Path Dependency of Smart Cities: How Technological and Social Legacies Condition Smart City Development

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Abstract This chapter develops a theoretical perspective on the path dependency of smart cities. Our perspective will highlight both the physical and social dimensions of path dependency and also reflect on their interrelations. We will present a case study of the city of Rotterdam in the Netherlands to show the value of this perspective on the smart city. The empirical analysis highlights the importance of *technological and social legacies*. The research shows how an innovation program called the Glass River Maas formed an essential information infrastructure for further developing smart city projects (technological legacy). In addition, we identify certain networks of innovators that started to collaborate on earlier projects and now form the driving force behind current smart city developments in the city of Rotterdam (social legacy). This chapter concludes that smart city choices can be understood on the basis of a historical analysis and therefore challenges the dominant assumption that the smart city is something totally new. We conclude that more comparative work is needed to understand the different smart city trajectories as evolving from technological infrastructures that were constructed in the past and social networks that were developed in earlier collaborations. Understanding the past of the city is crucial to understanding how its future is currently being shaped.

Keywords Smart city projects · Technological legacy · Smart city technological infrastructure · Smart city social networks · Smart city case study

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E. Estevez et al. (eds.), *Smart Cities and Smart Governance*, Public Administration and Information Technology 37,
https://doi.org/10.1007/978-3-030-61033-3_2

Introduction

The idea of a smart city guides the work of urban planners around the world in their efforts to improve the problem-solving capacities of current (and new) cities. The basic promise is that new technologies will help to tackle wicked problems such as congestion, air quality, and urban safety by proving more information and new options for coordinating actions. The promise of the smart city—as propagated by big companies and high tech gurus—is a technological answer to social problems. The basic notion is that better data about urban issues—'reading the city'—can result in better knowledge about urban dynamics—'processing the city' and thus form the basis for more effective interventions in these dynamics—'steering the city'. This 'computational logic' of urban governance has gained widespread momentum and provides the basis for projects focusing on urban mobility, urban safety, urban energy, etc.

This technological turn in urban governance has not gone unnoticed in the academic community. Academics in a variety of disciplines have started to investigate smart cities from a conceptual but also an empirical perspective. Even though there is quite some discussion on definitions and conceptualizations, most papers about smart cities highlight that they constitute a radical change that consists of the use of new technologies, in new collaborations to realize a new vision for the city (Meijer & Bolívar, 2016). Throughout the past two decades, however, three types of academic analyses of the smart city have been presented in the literature.

The first wave of techno-optimistic papers about smart cities suggested that urban problems around the world are quite similar and that the use of new technologies for urban management presented (Lee, Phaal, & Lee, 2013; Odendaal, 2003; Walravens, 2012). Many of these papers were written by academics with a background in information technology and, seemingly, little knowledge about the dynamics of cities and high confidence in the power of new technologies to deliver upon their promise. The analyses focus mostly on how to implement the new technologies and which preconditions need to be fulfilled to make this implementation to a success.

The second wave of papers about smart cities unmasked these techno-optimistic visions as neoliberal positions that, under the disguise of technological advancement, try to capture the urban dynamics from the perspective of the market (Greenfield, 2013; Grossi & Pianezzi, 2017; Hollands, 2008). Various critical authors from the geo-sciences stressed that the techno-optimistic papers paid little or no attention to the role of citizens, contextual differences, power play, framing, etc. These publications often radically argue 'against the smart city'—the title of Adam Greenfield's (2013) insightful analysis—and stress that we need to argue against this dangerous discourse.

The third wave of papers on smart cities develops a perspective on smart cities based on a socio-technical understanding of these developments (Carvalho, 2015; Kitchin, 2014). Academics from Science and Technology Studies are dominant in this line of research and the choices of smart cities are studied on the basis of insti-

tutional rules (Raven et al., 2017), stakeholder engagement, physical context, and political dominance. The objective of these approaches is to develop a contextual understanding of smart city dynamics based on a study of the interactions between the various actors in a specific institutional setting. The dominant message is that a smart city may be a good idea but only if it is based on a sophisticated, contextual socio-technical understanding of the smart city and if it is embedded in democratic forms of decision-making.

This chapter aims to contribute to this third wave of publications by bringing in a perspective that until now has received limited attention: path dependency. Contextual studies of smart cities result in interesting findings but tend to ignore (1) that the fact that smart city technologies generally build upon existing physical infrastructures and (2) that networks of actors working on smart cities often build upon earlier collaborations. A smart city, in short, can also be studied from the perspective of path dependency (Cowan, 1990; Pierson, 2000): earlier situations condition the way current choices are being made.

The ambition of this chapter is to develop a historical institutionalist perspective on smart cities that helps us to develop a better understanding of the differences between the playing fields in which actors in different smart cities operate. How does the pathway of the smart city condition current options? We will use the literature on path dependency to develop a historical institutionalist framework for smart cities and highlight the value of this framework through an illustrative case study.

Path Dependency of Smart Cities

Many analyses of smart cities emphasize the newness and the disruptive nature of these technologies. The technologies are said to radically change the way the city is perceived and steered by bringing in new forms of monitoring, new forms of data analyses, new visualization technologies, etc. At the same time, from work on large technological systems, we know that new technologies are never introduced into a vacuum. The existing infrastructure, hardware, software and data of organizations form an important context for the introduction of new technologies. This means that we need to zoom out and consider how this context was formed to understanding how the context conditions the opportunities and limitations for introduction new smart city technologies. The perspective of path dependency is most helpful for providing this broader perspective.

The approach of path dependency fits in the theoretical frame that is referred to as historical institutionalism (Hall & Taylor, 1996). This approach is built upon the notion that social causation that is ‘path dependent’ which means that contextual features of a given situation inherited from the past condition current operative forces. This effectively means that the same operative forces can have different outcomes in different situations because these situations were shaped by their specific historical trajectory. Historical institutionalism stresses that institutions are

seen as relatively persistent features of the historical landscape and central factors pushing historical development along a set of 'paths'.

Even though the path dependency perspective has not yet been applied to the smart city, the path dependency perspective in political science is well established (Pierson, 2000). In general, the path dependency perspective stresses that the options for decisions in the present are limited by the decisions have been made in the even though past circumstances may no longer be relevant. The classic example of path dependency is the monarchy that we still have in many European states. The monarchy is certainly not an option for democratic governance that we would select now but the options to change our form of governance are conditioned by the fact that in the past a monarchy was created. Similar analyses have been applied to a variety of political institutions.

The same logic of path dependence has also been applied in the study of technology. The various studies of the history of technology highlight countless examples and the QWERTY-keyboard is probably the most famous one (David, 1985; Noyes, 1983). These studies highlight that the current logic of computer keyboards provides no rationale for a QWERTY-keyboard but studies suggest that the earlier logic of a mechanical typewriter demanded a keyboard that would not result in blockages. At the same time, all the training programs are now focused on the QWERTY-keyboard and therefore the switching costs of moving to another, probably more efficient, keyboard are too high and we keep on using the QWERTY-keyboard. Therefore, just like the monarchy, the QWERTY-keyboard is still an important part of our life.

Smart cities introduce new technologies to the city but also build upon existing structures that condition choices. These existing structures are both social—similar to the monarchy—and technological—similar to the QWERTY-keyboard. A path dependence perspective on smart cities therefore needs to highlight both the physical and social dimensions of path dependency and also reflect on their interrelations. Therefore, we have developed a framework which build upon theories of historical institutionalism from political science and sociology (Hall & Taylor, 1996) but also technology and technological systems from STS studies (Bijker, Hughes, & Pinch, 1987; Cowan, 1990; Hughes, 1989). The term 'lock in' is often used to discuss how paths of development limit choices but we prefer to use the more open concept of the 'legacy'. Central to this framework is the concept of the legacy which we define as a structure that results from the past but still plays a key role. On the basis of this literature, we propose that the path dependency should be analyzed from two, interconnected perspectives:

- *Technological legacies*. Technological choices in the past condition choices about new technologies. The developments of a railway infrastructure, for example, influences subsequent choices about transport. Translating this to the topic of this chapter, this means that ICT-infrastructures such as fast speed networks also condition the options for smart city technologies.
- *Social legacies*. Social choices and experiences in the past result in formal and informal social structures that condition our choices. Well-known examples are

the role of kings in European democracies and the theatrical appearance of judges in courts all around the world. These are social structures that we would not develop now but that remain to exist because of the historical embedding.

Our perspective highlights that these two components are interconnected in socio-technical pathways: social and technological features interact to generate specific routes in the developments of new technologies (Bijker et al., 1987). A purely economic perspective highlights that impact of these pathways on choice options and switching costs. Sociological perspectives, however, also stress that these pathways influence the framing of issues at cognitive levels. An institutional perspective stresses that the structures embed values and power and therefore the introduction of new technologies is never only about functional issues but also about social transformation.

The relevance of this framework is that it means that previous socio-technical pathways of cities influence current framing of smart city options and policies developed to enhance the smartness of cities. It helps us to challenge the idea—Smart City Out Of A Box—that cities around the world can use the same technologies to tackle challenges in a similar way. Every city is unique in tot only its physical features but also its history. The specific contextual nature of smart city developments can be understood by broadening up the analysis to earlier choices regarding both the technological and social structure of technological infrastructures. We will explore the relevance for this argument by exploring how a specific socio-technical pathways conditions current debates about smart city strategies in the Dutch city of Rotterdam.

Research Methods

An in-depth single case study is used to illustrate how path dependence influences the construction of the smart city. We will present a case study of the city of Rotterdam in the Netherlands to show the value of this perspective for understanding the dynamics of the smart city. The case study specifically focuses on the development of an open glass fiber network called the Glass Maas River through a public–private partnership (PPS) and the way this infrastructure influences subsequent discussions, actions and decisions about the future of Rotterdam as a smart city.

The city of Rotterdam is the second largest city in the Netherlands with a population of more than 630.000 inhabitants. The city is mostly known for its port: its port was formerly the largest port in the world and is still the largest port in Europe. The port is well connected to distribution systems such as rail and roads and this key focus on transport have earned Rotterdam the nickname ‘Gateway to Europe’. As the employment in the port is declining, the city is in the process of making a transition to an economy that is based on more knowledge-intensive activities such as healthcare and design. The smart city strategies of the city can thus be positioned in

the context of both the old ambitions—transport—and the new ambitions—healthcare and design.

The city of Rotterdam has developed a variety of smart city initiatives. Key examples are the use of sensor networks for maintenance of objects in public space,[1] a digital twin city[2] and the knowledge hub urban big data.[3] At the same time, they have no overarching, integrated smart city strategy for the city. For our case study into the path dependency of smart cities, we chose to analyze how the development of a glass fiber network that started 15 years ago influences recent debates about the development of an integrated smart city strategy. The analysis aimed to reconstruct how an infrastructure that was created before conditioned current debates about a smart city strategy.

A key activity for upgrading the knowledge infrastructure of the city was the Glass Maas River Project. This project started in 2005 and continued until 2012. The main objective of the project was to develop a future-proof ICT-infrastructure as a precondition for strategic projects in the city. The project resulted in various outputs such as a glass fiber network in certain areas, the realization of a data center, the realization of the Rotterdam Internet eXchange, a start-up accelerator (Rotterdam Internet Valley), Rotterdam Wireless as a testbed for countless initiatives and various other projects and initiatives. The program ended in 2012 and certain initiatives such as the Data Center and the Rotterdam Internet eXchange were sold. A private company explores the glass fiber network on behalf of the city of Rotterdam. Finally, the foundation CoDE Rotterdam was created with the money from the sale of these initiatives to contribute to further technological developments in the city of Rotterdam.

Separately, but also connected as this case study will show, the city of Rotterdam has started to develop plans and strategies to become a smart city. These plans are less concrete and more at the strategic level but they provide the basis for a variety of other initiatives. An explorative investigation into the perspectives and preferences of the various stakeholders in the city was conducted in 2014 and 2015.

This single case study is based on two research projects.

- *Project 1: the development of the Glass Maas River*. In-depth interviews were conducted with 15 respondents. Respondents were selected from the city of Rotterdam and from entrepreneurs. The selection criterium we used was the basis of their knowledge about and involvement in the development of the Glass Maas River. In addition, relevant (policy) documents were analyzed.
- *Project 2: the potential of Rotterdam as a smart city*. A series of 33 in-depth interviews was conducted with various stakeholders and experts in the city of Rotterdam to identify the potential of smart city technologies for this city. The

[1] https://www.rotterdam.nl/werken-leren/assetmanagement/2018-05-30-Smart-city-sensoren-in-het-risicogestuurd-beheer.pdf.

[2] https://eu-smartcities.eu/news/rotterdams-digital-twin-redefines-our-physical-digital-social-worlds.

[3] http://urbanbigdata.nl/.

selection criterium we used was their knowledge about and stake in the development of Rotterdam as a smart city.

We used a standardized list of topics for these interviews and analyzed the outcomes qualitatively on the basis of the framework that we had developed for the historical institutionalist analysis of smart cities.

Findings

Glass Maas River Program[4]

The city of Rotterdam started the Glass Maas River Project in 2005 with a variety of stakeholders in the city and the program ran till 2012. The objective of the program was to develop a future-proof ICT-infrastructure as a necessary precondition for a variety of strategic projects in Rotterdam. The basic ambition was to realize an innovative ICT-sector by providing a glass fiber infrastructure, ICT-facilities and new services. A variety of projects was realized within this program:

- A glass fiber network was realized by the city of Rotterdam and the Glass Maas River Program was responsible for the construction, maintenance and exploitation;
- A network has been launched for innovative communications with citizens in Rotterdam (City Media);
- Rotterdam Wireless became operational as a testbed for a variety of applications;
- A Rotterdam Fiberlab Conference was organized to raise attention for all the ICT and glass fiber initiatives in the city;
- A variety of smaller and larger activities that use the glass fiber network have been developed and implemented;
- A data center—the Spanish Cube—was realized;
- A platform for exchanging knowledge and experiences within the ICT-sector—Rotterdam Fiber Glass—was initiated;
- Many next generation projects were started that focus on the continuing innovation of the infrastructure;
- The Rotterdam Internet Exchange—a key player in new technological developments and for the acceleration of start-up companies—was founded.

Participants in the Glass Maas River Program highlight that the value of the program lies in realizing a basic and relatively low cost ICT-infrastructure and providing a platform for a variety of other innovative activities. In addition, they emphasized

[4] The outline of this program is provided on basis of interviews with 15 respondents. The analysis focuses on factual features and shared perceptions and therefore no analysis of individual perceptions of the respondents is presented.

that it contributed to raising awareness in the city about the potential of ICT and providing a positive climate for high tech start-ups. They emphasize that the management of the variety of interactions between stakeholders by the city was key to its success. The city managed to stimulate the collaboration but also provide room for the other stakeholders. Creating a team spirit based on a clear vision and raising enthusiasm were crucial and were combined with a pragmatic approach to tackling problems.

The project ended in 2012 and key activities have been sold—such as the Data Center and the Rotterdam Internet Exchange—or positioned in another organization—the glass fiber network is now managed by a company that is fully owned by the city of Rotterdam. The money that was gained by selling the Data Center and the Rotterdam Internet Exchange was used to start a specific fund for stimulating ICT-developments in the city.

Toward a Smart City Strategy for Rotterdam[5]

In 2014 and 2015, the city of Rotterdam asked us as researchers to explore what the contours could be of a smart city strategy for the city of Rotterdam. For this research, we conducted interviews with a wide variety of stakeholders and this enabled us to provide an overview of the shared perspectives on the future of Rotterdam as a smart city. We will present these shared perspectives in this section and then we will analyze how these are related to the Glass Maas River Program that had already ended.

The respondents highlight that there is much potential but also an urgency to develop a strong vision on Smart City Rotterdam as a basis for more coherence between the variety of projects and initiatives. Political commitment is seen as crucial for the further development and realization of a smart city strategy. The shared vision for the development of Rotterdam as a smart city can be summarized in the following features:

- Rotterdam has the potential to become a smart city because of its political ambition, collaboration between stakeholders, technological infrastructure, economic basis, and attractiveness for international actors.
- Support for realizing Smart City Rotterdam is high both among externa actors as within the various departments of the municipal organization.
- The main challenge for Rotterdam is to generate more cohesion in the variety of initiatives in the city.
- Cohesion can be realized through an overall vision, political commitment, a structure for collaboration, a responsible unit within the municipal organization, and a smart city roadmap for the next years.

[5] The shared perceptions are based on 33 interviews with a wide variety of stakeholders. Again, our analysis will not focus on individual differences but on shared perceptions.

These main features are hardly surprising and could be formulated for many cities around the world. However, the specific actions to be taken to realize Smart City Rotterdam highlight the influence of the past. The perceptions of a strategy for Smart City Rotterdam emphasize the importance of building upon existing strengths of the city. The following suggestions for building upon existing strengths are highlighted by the various respondents:

- The technological infrastructure is of high quality and forms a key asset for the city. The vision document specifically refers to the glass fiber network, the Rotterdam Internet Exchange, and the Rotterdam Data Centers. The respondents indicated that this infrastructure needs to be extended and strengthened to realize a strong infrastructure for the smart city.
- The respondents refer to the existing (informal) networks between stakeholders as a 'coalition of stars'. There is much enthusiasm in the city and a high willingness to collaborate with other actors on new technological developments. At the same time, the respondents highlight that it the synergy between the variety of initiatives needs to be strengthened.

These perspectives on building upon existing strengths highlight ore specific features of Rotterdam. These features result from historical pathways and, as the next section will show, they can be connected quite directly to the Glass Maas River Program.

Analysis

The description of the Glass River Maas Program highlights the variety of activities and diversity of stakeholders involved in the program. In our analysis, we focused on identifying the legacies that resulted from the program and that condition current smart city choices. In the findings, we identified the two types of legacy that were expected on the basis of the literature: the technological and the social legacy. Our analysis of the opinions on a smart city strategy shows that the impact of these legacies was visible in the perspectives on further development of Rotterdam as a smart city.

The *technological legacy* consists primarily of the fiberglass network but in addition various other technological elements that conditions further choices were identified such as the wireless network and the data center. The empirical analysis highlights how the Glass River Maas forms an essential information infrastructure for further developing smart city projects. In the perspectives on a smart city strategy for Rotterdam, ICT-infrastructure was regarded as a starting point for new applications. The Glass Maas River Network forms an enabler for various forms of collaboration between public and private actors in the smart city. At the same time, this network only offers advantages to the users that are at a short distance from the network. This infrastructure is therefore more suitable for collaborations between companies and governments that for direct citizen engagement.

The *social legacy* consisted of the variety of formal and informal structures between actors in the city that had been created by the Glass Rover Maas Program. We identified networks of innovators that started to collaborate on earlier projects and now form the driving force behind current smart city developments in the city of Rotterdam. We found that in perspectives on a smart city strategy for Rotterdam, these informal networks are seen as a basis for more formal collaboration. The exploration of the potential of Rotterdam as a smart city highlighted the need for strategic structure for collaboration. This strategic structure can be developed on the foundations of the informal networks and various collaborations that have already been established. Many of these networks and collaborations have their origins in the Glass Maas River Project. A specific type of social legacy was the creation of an actor for investing in smart city projects. Some elements of the Glass River Maas—the Data Center and the Internet Exchange—were sold to the market and the money was used to create a nonprofit organization for the future development of technologies in the city of Rotterdam: the CoDE Rotterdam. In the perspectives on a strategy for smart city Rotterdam, the availability of dedicated funding for technological development played a (limited) role. The availability of extra resources from CoDE Rotterdam forms a facilitator for the development of innovative projects.

In addition, many elements were mentioned that were not or hardly related to the legacy of the Glass Maas River Project such as a smart port and a focus on the connection with the Rotterdam port. In that sense, the smart city strategy was much broader then the Glass Maas River with its specific focus on the value of ICT-infrastructures for the development of the city.

Conclusions

This chapter shows that the development of a smart city strategy can be understood on the basis of a historical analysis. This chapter therefore challenges the dominant assumption that the smart city is something totally new and radically breaks with previous solutions. Our research specifically identified the relevance of not only the technological legacy—i.e., the nature of technological infrastructures that facilitates new smart city applications—but also of the social legacy—i.e., the mutual trust and willingness to collaborate on innovative solutions and project in the city and the creation of dedicated actors to stimulate new technological developments.

The perspective of path dependence helps to open up the black box of context. Context is often either mystified—'each city is different'—or reduced to a set of variables that are supposed to characterize all the main features of the city (e.g., political system, size, location, prosperity). The path dependence perspective helps to conceptualize the uniqueness of the city without mystifying it. The path dependence perspective helps us to zoom out on the history of the city to position current conditions. Understanding the past of the city is crucial to understanding how its future is currently being shaped.

Our research provides a new basis for the growing acknowledgment that each city needs to develop its own understanding of what it means to be a smart city. Approaches from other cities cannot be copied because of differences in historical trajectories that have resulted in different technological and social structures. This also means that we need to approach current strategies for smart city developments as the choice for pathways that condition future options. A consideration of the pathways that are chosen needs to take future developments into account and not only direct outcomes.

Our in-depth case study provided rich information about the city of Rotterdam. A next step would be to analyze how the conditions for smart city strategies in Rotterdam differ from other cities. We conclude that more comparative work is needed to understand the different smart city trajectories as evolving from technological infrastructures that were constructed in the past and social networks that were developed in earlier collaborations. It provides a new angle for comparative research since it shows the importance of understanding historical trajectories.

Another issue for further research is whether legacies stimulate or hamper smart city developments. In the case of Rotterdam, the legacies seem to provide a strong basis for subsequent smart city activities but one can also imagine that legacies—for example related to outdated technology or ineffective institutions can hamper the realization of a smart city. Additional research is needed to identify when a legacy stimulates further developments or when it provides as 'dead-end road' for smart city development.

This chapter highlights that our studies of smart cities have been focusing too much on understanding current and future situations and too little on understanding the past. By highlighting the unique and disruptive nature of smart cities, the disconnect with the past is emphasized. This disconnect, however, does not acknowledge that physical and social structures indeed condition our current options and that we need to study the past to understand the future of cities.

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