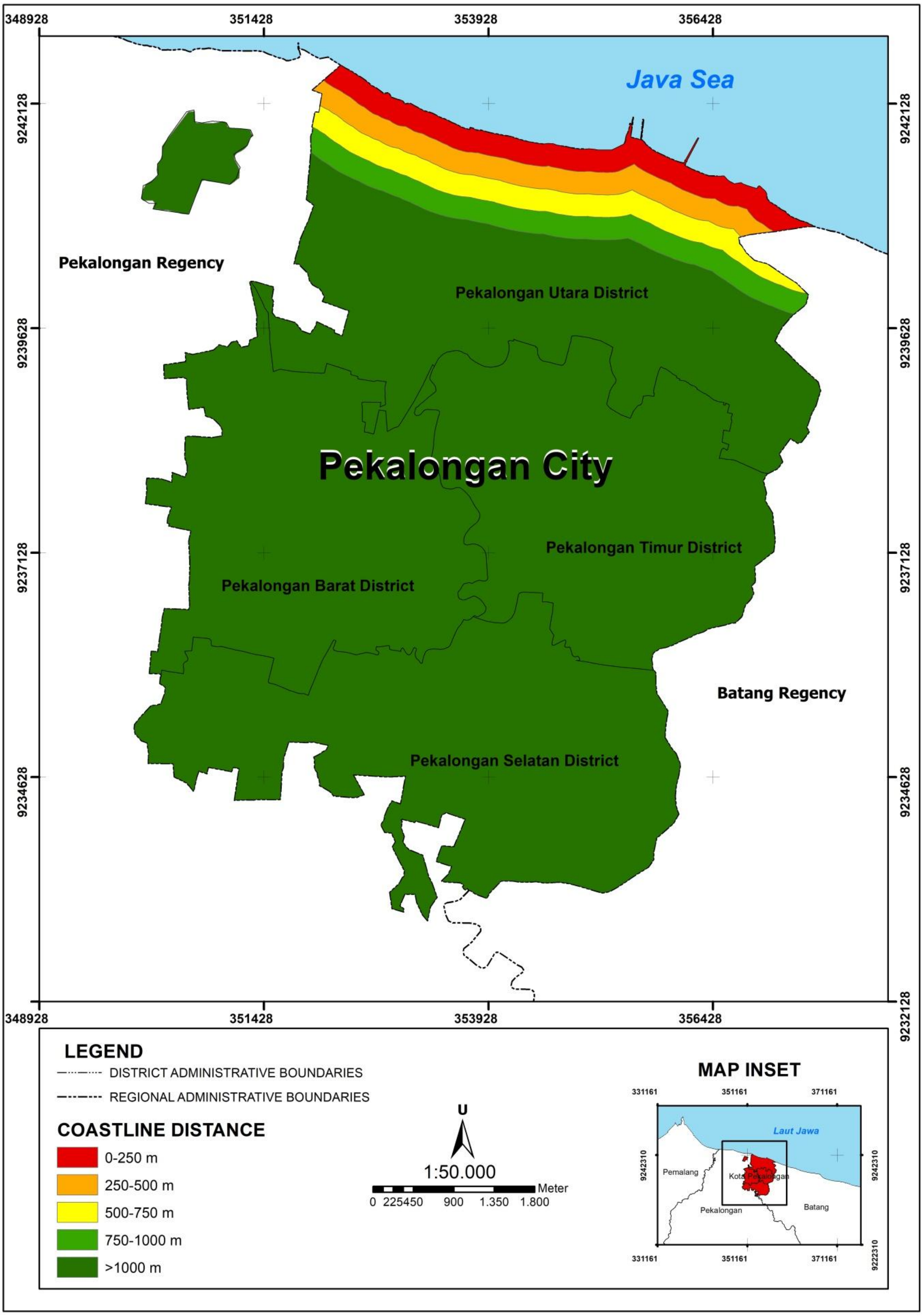

Figure 1. The Geographical Position of Pekalongan City as a Coastal City and the distance of the urban area from the coastline

2. A Brief Literature Review

2.1. The Wave of Smart City

Since the global success of the Smart city became an imperative grand urban vision, public government, whether it is a supra-national institution, national government, and local government, has acknowledged the importance of the smart city [5]–[8]. The first wave of Smart cities might be attributed to the concept proposed by the giant IT Enterprises IBM, Siemens, Cisco, and Microsoft [9]–[11]. IBM considered the public sector a vast untapped market, and the Smart City concept could be the gate to enter those opportunities [12].

The first concept of which Smarter Cities – Smarter Planet designed by IBM could be found in the 2008 Annual Report comprised early outset of Smart City as follows: (a) Smarter Traffic, (b) Smarter Healthcare, (c) Smarter Grids, (d) Smarter Food, (e) Smarter Money, (f) Smarter Telecommunication, (g) Smarter Oil.

Some aspects, such as Smarter Traffic, Smarter Healthcare, Smarter Grids, and Smarter Telecommunication, are commonly issued today as the component of a Smart city. During the years, these 7 initial dimensions were completely revised into (a) Smart economy, (b) Smart mobility, (c) Smart society, (d) Smart environment, (e) Smart living, and (f) Smart governance. Figure 2 explains the conceptual changes of IBM Smart cities. It is argued that Smarter Money and Smarter Oil appeared to be a pillar of a Smart city, proving the Smart City concept was born from an industrial perspective. Thus, urban studies scholars deplored the Smarty city as not rooted in the traditional idea of urban planning heritage. The Smart City was the by-product of the IT corporate business model [13].

The flagship model of the first Smart City was the Command Center in Rio De Janeiro through a collaboration with IBM and the Songdo Project of Cisco and Gala International in South Korea. The latter was a very ambitious project to build a new high-technology central business city in the peninsula of Korea [14], [15]. In the circuit of the global city attractiveness, Songdo was prepared to compete with Shenzhen as the new capital business in Asia in which the city design and development under the banner of Smart city have brought a new model of collaboration marked by the presence of Corporate IT expert [12], [16].

As the first wave of Smart cities began, the focus was invested notably in developing the technological layer. The IT features governed the early stage of Smart city implementation through high connectivity infrastructures, development of RFID systems and IoT, and close monitoring of the city movement and activities. As the head of Smart city development of IBM clearly stated in an interview conducted by Townsend [12]: Smart city marks the end of an era of "theoretical hypothesis" [17], with the ability to collect voluminous data with more incredible velocity and variety, the 3V Data modeling could drive the city. Thus, the city system needed to be rewired with a higher connectivity system as the fourth infrastructure [18].

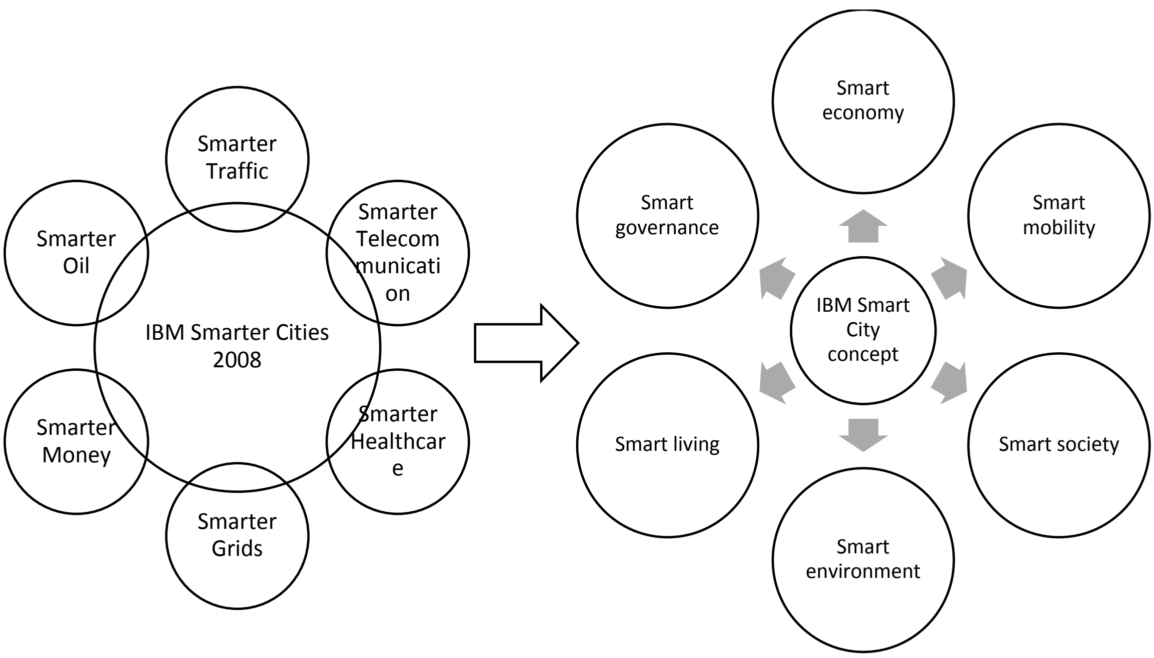

Figure 2. Conceptual Changes from the 2008 IBM Smarter cities – Smarter Planet to the current IBM model

Lately, our previous research argued as a Smart city becomes more and more a new urban vision, many attempts through the academic realm and city activists have put Smart cities into the traditional discourses of city development and management [19], [20]. Smart city has become an inseparable component of the urban planning paradigm in the digital era and has become increasingly entrenched among urban planning institutions. The meaning and definition of a Smart city were detached from its initial IBM model. At some point, a rethinking of the human dimension and the human scale cities reappeared strongly to challenge the power of digital cities dystopian [21]–[23]. Here, the rise of militant Urban studies works from prestigious international urban planning university research centers elaborated critical thinking on Smart cities. Specific terms are employed, such as Smart City and The Right of the City, From Smart City to Human Smart city, the right to the sustainable urban Smart city, Alternatives of Smart city – grassroots digital consideration, the call to citizenship, and the justice in Smart city era [24]–[29]. More concretely, a manifesto to scaffold citizen rights and people-centric action in Smart cities accumulated in Cities' Coalition for Digital Rights involving cities worldwide from west to east, Amsterdam, Amman, Sydney, San Jose, Sao Paolo, etc. [30].

2.2. Built Areas and EBBI

Built-up area is land that has undergone a construction or pavement process on the ground [34]. Another term for built-up land is everything created, arranged, and maintained by humans to meet human needs, namely everything that mediates the environment because of the influence of its ecological context. The built-up area includes buildings, roads, public facilities, and others.

Meanwhile, according to As-Syakur, 2012, the appearance of urban areas based on remote sensing data shows that rural and urban areas are very different. In general, the appearance of objects in villages is still dominated by various vegetation types, while houses, government offices, hospitals, and Streets dominate urban areas [35].

The mapping of built-up areas has many problems, one of which is the difficulty of distinguishing built-up areas from vacant land. Ambiguity often occurs so that it is not uncommon for misunderstandings in the interpretation of the built area. Initially, the method for determining built-up areas used the NDBI (Normalized Difference Built-up Index), UI (Urban Index), and NDBaI (Normalized Difference Bareness Index) indexes to map vacant land. However, the use of this index is felt to be less effective in mapping built-up areas and vacant land simultaneously because built-up areas and vacant land will later become one class if this index is used.

There are deficiencies in this index. Other indices are used in mapping physical areas, built-up areas, and vacant land because this index uses NIW, SWIR, and TIR waves. NIR is used because it can detect vegetation areas better when compared to built-up areas. In contrast, SWIR can see built-up areas better than vegetation areas. The TIR with low albedo effectively maps built-up areas because it eliminates shadows and water.

The Enhanced Built-Up and Bareness Index (EBBI) can map and distinguish between built-up areas and vacant land, and the EBBI Index uses radio waves of 0.83 μm, 1.65 μm and 11.45 μm (NIR, SWIR, and TIR) on Landsat 9 OLI/TIRS imagery. This wavelength was chosen based on the reflection range of contrast and absorption in built-up areas and vacant land (As-Syakur, 2012).

3. Research Methodology Approach

This study employs quantitative research methods. Using Geographic Information System instruments is an integral part of this research to conduct data analysis. This research implements the Analytical Hierarchy Process (AHP) as an unstructured, multi-component approach method for solving complex situations hierarchically by assigning subjective values to the relative importance of each variable and determining which variable has the highest priority to influence an outcome. AHP is needed as input for map processing in GIS to obtain scoring, weighting, and overlay data in spatial analysis. The following are the stages in the implementation of this research:

1. Identifying the problem as part of the research process can be interpreted as an effort to define the problem and make the problem measurable and as the first step of research.
2. A literature study was conducted to identify existing problems in Pekalongan City, Central Java Province. In this case, the issue of Flood disasters. This problem will be solved using a Geographic Information System (GIS) later.
3. Data collection is described as follows:
    a. Pekalongan City Administration Map
    b. Pekalongan City Land Use Map
    c. DEM of Pekalongan City
    d. Map of Soil Types of Pekalongan City.
    e. Map of Pekalongan City River Network Types
    f. Pekalongan City Road Network Map
    g. Pekalongan city rainfall data
    h. Tidal data of Pekalongan waters
    i. Data on Flood disaster events in Pekalongan City in 2020-June 2022
    j. Sub-district data in Pekalongan City figures
4. The weighting value is obtained from the AHP (Analytical Hierarchy Process) method, in which the informant represents vital stakeholders in Pekalongan City government agencies.
5. Performing tidal flood modeling processing
6. Perform weighting with the AHP method in a tabular way

7. The results of the data overlay are then classified into 3 (three) classes, including low, medium, and high, based on the range of the AHP weighting results.
8. Overlaying the threat of flooding, flood modeling results with the built-up area processing index with the help of imagery.
9. The analysis results are a threat map for floods and tidal disasters in built-up areas in Pekalongan City.
10. The descriptive analysis acknowledges the advantages and disadvantages of implementing GIS as tidal flood risk identification. The following figure 3 demonstrates the Allure of the research.

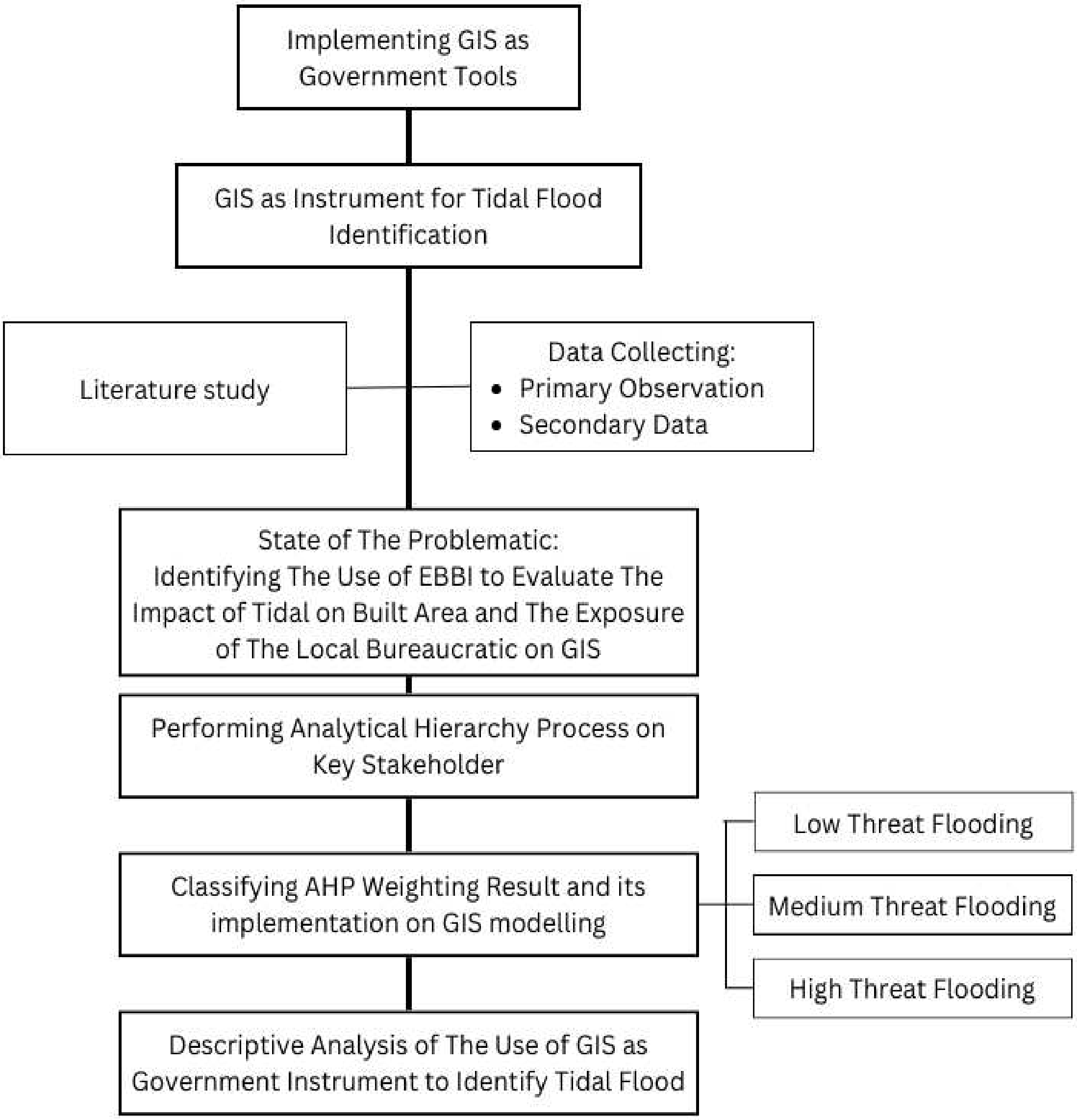

Figure 3. The Allure of the research

4. Result and Discussion

4.1. Flood Threat Level in Built-Up Areas

After obtaining the results of processing the flood hazard maps and the area of the built-up area, it is necessary to carry out a union process on the processed data. This process is needed to understand the total size of the built-up area, which is classified into low, medium, and high threat classes to flood disasters. From these results, a classification of flood and tidal hazards was obtained for each built-up area in Pekalongan City which was divided into 3 classes, namely low, medium, and high. The figure below shows that red indicates high risk, orange is medium, and yellow is low risk.

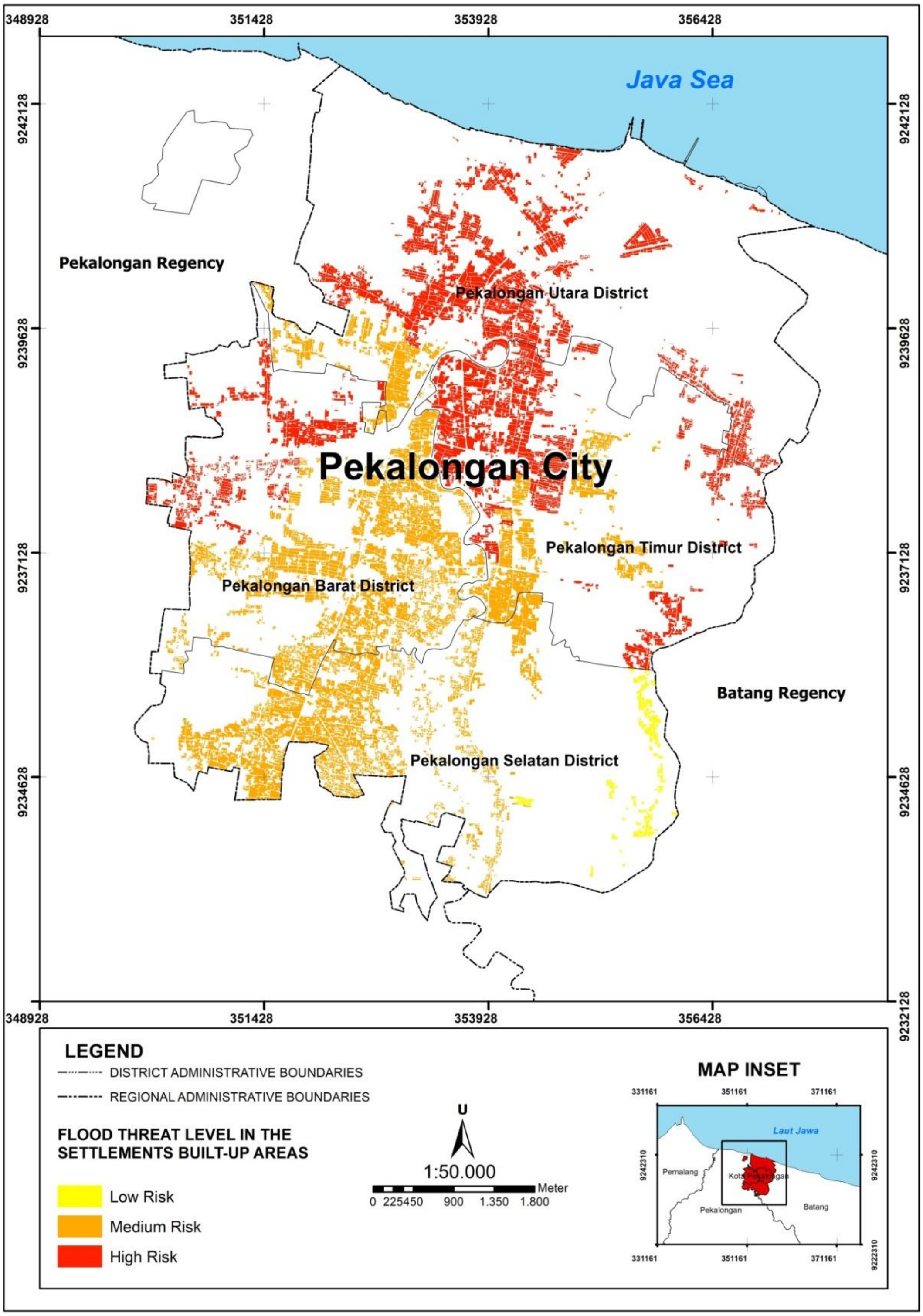

Figure 4. Map of flood and tidal threats in built-up areas

The results of the spatial mapping analysis above it are then outlined in Table 1 to show the built-up area with different levels of flood and tidal threats. The yield of low-threat classes was 22,25 hectares with a percentage of 1.58%. As for the intermediate threat class, 784,54 hectares were produced with a portion of 55.5%, while for the high threat class, 604,62 hectares were made with a percentage of 42.8%.

While the classification of flood threats of built-up areas in each district is presented in table 2, based on the results of the category of flood threats of built-up areas per sub-district in Pekalongan City, the highest number of the built-up regions affected by floods in high hazard class is found in North Pekalongan District with a built-up area of 277,402 ha. Meanwhile, the built-up area with a low threat class is in West Pekalongan District, with an area of 0.002 ha of affected built-up area. Three out of four sub-districts in Pekalongan City do not have low-class built-up areas. The results indicate that most of the flood and tidal hazard classes in Pekalongan City belong to the high and moderate classes.

Table 1. Classification of Flood and Tidal Hazards in Built Areas

No	Treat categories	Built-up areas (Ha)	Percentage
1	Low	22.257	1.58%
2	Medium	784.544	55.59%
3	High	604.620	42.84%
	Total	1411.421	100.00%

4.2. Flood Risk on Population

The analysis of built areas can be related to the population or residents who occupy a built space. Calculation of the number of people affected by the threat of floods and tidal disasters can be carried out so that it can be seen the number of people affected by floods and tidal disasters in Pekalongan City. The total population data per sub-district was obtained from the Central Bureau of Statistics (BPS) for the City of Pekalongan, contained in the City of Pekalongan Figures for 2022.

In the analysis stage of the number of people affected, it is necessary to use the help of building shapefile data for the City of Pekalongan. The step was done because the processing of the EBBI index cannot classify more detailed impervious surfaces such as office buildings, settlements, industrial plants, etc. Therefore, additional data is needed to determine a more detailed built-up area. The number of affected populations in each hazard class is determined by estimating the people living in the built-up area. This assumption is intended because residents only live in residential areas. So that detailed calculation results can be obtained and continued for calculating the number of affected populations for each hazard class in each sub-district in Pekalongan City.

The overlay results of the two EBBI data and supporting data in the form of digitized shapefiles of built areas focused on settlements show quite different results from the resulting EBBI results. The EBBI could not be classified in detail the types of built-up land cover. From these results, the total population threatened by floods and tidal disasters was calculated for each parameter class in each sub-district in Pekalongan City, which can be seen in table 3 below.

Table 2. Classification of Flood Threats and Robust Built Areas per District

No	Districts	Categories	Area (Ha)	Percentage (%)
1	Pekalongan Barat	Low	0.002	0.00%
		Medium	336.142	23.82%
		High	101.024	7.16%
		Total	**437.168**	**30.97%**
2	Pekalongan Timur	Medium	108.948	7.72%
		High	226.195	16.03%
		Total	**335.142**	**23.75%**
3	Pekalongan Utara	Medium	63.906	4.53%
		High	277.402	19.65%
		Total	**341.307**	**24.18%**
4	Pekalongan Selatan	Medium	22.255	1.58%
		High	275.549	19.52%
		Total	**297.804**	**21.10%**
	The sum of All districts		**1411.421**	100.00%

Table 3. Threats of Floods on Settlement-Built Areas

No	Districts	Risk Categories	Area (Ha)	Percentage (%)	Population	Vulnerable population	
1	Pekalongan Barat	Medium	202,081	78,31%	95.187	Medium	74.543
		High	55,965	21,69%		High	20.644
		Total	**258,047**	100,00%		**Total**	95.187
2	Pekalongan Timur	Medium	63,266	30,80%	69.010	Medium	21.253
		High	142,167	69,20%		High	47.757
		Total	**205,433**	100,00%		**Total**	69.010
3	Pekalongan Utara	Medium	39,980	19,13%	78.691	Medium	15.054
		High	169,012	80,87%		High	63.637
		Total	**208,993**	100,00%		**Total**	78.691
4	Pekalongan Selatan	Low	15,548	8,68%	65.422	Low	5.679
		Medium	163,565	91,32%		Medium	59.743
		Total	**179,113**	100,00%		**Total**	65.422
Total sum			**851,586**		**308.310**		**308.310**

The overlay of the built-up area index with the shapefile data of residential areas, the results showed that the highest class of residents at risk of flooding and tidal flooding is in The North Pekalongan District with a threatened population of 63.637 people with a percentage of 80.8% of the total population in North Pekalongan District. The lowest class is in Pekalongan Selatan District, with a population of 5,679 people with a percentage of 8.68%. Each sub-district in Pekalongan City has a variety of threat levels, from low, medium, and high.

4.3. Discussions

4.3.1. Importance of GIS as Flood Risk Assessment

Performances of GIS as a tool for flood risk assessment tools here were discussed as an essential part of the research results. Validation of built areas with a threat of flooding is carried out using field validation techniques by photographing the part of the area used as the validation point and followed by short interviews with residents around the validation point to ask about the threat of flooding in the area. The level of danger of flooding can be classified by assuming that if residents say "frequent" floods occur, the site is organized with a "high" threat class. If residents say "ever," then it is assumed that the area has a threat of flooding in the "moderate" category, and if residents say "never," then the site can be classified in the class of danger of flooding "low." The following field validation results can be presented in the table below:

From the five validation examples above, the results of the suitability of the flood and tidal hazard classes in Pekalongan City can be seen. The weakness in the EBBI can cause a discrepancy between processing and validation regarding the built-up area of the built-up index. In that case, the incompatibility of flood and tidal hazard classes can be caused by several things. Based on the results of going directly to the field and brief interviews with some of the residents, it is true that areas that are closer to the river flow will be more prone to flooding. The Pekalongan City Government is intensively revitalizing and revamping river embankments and seawater breakwaters to reduce and anticipate river and seawater overflows that will occur. Flood and tidal hazard areas in Pekalongan City are spread evenly in almost all regions in Pekalongan City.

Based on the validation results, there is a conformity between the processing results and field validation of 84%, with 58 appropriate points and 11 inappropriate points.

Table 4. Validation Results of Built-Up Areas Threatened by Floods

No	District	Coordinate		GIS result		Field check	Field Documentation
		latitude	longitude	Flood and Tidal	Built Areas		
1	Pekalongan Utara	109.681	-6.8654	High	Built area	Confirmed	
2	Pekalongan Utara	109.6851	-6.8598	High	Built area	Confirmed	
3	Pekalongan Utara	109.6904	-6.8622	High	Built area	Confirmed	
4	Pekalongan Utara	109.6855	-6.8653	High	Built area	Confirmed	
5	Pekalongan Utara	109.6873	-6.8678	High	Built area	Confirmed	

Source: Fieldwork realized by Akhmad Rizky Fernanda, 2022

4.3.2. Advantages and Disadvantages of GIS for Local Government

During the implementation of this research, GIS has become one of the most fundamental tools for local governments to carry out identification, mapping, analysis, and rapid evaluation of regional disaster conditions. However, the results of this study also show a very critical aspect, where the lack of human resources is a strategic issue. It was s confirmed by several previous studies in Indonesia, which underlined the lack of human resources in the field of GIS, which is a barrier for local governments in implementing GIS as an instrument of governance [36], [37]. These studies highlight the lack of human resources in implementing GIS as a fundamental instrument.

Therefore, many of the objects of this research, especially local government circles, hope that GIS will become one of the mandatory materials for increasing capacity building for government human resources. In addition, it is expected that GIS applications based on Open Source will be considered for standardization in Indonesia to be used as instruments in government.

5. Conclusions

From the contextual perspective, it should be noted that the Smart City concept in Indonesia has brought a wave of digitalized instruments into the public government in many sectors. In this case, GIS is considered a Smart city representative. Beyond that point of view, using GIS and EBBI methods should provide essential elements for the local government. From the results of processing flood threats in built-up areas in Pekalongan City, the following conclusions can be obtained:

1. The level of threat of floods in Pekalongan City is classified into 3 threat classes, namely low, medium,

and high threats, based on the results of the hazard map issued by BPBD Pekalongan City. The area of flood threats in the low class is 305,79 hectares, with a percentage of 6.67%. The medium category is 1897.94 hectares with a portion of 41.94%, and the area in the high class is 2.321,25 ha with a percentage of 51.30%. In general, the threat of floods and tidal disasters in Pekalongan City is dominated by the high-threat zone because Pekalongan City is close to a river that flows directly into the sea and has a low topography compared to rivers and sea. Hence, if there is heavy rain and high tides simultaneously, the City of Pekalongan tends to be flooded from river runoff, seawater, and direct tidal floods from the sea.

2. The built-up area obtained from the processing of the EBBI built index is 15,830 pixels or 1.411,42 hectares. The most significant number of the built-up regions is in West Pekalongan District, with an area of 437,13 hectares with a percentage of 30.97%. Meanwhile, the least number of built-up parts is in South Pekalongan District, with an area of 297,80 hectares with a portion of—21.10%. From the total built-up area to the sub-district area, it will be obtained that West Pekalongan District, with a percentage of 43.5%, is the sub-district with the most dominant built-up area compared to the number of the built-up regions of other sub-districts.
3. Combining parameters with the overlay method from processing built-up areas with the threat of floods and tidal disasters shows that as many as 22,257 hectares of the built-up regions are categorized into the low threat class with a percentage of 1.58%. Furthermore, 784,54 hectares of built-up areas, or 55.59%, are categorized as medium threat class. And built-up areas classified as high-threat type resulted in 606,62 hectares of built-up areas with a percentage of 42.84%. The overlay process was carried out between the built-up area index and the shapefile data of residential areas. The results were that the highest class of residents at risk of flooding and tidal flooding was in North Pekalongan District, with a population threatened of 63,637 people with a percentage of 80.87%. In North Pekalongan District. Followed by the results of the number of people at risk of flooding, with the lowest class being in Pekalongan Selatan District, with a population threatened of 5,679 people with a percentage of 8.68%. It determines that the population in each sub-district in Pekalongan City has a variety of threat levels, from low, to medium and high.

This study's advances led to digging deeper into the need for GIS implementation. The latter is not only based on the competence and agility of the GIS instrument itself, but the fundamental problem lies in the market for the public government to obtain increased capacity in GIS operations and standardization of Open-Source GIS.

REFERENCES

[1] H. I. Wahyuni, A. A. Fitrah, F. Handayani, and D. Robie, "Ecological communication in Asia-Pacific: A comparative analysis of social adaptation to maritime disaster in Indonesia and Fiji," *Pacific Journal. Rev.*, vol. 24, no. 1, pp. 12–36, 2018, doi: 10.24135/pjr.v24i1.390.

[2] M. B. Pratama, "Tidal Flood in Pekalongan: Utilizing and Operating Open Resources for Modelling," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 676, no. 1, 2019, doi: 10.1088/1757-899X/676/1/012029.

[3] A. Ramadhani Maharlika, S. Prawata Hadi, Kismartini, and A. Lenty Hoya, "Tidal flooding and coastal adaptation responses in Pekalongan City," *E3S Web Conf.*, vol. 202, pp. 1–8, 2020, doi: 10.1051/e3sconf/202020206027.

[4] M. Zainuri, M. Helmi, M. G. A. Novita, H. P. Kusumaningrum, and M. Koch, "Improved Performance of Geospatial Model to Access the Tidal Flood Impact on Land Use by Evaluating Sea Level Rise and Land Subsidence Parameters," *J. Ecol. Eng.*, vol. 23, no. 2, pp. 1–11, 2022, doi: 10.12911/22998993/144785.

[5] P. D. Mullins and S. T. Shwayri, "Green Cities and 'IT839': A New Paradigm for Economic Growth in South Korea," *J. Urban Technol.*, 2016, doi: 10.1080/10630732.2015.1102825.

[6] M. De Jong, S. Joss, D. Schraven, C. Zhan, and M. Weijnen, "Sustainable-smart-resilient-low carbon-eco-knowledge cities; Making sense of a multitude of concepts promoting sustainable urbanization," *J. Clean. Prod.*, 2015, doi: 10.1016/j.jclepro.2015.02.004.

[7] R. Kitchin, "Big Data, new epistemologies and paradigm shifts," *Big Data Soc.*, vol. 1, no. 1, p. 205395171452848, 2014, doi: 10.1177/2053951714528481.

[8] A. Datta, "The digital turn in postcolonial urbanism: Smart citizenship in the making of India's 100 smart cities," *Trans. Inst. Br. Geogr.*, 2018, doi: 10.1111/tran.12225.

[9] A. Caragliu, C. F. Del Bo, K. Kourtit, and P. Nijkamp, "The winner takes it all: forward-looking cities and urban innovation," *Ann. Reg. Sci.*, 2016, doi: 10.1007/s00168-015-0734-5.

[10] M. Batty, "How disruptive is the smart cities movement?," *Environ. Plan. B Plan. Des.*, vol. 43, no. 3, pp. 441–443, 2015, doi: 10.1177/0265813516645965.

[11] J. Gabrys, "Programming environments: Environmentality and citizen sensing in the smart city," *Environ. Plan. D Soc. Sp.*, 2014, doi: 10.1068/d16812.

[12] A. Townsend, *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia*. 2013.

[13] A. Picon, "Smart Cities: A Spatialized Intelligence," *Digit. Birmingham*, 2015, doi: 10.1007/978-3-319-47361-1.

[14] E. Strickland, "Cisco bets on {South} {Korean} smart city," *IEEE Spectr.*, 2011, doi: 10.1109/MSPEC.2011.5960147.

[15] O. Kolotouchkina and G. Seisdedos, "Place branding

strategies in the context of new smart cities: Songdo IBD, Masdar and Skolkovo," *Place Brand. Public Dipl.*, 2018, doi: 10.1057/s41254-017-0078-2.

[16] P. Maillard and P. Brunet, "Urban Environmental Monitoring (UEM): a demonstration project pooling corporate expertise for smarter cities implemented in Nice Plaine du Var," *F. Actions Sci. Reports [En ligne], mis en ligne le 01 juin 2017, Consult. le 07 mai 2019.*, no. Special Issue 16 | 2017, pp. 24–29, 2017.

[17] C. Anderson, "The End of Theory: The Data Deluge Makes the Scientific Method Obsolete," *Wired Mag.*, 2008, doi: 10.1016/j.ecolmodel.2009.09.008.

[18] R. Kitchin, "The Real Time City," *'Smart Urban. Utop. Vis. or False Daw. Work. Univ. Durham, 20-21 June 2013.*, 2013, doi: 10.2139/ssrn.2289141.

[19] Y. Wahyuddin, L. M. Sabri, and F. Hadi, "Smart Meter as Technical Brick for Ecological Transition, or the New Knowledge Capital for Industries?," *Environ. Ecol. Res.*, vol. 10, no. 3, pp. 346–354, 2022, doi: 10.13189/eer.2022.100303.

[20] Y. Wahyuddin and M. A. Wibowo, "The socio-technical governance of smart city to scaffold city energy transition policy," *Civ. Eng. Archit.*, vol. 9, no. 5, pp. 1409–1420, 2021, doi: 10.13189/cea.2021.090514.

[21] G. Eldeeb, M. Shehata, and H. Hafez, "Towards More Human Cities in Egypt : Human-City Urban Planning Model HCUPM," *Civ. Eng. Archit.*, vol. 10, pp. 47–70, 2022, doi: 10.13189/cea.2022.101403.

[22] S. Al Zahrani, R. Babonji, and H. Alhalabi, "End of Utopia: Dystopian Architecture," *Civ. Eng. Archit.*, vol. 10, no. 3A, pp. 93–101, 2022, doi: 10.13189/cea.2022.101312.

[23] Á. Depiné, V. Eleutheriou, and M. Macedo, "Human dimension and the future of smart cities," *V Congr. Int. Cid. Criativas*, no. September, p. 10, 2017.

[24] F. Bidandi and J. J. Williams, "Understanding urban land, politics, and planning: A critical appraisal of Kampala's urban sprawl," *Cities*, vol. 106, no. April 2020, p. 102858, 2020, doi: 10.1016/j.cities.2020.102858.

[25] A. M. Levenda, D. Mahmoudi, and G. Sussman, "The Neoliberal Politics of " Smart " : Electricity Consumption, Household Monitoring, and the Enterprise Form," *Can. J. Commun.*, vol. 40, no. 40, pp. 615–636, 2015, doi: 10.22230/cjc.2015v40n4a2928.

[26] N. Vadiati, "Alternatives to smart cities: A call for consideration of grassroots digital urbanism," *Digit. Geogr. Soc.*, vol. 3, p. 100030, 2022, doi: 10.1016/j.diggeo.2022.100030.

[27] J. Evans, A. Karvonen, and R. Raven, "The experimental city: New modes and prospects of urban transformation," in *The Experimental City*, 2018.

[28] S. Heitlinger, N. Bryan-Kinns, and R. Comber, "The right to the sustainable smart city," in *Conference on Human Factors in Computing Systems - Proceedings*, 2019, doi: 10.1145/3290605.3300517.

[29] R. Kitchin, P. Cardullo, and C. Di Feliciantonio, "Citizenship, Justice and the Right to the Smart City," *Program. City*, pp. 1–28, 2018.

[30] I. Calzada, M. Pérez-Batlle, and J. Batlle-Montserrat, "People-Centered Smart Cities: An exploratory action research on the Cities' Coalition for Digital Rights," *J. Urban Aff.*, pp. 1–26, Nov. 2021, doi: 10.1080/07352166.2021.1994861.

[31] D. S. Naidu, "GIS Applications to Smart Cities," *Int. J. Adv. Multidiscip. Sci. Res.*, vol. 1, no. 1, pp. 5–7, 2018.

[32] W. Li, M. Batty, and M. F. Goodchild, "Real-time GIS for smart cities," *Int. J. Geogr. Inf. Sci.*, vol. 34, no. 2, pp. 311–324, Feb. 2020, doi: 10.1080/13658816.2019.1673397.

[33] M. S. Rana and S. Sarkar, "Prediction of urban expansion by using land cover change detection approach," *Heliyon*, vol. 7, no. 11, p. e08437, 2021, doi: https://doi.org/10.1016/j.heliyon.2021.e08437.

[34] T. J. Bartuska, "The Built Environment: Definition and Scope," 2007.

[35] A. R. As-syakur, I. W. S. Adnyana, I. W. Arthana, and I. W. Nuarsa, "Enhanced built-UP and bareness index (EBBI) for mapping built-UP and bare land in an urban area," *Remote Sens.*, vol. 4, no. 10, pp. 2957–2970, 2012, doi: 10.3390/rs4102957.

[36] R. Astuti, "Peranan sistem informasi geografis," vol. 5, no. 3, 2006.

[37] A. Yani, "Kebutuhan Basis Data untuk Aplikasi Sistem," no. 3, 2011.