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Smart cities and digital technologies: the case of bike-sharing systems

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Abstract

In this paper we use three contrasting case examples to illustrate how digital technologies underpinning smart cities can be used to enable the development of much more efficient "bike sharing" systems. We present a framework integrating smart cities and big data with sharing systems. We use this framework to assess bike sharing system in a future city context around their feasibility, vulnerability, adaptability and acceptability. The potential benefits and problems of sharing system as a basis for future operations models in smart cities are discussed.

Keywords: Smart cities, operations models, bike-sharing systems

Introduction

The growth of e-commerce, home delivery, automated packaging stations and click & collect services are pushing the limits of existing logistics network designs. Future city logistics networks will need to support omni-channel retail models, smaller store formats, increased intensity of deliveries, coordinate multiple trans-shipment points, engage a wider range of vehicle technologies – including electric and autonomous vehicles – and support complex inventory balancing and deployment strategies. The two key OM challenges facing future city planners is that of freight and people mobility.

Mega-cities, defined as greater metropolitan regions with over ten million inhabitants, are currently swelling in size and number all over the world (Linden, 2003). Mega-cities offer opportunities for an improved quality of life for residents and economic growth for countries, they simultaneously present massive urban management challenges. Mega-cities are host to colossal urban management challenges and developing countries are hardest hit. Congestion overwhelms finite urban spaces, and, as a result, the demands for housing, infrastructure, transportation, water and sewer, and other basic urban services skyrocket. Yet these demands increasingly cannot be met, as urban governments are often stricken by budget crises and simply do not have the funds to provide the services. In many developing nations, urban centres are increasingly central to economic activity, attracting population from the surrounding towns and villages. But the infrastructure to support these growing populations often lags.

Social pressure is growing on cities to facilitate more efficient movement of freight and people (Graham, 2014). The Smart City concept is a container for many other "Smart things" from utilities to traffic to environmental to social data, functions and services. Some cities are already "smarter" than others without labelling themselves as such, e.g. in Stockholm the local authority publishes data about many of these “Smart things” and empower their own government or third parties to take action from it. Smart cities are now positioned by the ICT sector (by firms such as IBM, Siemens, Hitachi) as a series of worldwide initiatives (development projects) focused on company contexts and activities; moving from global to local, from competitive to collaborative, and from a shareholder to a multiple stakeholder view on city logistic decision making (Herrschel, 2013).

The sharing economy (sometimes referred to as the peer-to-peer, mesh, or collaborative economy; also collaborative consumption) is a socio-economic system built around the sharing of human and physical resources. It includes the shared creation, production, distribution, trade and consumption of goods and services by different people and organisations. These systems take a variety of forms, often leveraging information technology to empower individuals, corporations, non-profits and government with information that enables distribution, sharing and reuse of excess capacity in goods and services. A common premise is that when information about goods is shared, the value of those goods may increase, for the business, for individuals, and for the community.

While smart cities resemble an OM resource sharing approach in their descriptions, sustainability concerns; how smart cities interlinks between policy or societal levels and company ones, also point to characteristics that generally would be new to people and freight logistics. Smart city solutions could be seen as shaped through those companies (and other organisations) that act as part of them. They could also be seen as shaped by very specific principles (Bonilla, 2014; Manville, 2014), where previous literature for the most part has focused on smart cities on policy levels. But, what we experience is how policy levels would follow from company levels, and reverse, thus indicating overall structures are driven by organisations, while creating their context. Therefore we identify the need for greater OM understanding of the implementation of sharing systems at the project level.

The characteristics of smart cities, and the associated transparency and predictability they potentially offer, enable the development of new operations models across different sectors. The digitised infrastructures on which smart cities are based present new ways and challenges, to design and deliver products or services in more resource-sharing, customer-centric and environmentally-friendly manners. The purpose of our investigation is to answer the question of how the smart city will change the future urban mobility of citizens. In order to begin to answer this question we present case study findings to illustrate: i) how a smart city can enable the development of new service operations models (linked to bike sharing systems); ii) how a smart city can help address some of the future mobility challenges facing city residents; iii) how a smart city can enable the creation of new market niches. We have chosen public bike sharing systems as our unit of analysis as they are experiencing rapid growth in over 800 cities worldwide. In spite of such growth little convincing research to date has been published in the OM/SCM discipline.

We contribute to previous research through connecting smart city descriptions to research on managing shared resources in city logistics networks. As mentioned, previous literature on smart cities has focused on the policy level but not individual project implementation, and the introduction of the resource sharing approach to that type of literature reflects a new theoretical perspective and also a means to focus on the OM implementation level in smart cities. Through also describing how smart cities become shaped by the organizational actions of firms, we theoretically integrate together smart city initiatives with sharing economy ideas at the project level. We analyse three smart city-bike sharing projects currently being implemented.

Bike sharing and city mobility

Recent years have seen rapid development and implementation of public bicycle systems (PBS). There are more than 500 cities in nearly 50 countries which host advanced PBSs (Larsen, 2013). PBS as a convenient and green form of public transport for nations both rich and poor, represents a strategic choice for urban sustainable development (Shaheen et al, 2012). While UK PBS schemes struggle to survive, China is currently leading the world with some 80 PBSs and a total fleet of 400,000 bicycles. The Chinese experience in the design and development of PBS (Zhang et al, 2014) offers opportunities for learning and innovation and can serve as a springboard for an implementable, sustainable solution to the challenges facing UK stakeholders such as a declining cycling culture.

The concept and practice of 'sharing a bike' originated from European cities with a history of rise-and-falls (DeMaio, 2009). Advances in green and digital technology seem offer unlimited scope and hunger for developing the traffic network for both smart cities and not so much smart. This individual-based mobility means appears attractive when facing the presures of globalisation, urbanisation and urban-regeneration. In reality few successful business model are created to manage a complex and bespoke bike-sharing system particularly when it passes its start-up stage. Re-configuring the value chain is crucial as bike-sharing is deeply imbedded in the eco-system of its city and its larger transportation system. The costs of developing and maintaining it are high but the benefits it (potentially) generates are difficulty to measure and thus to appropriate.

Smart cities and sharing systems

The framework (presented in Figure 1) suggests there is growing "social pressure" from city institutions on firms to design more sustainable "city-production" transport networks (Li et al., 2015). It argues that private organization and public institution co-evolve and interact mutually through complex social interactions (DiMaggio and Powell, 1983). However there needs to be reciprocal trust between smart city institutions and the transport network companies. That the city institutional management of these interactions needs to spot and punish opportunistic behaviours while collaborative behaviours towards integration need to be socially valued and rewarded. Our framework suggests that understanding the key co-operative institutional pressures between a network and the city provides the strategic foundation for future economic and social value creation.

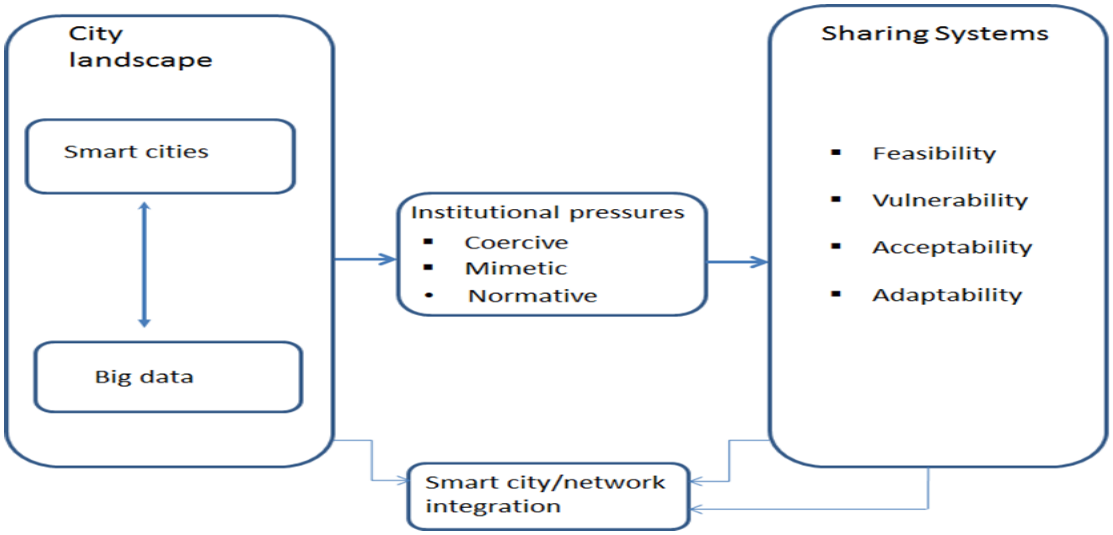

Figure 1 Integrated Smart City - Sharing Systems Framework (Adapted from Li et al., 2015)

Smart Cities

Smart cities indicate how cities (understood as geographical locations, or as municipal administrations), become concerned with sustainability issues. The smart city has displaced "the sustainable city" as the choice of word to denote ICT-led urban innovation and new modes of governance and urban citizenship, and based on how some observers have pointed out that smartness as a term is more politically neutral than sustainability. Herrschel (2013: 2332) points to how the smartness of smart cities has come to include "innovativeness, participation, collaboration and co-ordination", thus pointing to how it stretches beyond pure sustainable concerns.

Smart cities put focus on the local as oppose to the global, both in terms of how the city becomes the unit of description (rather than the global economy), but also in how local organizing decreases congestion impact through minimizing transportation distances, for instance. Literature though indicates quite major varieties in definitions. Herrschel (2013) point to how a smart city incorporates at least one of the following dimensions: smart economy (e.g., innovation, entrepreneurship, productivity); smart mobility (e.g., accessibility, sustainable transport system); smart environment (e.g., pollution, sustainable resource management); smart people (e.g., level of qualification, creativity and flexibility); smart living (e.g., quality of life); and smart governance (e.g., public and social services, transparent governance). Dirks et al. (2010) add smart homes to this description. The various dimensions indicate different societal functions, including health, energy, water, waste, communications, buildings, and transport; but also their potential integration. Additionally, items connected to smart cities could either be seen as their means or end; smart city initiatives may be enabled through information technology, or the technology is in itself one factors that characterizes the smart city, according to literature.

Two items come across as central in most descriptions on smart cities: the transportation/logistics aspects, predominately from a sustainability point of view; and new technology to facilitate the organizing of smart city activities, including the capturing of data and its analysis. As for technology, smart cities are still associated with either sensor or household data. Big data is seen as central to smart cities, in how large sets of data would inform about activities of different city actors (Dirks et al, 2010). The concept of big data can be defined as large pools of unstructured data that can be stored, managed, and analyzed (Manyika et al., 2011). Integration of city systems is an important sub-theme of city government-led smart city visions and plans, which though seems to suggest that data is pooled rather than integrated, and that analyses need to establish interaction patterns rather than be based on how actors actually interact. The big data analyses are referred to as what bring meaning to the data through interlinking it, while it in its capturing is unstructured and unconnected.

The logistics/transport aspects point to how transportation would need to be reorganized so as to deal with CO2 footprint. The logistic aspects could be seen as a move from individual firms optimizing their transportations, over collaborative, or system level analyses of flows, to redrawing the landscape and focus on local production, and thereby foremost short-distance transportations. Ideas are radical changes driven by, or leading to local production, thus rather going from centralized transport solutions to distributed, than reverse (Caplice, 2013). Logistics firms would in a sense lose business, while companies utilizing their offerings would change interaction partners to more local alternatives. The changed interaction patterns would hence transform entire interaction systems, with geography increasing the impact on interaction decisions.

Big data

The explosion of measurements and statistics produced by and available to cities - the emergence of big data - is providing new opportunities for citizen engagement and citizen-led innovation. City authorities and communities can also use ever-growing bodies of data to improve understanding of citizen behaviour and service usage and build transparency and accountability by opening up their records and statistics for public consumption - the growth of “open data”. With the growth of technology and datasets also come new piracy surveillance and data misuse challenges for future cities. Cities also face challenges around data quality, comprehensiveness, data collection and analysis particularly aligning data from data sources and managing the sheer volume of data which is produced. Big data need to be robust, accessible, and “interpret-able” if it is to provide cities and companies with meaningful opportunities and solutions.

Big data analytics is the process of examining large amounts of unstructured data to uncover hidden patterns, unknown correlations and other useful information (Manyika et al 2011). Smart cities provide an ideal background for exploitation of big data and the interactions in the value chain can generate “exhaust data” (Manville, 2014). Indeed many big data applications are implemented far from the purposes for which the data was collected. For example, location information that cell companies gather (so that they can efficiently route calls) can be used to make predictions.

The transport network applications of big data can be utilised to the key operational processes. For example, big data is useful to define mobility strategies based on actual consumer patterns (e.g. location based data generated by mobile phones) rather than surveys and samples. Additionally transport planners can use big data algorithms (instead of small data samples) to fine tune mobility planning based on real-time in store and online sales (Manyka et al., 2011).

Pressures for Integration

Alongside the internal pressures it is important to note that external "social" pressures are also placed on the firm to integrate with larger citywide systems. "Coercive" pressures come from city government and professional regulatory agencies and also the threat of losing competitive advantage. Several studies have also demonstrated that there is "normative" pressure for imitation. In the context of supplier networks, normative pressures will mean that firms are more likely to interact with smart city policies, if they perceive that a considerable number of other firms have already adopted these technologies. In many cases they will feel that they are uncompetitive if they don't follow the current trend.

Therefore the firms social actors are forced by "mimetic" pressures to seek examples of established behaviours and practices of high status and successful actors (Di Maggio and Powell, 1983), due to the belief that the actions by successful actors will lead to a similar positive outcome for themselves. In addition, through imitation actors can replicate with a minimal effort, search costs and experimentation costs and avoid the inherent risks of being the first mover.

Sharing Systems: OM Model Assessment

The sharing economy encompasses public and private sector organizations and firms working within the various realms of the sharing economy, the peer economy, the collaborative economy and the circular economy. The shift from defining unused value as waste to defining it as an opportunity to create value from more efficient resource use is the common factor among all mesh economy organizations. This shift surfaces in two primary ways. First are new models for reusing the excess capacity of infrastructure, owned assets and talents available to the wider market through networks, community and technology-enabled platforms. The second approach seeks to redefine waste from something that we throw away to an opportunity for reuse and redistribution, which is a hallmark of the circular economy approach. These two approaches to unused value as a resource emerge in mesh economy models as a commitment to the design, development and distribution of products, services and information that supports sustainable resource use and strong, resilient communities.

Previous works have examined general and overarching frameworks and decision models around the development of smart cities (Lee, 2013). However, little attention has been placed on the implications for the operations model of an organisation. For every operation it is imperative that they evaluate smart technologies and the implications, both for their operation and their customers or users. This evaluation involves determining its value or worth, and also should include some consideration around the adoption of alternatives or the consequences of not adopting at all (Slack and Lewis, 2011). We align with Slack and Lewis' (2011) and Li et al's (2015) broad classes of evaluation criteria and apply them to a smart city context:

- Feasibility,
- Vulnerability,
- Adaptability, and
- Acceptability.

Feasibility relates to the degree of difficulty in implementing and adopting new operations models and the supporting technology required, as well as the resources required to effectively implementing them. The financial feasibility pertains to the amount of financial investment that smart technologies and the new operations models will require. Market Feasibility: Determining the changes required in current resource and capability base is an important consideration for operations. To borrow Fawcett and Waller's analogy (2012: 161): "New competitive rules demand a new type of team".

Acceptability is a multifaceted term which includes financial and resourcing acceptability alongside factors associated with the market and customer preferences (Li et al., 2015). Financial Acceptability: Perceptions or ideals around what is deemed 'financially acceptable' will differ across industry and depend on the nature of the operation. It should be defined with particular attention to the value proposition of the operation. Citizen/Customer Acceptability: As has been acknowledged, some operations require the customer to take on a 'prosumer' role and participate more concertedly in the service provision or production process (Roth and Menor, 2003).

Adaptability pertains to the risks that an operation may be open to if anything goes wrong with the technology once the decision to invest has been made (Li et al., 2015). Privacy and Security: Issues of privacy and security influence the vulnerability of the technology and the operations it supports. The smart city often requires that customer information and data sharing be more fluid. However, embedded security and privacy preserving mechanisms need to be considered at a systematic level by the operation and embedded into the design of the operation in order to ensure adoption (Miorandi, 2012).

Adaptability. The role of smart cities in operations can be described in relation to the stability of the processes that surround them and the capacity growth they can enable. Scalability is defined as the "ability to shift to a different level of useful capacity, quickly, cost-effectively and flexibly" (Slack and Lewis, 2011). Some technologies will be more scalable than others and the implications for the operation can be significant if the technology cannot match the level of customer demand or engagement.

Bike-sharing: a smart service system to be developed

Cities, with their densely connected populations, are generally agreed by most economists and urban planners to be more efficient and productive than sparsely occupied areas. This trend toward urban connectivity creates an optimal environment for mesh businesses and organizations. Cities as platforms for sharing is emerging as a powerful concept heralded by many observers of the sharing or collaborative economy. Cities as platforms for sharing is gaining traction in part through the open data and open gov movements, which have encouraged many cities to share data sets in areas such as transportation, health and sanitation information, and infrastructure. These data sets have led to a number of entrepreneurs to form businesses that serve the public good, such as SeeClickFix and OpenCity. These early efforts have set the stage for a host of city-based sharing services to emerge. Bike Sharing is now in 500 cities around the world, for example. Lisa Gansky, author of The Mesh: Why the Future of Business is Sharing and founder of Mesh Ventures, states, "Data is the gateway drug to the sharing economy. The larger shift is about bringing commerce and community together using mesh concepts, converting waste to value."

A complex design "architecture" is built from specific structural (buildings, equipment), infrastructural (policies, job design, and labor management), and coordinative resource choices (Roth and Menor, 2003). A careful design of incentive structures is essential to achieve effective co-ordination between the process of equipment design and service development that are mutually influenced. We build on previous work on product-service system (e.g. Martinez et al., 2012) and service design (Roth and Menor, 2003) to address following aspects of the smart bike-sharing operations:

- Facilitating systems,
- Facilitating goods,
- Facilitating information,
- Tangible services, and
- Implicit services.

Facilitating systems are those that both operators and individuals use to deliver services and good experience. An eco-transportation system in a mega-city encompasses a number of imbedded sub-systems which enable various accesses and affordability to the need of connectivity and mobility. Smart city solutions facilitate and encourage city dwellers to shift to pedestrian and cycling modes of transport to both ease congestion and improve public health. On the other hand, a centralized operations system may mean vulnerable in case of it breaks down or faces terrorist attack (Guardian, 2014).

Facilitating goods are physical products that customers carry on or carry away. Bicycles in the bike-sharing system and food served in a restaurant are the example of facilitating goods. Green technologies function alone, or in combination with digital technologies, to ensure that customer self-services are seamless and smooth.

Facilitating information such as schedules, maps and webpages. What information can support and enhance the execution of designated services; how can variety of urban service facilities be accessed at an affordable level?

Tangible services are what the operators do to users. In the case of bike-sharing there are benefits that users can receive such as self-moving from place A to B. what is challenge is how green benefits such as pollution reduction are measured and properly priced.

Implicit services regard psychological benefits and customer learning experiences. Do you like the service, is it affordable, can you gain traffic knowledge to better your travel route design and sefl-control? Do you think a bike-sharing in wide use will lead to more social equality and democracy, and less poverty, or the opposite (Guardian, 2014)?

Method

Three cases were purposively selected in order to advance the smart-city sharing framework presented. Described as ‘theory-guided’ cases studies (Levy, 2008), their structure is determined by the framework and therefore allows us to examine the selected underpinning theoretical concepts. In comparison to inductive studies, theory guided cases provide better explanations and understandings of the important dimensions of the case material. Three cases were developed with bike sharing providers in three UK urban areas. This research will use a comparative case study method. Case studies are suited to investigating contemporary, real life, complex phenomena (Yin, 2003) such as the smart city bike sharing networking system. Specifically, three case studies in the UK have been chosen: all based in urban locations are embedded within a particular community or location and have an identifiable focal agent central to the bike sharing vision. Numerous methods of data collection were undertaken and documented within each case study: documents, archival records, interviews and direct observations. Exit questionnaires will also be undertaken with participants with the aim of understanding their experiences of using bike sharing systems.

Results

Three cases of bike-sharing in the UK have been closely followed and systematically used to emerge and illustrate the multi-links between smart solutions, mobility performance considerations and new services model. Table 1 summarises preliminary findings that helps to extend the framework (in Figure 1) into operations system design and implementation. For example, facilitating systems which usually consist of large capital investment are mostly vulnerable to unexpected events such as large scale vandalism and radical system and technology changes.

Table 1 provides a new kind of explanation on the issue of mobility performance as compared to traditional understanding from transportation point of view. We regard this as an important development for future and smart cities, as Table 1 is found useful for both operations and users in their co-developing and co-generating services. It is perceived to be of usefulness to small bike-sharing operators and large company alike.

Table 1 Smart cities, mobility performance and bike-sharing operation systems

	Feasibility	Vulnerability	Adaptability	Acceptability
Facilitating systems	Capital investment	Vandalism, System change	System change and expansion	Cultural change, Information
Facilitating, enabling goods	Operations investment	Inventory policy, Repairing,	Product innovation	Inclusive design,
Supporting information	Time: A to B, Tariffs	Trustworthiness, Up to date	Service facilities around	Language,
Explicit experience	Self-achievable, Affordability	Safety, security in peddling	Multi-model traveling	Public health, Inclusive design
Implicit experience	Connectivity and mobility	Social convenience,	Work life pattern and personal life	Development need,

Conclusion

A smart city environment enables the production and use of such data in the provision of services in these cities. This fast-growing data generated in an online community-like setting is shared across the city network amongst industry, the public and bike-service operators. This on the one hand enables local governments, businesses and other organizations to act smartly by processing the data to provide customized bike sharing services that respond to emerging needs within cities; and on the other hand, allows citizens to take an active role in data sharing with service providers and providing real-time feedback on services. The development of smart cities presents unprecedented challenges and opportunities for operations managers: they need to develop new tools and techniques for network planning and control, and the increased transparency and convenience that can be derived from smart city infrastructure and services call for the development of new operations models. The paper aims to make a contribution to theory by presenting the potential of the smart city to facilitate a city-network perspective to capacity sharing decision making, which is more efficient than individual bike sharing schemes taking independent decisions, which often leads to duplication and inefficiency with cycling capacity failing to meet volatile and rapidly changing demand. Our primary purpose is to explore the contribution that smart city driven integration could have on the performance of "bike sharing" as part of a future city transport mobility system.

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