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Research Article

A review on worldwide urban observatory systems' data analytics themes: Lessons learned for Malaysia Urban Observatory (MUO)

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ABSTRACT

The application of data analytics in urban governance is crucial in addressing municipal issues. However, there are limited sources to review and discuss research related to urban observatories, which is one of the monitoring systems implemented in an urban area. This study aims to review existing urban observatory systems around the world to understand the pattern of data analytic themes, the analysis involved and types of the data. A total of 30 urban observatories were used as secondary data as an inductive analysis of thematic content using NVIVO 12 Plus. Environmental, economic, social, physical, and global agenda are the five key data analytic themes. The finding of the study is that environmental and social data analytics were the most commonly used themes in the 30 UOs surveyed. Also, the UO system developers focused on GIS (Geographic Information System) data relating to the physical environment and land cover. While efforts are being made to improve spatial data, in advanced analysis, however, data modelling and prediction/forecasts are still lacking. In conclusion, examining existing urban observatory systems are critical to the Malaysia Urban Observatory's development. Later, MUO will assist Malaysia in tracking the trajectory of urban development and well-being of its citizens.

1. Introduction

More than half of the world's population already lives in urban areas, and two-thirds of the world's population by 2050 is expected to reside in urban areas, while Asia has approximately 50% of its population living in urban areas (United Nation, 2018). The urban population of Malaysia is estimated to increase to no more than 85% by 2040, from 71% in 2010 (PLANMalaysia, 2016). Cities have been repeatedly identified as hotspots to address the interrelated environmental, health, and social concerns afflicting our rapidly urbanizing world (Dickey et al., 2021). In order to solve municipal issues, it is critical that the urban governance thoroughly understand the current situation in urban areas so that the proposed solutions are accurate and appropriate. Urban development produces a plethora of data via various formal and informal channels, but these data are not always accessible or collected in useable formats. Malaysia and

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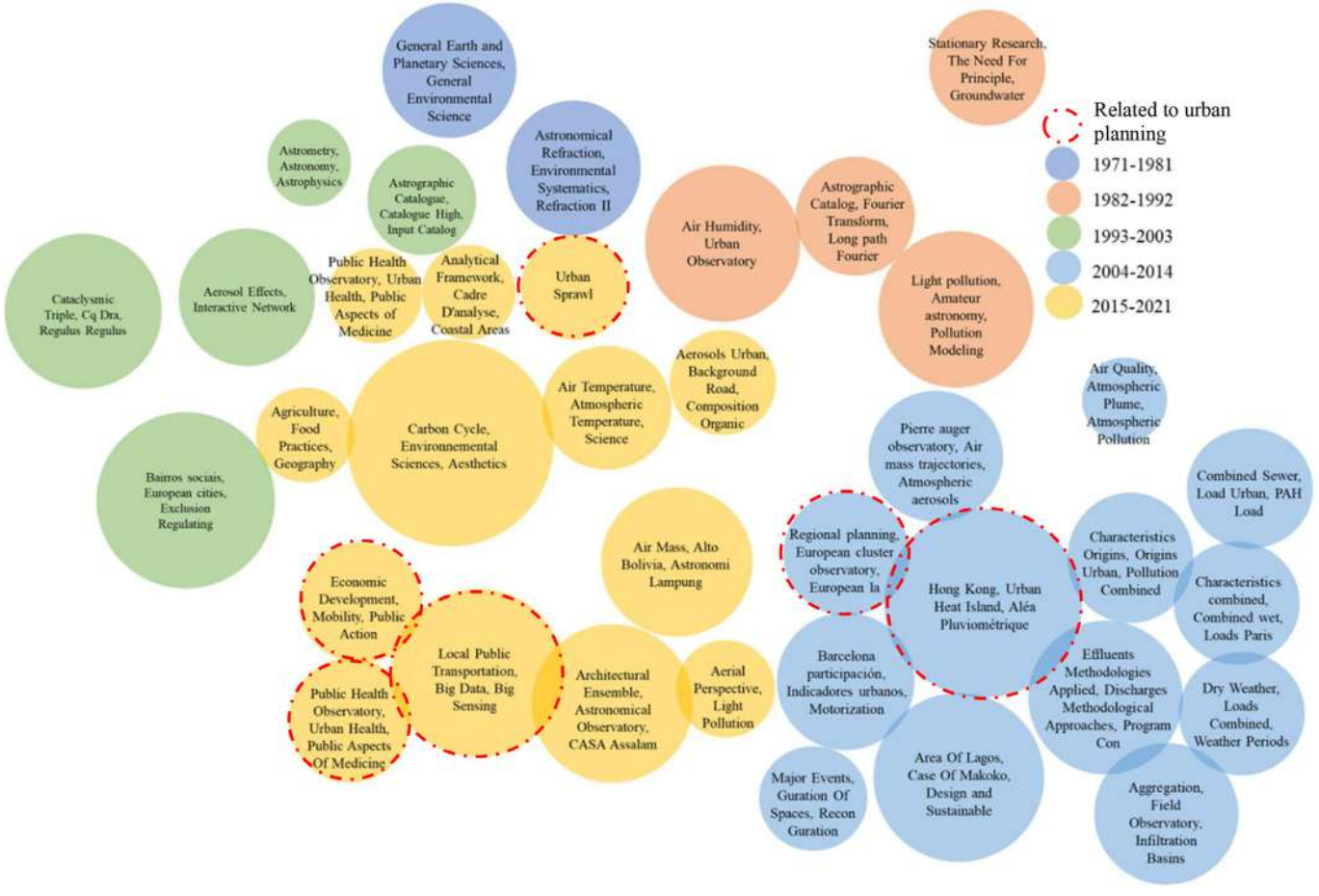

Fig. 1. The pattern of "urban observatory"-related publications from 1971 to 2021
Data analysis from (Open Knowledge Maps, 2021).

others are still struggling with the effort to collect municipal data in a geographically referenced format that is up to date, valid and reliable. The traditional data collection method used by PLANMalaysia and most Malaysian government agencies is project-based and not open to the public. This results in other project operators duplicating the same data collection process, as most project managers consider the data collected to be confidential and cannot be shared with others. Regrettably, a great deal of data is not systematically stored and thus lost. As a result, in the absence of a centralized database that specifically collects data related to municipal issues, the urban management and monitoring process becomes less efficient and the decision-making process becomes more time-consuming. The impact on the country, on the other hand, is that the policies that are developed are less effective in terms of resolving a problem. It is not only necessary to use the most recent data for synthesis, but it is also critical to consider historical data when attempting to determine the pattern of an issue.

Therefore, in 1996, UN-Habitat introduced an "urban observatory" system to monitor urban areas. However, the implementation of UO is limited, nor is it a popular topic for scholarly journal articles. From on research patterns for journal publications, it was discovered that from 1971 to 2021, there are still fewer studies examining UO specifically for the topic of urban planning (Open Knowledge Maps, 2021). Open Knowledge Maps (OKM) give a fast overview of the subject by displaying the main areas and documents associated to each area at a glance. This enables to identify useful and relevant information quickly, and similar publications cluster together. This facilitates identifying the appropriate information when searching for an ambiguous phrase or when users want to locate content in a multidisciplinary topic from one discipline.

During the first three (3) decades (1971–2003), the term "urban observatory" referred to earth observation studies (see Fig. 1). Earth observation is the collection of data on the planet's physical, chemical, and biological systems. It entails monitoring and assessing the state of and changes in the natural and man-made environments. Then, from 2004 to 2021, UO's studies on urban planning began to emerge. However, the number is still small, and studies related to earth observation continue to predominate.

Urban observatories, according to UN-Habitat, are institutions that span geographical boundaries and perform an explicit monitoring function in one or more urban settlements. On the whole, observers should perform five key functions: data and information gathering, research and knowledge production, policy development, capacity building, and facilitating dialogue and collective advocacy for urban priorities across a variety of global agendas (UN Habitat, 2015). As a result, urban observatories have emerged as organizations that are able to facilitate the transfer of knowledge between research and decision-making environments. Meaningful adjustments and improvements are more likely to be achieved in troublesome urban problem areas. Public and private decision-makers, academic researchers and educators, professionals associated with local governmental units, and members of the general public are all directly involved (Cape, 1971).

An initial prototype of a global urban observatory (GUO) was presented at the Habitat II Conference, which took place in Istanbul in 1996. It was first mentioned and documented in Agenda 21, chapter 40, in 1992 (Holden, 2015). Earlier, UN-Habitat published Global Urban Indicator Database Version 1 (GUID 1) in 1993 to track a set of key indicators related to sustainable development issues (Michalos, 2015). As part of the Habitat Agenda and the Millennium Development Goals, the GUO has established a network of local and national urban observatories and has assisted in the development, training, and use of indicator-based tools to measure progress towards these goals. The GUID had a total of 77 indicators in the most recent update, with 132 countries and 1500 urban areas covered (UN-Habitat, 2021b); excluding Malaysia.

Therefore, in 2016, National Physical Plan-3 (NPP-3) outlined the development of Malaysia Urban Observatory (MUO) in Chapter 7, thrust P2 (PLANMalaysia, 2016). When it comes to the National Land Use Planning System in Malaysia, the National Physical Plan (NPP)

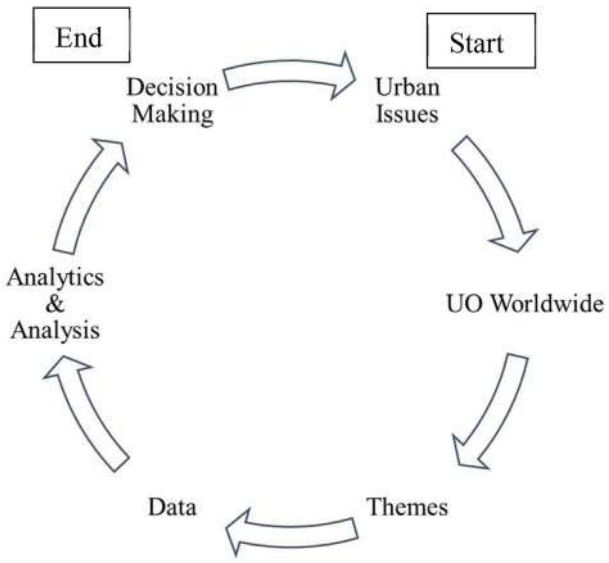

Fig. 2. The process of determining themes for the development of an urban observatory system.

is at the top of the hierarchy. In accordance with Section 6B of the Town and Country Planning Act 1976, the information is provided in Act 172. MUO will be a central database platform that integrates smart information technologies to achieve long-term sustainability for urban development. Sustainable Development Goals (SDGs), New Urban Agenda, and the National Prosperity Vision Policy 2030 will all be incorporated into the MUO's strategy and information dissemination (PLANMalaysia, 2019).

MUO Phase 1 development began in November 2021. It is still in its early stages, and a benchmarking study to identify common themes among existing UO systems worldwide is necessary. This is because the fundamental themes of UO must be incorporated into MUO and adapted to address local urbanization issues. These fundamental themes will serve as a springboard for developing specific local themes for MUO. These fundamental themes can also serve as a starting point for constructing MUO data management system. Additionally, by understanding the themes to be used, the UO system developer can identify a list of the data required for the analytics and analysis process, which will aid the authorities in making efficient decisions related to urban issues (see Fig. 2). Therefore, this study aims to review existing urban observatory systems around the world and; to understand the pattern of analytic data themes, the analysis involved and the types of the data.

2. Overview of Malaysia Urban Observatory (MUO)

In Malaysia, MUO is crucial to address municipal issues such as rising housing costs, increasing urban living costs, solid waste generation, vehicle use and traffic congestion, increased use of water resources, and environmental preservation. The MUO requirements for assisting Malaysia become a sustainable country are as follows; in comparison to the achievements of other cities around the world, achieving global urban development targets. With a platform for analysis, more accurate and straightforward planning decisions can be made to meet increasingly complex urban concerns. It makes it easier to manage and share current data and information.

The first step toward developing the MUO's framework is forming a focus group discussion (FGD) and participation in engagement sessions with various agencies and organizations. The goal is to identify critical success elements in the implementation of MUO and the suggested organizational structure. To facilitate MUO development, it's crucial to enable database and system integration among agencies.

PLANMalaysia has extensive experience developing GIS-based planning databases, such as the I-Plan, the Safe City Monitoring System, and the urban sustainability network system (MURNInets) (PLANMalaysia, 2019). Consequently, the next step is to provide an instrument and platform to assist Malaysia in charting the direction of urban development and well-being and forming the MUO in the country's development strategy.

As outlined in the 3rd National Physical Plan (PLANMalaysia, 2016), the Malaysian Urban Observatory (MUO) will serve as a national database, as well as a reference, monitoring and reporting centre, which will monitor the level of well-being and sustainability of Malaysian cities in terms of social, urban, economic, and environmental aspects. MUO aims to serve as an integrated smart information collaboration network for urban well-being and sustainable development. MUO will also be a tool for tracking Malaysia's progress in implementing the Sustainable Development Goals, New Urban Agenda, National Development Plan, urban conditions, and urban trends.

Overall, the urban observatory (UO) is comprised of four fundamental components, which are the custodian, global monitoring system, hierarchy, and geographic information system (GIS) platform. UO can be centralized and administered by one of the following: the federal government, municipal, institutes of higher learning and research institutions, the private sector, or a combination of these. Meanwhile, UO must be a systematic database that allows users to quickly and accurately access data and information and issue reports. The four hierarchies of UO are; Global Urban Observatory (GUO), Regional Urban Observatory (RUO), National Urban Observatory (NUO) and Local Urban Observatory (LUO) (UN Habitat, 2015).

In Malaysia, the formation of an Urban Observatory (UO) can be carried out at the national (MUO), state (SUO), and local (LUO) levels. For the time being, the formation of UO is advocated at the national level. However, it is proposed that the initiative to establish SUO or LUO be started concurrently with establishing MUO for states or local authorities that are financially capable and have a set of municipal information in the GIS environment, especially for local authorities located in Kuala Lumpur conurbation.

The implementation of MUO will be based on the MUO development framework and three phases of development, beginning with the 12th Malaysian Plan. Currently, MUO is in the first implementation phase from 2021 to 2025. This phase will concentrate on establishing an operations centre in PLANMalaysia, system development, integration of the co-owners database, and data providers.

3. Research methodology

3.1. Data collection and processing

UN-Habitat was in charge of 374 urban observatories worldwide, including 101 in Africa, 143 in Asia, and 130 in Latin America (UN-Habitat, 2021a). UN-Habitat created the urban observatory model in collaboration with its stakeholders, an innovative model for monitoring, collecting and analyzing urban data. On the other hand, UN-Habitat does not list all 374 urban observatories it operates. Furthermore, searches on the internet using the keyword “urban observatory” were meaningless because most UO names did not include the phrase “urban observatory” in their system's naming convention. In the UN-Habitat monitoring report, only 32 names of UO were found (Dickey et al., 2021). Then, an additional list of 10 urban observatory names in South Africa (Coetzee & Smit, 2015) was compiled.

In addition, Malaysia Urban Observatory includes six urban observatory names as a reference for the study of the development of MUO documents (PLANMalaysia, 2019). The names of each of the 48 urban observatories were checked one by one to ensure that the

theme of analytic data could be extracted from their websites. During the review process, it was discovered that 18 of the listed urban observatories did not have a website and that no other documents, such as journals or reports, could be used to identify the themes used. Finally, only 30 urban observatories were reviewed, and their data analytics theme was identified in this study. This list contains two urban observatories (UOs) that collect data from cities all over the world, namely UN-Habitat and the Environmental Systems Research Institute (ESRI) (see Table 1 and Fig. 3).

Then, content analysis was used to develop the thematic content. As a qualitative study, a research method interprets text data through the systematic classification process of coding and identifying themes and patterns (Hsieh and Shannon, 2005). The content analysis incorporates both quantitative and qualitative research strategies. The quantitative analysis result is expressed in terms of frequency, typically used to answer the question "how many?". The results of qualitative analysis are presented in the form of categories, which allows for the interpretation of the text (Bengtsson, 2016). The purpose of this research is to propose the thematic content of data analytics for MUO. As a result, the unit analysis is the manifest theme of 'data analytics'. Inductive reasoning is employed to do this analysis, which concludes collected data by weaving together new information to form theories.

Each of these UOs is reviewed via their website, which hosts the UO system. The search focuses on the theme of analytical data and the data involved in each theme. Furthermore, additional information is considered, such as the goals of the UO's establishment, urban indicators, and monitored policies. Quantitative and qualitative analyses were performed using the NVIVO12 software. Before the coding process begins, these themes are examined together to comprehend the data pattern. Then, the theme of data analytics was reviewed to identify meaningful subjects that respond to the purpose of this research (see Fig. 4).

4. Results and discussion

4.1. Urban observatories' vision

After analyzing the stated visions of the 30 observatories, four common aspirations emerged, which are; (i) gather and develop urban knowledge about a specific area; (ii) deploy urban knowledge to affect urban governance, decision-making and growth; (iii) connect to urban knowledge and sharing information and (iv) provide a forum for different stakeholders to discuss urban concerns stimulate knowledge exchange (see Fig. 5). These aspirations were also aligned with the characteristics of the urban observatory, as stated by UN-Habitat. The UN-Habitat's Data and Analytics Unit describes urban observatories as boundary-spanning institutions with an explicit

Table 1
The list of urban observatories systems examined in this study.

Urban Observatory	City	Origin	Reference links
Gauteng City Region Observatory (GCRO)	Johannesburg	Africa	http://www.gcro.ac.za/
Sierra Leone Urban Research Centre (SLURC)	Freetown	Africa	https://www.slurc.org/
South African National Biodiversity Institute (SANBI)	South Africa	Africa	http://www.sanbi.org/
South African National Space Agency (SANSA)	South Africa	Africa	http://www.sansa.org.za/
Spatial temporal evidence for planning (StepSA)	South Africa	Africa	http://stepsa.org/
Afghanistan Research and Evaluation Unit (AREU)	Kabul	Asia	https://areu.org.af/
Al-Madinah Local Urban Observatory (Al-Madinah LUO)	Medina	Asia	https://www.sa.undp.org/content/saudi_arabia/en/home/our-focus.html
Iskandar Malaysia	Malaysia	Asia	https://www.malaysia.gov.my/portal/content/30626
Japan	Japan	Asia	https://www.gdrc.org/uem/observatory/index.html
Karachi Urban Lab (KUL)	Karachi	Asia	http://karachiurbanlab.com/
Manila Observatory	Manila	Asia	http://mapsanddata.observatory.ph/
Riyadh	Saudi Arabia	Asia	http://www.ruo.gov.sa/EN/
Urban Expansion Observatory (UXO)	New Panvel	Asia	https://uxo.mes.ac.in/about-us/urban-expansion-observatory/
Urban Resource Centre (URC)	Karachi	Asia	https://urckarachi.org/
ESRI	World cities	ESRI	https://www.urbanobservatory.org/compare/index.html
All-Island Research Observatory (Ireland) (AIRO)	Ireland	Europe	http://www.airo.ie/
Centre for Cities	London	Europe	https://www.centreforcities.org/city-monitor/
Dublin Dashboard	Dublin	Europe	https://www.dublindashboard.ie/
LSE Cities	London	Europe	https://www.centreforcities.org/city-monitor/?path=city/leicester
Metropolis Urban Observatory (Metropolis)	Barcelona	Europe	https://www.metropolis.org/projects/metropolitan-indicators
Mistra Urban Future	Gothenburg	Europe	https://www.mistraurbanfutures.org/en
Newcastle Urban Observatory	Newcastle	Europe	https://newcastle.urbanobservatory.ac.uk/
United Kingdom	United Kingdom	Europe	https://urbanobservatory.ac.uk/#
Urban Flows Observatory	Sheffield	Europe	https://urbanflows.ac.uk/
European Spatial Planning Observatory Network (ESPON)	European	Europe	https://www.espon.eu/sdg-tool
Lab CDMX	Mexico City	Latin	https://labcd.mx/
World Council on City Data (WCCD)	Toronto	North America	https://www.dataforcities.org/
World Resources Institute: Ross Centre for Sustainable Cities (WRI)	Washington D.C	North America	https://wrirosscities.org/
Australian Urban Research Network (AURIN)	Melbourne	Oceania	https://aurin.org.au/resources/workbench/
UN-Habitat	World cities	UN-Habitat	https://data.unhabitat.org/

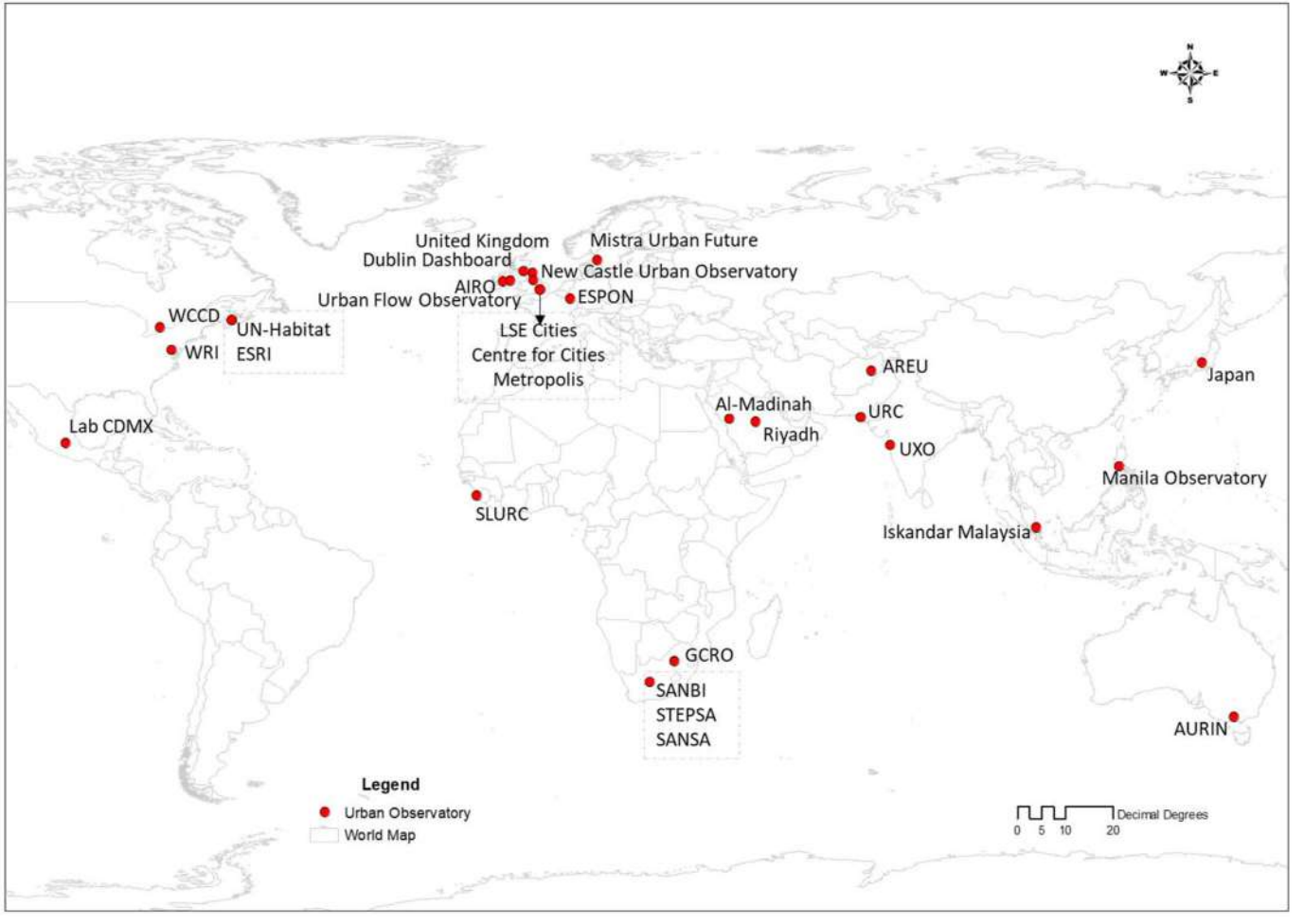

Fig. 3. The spatial distribution of 30 urban observatory location used in this study.

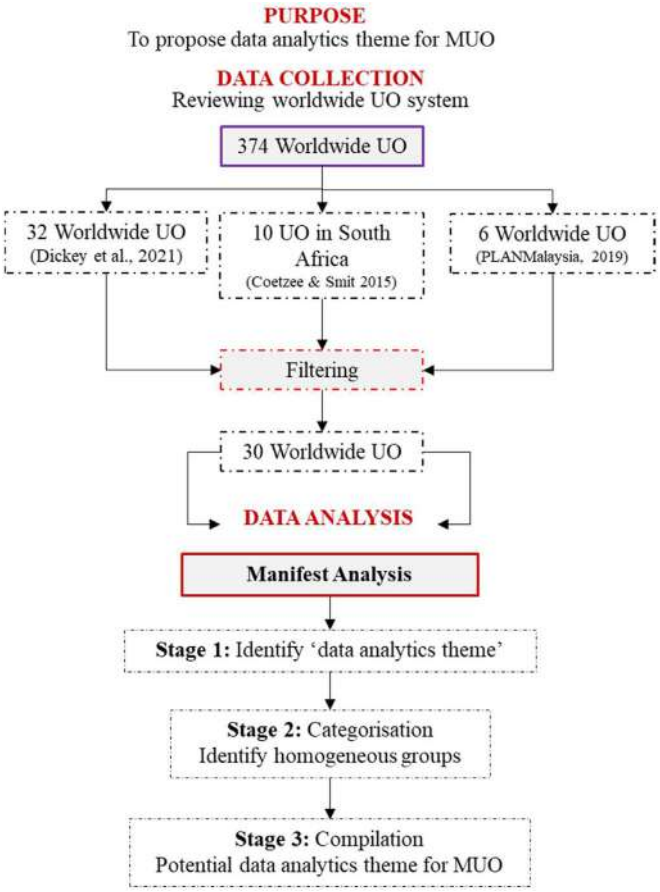

Fig. 4. A methodical flow process of reviewing existing urban observatory systems in order to identify the themes used through content analysis.

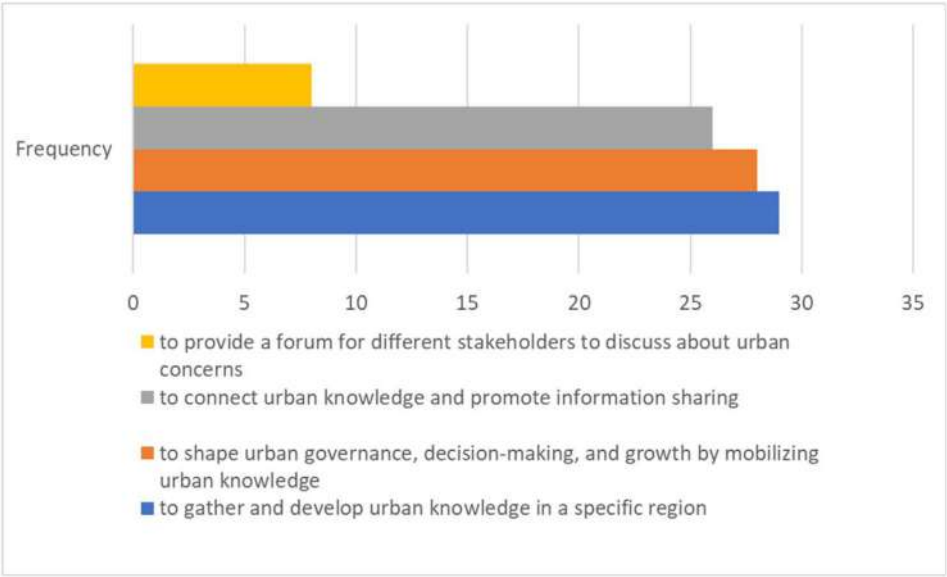

Fig. 5. Visions shared by 30 urban observatories systems around the world.

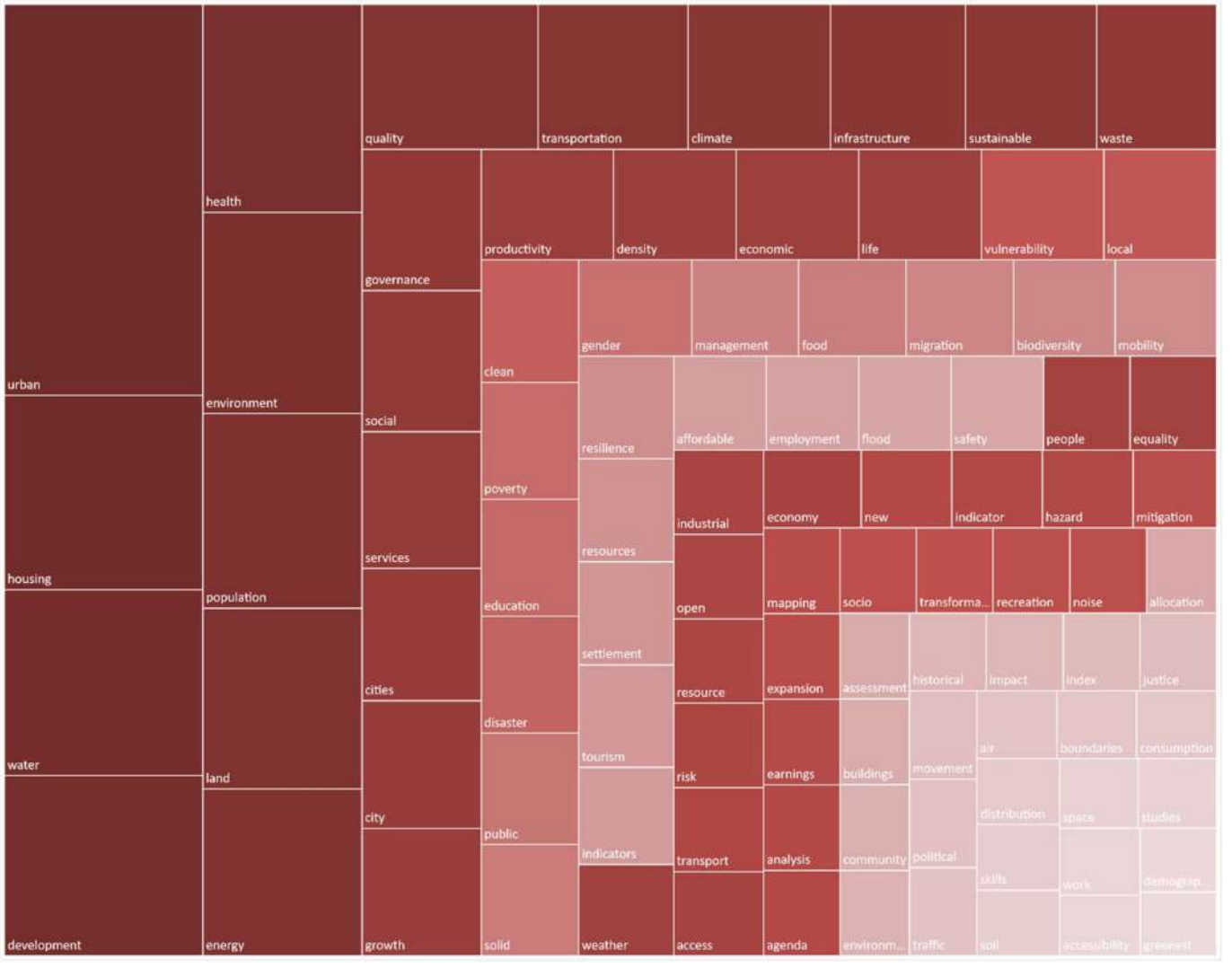

Fig. 6. The frequency of themes derived from content analysis and used in UO worldwide. Note: Bigger box area represent higher frequency.

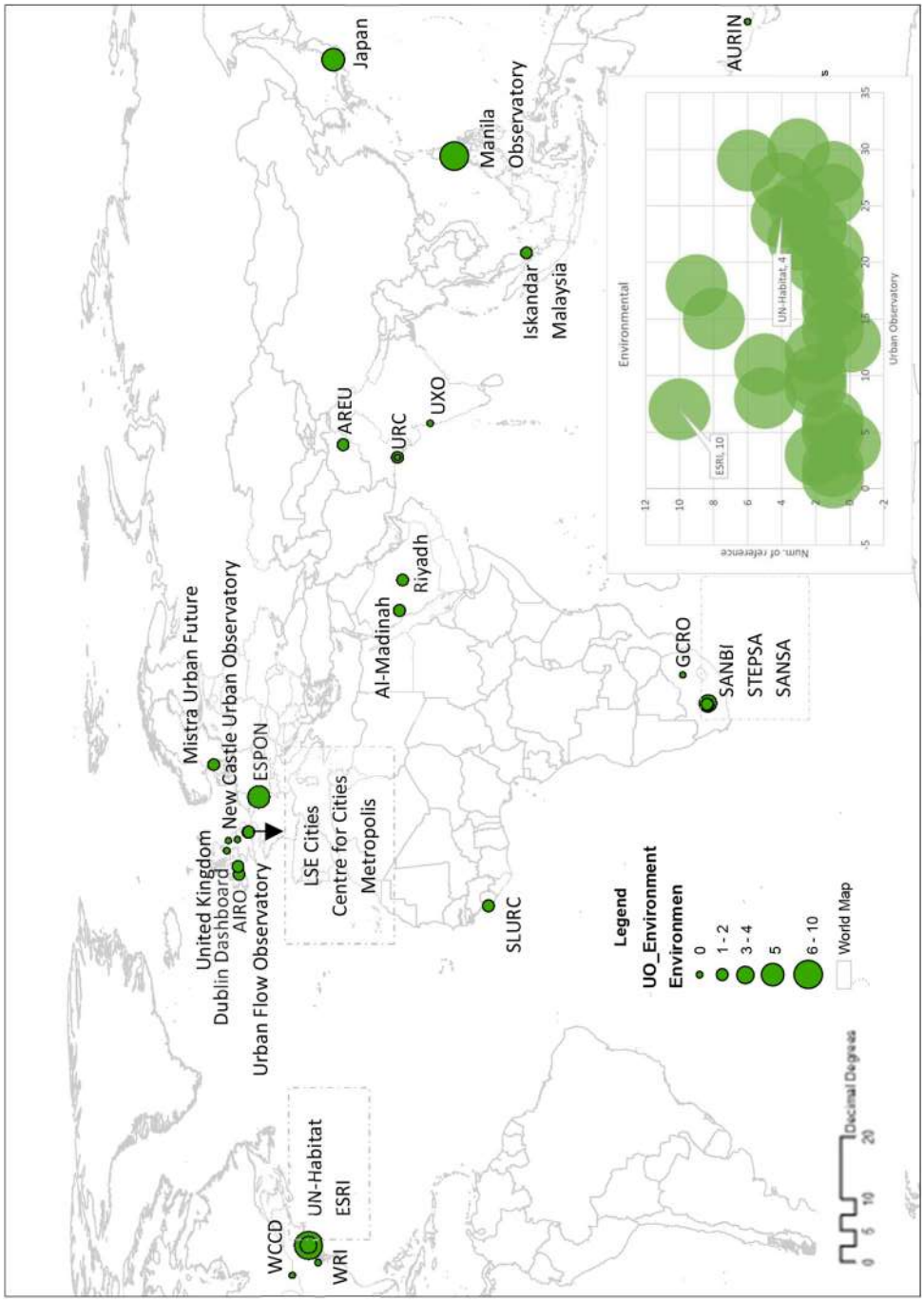

Fig. 7. Environmental theme distribution locations in 30 UOs.

monitoring role focused on one or more urban settlements. Observatories intend to provide five essential functions: data collection, research and knowledge generation, policy development, capacity building, and conversations facilitation, and advocating for urban objectives across global agendas (Dickey et al., 2021).

4.2. Developing the main theme and sub-theme

Almost all of the examined UO websites use the theme of digital analytics in a short phrase. For example, short phrases such as "urban density" and "population" can be found on the majority of the UO websites. The shortest theme found is one word, and the longest is 10 words. These themes undergo a frequency analysis to identify the popular themes among UO system developers (see Fig. 6). These themes also indicate valid issues that each UO developer attempts to resolve. A total of 94 important themes have been identified. Based on the results, the top 10 themes identified are urban (6.7%), housing (3.3%), water (3.2%), development (3.1%), health (2.9%), environment (2.8%), population (2.7%), land (2.5%), energy (2.3%) and quality (2.2%). It is not surprising that "urban" has such a high percentage of frequency due to the focus of UO in the urban area.

Thematic patterns can be identified based on all of these themes. The 94 original themes are then subdivided into five major theme categories: environmental, economic, social, physical, and global agenda. A more detailed analysis of the five main themes was performed "hierarchy" menu function using the NVIVO12 software. Each main theme is researched on the items it contains to identify the items that belong to the same category. This new category is referred to as a sub-theme to the main theme.

Further investigation revealed that environmental and social themes are frequently addressed in the UO system, with 83 references each. This is followed by the physical (36 references), economic (19 references), and global agenda themes (13 references). The ESRI UO system addressed the highest theme of environmental (10 references) among other UOs. ESRI's UO system lists nearly 170 cities, allowing users to compare and contrast maps of cities all over the world, all from one interactive location (ESRI et al., 2014). The ESRI UO system seeks to make the world's data understandable and useful. In addition to ESRI, the Newcastle Urban Observatory (8 references) also emphasizes analytical data about environmental issues. This demonstrates that the environmental theme is a critical urban issue that affects people all over the world (see Fig. 7).

Environmental themes are things that have to do with the environment of humans, plants, and animals. They can be found in all three elements: climate, water, and land. Following this definition, four new sub-themes have been identified. According to the findings, 42 of the references in the environmental theme are related to land in some way (see Fig. 8). The land is defined as the earth's surface that is not covered by water. This theme also included the sub-theme of disaster and waste.

Meanwhile, the sub-themes of climate and water each have 15 references. The climate sub-topic contains several phrases about "temperature", "rainfall", "pressure", and "climate change". The energy sub-theme has nine references and covers everything within the definition of energy, which is the power derived from something like electricity or oil that can be used to perform work, such as providing light and heat (Energy Information Administration, 2020). Phrases such as "resources", "clean", "affordable", and "allocation" are also mentioned in the energy sub-theme.

The social theme is also a concern in most UO systems, as is the environmental theme (see Fig. 9). The European Spatial Planning Observatory Network (ESPON) used the most socially related themes (7 references) compared to other UO systems. ESPON, also known as the SDGs benchmarking tool, monitors the implementation of 17 SDGs across 32 European countries. The SDGs benchmarking tool aims to support the localization and achievement of SDGs by governments at all levels (**). This web application is simple, intuitive and user-friendly, helping policymakers turn a large breadth of indicators into insights to respond to municipal issues. ESPON, 2021

There are 10 additional sub-themes in the social theme that are related to the way people live together. The sub-themes are governance (20 references), housing (17 references), employment (13 references), health (11 references), culture (10 references),

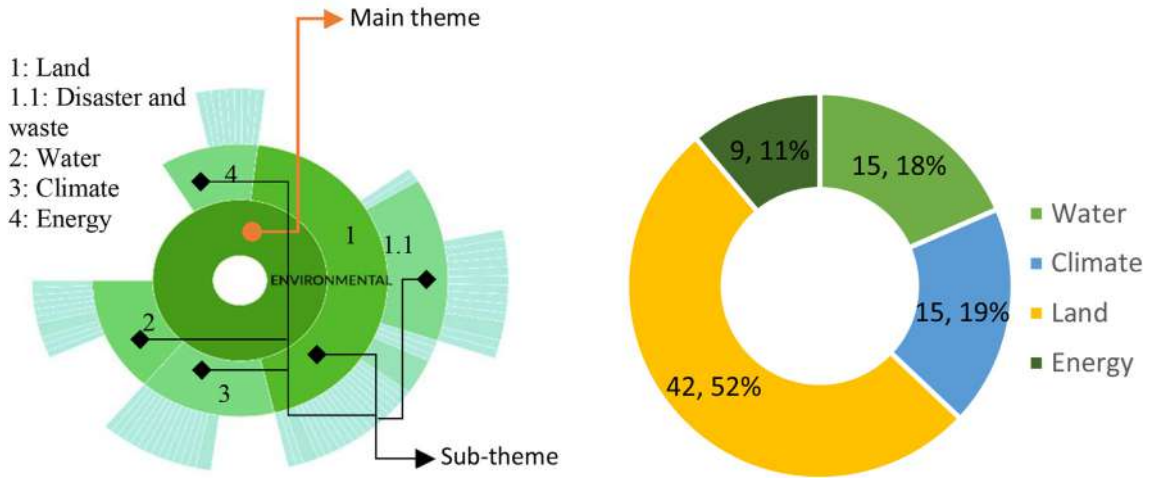

Fig. 8. The main theme, sub-themes, and frequency of references for the environmental sub-themes.

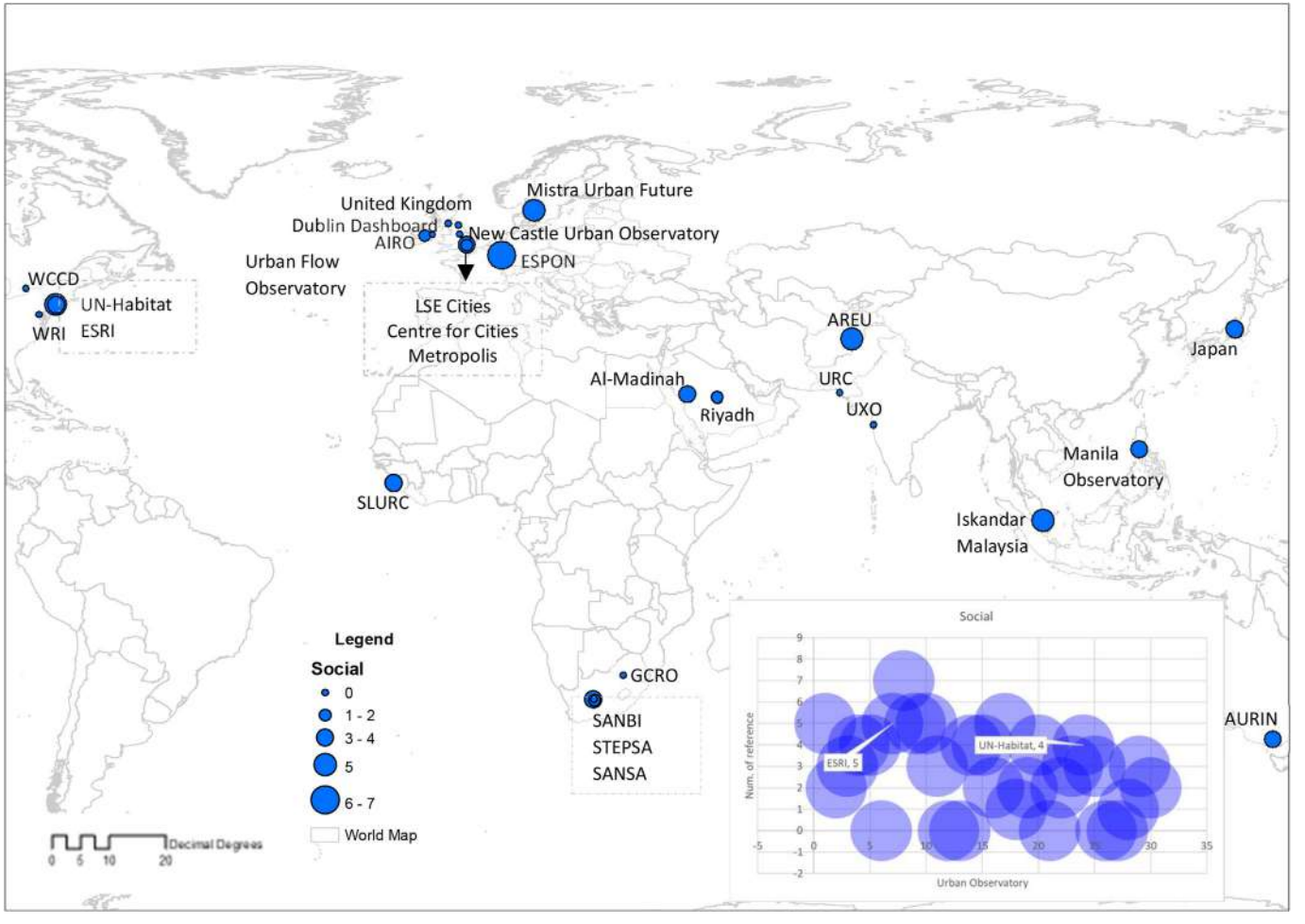

Fig. 9. The distribution location of the social theme in 30 UOs worldwide.

education (8 references), population (7 references), vulnerability (6 references), woman and gender equality (6 references) and quality of life (3 references) (see Fig. 10). The many sub-themes within the social theme indicate that many municipal issues are intertwined with issues affecting the surrounding community. Consequently, all of these issues must be thoroughly addressed by the governments to ensure that residents of urban areas can enjoy a better quality of life.

Housing and employment are non-seasonal issues that are becoming more severe due to the COVID-19 pandemic. In Malaysia, the availability of affordable housing remains a problem. Homeownership for people in the low to moderate-income group (LMIG) is becoming increasingly difficult (Kamal et al., 2020). Furthermore, according to projections, a total of 951,000 people will lose their jobs by March 2020 (out of 16 million employed labour in 2019, presumably mostly non-salaried jobs); and household income losses totalling 41 billion ringgit (a decrease of 5.2% from the projected baseline in 2020) (Lim, 2020). This is due to the socioeconomic consequences of the COVID-19 pandemic and the Movement Control Order (MCO) as implemented in Malaysia.

In contrast, themes classified as "physical" have only one core theme. Physical refers to any physical objects that occupy space and is associated with things that can be seen or touched. It also refers to the physical infrastructure that supports the fundamental processes and services, such as transportation, on which a country or organization relies on functions efficiently. The distribution frequency of the "physical" theme shows in Fig. 11. This theme contains phrases such as (for example) "accessibility," "transportation," "open space," "topography," "slope," "infrastructure," and "highway access.

Next, the frequency of the "economy" theme distribution shows in Fig. 12. Economic related encompasses activities, such as the production, consumption, and trade of products and services in a certain geographical area. In an economy, the production and consumption of goods and services are used to meet the requirements of individuals who live and work within the boundaries of the economy (Kenton, 2021). Phrases such as "business dynamic", "consumption and production", "eco-tourism", "finance", "industrial", "commercials" are found in this theme.

Meanwhile, the global agenda theme is; it is not a popular theme choice because it requires monitoring global indicators, whereas the majority of UOs that have been developed are either national UO or local UO (see Fig. 13). As a result, the focus of analytics data is more on local issue-specific analysis. This is because the development of the UO system is also expensive and requires collaboration, particularly data sharing from other agencies. Therefore, the authorities must wisely determine which municipal issues should be prioritized and be critical to the local community.

4.3. *Proposing for MUO's data analytics theme*

For the theme categorization process to be accurate, each analytics data theme must be understood in its meaning and scope. These themes must also be tailored to the existing urban planning ICT (information and communication technology) system in PLANMalaysia; which are; Integrated Planning Land Use Information System (i-Plan); Malaysian Rural Sustainable Development Indicator Network System (MURNInets); and Safe City Monitoring System (SCMS).

I-Plan comprises a geodatabase and web-based tools that display integrated land use planning data for existing, committed and zoning land use. Through an integrated land use database and online smart sharing, I-Plan enables land use data management, storage, and updating (Zubi, 2018). Meanwhile, MURNInets is a tool for assessing the performance and sustainability of Malaysian local governments. It allows local, state, and federal governments to gather, store, analyze, evaluate, manage, and display data on sustainability (PLANMalaysia, 2018). The SCMS uses WebGIS Application to evaluate the success of crime prevention measures adopted by the Royal Malaysian Police, Local Authorities (LA), Ministry of Home Affairs (MOHA), and other associated agencies (Shamsudin et al., 2013).

These systems, on the whole, work well to satisfy the needs of their users. Therefore, the MUO function is based on the analysis of various criteria involving spatial and non-spatial, making it necessary to improve existing infrastructure, hardware and software. Fig. 14

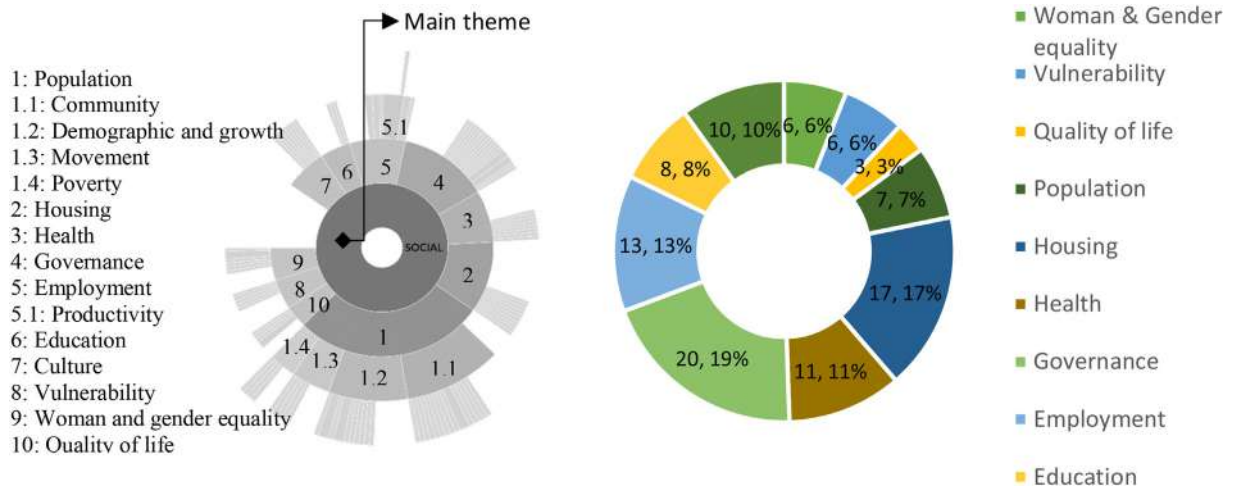

Fig. 10. The main theme, sub-themes, and frequency of references in the sub-themes of social.

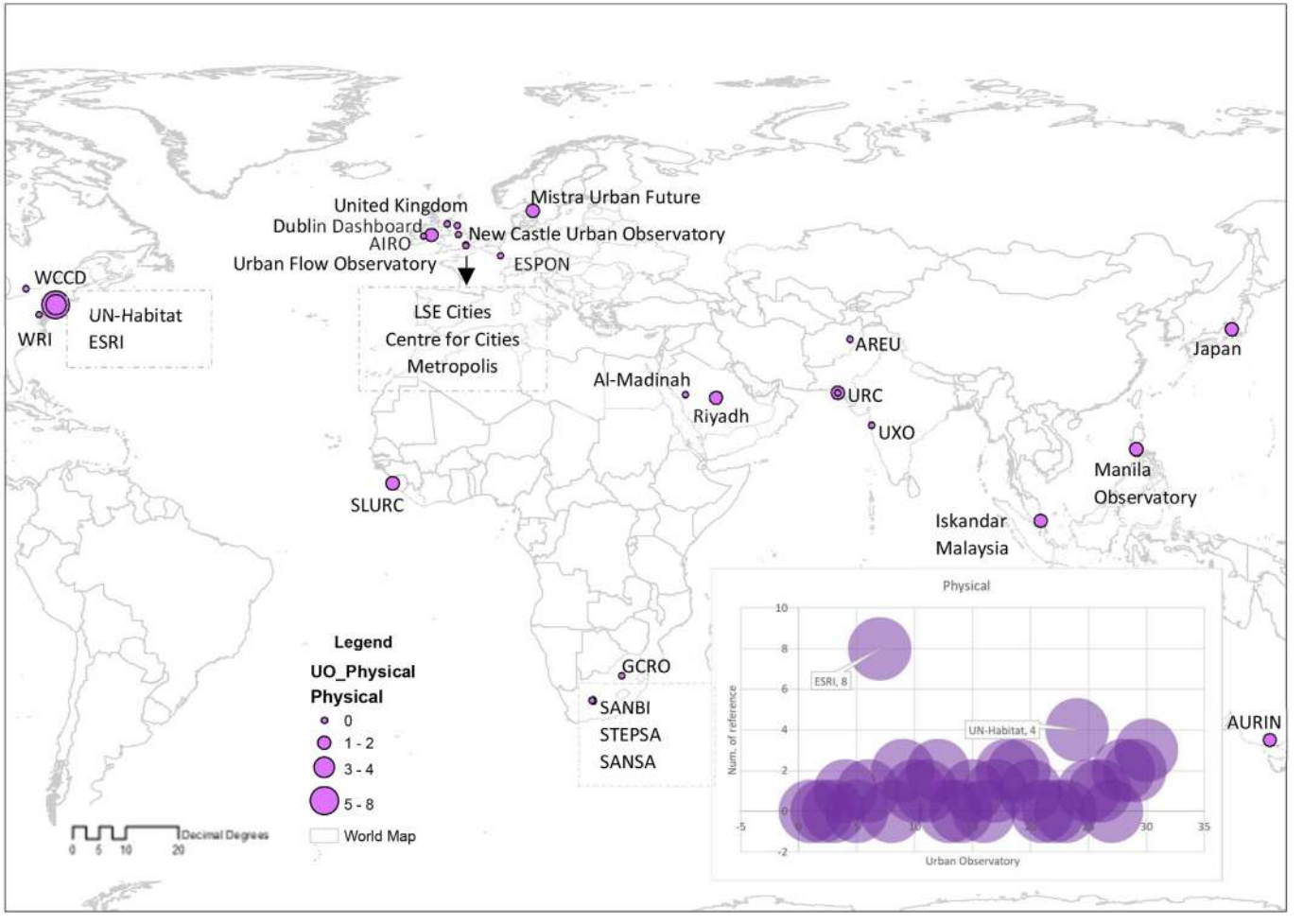

Fig. 11. The physical theme's distribution location in 30 UOs worldwide.

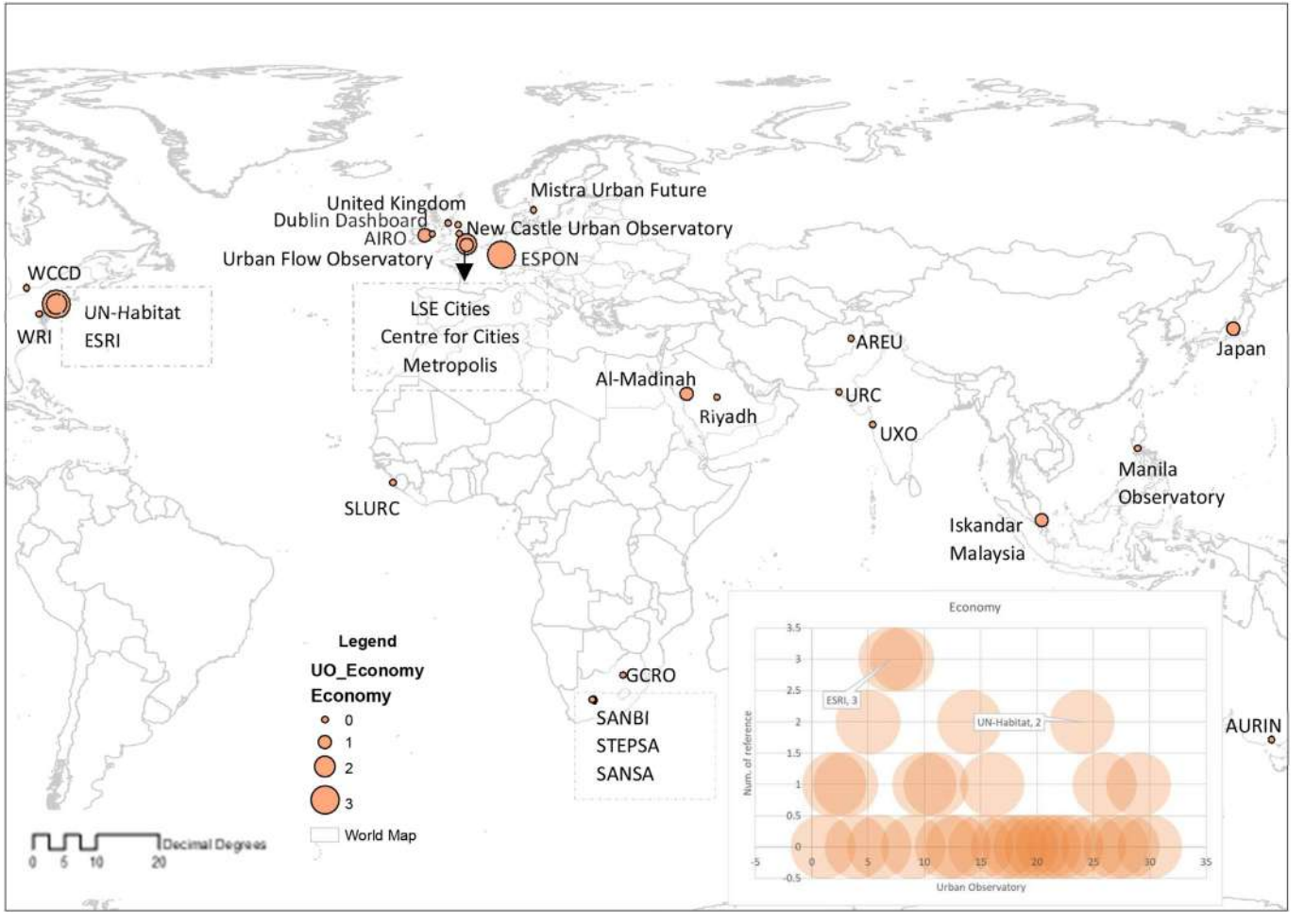

Fig. 12. The distribution of the economy theme in 30 UOs around the world.

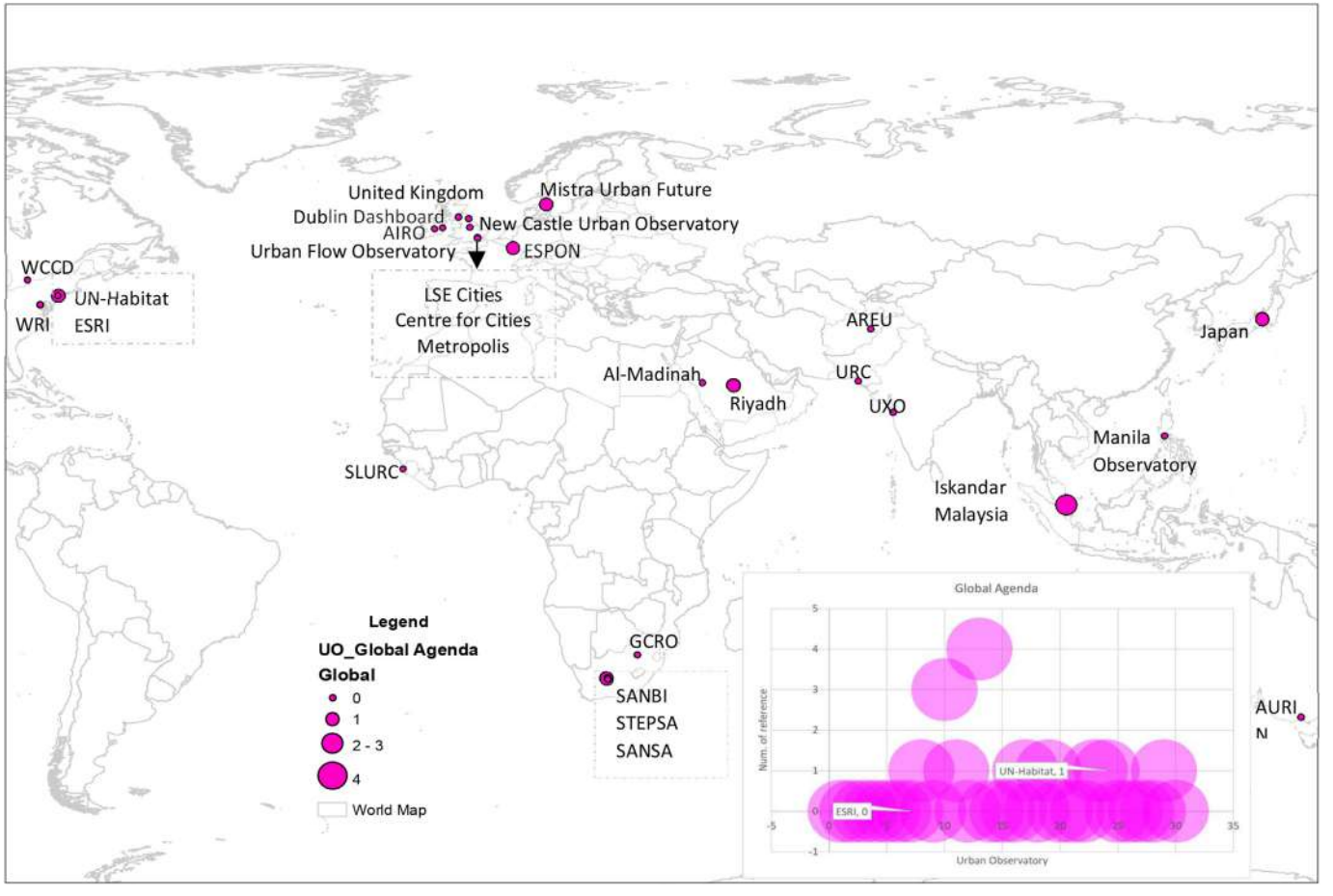

Fig. 13. The theme of the global agenda is being discussed in 30 different UOs all over the world.

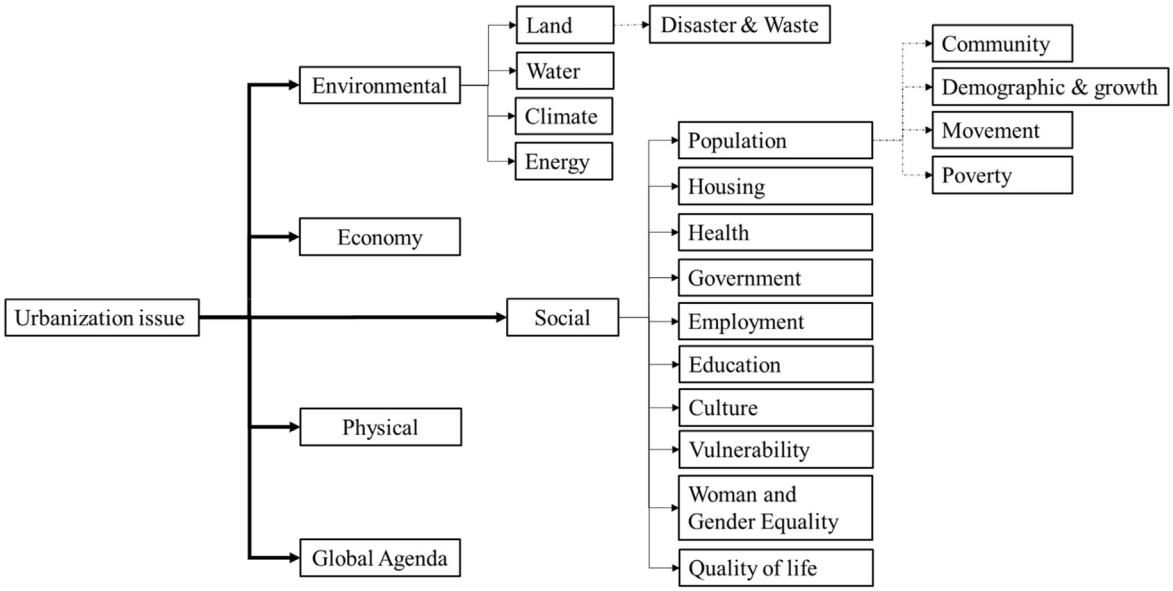

Fig. 14. The proposed framework for MUO's data analytics theme is based on global urban observatory systems.

shows the proposed framework for MUO's data analytics theme based on the analysis and output of this study.

Each of the themes is linked to a specific goal from the Sustainable Development Goals (SDGs) (see Table 2). Even though urban operations (UOs) are supposed to be devoted to addressing the urban issues addressed by Sustainable Development Goal 11 (SDG 11), the process of identifying the relevance of analytic data themes to the SDGs is extremely important to ensure that the overall SDGs can be integrated with these themes.

The proposed data analytics theme also contributes to the aspirations outlined in the New Urban Agenda (NUA), which are coordinated within five key elements; governance structure, social inclusion, spatial development, urban prosperity, and environmental sustainability.

However, the outcomes from the themes are still too general. As a result, these themes have been incorporated to the UN Habitat UO Guidebook (UN Habitat, 2015), the Sustainable Development Goals (https://sdgs.un.org/goals), and the Fourth National Physical Plan (NPP-4). The 4th National Physical Planning is the highest hierarchical planning document in the Malaysian land use planning system. It

Table 2
The following is a list of themes and sub-themes related to the Sustainable Development Goals (SDG).

Theme	Sub-Theme	Related SDG
Environmental	Land	15: Life on land
	Water	14: Life below water
		6: Clean water and sanitation
	Climate	13: Climate action
	Energy	7: Affordable and clean energy
Economy		1: No poverty
		2: Zero hunger
		8: Decent work and economic growth
		9: Industry, innovation and infrastructure
		12: Responsible consumption and production
Social	Population	11: Sustainable cities and communities
	Housing	11: Sustainable cities and communities
	Health	3: Good health and well-being
	Governance	16: Peace, justice and strong institution
	Employment	8: Decent work and economic growth
	Education	4: Quality education
	Culture	11: Sustainable cities and communities
	Vulnerability	11: Sustainable cities and communities
	Women and gender equality	5: Gender equality
		10: Reduced inequalities
	Quality of life	11: Sustainable cities and communities
		3: Good health and well-being
Physical		14: Life below water
		15: Life on land
Global Agenda		17: Partnerships for the goals

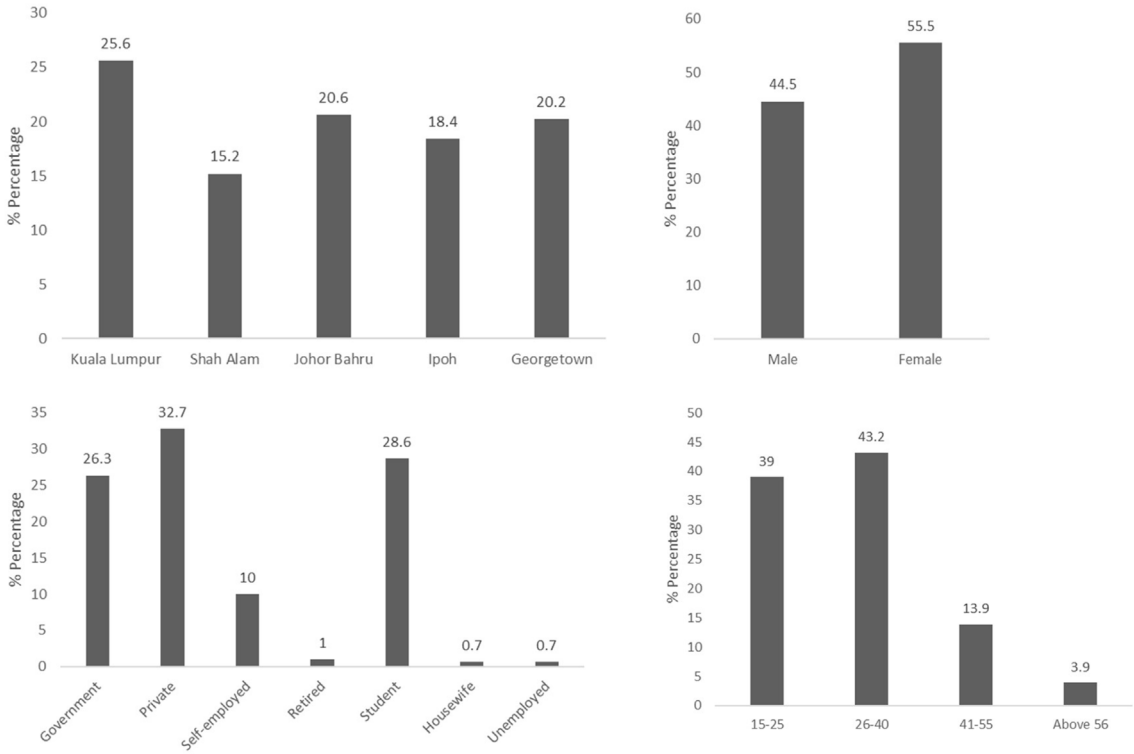

Fig. 15. The percentage of people asked about urban issues in Malaysia's five major cities who are from those cities.
Source: Modified from Development Study of Malaysia Urban Observatory (PLANMalaysia, 2019)

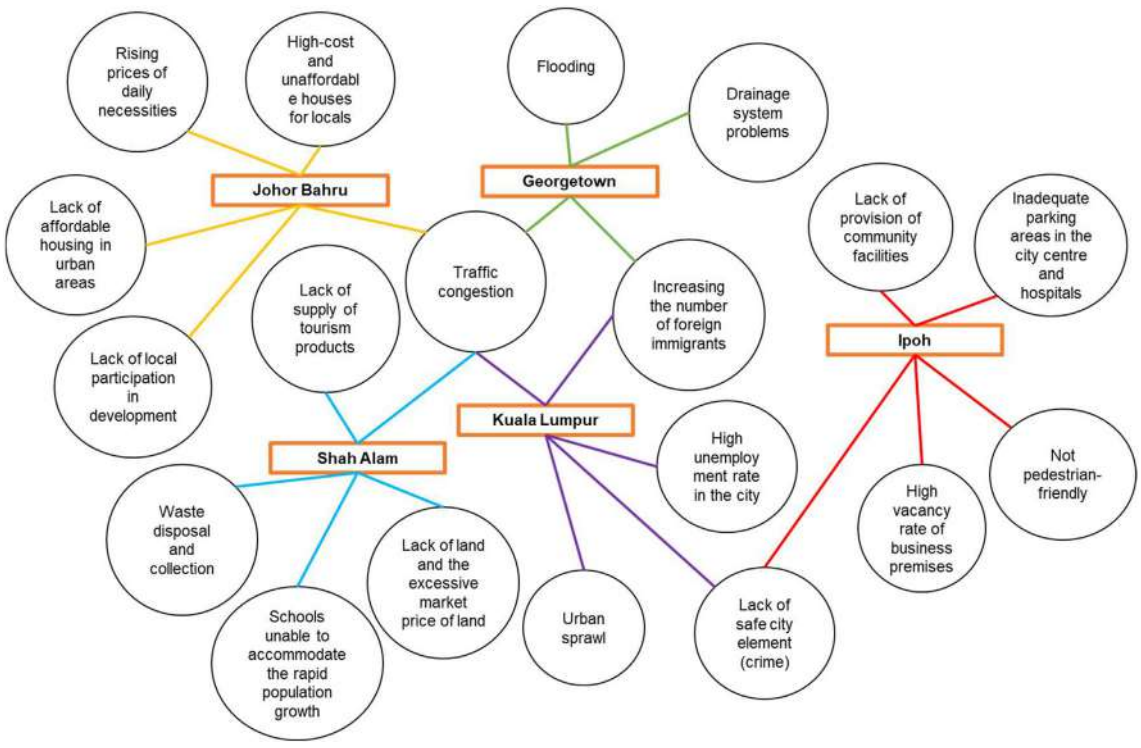

Fig. 16. Municipal issues in five (5) major cities in Malaysia.

Table 3
Detail theme, sub-themes and characteristics for MUO's analytics theme.

Theme	Sub Theme	Physical				Economy				
		Landuse	Transportation	Infrastructure & Utilities	Landscape	Fundamentals of Economics	Industry	Commercial/ Service	Agriculture	Tourism
Spatial Development Sustainability	Infrastructure & Utilities	x	x	x			x	x	x	
	Urban Mobility	x	x	x						
	Accessibility	x	x	x						x
	Rural Development	x								
	Urban Diversity	x								
	Land Use	x					x	x	x	
Dynamic & Balanced Economic Prosperity	Economic Competitiveness	x	x	x		x	x	x	x	x
	Economic Resilience	x	x	x		x	x	x	x	x
	Equity Economics	x	x	x		x	x	x	x	x
	Food Security	x					x	x	x	
	Digital Economy					x	x	x		x
Liveable Environment & Inclusive Community	Demographics					x				
	Occupation					x				
	Poverty					x				
	Woman empowerment					x				
	Sosial *Vulnerability*	x								
	Quality of Life	x	x		x	x				
	Housing	x								
	Education	x								
	Health	x								
	Social influence									
	Security	x								
	Public Space	x								
	Green Area	x								
Environmental Sustainability	Environmental Quality									
	Sustainable Energy		x	x			x			
	Low Carbon Cities									
	Green Technology		x	x			x	x	x	
	Climate change									
	Waste Management									
	Forest Management	x								
	Coastal Management	x								
	Biodiversity Assets									
	Natural resource management	x								
	Heritage resource management	x								
	Disaster risk management	x								
Good Governance Planning	Public Involvement	x								
	Legislation									
	Financial allocation					x				
	Institutional Capacity									
	Asset Management									

Social							Environment					Governance
Population	Housing	Education	Health	Security	Public facilities	Open Space & Recreation Area	Land	Water	Air	Climate	Energy	
	x	x	x	x	x							
	x	x	x	x		x						
x	x	x	x	x								
	x	x	x	x		x	x					
x		x		x								
		x		x								
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is a national development planning plan that translates and coordinates other economic, social and sectoral development policies into physical and spatial dimensions. The policies contained in the NPP will be translated at the regional/state planning level through state structure plans and economic corridor development plans. This policy can also be translated at the local plan level through local plans/special area plans. The implementation period is from 2021 to 2025 for the planning period from 2020 to 2040. The main goal of the NPP is to achieve a prosperous and resilient of Malaysia. All of the themes found in these documents are arranged and altered in accordance with the themes developed in the first phase (Fig. 14).

In the process of developing these themes, local issues have also been taken into consideration. A strong relationship exists between MUO development and urban management, which will be used as decision-making support if and when it is required. Municipal concerns are dealt with under the administration of the city. There are various types of municipal difficulties, such as those that are now affecting local governments, those that concern the Second National Urbanization Policy (NUP2), and so on. In general, municipal issues are diverse and differ from one city to another. As a result, the issues that will be the focus of urban observation and monitoring are the main issues that were identified in a survey that was conducted in five case study cities, namely Kuala Lumpur, Shah Alam, Ipoh, George Town, and Johor. Total of 539 respondents were surveyed their opinion (PLANMalaysia, 2019) on current issues in these five (5) cities (Fig. 15).

According to the results of the survey, there are certain commonalities in municipal issues among the five cities, particularly in the areas of traffic congestion, safety (crime) and the increasing number of foreign immigrants (see Fig. 16). Kuala Lumpur, Shah Alam, Johor Bharu, and Georgetown are among the cities experiencing traffic congestion. Meanwhile, issues involving public safety happened in Kuala Lumpur, Georgetown, and Ipoh.

In order to determine analytical big data-based solution techniques for municipal challenges, it is necessary to first determine what

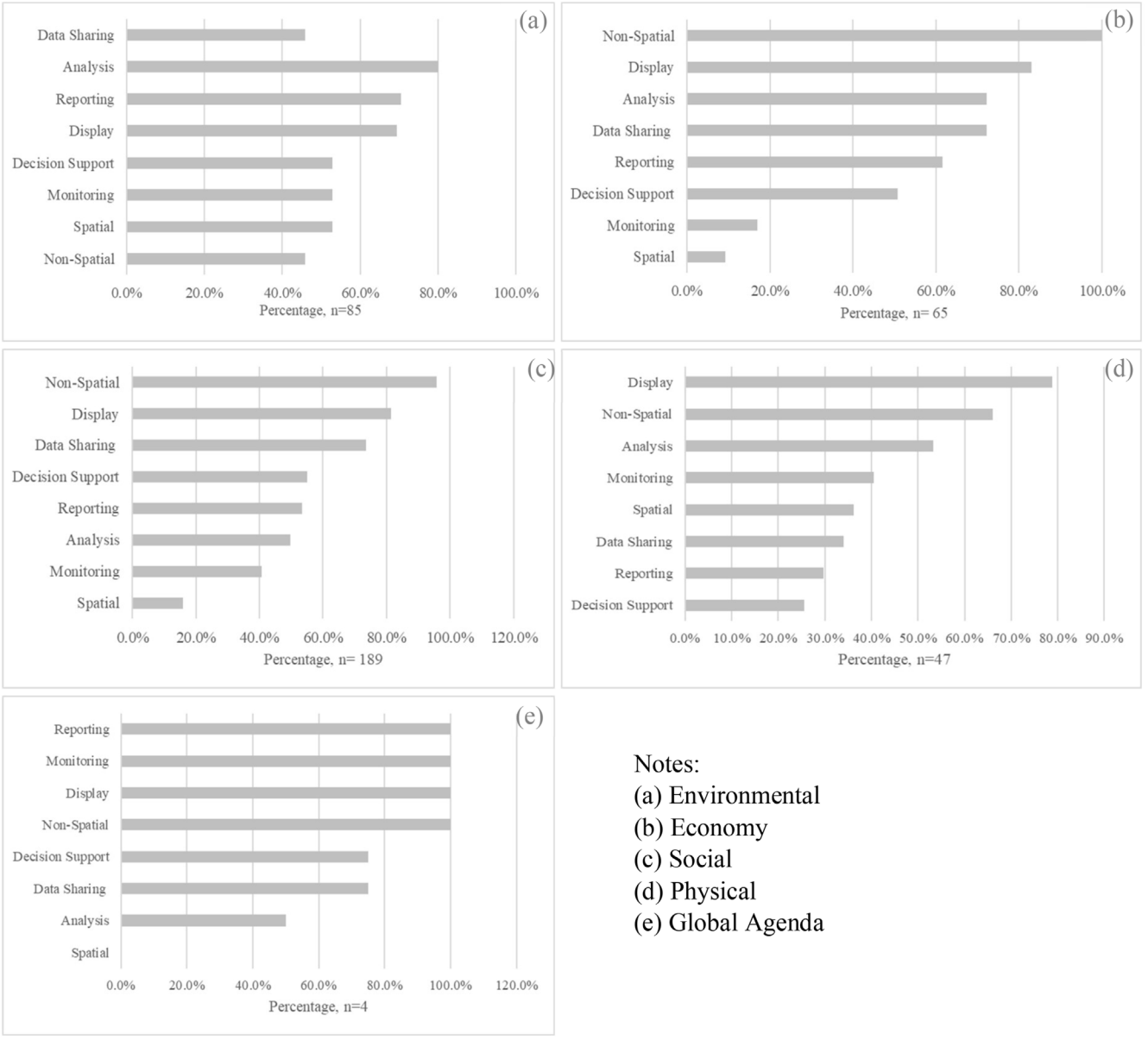

Fig. 17. The primary functions of the data analytics theme in urban observatory systems around the world.

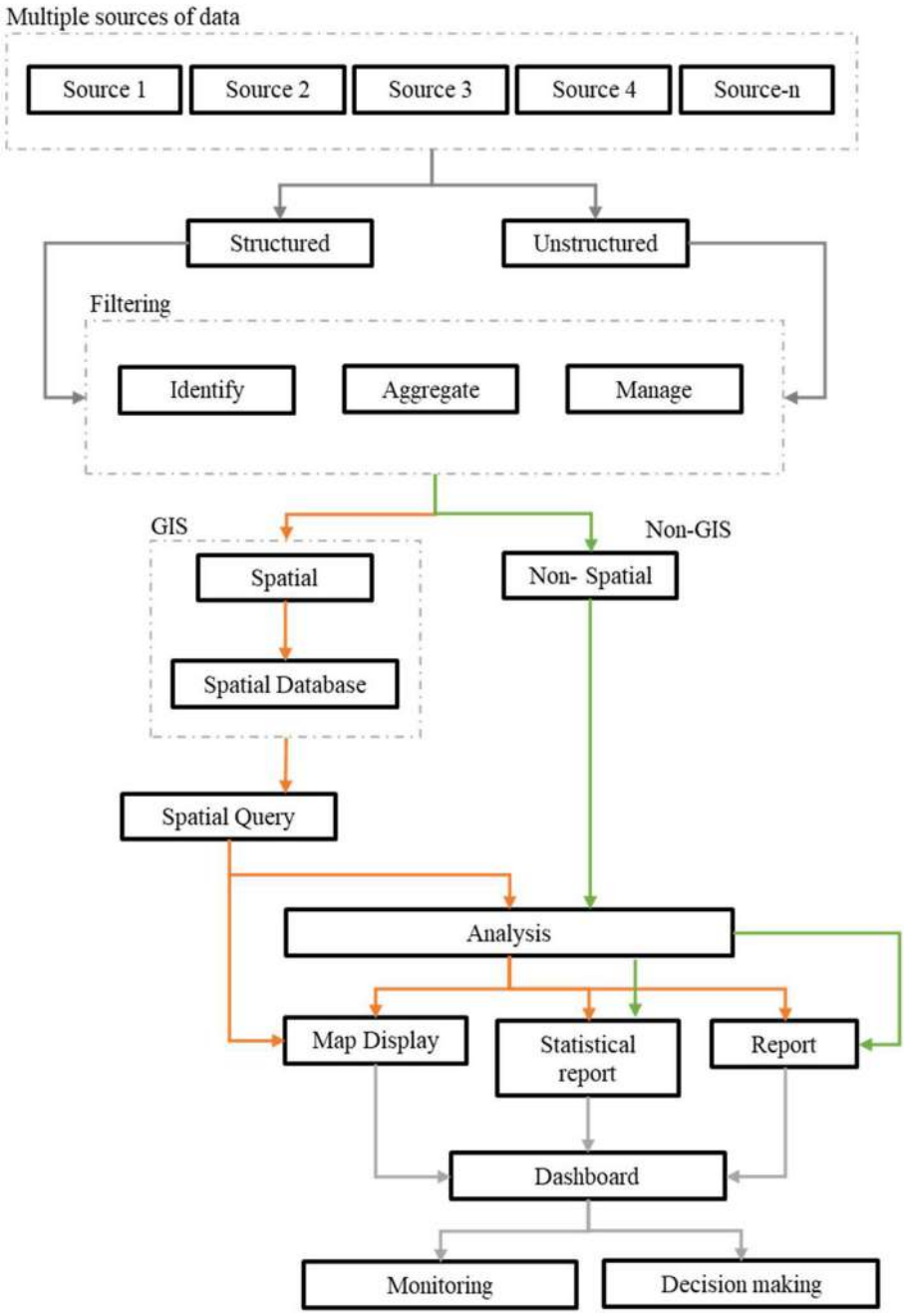

Fig. 18. The analysis of the flow of data for the UO GIS big data. Note: n-is number of data sources.

the problems are and how they may be solved. Despite the fact that municipal concerns in these five cities are similar, there are significant disparities in issues depending on geographic location amongst them. For example, in Shah Alam, there are concerns such as a shortage of supply of tourism products that are not available in other cities.

Following that, for each general theme that has been generated, new themes and sub-themes are developed through focus group discussion with subject matter experts (SME) (environmental, economy, physical, social and global agenda). The SMEs are made up of government officials and scholars from local universities. The final theme result is displayed in Table 3.

Spatial Development Sustainability theme; emphasizing aspects of monitoring sustainable physical development by taking into account the geographical position of each development. This theme includes aspects of infrastructure and utilities, urban mobility, accessibility, rural development, urban diversity and land use. Meanwhile, 'Dynamic and Balanced Economic Prosperity' theme; will have an emphasis on several aspects of tracking economic growth across the country, including the robustness and competitiveness of

the economy. In addition to this, it places an emphasis on the growth of the digital economy as well as concerns regarding food security, both of which have the potential to upset the economic equilibrium.

When it comes to the monitoring component of community well-being, this component encompasses the subthemes of human capital development, community involvement in development, housing planning, education, health, and safety as areas that have the potential to improve people's overall quality of life which portray in 'Liveable Environment & Inclusive Community' theme.

Monitoring the environment (theme: Environmental Sustainability) encompasses aspects of sustainable land use planning, conservation and preservation of the environment and heritage resources, and disaster risk management, all of which can contribute to the fight against climate change. Aspects of monitoring and planning for good governance will be included under the umbrella theme of 'Good Governance Planning', with the goal of increasing openness and accountability. Legislation, the distribution of financial resources, the administration of assets, public participation in planning activities, and an institution's capacity are all included.

4.4. Understanding types of data and data analytics for UO

In total, 390 different types of analysis were included in the 30 specified UOs. Based on these sorts of analysis, eight important elements were found, including the data types, whether spatial or non-spatial, data sharing capabilities, data visualization, and the purpose of the data, either was designated for monitoring, reporting, analysis, or decision support (Fig. 17).

4.4.1. Application of GIS in big data analytics

GIS (Geographic Information System) is commonly used in UO systems worldwide for database administration, visualization, spatial analysis, and spatial modeling. The Geographic Information System (GIS) acts as a database and a toolbox for urban planning. Since the beginning of time, geographic information systems (GIS) have played a significant role in assisting urban planners in making planning decisions. GIS is just one of the many computer-based information systems that can combine data from several sources (Han and Kim 1989). Spatial data is the type of data used in the GIS tool. It is sometimes referred to as geospatial data. Geospatial data is any data related to or containing information about a specific location on the Earth's surface.

The big data environment will undoubtedly emerge when considering analysis in urban observatory systems. Big data is a word used to denote vast amounts of data, both structured and unstructured, and the big data analytics process. Integrating big data with GIS enables analysis and decision making from massive datasets through algorithms, query processing, and spatiotemporal data mining. This entails pulling data from as many sources as possible using established protocols and computational approaches.

According to Fig. 17, the utilization of spatial data is still minimal, with the maximum being solely on the issue of environmental analytics (53%). In comparison, the minimum on the global theme of the agenda is 0%. The availability of complete and trustworthy geographical data is the primary difficulty in developing UO systems. In general, developed countries have greater access to data than developing countries. A fair amount of geographical data is available in developed countries, making the development of a GIS relatively simple. It is challenging to provide a large amount of data since it requires the collaboration of multiple parties and agencies and additional costs such as human labour, particularly for the process of standardizing the data obtained so that further analytical data processing can be carried out. Furthermore, not all of the essential data can be gathered from other parties unless the UO system developer must collect it themselves. As a result, it is not surprising that the preparation of non-spatial data is more convenient, with a minimum, 46%, and maximum of 100% of the themes of analytical data using non-spatial data; that is, data that does not contain location information on the earth's surface, such as reporting documents.

Moreover, the developer of the UO system focused on GIS data relating to the physical environment and land cover in this study. Data such as socioeconomics, which is critical for planning, is still difficult to acquire in GIS data format and is confined to population census data. According to Yeh (1999), socioeconomic data necessitate field surveys, both costly and time-demanding. As a result, a lack of financial resources and skilled employees for data collection and a lack of current and effective data processing technology were highlighted as complicating data preparation. The public's access to data is another must-have feature in constructing a UO system. 82.5% of UO developers display their data on average, while just 60.2% share the data by allowing users to download it. Data security concerns are one of the reasons why the percentage of data that the general public can download is limited.

Only 61% of the data from the analytical data theme were used in the analysis procedure on average. This approach is also restricted to producing total numbers, ratios, averages, densities, and frequencies. While for spatial data, efforts are still concentrated solely on a map visualization. Meanwhile, modeling and prediction/forecasting are still deficient in advanced analysis. Based on the general review of 30 urban observatories, it can therefore be concluded that the analytic data structure for the UOs is as shown in Fig. 18.

The data will be acquired from a variety of sources and agencies. It is also available in various formats and types, including structured and unstructured data. All of this data will be filtered through a process that includes identifying, aggregating, and managing. The spatial data will then be collected and stored in a spatial database in a GIS environment. The spatial query process will occur from the spatial database. The data will either be map displayed alone or go through the next analytical phase, spatial analysis. Non-spatial data will also be analyzed, and the results will be in the form of reports or statistical reports. Following that, most UO employ dashboards to display the outcomes of their analyses or the data they have. A dashboard functions to track, analyze, and display the key performance indicators, metrics, and data points. It is a visual illustration that comprises maps, charts and graphs for a glance to provide information. Later, the authority will use it as a monitoring or decision-making tool based on this information.

5. Conclusion

The use of data analytics in urban government to address municipal challenges is becoming increasingly important today. Urban

governance must have a complete awareness of the existing issues in urban areas so that the solutions offered are precise and acceptable when attempting to resolve municipal concerns. This goal will only be met if we have a structured monitoring system with extensive data and accurate analytical data procedures. Therefore, this study aims to review existing urban observatory systems around the world and; to understand the pattern of analytic data themes, the analysis involved and the types of the data.

The five major data analytic themes are identified, which are environmental, economic, social, physical, and global agenda. As a result of these five themes, it was found that the themes of environmental data analytic and social data analytic were the two most frequently employed themes in most (if not all) of the 30 UOs surveyed. It demonstrates that both of the data analytic themes are significant urban challenges; that impact people all around the world. Furthermore, the themes of data analytics derived are relevant to the goals contained in the Sustainable Development Goals (SDGs). Determining the relevance of analytic data themes to the SDGs is critical to ensuring that the overall SDGs can be integrated with these themes. The themes also complemented and clarified with the Fourth National Physical Plan (NPP-4) and Second National Urbanization Policy (NUP2), as well as the Sustainable Development Goals and UN Habitat UO Guidebook. The results then validated by FGD with subject matter experts (SME) in environmental, economy, physical, social and global agenda (PLANMalaysia, 2019). In total, there are five main themes proposed to Malaysian Urban Observatory which are; (i) Spatial Development Sustainability, (ii) Dynamic & Balanced Economic Prosperity, (iii) Liveable Environment & Inclusive Community, (iv) Environmental Sustainability and (v) Good Governance Planning. In the future, the research can be incorporated with qualitative research by conducting interviews with Malaysian government officials in order to validate the identified themes.

When considering the analysis of urban observatory systems, the big data environment will be unavoidable. The integration of big data with GIS enables analysis and decision making from massive datasets through algorithms, query processing, and spatiotemporal data mining. This entails pulling data from as many sources as possible using established protocols and computational approaches. This study also successfully connected the framework between big data analytics and GIS technologies. Meanwhile, the majority of the UO system's developers concentrated on GIS data related to the physical environment and land cover. Data such as socioeconomics, which are crucial for planning, are still difficult to obtain in GIS data format and are limited to population census data. The available data is also limited to analysis, such as generate total numbers, ratios, averages, densities, and frequencies. In the case of spatial data, efforts are still focused mainly on the map display. Unfortunately, data modeling and prediction/forecasting are still deficient in advanced analysis.

Finally, this study can provide an initial overview of the implementation of an urban observatory, particularly in terms of the selection of analytical data themes, the analysis involved, and the initial overview of the data involved. This study can be improved by identifying data management strategies despite the above insights and contributions. For example, who is the data custodian, how frequently data is updated, how accurate data is, and how much data integration costs in an urban observatory system.

The examination and comprehension of current urban observatory systems around the world are therefore essential to produce meaningful thematic content for the Malaysia Urban Observatory. With an understanding of the analytic theme that will be used, the UO system developer may generate a list of the data necessary for the analytics and analysis process, which will assist the authorities in deciding solutions for municipal issues. As a result, the establishment of the Malaysia Urban Observatory (MUO) is an important milestone in the country's growth plan because it will serve as an instrument and platform to aid Malaysia in charting the course of urban development and well-being.

Credit author statement

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