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Application of real-time GIS analytics to support spatial-intelligent decision-making in the era of big data for smart cities

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Abstract

The rapid growth of the urban landscape from natural development, traffic congestion, crime, and waste management has become a challenge to the city dwellers and decision-makers, thus requiring smart and efficient ways to tackle these problems. The combination of big data and Internet of Things (IoT) is guiding local communities in achieving the goal of building creative communities. This study aims to use real-time spatial analytics that integrates state–of–the art ICT approaches with interdisciplinary synthesis for smart solution making process across different sectors of the community. The use of real-time data and coordination of information from multiple city agencies enable policymakers to adjust management strategies in near real-time and can also provide citizens with situational awareness on emergency and non-emergency conditions. Using state-of-the-art technologies, and communication-based applications within the context of smart cities, three smart city examples were developed with the case study of Grand Forks, North Dakota. Using Web AppBuilder, a health resources inventory for the town of Grand Forks was designed with real-time integration of medical information and treatment facilities within the community. For emergency response and preparedness, we developed and deployed a solution that combines information from all the sectors of the city using Survey123 for ArcGIS to collect data and display it on an operational dashboard with multiple visualizations for real-time monitoring of people, services, assets and analysis of events or activities.This operation offers real-time verification and can be an essential resource for team leaders and emergency operations centers. The information collected also provides the flexibility to show layers of information, and task force leaders have a view of their task forces and, consequently, the enrichment of life by making the community safe, healthy, and sustainable.

Keywords: Smart city, ICT, IoT, real-time GIS, big data, spatial analytics, and spatial intelligence.

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1. Introduction

Increased urban sprawl associated with social, environmental, and economic effects, has led to pollution, environmental destruction, poor land use management, unsuitable urban design. These problems have caused public disruption, ineffectual movement, transportation congestion, general well-being, and increase health risks. All these city problems are related to city infrastructures facing technical and physical issues (Colldahl et al., 2013; Bibri & Krogstie 2017). Less than 5% of the world's population lived in cities in the 18th century (Harrison, & Ian 2011, Jacobs, 2016), however, it has been estimated that by 2050, 60% of the world population will live in urban centers (Weisz & Julia, 2010, Cohen, 2003, United Nations, 2015, Bibri & Krogstie, 2017), adding pressure on the environmental and social sustainability of society (Ness et al., 2007, Seyfang & Smith 2007, Ageron et al., 2012). The economic and social activities of cities are inherently related since they consume about 70% of the world's resources (Bilgen, 2014). The focus of geospatial scientists and city planners has been the implementation of smart cities strategies to respond to considerable challenges facing the current urban landscape in an attempt to adopt plans for building a sustainable society (Miaoxi et al., 2014, Joss, 2015, Un-Habitat, 2016) that is effectively managed. There is increasing pressure in the way in which cities organize and operate their critical infrastructure, human services, ecosystem services, and administration due to severe challenges related to having a sustainable city (Lovell & Taylor, 2013, Connolly et al., 2014, Bibri & Krogstie, 2017).

These problems that threaten the economic, environmental, and social sustainability of cities (Neirotti et al., 2014, Al Nuaimi et al. 2015, Bibri & Krogstie, 2017) have given birth to the use of holistic and long-term urban management approaches requiring spatial thinking. Several communities have developed and are using innovative strategies for daily operations to overcome the challenges of urbanization (Bibri & Krogstie, 2017), where urban computing and use of Information, Communication, and Technology (ICT), like infrastructures, applications, data analytics capabilities, and services have become a conventional discussion community management use in addressing a variety of environmental challenges in modern city. This holistic thinking has been made possible by incorporating data sensing and information processing into city management using well-managed systems that require smart data and data-centric approaches prompted by the large-scale proliferation of wireless networks (Batty, 2012, Batty et al., 2012, Bibri, Krogstie, et al., 2017).

In response to the challenges of urban society, city planners, urban geographers, and other scholars have developed the idea of the "smart city", which is a broad term that promotes the use of innovative, technology-based approaches to make communities more safe, livable, well-run, healthy, prosperous and sustainable (Kallerud et al., 2013, McCann & Ortega-Argilés, 2014). Made possible by advances in information, communication and technology (ICT), smart city strategies help intelligently manage urban systems so as to produce efficiencies and growth in the areas of transportation, economic development, energy, land use, communication, and service delivery (Palensky et al., 2011, Yu et al., 2012, Bibri, & Krogstie, 2017). Cities that are well-run, livable, safe, healthy, prosperous and sustainable attain this objective through ICT, and this has prompted other communities facing urban growth to seek and implement smart solutions to their problems (Kallerud et al. 2013. McCann & Ortega-Argilés. 2014). Modern societies use ICT saturated with computation and intelligence for functions, services, and designs for daily operations, and ground-breaking solutions and sophisticated methods are needed to manage a modern urban community. Advances in computing have shown that ICT holds remarkable potential for assessing, monitoring, understanding, probing, and planning (Bibri 2018), by making the environment smart (Cook & Schmitter-Edgecombe, 2009, Rashidi et al., 2011). Urban population growth and rapid urbanization (United Nations, 2015, Hashem et al., 2016, Bibri & Krogstie, 2017), has resulted in numerous smart applications (Hashem et al., 2016) which include including smart homes (Li et al., 2011, Jala et al., 2012), smart grids (Lund et al., 2012, Dörfler et al., 2013), smart healthcare (Catarinucci et al., 2015), smart transportation (Ju et al., 2013) and smart cities (Batty et al., 2013, Townsend, 2013). These smart environment applications have been made feasible by IoT, where conventional devices are linked to network technologies (Hashem et al., 2016) with advanced ICT techniques leading to an increase in the magnitude of data, which is a service rendered by IoT.

While an established definition of a smart city is still to be considered (Brenner & Schmid, 2014, Morabito, 2015, Parnell, 2016, Hashem et al., 2016), within the context of this study, we will define a smart city as one that will 'invest in social and human capital and traditional (transport) and modern (ICT) communication infrastructure to promote sustainable economic development and a high life quality, with intelligent management of natural resources, through participating governance.'(Caragliu et al., 2012). This definition relies on six distinct classification systems based on smart living, smart environment, smart economy, smart mobility, smart people, and smart governance—through which smart cities can assess their development in the trend of smartness (Bibri,& Krogstie 2017). Inventive and smart solutions that improve livability and enhance sustainability through the integration of digital technology and urban planning is an endeavor all smart cities seek. Including the next generation of ICT into all walks of life, including roads, railways, tunnels, water systems, bridges, appliances, hospitals, buildings, power grid, and transportation system is the primary focus of every smart city (Su et al., 2011, Kresl & Daniele, 2016, Jeena, 2017). We describe a smart city where innovative ICT is combined with functional, operational, infrastructural, architectural, physical, and ecological systems at various spatial scales with city planning methods, to increase competence, safety, livability, prosperity equity and sustainability using big data analytics. The application of big data over the past few years in urban analytics has attracted massive attention among scientists, and big data is altering the way cities function and can be managed (Batty, 2013, Bibri & Krogstie, 2017). Big data has for a very long time characterized by velocity and volume, and there has been an increasing rate at which different data types have been created (Hu et al., 2014, Hilbert, 2015, Gani, et al., 2016, Hashem et al., 2016). Big data has the perspective to provide useful information obtained through numerous sources and can transform the economy of the city (Batty, 2013, Hashem et al., 2016) and improve the living standards of its citizens through the implementation of significant data applications (Jimenez et al., 2014). Big data is used and managed with cloud computing platforms to monitor situations, events, activities, processes, behaviors, locations, spatiotemporal settings, environmental states, and socioeconomic patterns in real-time.

Obtaining a large about of data and in real-time can be very valuable for managing different sectors of the city. Real-time data, analysis, visualization, and interpretation allow local governments and city planners to make smart and intelligent decisions regarding smart energy, street and traffic lights, grid, mobility, transport, safety, education, planning, healthcare, smart governance, and buildings at different scales (Bibri & Krogstie, 2017) with the aid of operational dashboards. ICT provide smart solutions that improve community management and improve the lives of citizens (Bibri, Krogstie, et al., 2017), by being able to connect urban systems, reducing redundancy in operations, services, and facilities, and performance enhancement through effective integration and coordination of tasks using smart solutions. The ability of numerous cities to address complex problems to make the community smart and prosperous has primarily been attributed to progress in ICT as a strategy to address the concerns and meet the urban development needs of the citizens (Nam & Theresa. 2011, Angelidou, 2014). Although at its infancy stage, there is considerable potential to improve smart city services with big data analytics (Batty et al., 2012, Al Nuaimi et al., 2015, Hashem et al., 2016), with colossal datasets currently being generated from computers, sensors, smart-phones, global positioning systems, cameras, social networking sites, commercial transactions etc. The continuous growth of these data sets prompted the development of data analytics platforms for storing and processing of the data generated to provide meaningful information (Marr, 2015, Hashem et al., 2016, Ibrahim et al., 2016), which has been made possible through cloud computing and IoT technologies (Gretzel et al., 2015). With big data, the smart city retains spatial intelligence (Gruen, 2013, Gilfoyle & Peter, 2016), where geospatial technology is used for information, cognitive processes, and problem-solving, through collective knowledge with real-time alerts, learning, and forecasting (Gruen, 2013, Consoli et al., 2017). The use of geospatial information science in the smart city has already transformed several cities at a more efficient management level. Through the application of GIS-based visualizations in smart cities, citizens are offered interactive and easy-to-use platforms by way of flexible devices and software applications based on modern technologies in the realization of the intelligent environment vision (Hashem et al., 2016).

This study aimed to use real-time spatial analytics that integrates state–of–the art ICT approaches in current and future planning practices using an operational dashboard which presents a detailed analysis, critical evaluation, and interdisciplinary synthesis for smart solution making process across different sectors of the community. We also intend to show the vital role geospatial science has in providing real measures for data collection, processing, analysis, and representation with operational dashboard for a smart city operation mamgememt like for safety, health and emergency preparedness. Our motivation behind this paper is because of advances in geospatial technologies and spatial thinking, the interdisciplinary nature of the concept of smart community, and the importance and relevance of the application of intelligent solutions to urban life. We show the significance of information technology in facilitating and shaping decision making in urban centers, and how they use of an integrated system can increase accessibility of information to better show how their cities work, allowing stakeholders to efficiently micro-manage the urban system with real-time data. The scientific contribution of this paper is the development of an integrated and innovative system that supports intelligent spatial decision-making justified by a data-centric system that uses real-time context-aware solutions to address the environmental concerns and socio-economic needs of the community.

2. Method

The growth of big data and the smart city has stimulated improvement and advancement of new intelligent applications (Hashem et al., 2016). The use of big data for spatial intelligence for smart cites necessitates networks that connect all the components capable of conveying collected data from the sensing layer to the application layer and be able to process and transfer responses back to the different elements in the smart city that need them. This permits the sharing of information across platforms using a unified framework, attained through seamless, ubiquitous sensing, data analytics, and information representation using the combined structure of cloud computing to enrich different smart city services (Gubbi et al., 2013, Hashem et al., 2016). The focus of an intelligent community is applying next-generation information technology to all sectors of society, embedding sensors, and equipment in buildings, power grids, bridges, railways, dams, oil and gas pipelines, tunnels, roads, hospitals, water systems, and other universal objects, thereby forming the IoT (Su et al., 2011, Al Nuaimi et al., 2015, Hashern et al., 2016). This era of IoT has effortlessly connected sensors in the smart city environment leading to a more efficient and faster way of sharing information across different platforms (Botta et al., 2014; Chen et al., 2014; Hashem et al., 2016). Wireless communication adoptions is making IoT become the revolutionary technology from all the prospects presented by the Internet technology through which smart cities have been able to develop intelligent structures like smart homes, smart grids, smart water, smart retail, smart healthcare, smart energy and intelligent transportation (Gubbi et al., 2013, Hashem et al., 2016). The opportunities for the use of big data for geospatial intelligence in smart cities are boundless with the existence of innovative tools and technologies, and with the right tools and methods, proficient and competent data analysis embolden cooperation and communication between components of the smart city and can enable additional services and applications to boost the intelligent city (Hashem et al., 2016).

More smart towns/communities and other organizations are now using real-time GIS to achieve operational cost savings and quality of life improvements. A real-time GIS has made database management for solution-seeking necessary. The fast growth of the internet and the World Wide Web has also made it possible for several GIS products to run on a web browser and through applications on mobile devices. We integrate a significant amount of data from several sources in a real-time application using geographic information systems (GIS) widely used for mapping and analyzing spatial data, smart environmental monitoring, intelligent life, smart traffic, smart healthcare, smart public safety, and smart transportation, which until recently has been a challenge to accomplish (Su et al., 2011, Gubbi, & Palaniswami, 2014). The integration of data from several sensors allows city planners to transform data into information, and this is very vital in decision making (Hashem et al., 2016) in our technology and data-driven era. People have become increasingly connected through technology and smart devices, so for a city to communicate with the people within it; the city will have to adapt to address their needs and wants. GIS data can be crowdsourced or generated in real-time by citizens, thus providing a more accurate picture of the urban system and allowing for quicker response times. Our approach includes a cloud-based system made up of passive sensors, participatory information, and communication networks to collect and diffuse data to and from the sensor layer to the application layer and vice versa (Figure 1).

Smart city architecture is diverse (Wenge et al., 2014), the approach we adopt here has a four-layer architecture (Liu &Peng, 2014), made of sensing or data acquisition layer, communication or transmission layer, data storage, processing and visualization layer, and the application or service layer (Figure 1). The sensing layer collects massive amounts of data through a set of IoT nodes across an urban area about various activities in the physical environment and provides data to data hubs in the data layer. Data obtained through these sensors can assist several segments of the city by delivering an improved consumer experience and service, and this can lead to increased performance in businesses (Ostrom et al., 2010, Dinh Hoang T et al., 2011, Hashem et al., 2016). The several billion IoT nodes spread across every smart city system make it possible for data transfer from one sector of the community to the other, necessitating vigorous communication technology to handle a tremendous amount of data traffic. The data transmission layer guides the end to end communication services with the smart city layered architecture by transmitting data from the sensor and transport networks (Gubbi et al., 2013, Liu & Peng, 2014, Wenge et al., 2014). The collected data needs data storage, processing, and visualization before it can be disseminated to citizens and the stakeholders for smart decision making. Intelligent data processing and mining are quite essential at this stage to reveal hidden and unknown valuable information (Wenge et al., 2014). With the assistance of IoT, it is nor possible for effective city management with systematically organized data, with data connected to the different data servers that are set to process different predictive, descriptive and statistical decision models help the city government to take proactive and data-driven decisions (Nam & Pardo, 2014, Gil et al., 2016, Molina-Solana et al., 2017). The processed, visualized and stored data, need to be used to for intelligent solutions by combining the synergy of information technology and industry-specialized technology (Liu & Peng, 2014). This data can be managed through an operation center for the cross-department, where various sectors of the city like energy, health care, transportation, city government, police department, etc, can use in sharing information through web portals/mobile applications built on this layer. When a subset of the data is provided to the general public, services can be developed through crowdsourcing to enhance the operations of the city and influence the political, social, economic, and environmental needs of the community. The architecture (Figure 1) used in our study exploits large amounts of data and information from different sectors of the smart city like home, health, and environment domain, and knowledge extraction (Gubbi et al., 2013, Gaur et al., 2015, Suciu et al., 2015, Gil et al., 2016). A real-time GIS is applied to combine sensors from the environment and home aimed at efficient, transparent,sustainable, and intelligent community management, driven by ICT and rendering a visual framework through an operational dashboard (Shin'ichi, & Roussos. 2016).

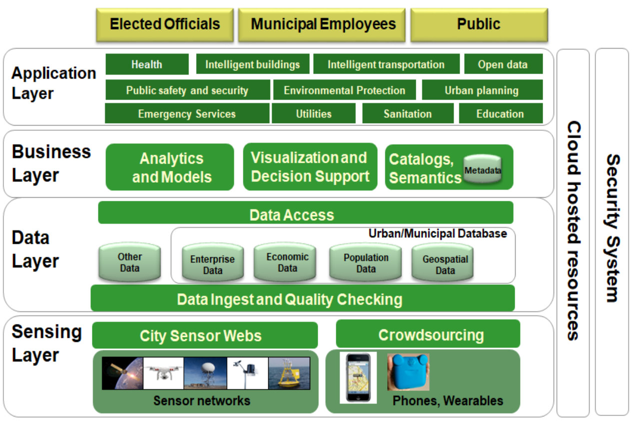

Figure 1. The Architecture of the smart city and big data technologies adopted from OGC (2014).

The real-time application integrates all the sectors of the smart city in the architectural framework, including smart environment, smart transportation, smart residential buildings, intelligent energy, smart health, smart security, smart services, and smart outcomes/policymaking. As demonstrated in Figure 1, each of the smart city domains delivers the primary data source for the generation of various information required for intelligent decision making. Satellite network is used in conjunction with smartphones, GPS devices, and the use of the internet for PCs and other navigation devices for raw data collection with the aid of semantic web technologies, processing and analyzing the data in real-time (Gubbi et al., 2013, Gaur et al., 2015). The architecture provided by web technologies and GIS offers an integrated cross-sectional platform to assemble, manage, gather, analyze and visualize spatiotemporal data for sustainable city planning, development, and management.

The healthcare sector has generated a vast quantity of data in the past decade (Chen et al., 2012; Demirkan, 2013), with rapid worldwide population growth creating changes in how health services are made accessible to a majority of the population. With practical tools, both professionals and the general public can quickly have access to data and make treatment decisions based on available data and services offered. Ease of access to information results in a faster rate at which an epidemic can be cured and prevented from spreading, thanks to spatial intelligent gadgets associated with dashboards that aid in monitoring services provided in the community. In an attempt to make the community healthier, offer greater access, efficient care, and increase the availability of health resources, we configured a Health Resource Inventory that can be used by health and human services for an inventory of alternative medicine, drug drop off, drug treatment, health and social services, homeless services, hospitals and clinics, and mental health services in the community. The app can be configured to work both on the web and mobile devices can also be used as a remedy for substance use and mental health resource inventory. This inventory of health resources uses Web AppBuilder by ArcGIS, which provides a foundation for location-based application accessibility. This application can be used by the general public to locate health and human services in a designated area (Esri, 2018). The health resource variables for this paper will include the locations of substance abuse treatment facilities, drug drop-off locators, mental health facilities, and homeless/emergency shelter services.

One area where smart city strategies could prove beneficial is emergency preparedness. With the concentration of activity in cities, it is essential to have procedures in place in the case of an emergency and make sure people are educated on what action they should take. However, to gauge the knowledge and preparedness of the population, there needs to be a way of intelligently surveying residents and analyzing their responses. Therefore, in keeping with the smart city concept, one of the objectives of this study was to develop a location-based emergency preparedness survey for the city of Grand Forks, North Dakota, using Survey123 for ArcGIS (Mantas et al., 2017). The application use ESRI's Survey123 for ArcGIS (Kolvoord et al., 2017), which is a form-centric data gathering platform for intuitive and straightforward creating, sharing, and analyzing surveys (Law 2017). The ESRI product enables the adoption of a citizen science approach (Newman et al., 2010) through participation GIS, using the public to gather data so that city officials can better assist the community's preparedness for floods and winter storms. The survey was designed to collect an assortment of information from each respondent. In the state of North Dakota, the two most prominent severe weather events for which people must be prepared are flooding and winter storms. Some emergency preparedness principles apply to any disaster, while other disaster types may require specific steps to be taken, thus making it essential to take a multi-hazard approach (Komendantova et al., 2014). By questioning residents about the condition of their residence, the items they have on hand, and their knowledge of emergency response, all while considering different hazard types, this survey can more efficiently help the community prepare for disasters like blizzards and floods. To respond to the needs of smart city management, we developed and deployed a solution that combines information from various sectors of the city using Survey123 for ArcGIS to collect data, and displayed on an operational dashboard with multiple visualizations for real-time monitoring of people, services, assets and analysis of events or activities. The survey asks for their location (which gives the data spatial attributes that allow it to be mapped), includes questions about the characteristics of their home and household, a series of safety checks to assess their emergency preparedness, and a list of items that they should have on hand.

The survey questions were developed by consulting literature from the Federal Emergency Management Agency's Ready Campaign (Ready 2018), the American Red Cross (Red Cross 2018), and the Centers for Disease Control and Prevention's disaster resources (CDC 2018). Survey123 has a variety of built-in tools for designing the survey (Figure 2), including different question types such as single and multiple-choice and text and number entries. The survey also incorporates conditional questions, where specific items will only appear if accurate answers are chosen in previous questions. Additionally, the survey also includes the option for the participant to upload a photo of their residence as shown in link below. https://survey123.arcgis.com/share/92dd674e577e49c28dfaa568acac3969

Once the survey is created, it can be filled out by anyone through a web browser on a computer or mobile device. Additionally, the survey can be downloaded to the Survey123 field app, where inquiries can be completed offline and then submitted later. As the data is collected, it can be analyzed by the survey creator. Various charts, tables, and histograms for each of the questions can be viewed, and the data can be queried by date. The data can also be displayed on a map with survey answers tied to the user-selected locations. Opening the data in the ArcGIS Online map viewer enables changes to be made to the data's symbology and pop-ups, and the map can then be shared as a web app from link below. http://nodak.maps.arcgis.com/home/webmap/viewer.html?useExisting=1&panel=gallery&suggestField=true&layers=979973e2139342b3bdca4724c72bcc7c

We also use an operations dashboard to monitor real-time incidents through the integration of maps and customized widgets. The operations dashboard allows for quick decision making and accurate visualization of situations as they occur. The first step in creating an operations dashboard for emergency management services (Goh et al., 2013, Lee et al., 2015) in Grand Forks was to assemble data for fire stations, police stations, hospital, and clinic locations, emergency shelters, a police call log, and ambulance incidents. These files contained information such as name, address, hours of operation, and phone numbers. This data also included accident and EMS call logs. Using ArcGIS Online the layers were individually edited with their unique symbology for local governments to represent the service locations (ESRI, 2018). The police and ambulance incident layers were enabled with editing and syncing capabilities, so police and EMS personnel could enter data in real-time in the field. This function creates direct communication between the field and the office, and both sides can see the same visualization (ESRI, 2012). These layers were also set to "within the organization" so they could only be edited internally. This would ensure no outside people could interfere by modifying or deleting information. The incident layer's editing and syncing capabilities also allowed the map to be used in apps such as Collector, so workers could easily download the map and use it in places without network connectivity. By doing this, it would ensure data uniformity and efficiency in reporting information. The app included fields such as date, time, address, call nature, and incident status. All officers and EMS personnel would have the same or a similar form, and there would be no discrepancies in how they entered information. For instance, a dropdown list could be created for the call nature, and they could select from a pre-determined agenda. As far as the general public, they could still have access to the map to see the locations of emergency services and incidents, but they would not be able to enter or edit any information. All data layers were imported into a web map viewer using an appropriate base map to allow users to identify surrounding buildings and streets as viewed on the link of a web map showing all the customized layers with unique symbology http://arcg.is/8a9ir

From this point, "Create an Operations Dashboard" was selected from the menu and automatically created with a default template. All the features on the map can be clicked on and will display a pop-up. The pop-ups for the service locations show information the public might need to know, like phone numbers or websites. The pop-ups for the incidents will display information entered in the field (ESRI, 2017). The header and sideboards were customized with different colors and titles. Several widgets were also created, which were relevant to emergency management in real-time. The first was the "Indicator" widget, which showed the number of total EMS and police incidents. This number would go up or down in real-time, so emergency personnel or dispatchers could know how many full episodes were out there or how many required a response (ESRI, 2017). It could also possibly be used to show the total amount of time emergency personnel are taking to respond to incidents (ESRI, 2017). The color selections corresponded to the color in the symbology, so these would stand out and be easily understood. An icon for the police and EMS were added, too, for precise identification. Next, the "Gauge" widget was created. The gauge widget can be used to display a value that is above or below a threshold (ESRI, 2017). In this instance, the gauge shows the number of incidents that are currently open. It is colored green as this is the color people typically associate with "open." Once it reaches the threshold, the gauge will turn red, and a warning will appear. As stated previously, this was a dummy number only used as an example. The indicator might also be created for emergencies to show how many people are hurt or how many people have been relocated to shelters (ESRI, 2017). A "Bar Graph" widget was also added to display multiple attributes of data as well as counts. In this case, the "Call Nature" field was selected to view the different types of incidents, and the total number is occurring. These include events such as accidents, suspicious activity, burglary, traffic stops, etc. In emergencies, personnel in the field and the office might need to know the types of incidents that are occurring, so they could visualize and understand patterns more easily (ESRI 2017). By doing this, they could identify which events require the most resources or are higher priority. The bar can be easily shifted up or down for a bigger or smaller view. Finally, the "Legend" widget was created, so anyone seeing the map could identify all the necessary symbols (ESRI 2017). They would not have to take time trying to figure out what a symbol meant or why it was included. The symbols were pre-determined based on the settings of the layers. The legend can disappear by sliding it to the left if it is not needed at any point in time. Operations Dashboard of Emergency Management Services in Grand Forks, ND *http://nodak.maps.arcgis.com/apps/opsdashboard/index.html#/062bb64a120d49ae81948106e463d94a*

The geo-enabled dynamic dashboard application provides the ability to access, query, and display real-time motion, improving situational awareness for at a glance decision making when shared with relevant city officials and the community and made available for desktop and mobile devices.

3. Results

Application of real-time GIS in smart cities

There is an abundant variety of smart city frameworks that have been established to facilitate the assessment and development of cities(Bibri & Krogstie, 2017). Smart cities have been classified using six dimensions of urban life, namely smart economy (industry), smart governance (e-democracy), smart environment (efficiency & sustainability), smart mobility (logistics & infrastructures), smart living (security & quality) and intelligent people (education) (Lombardi et al., 2012). These six dimensions are used in smart cities, with each using a set of factors to evaluate its success and make determinations on how to improve(Lombardi et al., 2012; Albino et al., 2015, Bibri & Krogstie, 2017). The framework adopted for this study uses the dimensions of safe, well-run, livable, healthy, prosperous, and sustainable by using GIS to connect the community and combine crowdsourced information to assess all the systems of the smart city and build a friendly and livable city.

3.1. Healthy city – health resource inventory

The enrichment of life in a community starts with the health of the community. Using real-time operations to integrate medical information and treatment facilities ensures fast, accurate, and consistent healthcare information across the district. This real-time application can also be used by the city to identify the right services that meet their health needs and safeguard that the best treatment and assistance is provided. The tool is tailored to allow the general public and the department of human services to crowdsource information for resource managers and the general public on the location of health-related facilities. One area where such an inventory can be very fruitful to provide information to the population is in battling the 'substance use disorder' (SUD) ravaging our communities. The substances incorporated will include; tobacco, alcohol, cannabis (marijuana), stimulants, hallucinogens, and opioids (SAMHSA, 2015), as each of the treatment facilities in this health resource application treats clients with any one or more of the substances mentioned above.

The consequences of substance use take an enormous toll on our nation. The combined healthcare, crime-related, and productivity costs of substance use exceed $700 billion a year (NIH, 2017), but the dollar amount does not approximate the overwhelming human toll of substance use disorders (National Institue of Drug Abuse, 2017). The prevalence of substance use disorders has been documented as a significant public health burden and safety issue throughout the United States (U.S.) in recent years (Hedegaard H, 2017). As of 2016, the average life expectancy in the U.S. has decreased for the second consecutive year (Reidhead, 2018). Substance use-related deaths, particularly deaths caused by overdoses are now the leading cause of accidental death in the U.S. (ASAM, 2016), with more than 115 individuals dying of an overdose on opioids every day (NIH, 2018). Reports show that sales, substance use disorder admissions treatment related to prescription and non-prescription opioid use as well as overdose death rates have simultaneously increased from 1999 to 2015 (ASAM, 2016). Deaths related to a drug overdose in the United States in 2015 was 2.5 times more than the rate in 1999 (6.1 per 100,000) (Centers for Disease Control and Prevention (CDC), 2017). Substance use disorders render complex and "continuously emerging challenges" that can be witnessed throughout the ongoing epidemic of prescription opioid substance use disorders in our nation (NIH, 2018).

Furthermore, this epidemic is now contributing to a rise in heroin use as well as a rise in Hepatitis C Virus (HCV) and Human Immunodeficiency Virus (HIV) outbreaks by the use of new drug delivery systems (National Institue of Drug Abuse, 2017). Substance abuse is often connected with homelessness and in a significant amount of cases, is both a cause and a consequence of homelessness, as substance use disorders often disrupt relationships with family and friends, as well as cause an individual to lose their employment. For these individuals who struggle with the financial obligations of bill paying, the exacerbation of a substance use disorder may ultimately cause them to lose their housing (National Coalition for the Homeless, 2009). For those struggling with substance use, mental illness can also be an issue. As of 2014, a reported 7.9 million adults struggled with both substance use and mental illness, side effects from drugs have been detected to cause mental illness symptoms in some cases as well (Screening for Mental Health (SMH), 2016). To examine an individual's willingness to access available resources with specific demographic areas, a study by Beardsley (2003), considered the association between approximate distance traveled to treatment, and treatment completion and length of stay, for 1,735 clients attending outpatient therapy in an urban area. The study found that clients who went less than one mile to participate in substance abuse treatment programs were 50 percent more likely to complete the program than those who moved more than one mile. They also found that clients who lived more than four miles away from a program were significantly more likely to have shorter lengths of stay in treatment than clients who traveled less than one mile. The considered factor is the distance from one's home to the closest drug treatment center (in minutes); and the number of treatment services within a 10-minute range of driving from one's home (Nallamothu et al., 2006, Kao et al., 2014, Donohoe et al., 2016).

Locations of substance abuse treatment facilities, drug drop-off locators, mental health facilities, and homeless/ emergency shelter services icons. http://nodak.maps.arcgis.com/apps/webappviewer/index.html?id=f0c3bb7ce6f7490493c549a4e5513fa4

Within each variable, a subset of additional information could be added, which would then appear in the pop-ups when a variable icon is clicked; an example is illustrated in link below:Substance use health resource inventory app. additional information in pop-ups http://nodak.maps.arcgis.com/apps/webappviewer/index.html?id=f0c3bb7ce6f7490493c549a4e5513fa4

This health inventory allows the health department and community to have real-time access to health-related facilities and will enable patients to quickly and efficiently pick the facilities that meet their health needs. The local government can also use this information for a quick count of available services in the community. This reliable means of data transfer results in smart management and service and can help solve the problem of regional development inequality. By integrating data sharing and visualization for the general public, a service-oriented government that promotes stability and harmony can be built (Nam & Pardo, 2011; De Jong et al., 2015). Smart health for a community also includes a system that is set up to manage emergencies and improve the safety of the city with other intelligent applications.

3.2. Safe city – emergency preparedness

Here we develop a multi-hazard approach (Komendantova et al., 2014) to efficiently help the community prepare for disasters like blizzards and floods by incorporating physical and social elements of the community to help the city adequately prepare for a catastrophe. Using Survey123 for ArcGIS, we adopted a citizen science approach (Newman et al., 2010) through participation GIS, where questions were used to assess the community's preparedness for floods and blizzard. The survey would get the participant's name and location and include questions about the characteristics of their home and household, a series of safety checks to assess their emergency preparedness, and a list of items that they should have on hand.

The results show that Survey123 for ArcGIS provides an easy way to design and administer surveys, which could be a useful tool for implementing public participation data collection in the development of a smart city. Beyond emergency preparedness, these tools could be used to gather data about streets in need of repair, city assets that require maintenance, or users of different amenities. The completed survey was shared to make it publicly accessible, and it can be found at the following link: https://survey123.arcgis.com/share/92dd674e577e49c28dfaa568acac3969 The survey includes 31 questions, with most about general emergency preparedness but also some that specifically address flooding and winter storm preparedness. The investigation would primarily be completed through a web browser, although it can also be downloaded to the Survey123 field app for offline data collection. Participants go through the easy to use interface and answer the straightforward questions from links below: The user interface for the survey. https://survey123.arcgis.com/share/92dd674e577e49c28dfaa568acac3969

https://survey123.arcgis.com/share/92dd674e577e49c28dfaa568acac3969

The survey application could provide city officials with information about the preparedness of their citizens, revealing the effectiveness of public education initiatives. If there are specific questions where the responses indicate a lack of readiness, officials can tailor their programs and public education efforts to try to address those shortcomings. Additionally, the location component of the survey could help inform which areas of the city are most prepared, and that can then be compared to which areas are most vulnerable to emergencies. It could also be used to inform where response efforts should be focused on the event of an emergency. Overall, the survey's usefulness is its ability to gather standardized data about the preparedness of a city's residents in an efficient manner. This scenario provides a benefit to both citizens and government officials. Those who take the survey become more aware of their level of preparedness and any areas where they may need to improve, while officials gain a sense of how well educated their citizens are and what areas may require better engagement with the public. The real-time data transmission using surveys completed in the field also has offline working capabilities, and anytime internet service is available, information entered in the form can be transmitted and viewed by stakeholders or the general population immediately. This real-time information is accompanied with customized operational dashboards to help filter information and provided the most relevant feedback for operation management

3.3. Safe city – emergency preparedness

The use of an operations dashboard and mobile application are useful tools that can be used in emergency management. The operations dashboard customized with a multitude of widgets enables ease of access to information. For dispatchers, this is essential because they can see everything on one screen. They can see what is happening without having to call and get an update from people in the field. They can more appropriately direct police or EMS based on what they see. The mobile application can also be used when there is no Wi-Fi and updated when a connection is available. This is also great because personnel can still enter information electronically when they are in remote locations. The form will also alleviate the issue of people entering different types of information. With the use of dropdowns, people can enter a pre-determined set of data. If they choose to download the data as tables, all the data will be the same, and they will not have to perform extensive cleanup of data. This will also make their job less tedious and eliminate costs as well as the security of knowing they will be presenting the most accurate data possible.

Not only do these tools provide the ability to see information updated in real-time, but more extensive analysis can be performed. Personnel could use the information presented on the map and might even be able to conduct quick hot spot analysis. This would help them identify critical areas where lots of incidents are occurring or where a particular type of event is more frequent. They might even be able to take this data and find out which time of day or day of the week most incidents are occurring. All of this would allow them to move resources more efficiently. Officers could patrol those areas more frequently, or perhaps a city program is needed to try and combat whatever incident continues to be an issue in a particular area. This will aid in better city decision making. This will be the most cost-effective way for the city to deal with problems. They can have all their information and data stored in one place. Not only that, but cities do not necessarily have to hire a person with extensive geographic knowledge as much of ArcGIS online contains basic operations. There are numerous ways to customize an operations dashboard or mobile app to fit a specific situation, but this was one example of how GIS is making cities smarter.

4. Discussion

Substance use disorders have increasingly become a significant public health burden and a safety issue throughout the United States. Although the potential relationship between spatial accessibility of resource utilization is relatively new, the introduction of Geographic Information Systems (GIS) has now given researchers a broader range of spatial tools to assist in the analysis of individual health and behavior in their proximal environments. In the findings, studies have indicated mixed results of increased and decreased treatment adherence in correspondence to spatial availability, and the impact on resource spatial availability and substance use is not entirely clear. A substance use service that individuals can afford is culturally relevant and is in a demographic area that has higher rates of substance use that may play an essential role in promoting a change in an individual's potential willingness to participate in a spatially available resource. Since it is accepted that data is vital in planning treatment and prevention efforts for substance use, it should be incorporated at all levels of planning. The app creation, using ArcGIS Pro and ArcGIS AppBuilder was quick, simple and self-explanatory to use. Our first objective aimed at examining the potential impact of spatial accessibility to the identified resources (e.g., substance use treatment facilities, prescription drug-drop offs, mental health facilities, and homelessness service) and how would they affect an individual's willingness to access these readily available resources within specific demographic areas. To address the spatial accessibility, we developed a health resource inventory application for mobile devices for the Grand Forks, ND area. The environmental framework of substance use disorder is beyond complex and requires a multilevel and ecological perspective, not to mention, access to substance use disorder services is a multidimensional issue in itself (Kao et al., 2014). According to Kao et al. (2014), spatial accessibility focuses on the geographic location of services and its potential effects on an individual's ability or willingness to access services. With the introduction of Geographic Information Systems (GIS) and similar technologies, researchers now have access to a range of spatial tools to assist in the analysis of individual health and behavior of their proximal environments. Although the influence of geography and other environmental factors on the treatment of substance use disorders is still relatively new, the analysis of SUD treatment locations and the use of GIS to better understand and respond to substance use disorders has been a topic for ongoing research (Kao et al., 2014). To attain our second objective which consisted of the development of an emergency preparedness survey using Survey123 for ArcGIS, we showed Survey123 and its different applications has the potential to be an alternative to Collector, with the critical difference being that collector is a map-centric mobile data collection application while Survey123 is a form-centric. Survey123 is still location-based, with each survey response tied to a user-specified location, but the form-style layout can be more intuitive to members of the general public. Survey123 can be accessed through a web browser or can be loaded onto an app for offline data collection. This can be particularly useful for field operations where network connectivity may not be guaranteed. When Survey123 is used on a mobile device, the device's GPS coordinates can be used to automatically record the location, streamlining data collection, and acting as an easy way to track study area coverage, thus reducing sample duplication (Andrade et al. 2017). Survey123 has the potential to replace traditional clipboard and paper data collection with smartphones and surveys (Hathaway 2018). This is another benefit of using Survey123, as it standardizes data collection and allows the collection and analysis to be completed more quickly and efficiently (Andrade et al., 2017). With Survey123 field operations can integrate GIS for a wide variety of applications (Hathaway 2018). Some examples include monitoring of immunization programs in developing nations (Kakakhan et al., 2016), damage assessment following a disaster event (Hathaway 2018), and in this project, it was used to address preparedness for floods and winter storms. While Survey123 is not revolutionary or overly complicated, its simplicity and usefulness make it applicable to almost any field. Its usefulness was demonstrated by the development of an emergency preparedness survey for the city of Grand Forks, North Dakota. Survey123 provides a simple yet powerful way to design and administer surveys and can be a useful tool for implementing public participation data collection in the development of a smart city. Beyond the example of emergency preparedness, these tools could be used to gather data about streets in need of repair, city assets that require maintenance, or users of different amenities. Utilizing technologies like Survey123 for data collection can inform and improve decision-making, thus furthering smart city goals (Kakakhan et al., 2016).

There exist significant challenges with the implementation of current smart city approaches to sustainable development goals for the city (Bibri & Krogstie 2017). These challenges stem from difficulties, inadequacies, misunderstandings, and connections between smart, sustainable towns and cities' concepts about management, operation, and urban system planning (Marcuse, 2009; Batty et al., 2012; Lee et al., 2014; Bibri & Krogstie 2016). It is vital for each sector of the city to understand how they relate to each other in a smart city concept where, for example, there is an integration of hospital, accident, and emergency data about the place of violent crime to help law enforcement focus their patrolling approach. Such strategy results in rapid response where the police could use the currently provided data to be present at violent crime scenes much quicker to prevent violence from escalating. Using a smart city approach, the citizen receives better information and can make a better judgment on which decision to take regularly from real-time data. With real-time data, emergency managers and responders share a standard view of the state of affairs and can make better decisions together with other agencies responding to the same event.

5. Conclusion

Cities will continue to expand, and emergencies will continue to happen. With a smart city management approach, cities can be more prepared for planning and responding to these incidents. Cities can achieve faster response times and analyze on the spot. They can better allocate resources and time to the episodes which may be a higher priority. Furthermore, they can enter information quickly, accurately, and uniformly even in intense situations. We aimed with this study to explore the use real-time spatial analytics with an operational dashboard for smart decision-making processes across different sectors of the community. We also intended to show the vital role geospatial science has in providing the theoretical context and real measures for data collection, processing, analysis, and representation. This paper is inspired by advances in geospatial technologies and spatial thinking, the interdisciplinary nature of the concept of smart community, and the importance and relevance of the application of intelligent solutions in urban life. The incorporation of data and technology in daily operations results in a safe, well-run, livable, healthy, prosperous city.

Using Grand Forks, North Dakota as an example, we developed a health resource inventory, emergency preparedness scenario for natural disasters, and smart government response to public safety using an operational dashboard to monitor real-time data for city operations. To make the community smart and healthier, we built a health resource inventory that integrates medical information and treatment facilities of all kinds of illnesses with relevant information needed by city dwellers across the community in helping them make smart healthcare decisions. Secondly, we used ArcGIS Survey123 to efficiently gather standardized data about the preparedness of a city's residents, which serves as a benefit to both citizens and government officials in natural disasters such as winter storms, blizzards, and floods. Finally, to make the city government smarter, an emergency and non-emergency management app was created using an operational dashboard to help law enforcement and city managers manage operations in real-time. The dashboard shows updated information on incidents in real-time so personnel in the field and the office can better communicate. Dispatchers will know the total events and types of activities occurring after they are entered, and emergency responders will be able to enter information on the fly. The public has a map with cohesive and integrated information all in one place, which could be particularly beneficial in an emergency.

Therefore, the use of information technology in smart city management provided real-time through different sensor networks plays a vital role and has excellent potential to produce more efficient decision-making in a community. The challenges facing intelligent cities have motivated researchers, developers, and decision-makers to work together and come up with new methods of restructuring and reorganizing municipalities through several spatial scales (Nam & Pardo, 2011). The goal of this approach to develop a more conclusive city model that accomplishes the requisite level of sustainability, particularly about incorporating its economic, social, cultural, and environmental dimensions. The use of innovative approaches to overcome challenges and issues facing cities of the 21st century require a real-time monitoring system that can be used for situational awareness, analysis, and city planning to aid smart decision and attain the vision of sustainability for urban operations. Practical and intelligent decision making is vital for societal sustainability (Yan et al., 2013; Kitchin, 2014; Zhuhadar et al., 2017). Effective data management plays a crucial role in retrieving and using environmental information. Management decisions that use data and technology require a means for real-time data retrieving and sharing. Technology development has made sensors more intelligent, more efficient, cheaper and smaller (Gubbi et al., 2013; Jin et al., 2014; Hashem et al., 2015). The potential of real-time GIS has significantly evolved in the last decade. Large amounts of real-time data are continuously collected; however, the value lies in the analysis and decision support that takes place afterward. One solution is using Esri's ArcGIS operational dashboard to integrate real-time data from many sources and compile and convert the input to an interactive tool for smart decision making.

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