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Movement Patterns in a Smart City

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Research-in-Progress

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Abstract

We provide an overview of research on smart city from a system thinking approach. The case study proposed in this study focuses on the analysis of movement patterns of people in the down town area of a small city. Analysis in this case will be done via triangulation of people's cell phones in relation to the free city Wi-Fi antennas in the downtown area coupled with Bluetooth discovery of the devices themselves. This information will also be useful for new businesses to select locations, for planning purposes, and for developing marketing strategies. A design Science research methodology will be used to implement the proposed systems.

Keywords

Smart Cities, Decision support Systems, Systems Thinking, Data Analytics

Introduction

Currently, there is significant amount of research being conducted concerning cities. Questions such as what a smart city is and how do we measure the smartness of a city, are the focus of researchers and smart city projects. Therefore, many definitions of what a smart city is have been put forward (Albino, Berardi, & Dangelico, 2015). This is because cities exist in different sizes, different geographies, and different cultural contexts. It is our argument that smart definitions and the addition of smart projects are not the complete picture when a municipal government is considering an investment in technology (Gil-Garcia, Pardo, & Nam, 2015). Nam and Pardo (2011) argue that a smart city, while innovative in its implementation of information and communication technologies (ICT) also requires innovation in city management and policy. We will utilize this view of smart city to inform our design decisions throughout this paper.

Citizen and business participation in municipal government is considered necessary to build public support for the municipal government's goals (Berner, Amos, & Morse, 2011). In general, a "smart city" attempts to provide better services to its stakeholders using ICT (Aguilera, Peña, Belmonte, & López-de-Ipiña, 2017) (Janowski, 2015). Unfortunately, there is little practical knowledge available beyond conceptual models to guide cities in their implementation of ICT systems and how success can be defined.

A city is a diverse, complex, multilevel, chaotic system, that is constantly changing (Mattoni, Gugliermetti, & Bisegna, 2015), we use Akoff's (1971) (Lyytinen & Grover, 2017) concept of a system of systems to define city systems design using a defined set of smart city components (Gil-Garcia, Pardo, & Nam, 2015) and design thinking (Cagnin, 2018) to identify specific problems to solve using the measures identified by Lombardi et al. (2012). We will utilize a small city in the Southeastern United States for our case study to apply the systems models and measure the results.

Academic research has generated much theoretical knowledge concerning smart cities, the design of the city ICT systems and their general operation. Practical knowledge has also been gained via the implementation of many smart city projects. This paper aims to systematically use theoretical foundations to identify core components of a smart city, generalize the system integrations, and create a framework that can be used within a case study to show the practical implementation of a sub-set of these systems.

We will then have an idea how the knowledge gained from the data generated can be integrated with other systems to meet the goal of a smart city, to incrementally make the city a better place to live in. This paper does not intend to define a city as "smart" or "not smart", but to show how well-defined goals coupled with a robust set of business analytics to measure and then feedback results can make a city incrementally a better place to live.

In a City, understanding patterns of people's movement within various areas of a small city, whether it is between businesses or places of entertainment, or within buildings themselves is of specific interest because, economic development is based on people numbers and how they navigate through the streets or between areas of a building. This information will allow businesses to effectively decide on specific locations and will allow land owners to be able to charge rents based on data, rather than the cost of land. Research questions that we seek to answer through this study are:

Q1. How to collect the anonymized data using the technological framework and analyze using different analytics approaches to maximize the benefit?

Q2: Are such techniques generalizable to other areas or cities of different size, geography, and culture?

Q3: Are there other benefits that could be derived from such information?

Literature Review

The Views of Smart City

Smart City has been the moniker that has been attached to a large proportion of projects that use information and communications technology (ICT) within a city context. The absence of a holistic view of a city and its municipal government (Mattoni, Gugliermetti, & Bisegna, 2015) and the many interactions of the multiple systems (Ackoff, 1967) involved or operating within a city makes it difficult to develop a comprehensive interpretation of a smart city.

Recent research on smart city suggests that there are several ways to look at smart cities. One approach is to see them as utilizing an information technology resource view (Jin, Gubbi, Marusic, & Palaniswami, 2014; Kim, Ramos, & Mohammed, 2017) focuses on the technology, its functionality, and the problems that the technology could solve (Brandt, Feuerriegel, & Neumann, 2018). Others have taken a resource view of a city (Gil-Garcia, et al. 2015) and have placed the focus on various natural, organizational or other tangible city resources such as a parking application service been made available via mobile devices (Lombardi, et al. 2012) (Chourabi et al., 2012). A newer approach to smart city is to view them from value-driven perspective (Moore, 2002; Wirtz, Weyerer, & Schichtel, 2018). This view of smart city projects denotes the success of projects in terms of the value that they can add to the city government, by either paying to provide a government service (Moore, 2002), or by using a government service to generate income (Wirtz, et al. 2018).

The citizen-centric view of smart city (Lee & Lee, 2014) has also become popular and is the focus of several large governmental initiatives in various nations. (Yin et al., 2015). A significant amount of research has led to a data-based, information services understanding of smart city (Chourabi et al., 2012). There is also a significant amount of research that provides an understanding of how to implement various ICT's to enable a smart city. Angelidou (2015) argues that a smart city is simply a city that enables its citizens to be more innovative, more connected, and more involved in the governance of their city. For example, the City of New York identified a four pillars approach to smart city, which includes digital industry, engaged citizens, internet access for all and open government (City of New York, 2011) while Barcelona's approach is called "The City of People" (Ajuntament de Barcelona, 2013) which focuses on open government, citizen mobility, and citizen participation. Both the New York and Barcelona are similar in the they identify citizen access and usage of smart city systems as a priority, with open government as a central tenet for information provision, New York then prioritizes business success whereas Barcelona focuses on citizen mobility. The citizen centric view of smart city places central importance on the people. Any implementation in such views are measured via its effect, either positive or negative on people.

The system's view of a city is outcome focused, and recognizes that each of these views is important, and equally valid if a smart city is to be implemented successfully. The interdisciplinary nature of a smart city implementation and smart city research requires an integration of technological systems, social systems and urban planning to ensure decisions are made for the benefit of the whole city (Albino, Berardi, & Dangelico, 2015). Ackoff (1967) stated that manager must have an adequate model for each decision they make, A city manager must thusly, be aware of the effect every decision he makes has on the whole city. Without analytics, faster feedback into the causes and effects each decision has will be impossible (Lyytinen & Grover, 2017).

System's Approach to Smart City Design

A city is a chaotic, and complex composite system that is built up from a very large number of subunits, or elements such as citizens with constantly changing boundaries and resources. This also implies that means that the whole is greater than the sum of its parts (Gharajedaghi, 2011; Gharajedaghi and Ackoff, 1984). It is also dynamic in that the citizens are constantly leaving and joining the city system. Cities can also be considered open systems (Ackoff, 1971), as they tend toward self-organization, but never settles into a static state of behavior. This is partly because a city's environment is constantly changing. We must also take feedback into account when thinking about a smart city; feedback is simply taking part or all an output and making it an input into the system. Positive feedback should increase the rate of change within the city system and negative feedback should reverse or change the direction of change. However, smart city research has predominantly focused on individual or subset components of a city. There is a lack of theory to explain or predict the phenomena contained within cities.

In systems thinking we can describe cities as social systems, and therefore; as purposeful systems, able to produce similar outputs in different ways in similar environments or in different environments (Gharajedaghi & Ackoff, 1984). Also, as social systems, each system that make up the city must also be a purposeful systems and smart city research must concern itself with the creation of these system artifacts and the study and management of the interactions of these many system artifacts (Churchman, 1979) (Ackoff, 1971). Systems thinking also requires that we look at the system complexity that makes up a city holistically and consider the interactions or integrations of the systems that make up a city as well as merely analyzing each component part (Gharajedaghi, 2011) (Churchman, 1979).

Smart City Analytics

Developing a comprehensive analytics models for a smart city poses several challenges. Evaluating the effectiveness of any specific system or system of systems but particularly a city-based analytics system is difficult due to the complexity in developing appropriate criteria for measurement (Grimsley & Meehan, 2007). This complexity is in part to the number of stakeholders a municipal government has, which include: citizens, businesses, educational institutions, non-profits, elected officials, and government employees. (Janowski, 2015) Also, the relationships between the stakeholders and their municipal government, maybe controlled via statute, regulation, or in a client – service provider relationship thus adding an addition layer of complexity (Grimsley & Meehan, 2007). The major problem in any analytics system within a city is the lack of a suitably realistic model or database of a city to make predictions against (Bostrom & Heinen, 1977). This is further complicated by the open nature of the system itself (Ackoff, 1971). This presents an epistemological issue, in that gaining knowledge from a city-based analysis system under condition of uncertainty, will make decision making using the data, subject to error caused by variation in the environment of the system (Elsbach & Stigliani, 2018). Thus, the results of the system must be fed back into the system as an input, so that new knowledge gained through the analytics can change how the analytics is interpreted in the future (Senge, 2006) (Churchman, 1979).

Analysis of a whole city is beyond the scope of this paper, and thus we are forced to break the city into smaller parts (Gharajedaghi, 2011), to prove an economic development specific analysis that will show prospective businesses, how people move in the down town area, and how they respond to the various community events that are organized in the down town area. However, our Design Science Research (DSR) artifact must consider analysis of data from the whole city as part of its design parameters (Gharajedaghi, 2011). Through the analysis on objects (Cell Phones) we aim to build a longitudinal ontology of human movement in the down town area, that will enable businesses to focus events and marketing at specific points to be more effective in reaching customers (Shamszaman & Ali, 2018).

Janowski (2015) identified four stages of digital government evolution, in stage 4, the concern is for digital transformation to be contextualized and to transform external relationships, the addition of the analytical component to the cities IoT systems and ICT networks allows the city to utilize anonymized data concerning the movements of people over time, to enable business/organizations to measure the effects of their events in terms of the number people in attendance and their dwell times (the amount of time people spent in a specific location).

Case Study and Design Science Research

We collect data from the Wi-Fi and Bluetooth systems to develop analytics models for understanding the movement patterns, the analytics process used by the city, and lastly the usage of the data to make decisions. The combination of evidence meets the requirements for a case study (Yin, 2014) in that we are creating a systems artifact.

The design of our artifact is for measuring the behavior of people in a specific environment over a specific period, considering different stimulus in the form of special downtown events. The data model produced after the case study should be able to predict the paths taken under normal conditions, and under categories of events that take place.

Artifact evaluation can take place after the instantiation phase, so we can test the design hypothesis

Can a systems artifact collect data and be used for the prediction of behavior based on an event category?

This case study then allows for the evaluation of the system artifact in a real environment, so true ethnographic data can be utilized and analyzed, giving a phenomenological view of a downtown area (Pries-Heje & Baskerville, 2008).

Methodology

Implementation and Case study Field analysis

In this paper we will consider an artifact as a designed system (Simon, 1996) that is part of a larger system (Ackoff, 1971). Each system, within a city, is considered part of a larger environment which is in its self, just a larger system (Churchman, 1979).

In this paper we will show an improvement (Gregor & Hevner, 2013) in smart city design. By taking a system thinking approach we will show that smart city projects should be integrated in to the city, and that each project, is both a cause and effect (Gharajedaghi, 2011) that should be measured as an effect on the performance of the city as a complete system, as well as the results of the project as a single system. In design of the artifact we will use the guideline setout by Hevner et al. (2004), and we will implement the artifact using a single case study (Yin, 2014) to provide rigor.

Problem relevance:

Design of Artifact

Our discussion with the city led us to convince the city government to adopt the system’s approach for designing a generalized analytic process that can scale to provide analytics for every system in the city (Gharajedaghi, 2011) (Churchman, 1979). By broadening the design parameters to view the city, this required that the city to change its design process from a project-by-project process to a more holistic process that requires each project to be part of the city system, rather than a set of independent systems.

Conceptual model:

Figure 1 shows the conceptual artifact as designed for the city to utilize generalized data analytics of collected movement patterns in a downtown area.

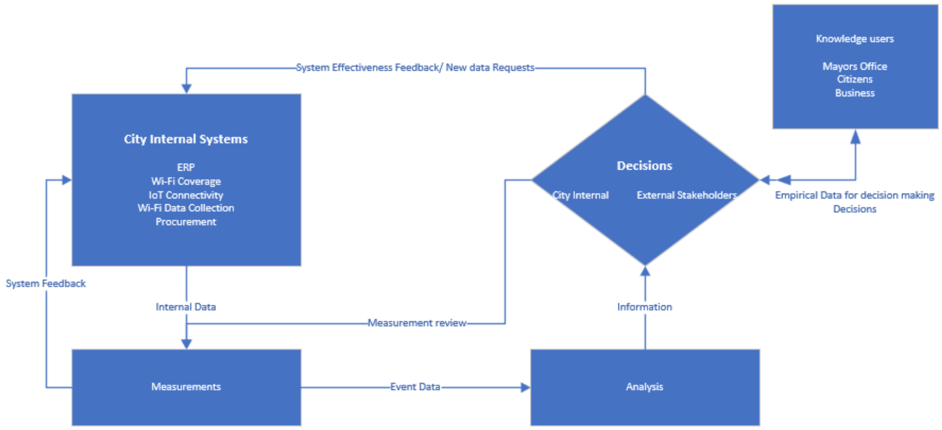

Figure 1. Conceptual Data Collection and analytics Artifact to support decision making within a smart city

City Internal Systems: This represents all the information systems and their integrations used by the city. This includes IT management systems, employee data systems, and public safety information systems.

Measurements: This conceptual module, includes all city measurements that can generate events. Separating this from the specific ICT systems, allows the city to look at measurements and levels holistically, as well as part of the specific IS that generates the measurement data.

Analytics: This is the process of looking at all measurement data generated by the city, to identify patterns and relationships, or behavior models, that can be used for decision making in the city.

Decisions: In a smart city, the movement to automated decision making is slow, and where automation can take place, it will. If automation is not available or desirable, the analytics data is made available to city decision makers, who can then make decisions based on the data and analytic information they have.

The data flow arrows show information flows between the different systems within the whole artifact. Each element of the system artifact provides feedback into the elements providing data. This allows the system to adapt to its environment based on the policies and controls inherent within the system, or directly inserted by decision makers as demands on the system or priorities change.

Instantiation Models and physical implementation

Figure 2: shows the as built Wi-Fi map of the city. This is the Wi-Fi system used to collect the movement data. The Wi-Fi system was designed by conducting a Wi-Fi survey of the area, and then selecting, based on ease of installation and cost, the best location for each wireless access point.

Figure 2. Wireless Installation map of downtown area

Data Collection

By placing, several geo-located Wi-Fi access points in the downtown area, it is possible using Wi-Fi and Bluetooth radios to triangulate the location of Wi-Fi or Bluetooth enabled phones as they move though the downtown area over time. The data chosen is people counts based on Wi-Fi enabled phones as they utilize businesses and move through the downtown area. By tracking this information and utilizing the city event calendar, the city can monitor the base use of the downtown area. The economic development agency has asked for this information so that new businesses can locate, where people travel on their journey through town.

Also, the success of events can be directly measured, in terms of attendance, as can individual behavior during the event. Thus, events can be better arranged and planned in subsequent years after studying how individuals used the event.

Data Analysis

To make sense of the data table 1 shows the analytics that will be used and the data.

Analytic	Data Used
Visualization (Heat Map of Wi-Wi Traffic)	Time of day, Day of Week, Season
Visualization (Above data + Dwell times)	Time of Day, Day of Week, Season
Visualization (Above Data + Event Calendar)	Event Calendar
Visualization (Above + ESRI GIS Data)	Integration of Businesses location and spatial data
Visualization (Above + Journey Analytics)	Identify individual journeys within geographic Wi-Fi zones
Visualization (Above + Repeat visitors)	Identification of repeat visitors across multiple days or multiple geographic zones.

Table 1. Analytic and Data Used to generate analytic

Discussion (Research Contributions)

Modern society is more complex, and digitalization of business has driven city stakeholders to expect similar behaviors, services, and technology usage from their city governments.

This paper focuses on demonstrating how analytics can be used in all city systems, to provide feedback into the decision-making process. However, while we have utilized city goals, as a marker for how the analytics system can be evaluated, research must be done to evaluate city goals within a cultural context to ensure cities have feasible, measurable, and relevant goals.

An inherent problem with the single case study is that of generalization. Can this study be replicated in other cities? Case studies must be done in other cities, using similar systems and design models to allow a generalized analytics system to yield specific results for individual cities. Measurement of how decision making is affected in individual cities can then take cultural context into account while also verifying effectiveness of the design artifacts within different cities and cultures.

Conclusion

The focus by citizens and businesses on municipal government goals should therefore be a focus of smart city research.

The case study in this paper covers analysis of movement patterns of people in various areas of a small city. Analysis in this case will be done via triangulation of people's cell phones in relation to the free city Wi-Fi antennas in the downtown area coupled with Bluetooth discovery of the devices themselves. This case study shows that the evolution of a smart city (Janowski, 2015) can be applied to all ICT systems within a city, as contextualization of the data contained within the Wi-Fi system, can be done through the use of analytics based on the geo-location of Wi-Fi access points and a corresponding triangulation based on Wi-Fi/Bluetooth signal strength in relation to the location of multiple Wi-Fi access-points both outdoors and within a building. By detecting the presence of Wi-Fi enabled or Bluetooth enabled devices, it is possible to monitor the path of any given device over time.

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References

Ackoff, R. L. 1967. Management misinformation systems. *Management Science*, (14:4), pp. B147 – B155.

Ackoff, R. L. 1971. Towards a System of Systems Concepts. *Management Science*, (17:11), pp. 661–671.

Aguilera, U., Peña, O., Belmonte, O., & López-de-Ipiña, D. 2017. Citizen-centric data services for smarter cities. *Future Generation Computer Systems*, 76, pp. 234–247.

Ajuntament de Barcelona 2013. Barcelona smart city; the vision, focus and projects of the City of Barcelona in the context of smart cities. http://www.slideshare.net/MicrosoftSuomi/city-next-smartbarcelona-28102013.

Albino, V., Berardi, U., & Dangelico, R. M. 2015. Smart Cities: Definitions, Dimensions, Performance, and Initiatives. *Journal of Urban Technology*, (22:1), pp. 3–21.

Angelidou, M. 2015. Smart cities: A conjuncture of four forces. *Cities*, 47, pp. 95–106.

Berner, M. M., Amos, J. M., & Morse, R. S. 2011. What Constitutes Effective Citizen Participation in Local Government? Views from City Stakeholders. *Public Administration Quarterly*, (35:1), pp. 128–163.

Bostrom, R. P., & Heinen, J. S. 1977. MIS Problems and Failures: A Socio-Technical Perspective PART II: The Application of Socio-Technical Theory. *MIS Quarterly*, (1:4), pp. 11–28.

Brandt, T., Feuerriegel, S., & Neumann, D. 2018. Modeling interferences in information systems design for cyberphysical systems: Insights from a smart grid application. *European Journal of Information Systems*, (27:2), pp. 207–220.

Cagnin, C. 2018. Developing a transformative business strategy through the combination of design thinking and futures literacy. *Technology Analysis & Strategic Management*, (30:5), pp. 524–539.

City of New York 2011. Roadmap for the digital city; achieving New York City's digital future. http://www.nyc.gov/html/doitt/html/about/reports.shtml.

Cosic, R., Shanks, G., & Maynard, S. B. 2015. A business analytics capability framework. *Australasian Journal of Information Systems*, 19. Pp. S5-S19

Chourabi, T. Nam, S. Walker, J. R. Gil-Garcia, S. Mellouli, K. Nahon, H. J. Scholl. 2012. Understanding Smart Cities: An Integrative Framework. In *proceedings 45th Hawaii International Conference on System Sciences* pp. 2289–2297.

Elsbach, K. D., & Stigliani, I. 2018. Design Thinking and Organizational Culture: A Review and Framework for Future Research. *Journal of Management*, (44:6), pp. 2274–2306.

Gharajedaghi, J. 2011. Systems Thinking: Managing Chaos and Complexity. A Platform for Designing Business Architecture. (3rd ed.). Burlington, MA: Morgan Kaufmann.

Gharajedaghi, J., & Ackoff, R. L. 1984. Mechanisms, Organisms and Social Systems.pdf. *Strategic Management Journal*, (5:3), pp. 289–300.

Churchman, C. W. 1979. *The systems approach (Rev. and updated).* New York, N.Y: Dell Pub. Co.

Gil-Garcia, J. R., Pardo, T. A., & Nam, T. 2015. What makes a city smart? Identifying core components and proposing an integrative and comprehensive conceptualization. *Information Polity*, (20:1), pp. 61–87.

Gregor, S., & Hevner, A. R. 2013. Positioning and presenting design science research for maximum impact. *MIS Quarterly*, (37:2), pp. 337–355.

Grimsley, M., & Meehan, A. 2007. e-Government information systems: Evaluation-led design for public value and client trust. *European Journal of Information Systems*, (16:2), pp. 134–148.

Hevner, A. R., March, S. T., Park, J., & Ram, S. 2004. Design Science in Information Systems Research. *MIS Quarterly*, (28:1), pp. 75–105.

Janowski, T. 2015. Digital government evolution: From transformation to contextualization. *Government Information Quarterly*, (32:3), pp. 221–236.

Jin, J., Gubbi, J., Marusic, S., & Palaniswami, M. 2014. An Information Framework for Creating a Smart City Through Internet of Things. *IEEE Internet of Things Journal*, (1:2), pp. 112–121.

Kim, T., Ramos, C., & Mohammed, S. 2017. Smart City and IoT. *Future Generation Computer Systems*, (76), pp. 159–162.

Lee, J., & Lee, H. 2014. Developing and validating a citizen-centric typology for smart city services. *Government Information Quarterly*, (31), pp. S93–S105.

Lyytinen, K., & Grover, V. 2017. Management Misinformation Systems: A Time to Revisit? *Journal of the Association for Information Systems*, (18:3), pp. 206–230.

Lombardi, P., Giordano, S., Farouh, H., & Yousef, W. 2012. Modelling the smart city performance. Innovation. *The European Journal of Social Science Research*, (25:2), pp. 137–149.

Mattoni, B., Gugliermetti, F., & Bisegna, F. 2015. A multilevel method to assess and design the renovation and integration of Smart Cities. *Sustainable Cities and Society*, (15), pp. 105–119.

Moore, M. H. 2002. *Creating Public Value: Strategic Management in Government (7th. ed.).* Cambridge, MA, USA, Harvard University Press.

Ostrowski, L., Helfert, M., & Gama, N. 2014. Ontology engineering step in design science research methodology: a technique to gather and reuse knowledge. *Behaviour & Information Technology*, (33:5), pp. 443–451.

Pries-Heje, J., & Baskerville, R. 2008. The design theory nexus. *MIS Quarterly*, (32:4), pp. 731–755.

Senge, P. M. (2006). *The fifth discipline: the art and practice of the learning organization (Rev. and updated).* New York, NY: Doubleday/Currency.

Shamszaman, Z. U., & Ali, M. I. 2018. Toward a Smart Society Through Semantic Virtual-Object Enabled Real-Time Management Framework in the Social Internet of Things. *IEEE Internet of Things Journal*, (5:4), pp. 2572–2579.

Simon, H. A. 1996. *The Sciences of the Artificial (3rd ed.)*, Cambridge, MA: MIT Press.

Simon, S. 1947. *Administrative Behavior: A Study of Decision-Making Processes in Administrative Organization. (1st ed.)*, New York, NY: Macmillian

Wirtz, B. W., Weyerer, J. C., & Schichtel, F. T. 2018. An integrative public IoT framework for smart government. *Government Information Quarterly*. (In Press)

Yeh, H. 2017. The effects of successful ICT-based smart city services: From citizens' perspectives. *Government Information Quarterly*, (34:3), pp. 556–565.

Yin, R. K. 2014. *Case study research: design and methods (Fifth edition).* Los Angeles, CA: SAGE.

Yin, C., Xiong, Z., Chen, H., Wang, J., Cooper, D., & David, B. 2015. A literature survey on smart cities. Science China Information Sciences, (58:10), pp. 1–18.