Developing a Smart City by Operationalizing the Co-creation of Value Model

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Keywords: Co-creation Value Model, Smart City, Storm Drains, Infrastructure Projects, Data Analytics, Geospatial Information Systems.

Abstract: This paper describes a project that used the co-creation of value model to collect and analyse data on storm drains for a city so that it could become smarter in managing the water drainage issues. The city worked with a University centre and ensured that the prerequisite conditions – mutual value-creation potential, commitment and trust, and demonstrated delivery performance – were met. The project was able to integrate science and technology through Information Systems, analyse, optimize, control, and monitor the conditions of the 27,000 storm drains in the city, and enhance the decision making process of the city. This case study provides an example of how a city and a university centre can co-create value thereby helping the city's management become "smarter" in managing its storm drains and the students obtain a rich field-based educational experience.

1 INTRODUCTION

One of the current popular jargons is "smart city" and many cities are claiming to be one of them (Hollands, 2008). Unfortunately, there is little guidance for city information technology (IT) departments and city leadership as to what is required to be a smart city and what models can be followed to become a smart city (Doran and Daniel, 2014). Creating a smart city is difficult, especially for smaller cities that do not have the staff and the funds to take on large infrastructure projects that require a large amount of funding and technical expertise.

While many academic disciplines have researched the societal impacts of a smart city on society, the MIS community has only addressed this topic to a limited extent. For example, Sankar and Cumbie (2014) have created a co-creation of value model where a university is the co-creator of value with a city that is prone to disasters thereby making the city smarter. We argue that the co-creation of value need not be limited to a disaster recovery effort but for other tasks as well. By partnering with universities, smaller cities may benefit far more than their larger city counter parts, simply through access to the expertise present within universities. Universities in and around smaller towns would benefit through increased research opportunities and access to city data.

According to the National League of Cities, in the United State there are 19,235 cities with a population under 100,000 (National League of Cities, 2015) and therefore, the scope of the problem of making them smarter is critical. As of 1997, almost 87% of U.S. Cities and counties had adopted the use of a GIS System (Esnard, 1998). The spatial nature of a city and its infrastructure, makes using maps as excellent place to display city resources and record their current state. (Harrison et al., 2010).

Therefore, the research question addressed by this paper is:

How to operationalize the co-creation of value model for both a city government and a university so as to create a project that can make the city smarter?

2 LITERATURE REVIEW

2.1 Smart City

Community Service Learning Project: Developing a Smart City. Smart city is defined by Hall as "…a City that integrates science and technology through information systems, integrating the conditions of

Dawe, S. and Sankar, C.
Developing a Smart City by Operationalizing the Co-creation of Value Model.
In *Proceedings of the 5th International Conference on Smart Cities and Green ICT Systems (SMARTGREENS 2016)*, pages 47-54
ISBN: 978-989-758-184-7

their critical infrastructures, to better optimize, plan and monitor resource utilization, and enhance the city management's decision making processes" (Hall et al., 2000). There is significant disagreement and concerns amongst different academic disciplines within the academic community concerning the implementation of "Smart City" technologies. Technology companies are marketing and selling the "Internet of Things" and how all these sensors can monitor every movement within a city and analyze all videos in real time (Taylor et al., 2015). This level of mass surveillance has been criticized by many public policy researchers as technocratic governance with too much potential for abuse. In public administration disciplines, concern over personal privacy is generally seen to take precedence over the saving and storing any personal information for long term usage. This includes CCTV footage that includes personal identifying features and vehicle tag information (Shelton et al., 2015). In terms of technology, cities must adhere to local privacy laws and must have the appropriate governance and processes in place to ensure their information systems are in compliance with all local laws.

2.2 Key Success Factors of Co-Creation Model

Co-creation, which is developing as a new paradigm in the management literature, allows companies, communities, and customers to create value through interaction (Galvagno and Dalli, 2014; Rai et al., 2010; Francesca et al., 2010). The way in which value is created, distributed, paid for, and exploited differs radically from the traditional demand vs supply model. This is a well-researched area and Galvagno and Dalli (2014) identify three different research streams: service science, innovation and technology management, and marketing and consumer research.

Our research will focus on collaborative and open processes involving communities, universities, and students and belongs to the innovation and technology management studies stream (Alavi, 2012; Zwass, 2010). According to this research stream, the interaction between customers and companies, which technological platforms often mediate, lead to innovation, customer participation, and better customer service. The value co-created by the partnership between the university and the municipality can be seen through the service-dominant logic, that provide a focus on the process rather than the final product Invalid source specified. Value is always co-created, however, in our research, there is not a sequential co-creation of value, but value is relationally created between, the students, university centre faculty and the city IT staff. (Vargo and Lusch, 2011). Co-creation of value, from the perspective of the university is in the processes and class assignments done by the students, within the context of a business analytics class, while the city gains value through the production of data that can be added to the GIS systems. The students gain context for the possible use of the data, by contributing to the collection process, and through interaction with university centre faculty and city IT staff. (Vargo and Lusch, 2011)

Given the importance of co-creation of value, it is important to identify the critical success factors that can lead to successful partnerships. Grover and Kohli (2012) identify three factors that determine co-created value: knowledge sharing, complementary capabilities, and assets. Burdon and Feeny (2011) discuss the difficulties in building competitive advantage from alliances via innovation with technical partners. They identify three prerequisites for a successful partnership as mutual trust, mutual commitment, and information exchange. We argue that in the development of projects between a university centre and a municipality, the critical success factors will be a combination of these factors.

Complementary capabilities require that the university centre and the municipality are committed to utilizing compatible IT resources, such as hardware and software. Prior to the project being released to the classroom, the assets necessary, to perform the project should be identified and it should be decided whether the university centre or the municipality should provide said assets. Information exchange between the university centre and the municipality should be continuous and wherever possible unrestricted.

2.3 Develop a Research Model

We developed a research model (Figure 1) to answer the question: *How do incorporation of the key success factors in a service learning project lead to effective value co-creation for students and a community?* The key success factors were derived from earlier research by Grover and Kohli (2012) and Burdon and Feeny (2011). The community service learning project in this study was development of a smart city through better information on condition of storm drains. Therefore, we used the expectations from a smart city as discussed by Hall et al., (2000) to develop the outcome of the model (Figure 1). When the community service learning project includes the key success factors, then there is a high probability of achieving the outcomes – that of becoming a smarter city. This model provides a framework for a university centre and a city IT department to work together to create community service learning projects that enable the use of new technologies. We used this model as a theoretical basis to develop a project that helped a city become smarter by mapping the location of the storm drain system. This model provides a framework for a university centre and a city IT department to work together to create projects that enable the use of new, "smart" technologies. We used this model as a theoretical basis to develop a project that helped a city become smarter by mapping the location of storm drains.

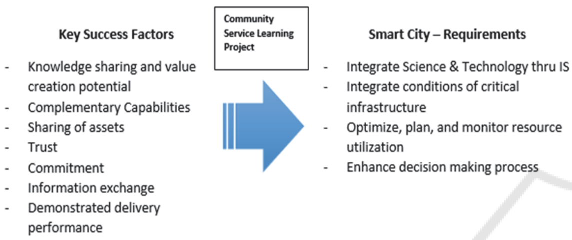


Figure 1: A Model of Co-Creation of IT Value.

3 METHODOLOGY

3.1 Choice of the Community Service Learning Project: Storm Drain Data & Business Analytics Project

A service learning project was chosen so that it incorporated the key success factors (knowledge sharing and value creation potential, complementary capabilities, shared assets, commitment, trust, information exchange, and delivery performance) identified in the research model (Figure 1). The Chief Technology Officer (CTO) of the City had identified GIS as a core strategic technology and wanted to use GIS in all city processes and workflows. However, the city did not have the in house expertise to make this vision a reality nor did it have the financial resources to commit to writing or paying consultants to design and build custom applications. At the outset of this partnership, in winter 2014, the university centre (the centre) and city CTO spent several months defining what the path to becoming a smart city is and what projects could utilize a significant multi-year investment in GIS technologies. Through these meetings, the CTO understood what expertise was available from the university and also understood how the students' learning would become part of the design. By doing this, the CTO understood, that students would be using experiential learning labs via a specific class and therefore would be integrating what work they did for the city and what they learned into class (Chan, 2012). The centre had GIS mapping equipment that was used in this project and the city provided tools such as crowbars needed to lift the storm drains. The City also shared its GIS database, so the university and city both had access to the same baseline of data. Thereby, both the centre and the CTO understood the value-creation potential of the project, had complementary capabilities, and agreed to share assets.

To avoid many of the privacy concerns promulgated by public administration and urban planning researchers and to avoid entering in to a project that could be seen as controversial, the city and university chose a storm drain data collection project to begin making the city smarter. By limiting the project to one specific item, the storm drains, the CTO and the Centre started a manageable project that realized benefits for the city in a short period of time. This project was also chosen because the city had previously contracted with a private company to collect information on all the storm drains' GPS data. The project with the private contract had been running for three years, and the city had invested over $375,000. The storm drain data was still incomplete and while the city's GIS application had the GPS location of over 27,000 storm junctions stored, it was estimated that 1000-3000 storm junctions still needed to be located and added to the GIS database. The city realized that the contractor had failed to collect drain depth data for any drains. The city needed to go back and measure the depth of every drain in the storm drain system. This will allow the city to plan for flood management based on rainfall forecasts, and to model storm drain performance in different parts of the city so as to meet EPA water drainage compliance rules (U.S. Environmental Protection Agency, 2011).

Table 1: Case Study Design.

Yin's Four Stages	University Centre	City
Planning	Written requirements documents	Needs analysis and co-create the requirements document
Data Collection	Collect depth data	
	Integrate into ArcGIS maps	
Analysis	Analyse results to identify outliers	Analysis of collected data performed

4 DESCRIPTION OF THE STORM DRAIN PROJECT

4.1 Stages in Conducting the Storm Drain Project

Yin (Yin, 2014) recommends that case study research follow the stages of (a) plan and design, (b) prepare and collect, (c) analyse, and (d) share. We used these four stages in conducting the storm drain project and describe the details in this section. (Table 1).

4.2 Project Plan and Design

This storm drain collection case study is a single project with multiple phases that allowed students to collect data on a city storm drain system and merge this data with the existing data in a City's GIS system. The students then analysed this data and interpreted their results.

4.3 Project Execution: Preparation, Data Collection & Analysis

The city staff in cooperation with the centre built a presentation so that students in each class understood what the project was, what each type of storm junction was, what data was going to be collected, and safety requirements. This presentation was refined each semester to take into account the class, the objectives of the experiential learning, and the technology being used by the students. The city also took this opportunity to allow the students to fill out the required city Human Resources' paperwork for work done within the City. The GPS devices were programmed to collect the information. The GPS unit could load the data directly into the ESRI GIS system, once it was returned to the computer lab. This system was tested by the graduate students and city staff to ensure the data was collected, stored and loaded in to the GIS system correctly. The centre divided the students in to groups of three or four that would conduct the learning activity for approximately 1 -2 hours.

4.4 Project Evaluation: Sharing and Reporting

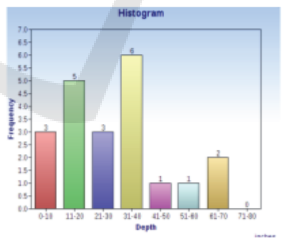
4.4.1 Phase 1: Importance of Correctly Collecting Data

Upon return to class, the students reviewed the data in class and reviewed the application and situation within which GPS data and mapping data in general could be used. Once the data was loaded in to the live production ERSI GIS database for the city, the CTO and GIS administrator returned to class to show the students how their data was being used. This presentation also included a lesson on how the city uses GIS and a demonstration of how the student's collected data in particular would be used.

4.4.2 Phase 2: Business Analytics Influences Decisions

During the data collection phase by the introduction to MIS class, it was noted that there were issues with the specialized GPS device. The CTO discussed with the student why that was and explained why more expensive and accurate GPS devices are needed. This discussion had not taken place in the planning sessions, but as the results from the tablet and the GPS device were both useable, this allowed the students to learn, how to choose the technology and accuracy parameters required for a project to be considered a success. The CTO also, attended the presentations done by the students in the business analytics class. The students used graphs and bar charts to highlight those storm drains where the depth was less than 10" showing that these needed immediate attention (Figure 2). They also produced charts that showed damaged storm drains. The CTO used the outlier analysis provided by the students to plan maintenance activities on these drains by the street repair crews.

As shown on the histogram, the majority of the drains are between the depths of 31-40 inches deep and those below 10" need immediate attention



Depth 1-10	Frequency 3
11-20	5
21-30	3
31-40	6
41-50	1
51-60	1
61-70	2
71-80	0

Figure 2: Outlier Analysis.

4.4.3 Phase 3: Feedback from City Helped Improve the Learning Activities

Using Google maps to locate and add the depth data made the data collection process very simple. The down side of this application was that if a storm drain was found that was not in the GPS table in Google maps, it could not be added to the system. Students recorded this data on paper, and the city went back and used a specialized GPS device to record the new storm drain GPS point and the data associated with

Table 2: Summary of Case Study.

Phase	***Student Experiential Learning Activities***	***City Use of Data***
1	1. Storm Drain location using Specialized GPS devices. 2. Uploading Data to ESRI GIS mapping system	1. Merged data collected to complete the storm drain mapping in GIS
2	1. Storm Drain location using specialized and an android tablet with specialized software. 2. Storm drain depth collection and Statistics analysis	1. Merged data collected to complete storm drain mapping in GIS. 2. Used statistical analysis to generate maintenance work orders for drains identified as outliers.
3	1. Storm drain depth collection using general use GPS devices. 2. Statistical analysis and modeling	1. Merged drain depth data to GIS system to complete required data set for each storm drain junction. 2. Added this semester's data to previous semester to better predict storm drain issues. 3. Used depth data in conjunction with existing LIDAR* data to predict water flow with pipes under the ground.

Table 3: How the Storm Drain Project met the Conditions for a Smart City.

Requirements to be a Smart City	**Phase 1: Storm Drain Location**	**Phase 2: Depth collection and analysis**	**Phase 3: Depth collection and advanced analysis**	**Requirements to be a Smart City**
Integrate Science and Technology through Information Systems	Document current GIS system maps and collect new storm drain data points	Collect depth data using IT tools	Use data analytics tools to perform outlier analysis	Integrate Science and Technology through Information Systems
Integrate conditions of critical infrastructure	Identification of all storm drains on city GIS map	Complete data about each storm drain available online	Analysis of data to identify defective storm drains	Integrate conditions of critical infrastructure
Better optimize, plan, and monitor resource allocation	Collection of information on all storm drains	Analysis of storm drain data	Regression analysis of storm drain data leading to identification of type of storm drains that cause issues	Better optimize, plan, and monitor resource allocation

this new point. After the statistical analysis portion of the project was complete, city IT staff again attended the student presentations of their data. The CTO also presented to the class how the collected data was being used and also showed how the data from the previous classes had been used to build a maintenance schedule for the storm drains that had depth information collected on them (Figure 3).

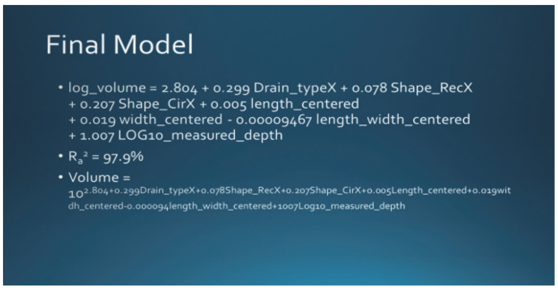


Figure 3: Slide from CTO presentation to show how drain volume can be calculate based on a multiple regression model. This equation is based on two semesters of data.

5 HOW INCORPORATION OF KEY SUCCESS FACTORS LEADS TO VALUE CO-CREATION

An analysis of the case study shows how this project led to creation of value for the students and the city. As described in Section 2, the project incorporated the key success factors shown in Figure 1. For a university-community partnership like this to work, the city staff must want to be part of the educational process. Without the city employees being an active part of this project, the experiential learning would not be complete and students would not get to see their data in use. We have been unable to find any research that includes such a close relationship between an experiential learning project and employer access to the classroom and students.

The city, by partnering with a university research centre, found it had access to massive amounts of talent, data, and infrastructure which can be used for meeting its vision of becoming a smart city. Without these projects, the city would not have started the process of becoming "Smart".

5.1 Value to Students

In general, students conduct many assignments in class, without any concept of how the data is collected or in what way business or government goes about collecting the data. The storm drain project shows students that correctly collecting data, is as important as the analysis itself. By getting out of the classroom and collecting their own data, the students had ownership of data, collected by their own efforts. By allowing city staff to define the project, have the students conduct their work, and then have the city staff return to class to show how the data was used, provided project closure for the students. These creative processes were only possible because the students had physically interacted with the system being analyzed.

While the statistical analysis of the data the students conducted was correct, they had little concept of how the results should be interpreted in terms of the city's goals. This was discussed during the presentations and the analysis process was further improved. They were delighted to learn that their analysis influenced the city's decision making process.

5.2 Value to City

Hall et al., (2000) provides four conditions for a project to be considered a contributor to a smart city. We analyzed the value received by the city in each of the three phases of the project according to these four conditions and developed Table 3. The first condition is to integrate science and technology through information systems: this project collected GPS and depth data to develop ArcGIS maps that were used by the city to trouble-shoot their storm drains. The second condition is to integrate information about conditions of the infrastructure; this project produced graphs and charts that showed the drains that were outliers so that attention could be focused in repairing them. The third condition is to optimize, plan, and monitor resource allocation. The city generally maintains the drains on a 5-year cycle irrespective of which ones are most critical. The analysis identified the drains that need to be maintained more often. The fourth condition is to enhance the decision making process. This project made it possible for the city to apply advanced analytics tools to the data thereby proactively identifying causes of overflow. This analysis indicates that this project provided a good opportunity for this city to become smarter by co-creating value by working with the University center.

6 LIMITATIONS, FUTURE RESEARCH AND CONCLUSIONS

This project has several limitations. First, it is an exploratory study based on a single service learning project, storm drains. Based on the positive results of this project, the city and the centre have already developed the next project –a cemetery management system – so as to provide citizens access to information on the people buried in the city emeteries.

Second, the metrics to evaluate the value obtained by the students and city is subjective. In the future, it is possible to create a set of metrics to evaluate the city's contribution to the class and student learning. This would enable the centre to manage the city staff's interactions with the students and provide a framework within which the project can function.

Third, this project provides experiential learning activity to about 200 students every academic year. But, about 800 students take the introductory data analytics course in this university. Developing service learning projects for large amounts of students are hard to find. In the future, it is possible to develop a process that integrates such experiences into the curriculum.

The literature showed that there are many definitions of a smart city, and the focus is on many areas. Research needs to be done to unify the current research and build a definition and model outlining all the pieces that need to fit together to make a smart city. For small cities, what is lacking, is a complete set of definitions, and a corresponding set of guidelines that focus on the 'how to' rather than 'what is?' a Smart City. Future research is needed so that practitioners can develop best practice guidelines for developing a smart city project that can be followed by any city. The ultimate goal of this storm drain data collection project is the subsequent building of a storm drain model within ESRI GIS system that will help the city predict the storm drain system's capacity and performance under various weather conditions.

Another future research project is to deploy sensors in each storm drain so that the information from them can be integrated with the ArcGIS database. But, this requires investigation and deployment of newer technologies that can perform such functions without need for electricity and can work under water.

In conclusion, this case contributes as follows. First, this case study was designed to show how, using the co-creation of value model, a centre and a city can make a small city "smarter" while also, creating value for a university's students, by providing a rich field based, educational experience. Second, the case study was conducted in semester size blocks to meet the needs of individual class experiential learning. Third, analysis of the case study and each of its parts showed how the city used the data generated. Lastly, we derive conclusions that answer the research question.

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