Urban Technological Innovation: Developing and Testing a Sociotechnical Framework for Studying Smart City Projects

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Abstract
Urban technological innovation—the innovative use of technologies to tackle urban problems—has become increasingly popular under the label *smart city*. Our understanding of this sociotechnical process is limited, and therefore, this article develops a framework on the basis of the literature on social and technological innovation. This framework identifies four perspectives—a technological, an instrumental, a collaborative, and a symbolic perspective—to generate a comprehensive account of urban technological innovation. The value of the framework is tested by using it to analyze the Living Lab Stratumseind in Eindhoven (the Netherlands). The case highlights the value of the framework and demonstrates the interactions between the social and technological dimensions. The case study suggests that, for successful urban technological innovation, it is crucial to link initial enthusiasm based on technological and symbolic value to the long-term dynamics of institutionalized collaboration and instrumental value.

Keyword
urban innovation, smart city, technology, network collaboration

Introduction

Urban governments face the enormous challenge of ensuring prosperity, sustainability, social inclusion, public health, and safety (Barber 2014; Landry 2006; Meijer and Rodriguez Bolivar 2016). Especially in times of financial crisis, traditional governance approaches are said to fall short and innovative solutions to tackle these challenges are argued to be needed. According to some, the rapid development of new information and communication technologies (ICTs) promises to transform urban governance

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into “smart city governance” as these ICTs enable city governments to function more effectively and efficiently (Hoon Lee, Phaal, and Lee 2013; Inayatullah 2011; Walravens 2012; Winters 2011). Local governments all around the world have smart city strategies and are experimenting with the potential of new ICTs to strengthen urban governance (Batty et al. 2012; Caragliu and Del Bo 2012). At the same time, these new forms of urban technological innovation are propagated by ICT companies such as IBM, Cisco, and Siemens (Townsend 2013). We see the re-emergence of a technological discourse about the city.

The technological discourse about smart cities has been criticized by several authors (Greenfield 2013; Hollands 2008). These authors highlight that the technological discourse should be understood as a neoliberal agenda to control the future of the city. Harvey (2000) stresses that analyses of some designated smart cities reveal how informational business interests are prioritized and growing social polarization is hidden. They contend that stories about “happy cities” with “happy citizens” are constructed to serve corporate interests in modern cities. Hollands (2008) concludes that a real smart city needs and requires the input and contribution of various groups of people and no exclusive focus on the producers of technology.

The debate about technology in the city is intense and important but needs to be enriched by a stronger empirical and theoretical understanding of the relation between technology and urban innovation. The new technological discourse about cities often ignores that these new technologies need to be embedded in social structures and processes to make them work (Cels, de Jong, and Nauta 2012). In line with the growing emphasis on open innovation (Chesbrough 2006), technological solutions are being developed and implemented in close collaboration with research institutes, business, and groups of—or even individual—citizens. In that sense, the notion of social or collaborative innovation as developed by Sørensen and Torfing (2011) and Cels, de Jong, and Nauta (2012) is a useful lens for studying urban technological innovation. This perspective shifts our attention from a focus on the technology to the social process of innovation. Urban innovation is analyzed in terms of the quality of the collaborative effort and societal support for innovative approaches to urban problems (cf. Hartley, Sørensen, and Torfing 2013).

An omission in the literature on social innovation is that explicit attention to the role of technology is often lacking (Cels, de Jong, and Nauta 2012). Technology is merely acknowledged as an instrument or outcome of the innovation process. The institutional features of technology are hardly acknowledged (Kling 1996; Snellen and Donk 1998). This seems to be an omission as technologies play a key role in visions that urban governments formulate for the future of their cities (Batty et al. 2012; Townsend 2013). For this reason, this article connects the literature on social innovation to the literature on technology in government to analyze both the technological and the social dimensions of urban technological innovation. The article aims to investigate the diversity in roles of technology to show that a mere

instrumental perspective on technology may not be sufficient for understanding the complex dynamics of urban technological innovation.

This article develops a sociotechnical framework for urban technological innovation and tests it in a specific case: the Living Lab Stratumseind (LLS) in the Dutch city of Eindhoven. New technologies—noise detection, twitter analyses, data analysis—are used for instantaneous monitoring to make a busy night area in Eindhoven into a safer and more pleasant environment. The social and technical dimensions of the innovation process and the interactions between these dimensions are analyzed to account for the dynamics of the innovation process.

A Sociotechnical Framework for Urban Technological Innovation

Urban innovation should be understood as innovative practices within urban environments with the aim of improving those environments. Glaeser (2011, p. 98) speaks of "self-protecting innovations" when cities are able to generate the solutions they need to solve their own problems such as lack of safety, pollution, traffic congestion, poverty, and so forth. This concept could be labeled as a specific form of collaborative innovation (Hartley, Sørensen, and Torfing 2013; Harvey 2000; Sørensen and Torfing 2011, 2012), public innovation (Bekkers, Edelenbos, and Steijn 2011; Hartley 2005), or social innovation (Cels, de Jong, and Nauta 2012; Goldsmith 2010), with the distinguishing feature that it focuses on urban problems and urban solutions.

Urban innovation tackles problems that are concentrated in a specific geographical area that is densely populated and filled with a range of social functions. Many of these problems are directly related, and solutions for one problem can have a direct impact on other problems (cf. Jacobs 1961). A city is a "beehive" of different citizens, businesses, nonprofit actors, government bodies, and so forth (see Glaeser [2011] for a comprehensive reflection on what the "urban" entails). Innovations emerge from this variety of actors and their relations and encounters. Finally, the political-administrative environment of citizens has specific features such as the central role of the mayor, the short distance between citizens and politicians, the focus on pragmatic solutions, the competition with other cities, and so forth (Pierre 2011). Building upon Sørensen and Torfing's (2011, 2012) works, we define urban innovation as "the intentional and proactive process that involves the generation and practical adoption of new and creative ideas, which aim to produce a qualitative change in an urban context."

Urban technological innovation is sociotechnical in the sense that it involves the use of new technologies and also changes in routines, collaborations, and roles of actors in the public domain. Technological approaches (Davis 1989; Rogers 1995) and social approaches to innovation (Cels, de Jong, and Nauta 2012) form quite separate bodies of literature, but in theories of transition management and innovation systems, a

sociotechnical approach has been developed (Geels 2005; Smith, Stirling, and Berkhout 2005). The key idea in these approaches is that we should study the interactions between technological and social changes to enhance our understanding of innovation and that technology and social environment develop in a processes of mutual shaping (Williams 1997).

What is the social dimension of urban technological innovation? Traditional notions of public innovation emphasized government as the locus of innovative capacity in the public sector, but more recent conceptualization highlights—in line with the idea of governance—that innovations result from interactions between government and various actors (Hartley, Sørensen, and Torfing 2013; Vries, Bekkers, and Tummers 2016). (Large and small) companies, (social) entrepreneurs, nongovernmental organizations (NGOs), knowledge institutes (such as universities and [semi] public research institutes), and (organized) citizens have crucial knowledge but also implementation capacity for public innovation, and therefore, government organizations need to look beyond the boundaries of their own organizations. The basic idea of collaborative innovation is that collaboration with a variety of actors strengthens innovation processes as innovation most often results from interactions between actors from different levels and organizations. Collaboration has advantages for all stages of the innovation process (Hartley, Sørensen, and Torfing 2013). The basic proposition of collaborative innovation is that more value for each individual partner can be realized when actors collaborate in processes of innovation.

The perspective of collaborative innovation heavily leans upon the literature on networked governance (Hartley, Sørensen, and Torfing 2013; Koppenjan and Klijn 2004; Sørensen and Torfing 2011). This perspective stresses that actors bring in not only different types of knowledge but also different perspectives on the problem. The dominance of certain actors or coalitions of actors explains the direction of collaborative innovation. These strategic interactions between actors in processes occur within an institutional context. A legal framework and also perceived rules for collaboration with various parties explain why actors think they can or cannot use a certain strategy. The overall notion in this perspective on urban technological innovation is that technology contributes to innovation by helping network partners to realize their individual objectives (instrumental value), by contributing to collective learning in the network (collaborative value) and by producing value for the broader community that results in legitimacy for the innovation process (symbolic value) (cf. Koppenjan and Klijn 2004; Provan and Milward 2001).

And what is the technological dimension in urban technological innovation? The technological dimensions of urban technological innovation will be developed by building upon the literature on the adoption and diffusion of ICT in (government) organizations (for an overview, see Greenhalgh et al. 2004). The key question in this research tradition is not whether technology provides solutions to problems but rather if users adopt new technologies. The challenge for technology developers is to ensure that

technology is seen as attractive by prospective users such as governments and also citizens, NGOs, businesses, and so forth.

Davis' (1989) technology acceptance model highlights that innovations are successful when the technology is accepted, adopted, and used. Although more nuanced perspectives have been developed, the notion of adoption and diffusion of technology is still a powerful one and provides the basis for both research and practice. At the moment, technological maturity is an important focus in e-government research (e.g., Lee and Kwak 2012). An analysis on the basis of this perspective focuses on the attractiveness of technology to different user groups to understand patterns of adoption and use. Technology has value in processes of urban technological innovation if the technology is being used (technological value) and if the technology helps the different actors to realize their objectives (instrumental value). The relation between these two is at the heart of this type of innovation studies: perceived usefulness is a key explanation for the adoption of innovations (Davis 1989; Korteland and Bekkers 2008; Rogers 1995).

We propose that a multidimensional sociotechnical framework is needed to assess urban technological innovation. The overview of the literature highlights that technology has different roles in the innovation process. First, and most obviously, technology has *technological value*: the acceptance, adoption, and use of technology in itself is seen as valuable. This type of value follows from the literature on the diffusion and adoption of innovations (Rogers 1995). The fact that a technology is adopted and disseminates in a population is itself a sign of its value for users (Davis 1989). Second, technology has *instrumental value*: it helps the participants to realize their specific objectives. This value also follows from the literature on innovations (Rogers 1995), and also the literature on collaborative innovation emphasizes the realization of the goals of individual network partners (Koppenjan and Klijn 2004; Provan and Milward 2001). Third, technology has a *collaborative value*: the technology as such does not matter but only forms a "pretext" to meet other actors and develop collaborations. The literature on collaborative innovation highlights that new encounters are crucial to innovative processes (Sørensen and Torfing 2011). Technological collaboration can result in "spillover effects" when trust and mutual appreciation have been created, and new forms of innovation may develop when different actors have learned to collaborate. Finally, technology has a *symbolic value*: the technology provides legitimacy to the process of innovation because of the idea that technology helps us to create a better future. Bekkers, Edelenbos, and Steijn (2011) highlight that public-sector innovation is not only about efficiency but also acquiring legitimacy. Sources of legitimacy differ according to the institutional dynamics of domains, but information technology as a symbol is an attractive means of building legitimacy (Feldman and March 1981). From this perspective, people provide meaning to and construct the success of innovation through symbols and stories. In modern societies, the reputation constructed in the mass media plays a key role. The symbolic perspective stresses that the social construction of success—in whatever form—is key to

the legitimacy of the innovation process. At the same time, symbolic value may also be negative and undermines the legitimacy of the innovation process (e.g., in the case of nuclear plants or genetic modification).

This sociotechnical framework for urban technological innovation highlights four different dimensions of the innovation process. The dimensions may support each other—a diffusion of technology results in more instrumental value and incentives for collaboration and will be framed as a symbol of success—but may also conflict. The different actors in the innovation process will engage to jointly create value and also to capture value for themselves (Ritala and Hurmelinna-Laukkanen 2009). As such the "politics of innovation" will manifest themselves specifically in the instrumental dimension—whose aims will be realized?—and in the symbolic dimension—what kind of success is constructed? A specific issue here concerns the ownership or appropriation of the innovation, that is, the capture of future profits from the innovation (e.g., Mazzucato 2013).

An emphasis on symbolic value through advanced technology, for example, may conflict with the instrumental value that would benefit from proven technology. The sociotechnical perspective highlights that interactions between the driving forces account for the dynamics of the process. However, little is known about the interactions between the dimensions, and synergy is often assumed. The different dimensions that we identified in the literature on both technological and collaborative innovation are summarized in Table 1.

Table 1. A Sociotechnical Framework for Urban Technological Innovation.

Perspective	Technology Is . . .	Theoretical Argument	Analytical Focus
Adoption and diffusion of innovation	An innovation	Perceived usefulness drives adoption and dissemination of innovations	Acceptance, adoption, and dissemination of innovations
Instrumental analysis of innovation	An outcome of innovation	Realization of individual needs drives participation in the innovation process	Expected and actual realization of the objectives of innovation partners
Collaborative analysis of innovation	A platform for innovation	Relational benefits drive the collaboration between innovation partners	Collaboration between innovation partners around technological issues and beyond
Symbolic analysis of innovation	A symbol of innovation	Socially constructed success drives the innovation process	Meanings attached to the innovation in public communications

This framework provides four conceptual lenses for analyzing processes of urban technological innovation at different levels. Is this framework helpful for studying actual processes of urban technological innovation? How

should we understand the interactions between the dimensions? To answer these questions, we will use the framework to analyze a case of urban technological innovation. The application of the framework to a real-life case will test its value for analyzing the role of technology in processes of urban innovation.

Research Methods

The selected case, the LLS in Eindhoven, should be considered as a most advanced case in terms of use of new technologies for urban safety (George and Bennett 2005; Yin 1984). The involvement of high-tech companies, such as Philips, and top knowledge institutes, such as Eindhoven University of Technology, makes for the innovative use of new technologies. The results of this case can by no means be generalized to other cities and other policy domains but provide insights into the value of the sociotechnical framework for analyzing urban technological innovation.

This case study is based on interviews with stakeholders and document analysis. The interviews started with the civil servant who manages the LLS (R1, May 15, 2014) and proceeded through snowball sampling (Morgan 2008). The selection of respondents was ended when no new names were mentioned by the respondents. This resulted in nine extensive interviews with key participants. In addition to the managers of the LLS, the following interviews were conducted: the director and an advisor of the key consultancy firm (R2, August 21, 2014), the key civil servant of the City of Eindhoven (R3, August 25, 2014), the responsible alderman of the City of Eindhoven (R4, October 24, 2014), an independent project consultant (R6, February 14, 2015), the contact person at Philips (R6, February 23, 2015), the principal investigator at Eindhoven University of Technology (R7, May 26, 2015), the owner of a bar on the street (R8, December 2, 2015), and a citizen who lives there (R9, December 3, 2015). We realize that post hoc interpretations of the actors may differ from their interpretations at the time of specific events. This methodological problem could not be fully solved but our questions specifically invited the respondents to formulate their perceptions at the various stages in the process.

In addition, we analyzed policy documents and media coverage of the LLS. Documents were retrieved both through the interviews and through an Internet search on the term “Living Lab Stratumseind” on Google and the Databank Lexis Nexus (April 24, 2015). From the large set of articles that we retrieved, we selected the documents that actually presented a substantial discussion on the LLS. This resulted in four policy documents, six web publications, and 15 newspaper articles. We analyzed these documents qualitatively with a coding scheme based on the sociotechnical framework to obtain an understanding of the innovation process (Miles and Huberman 1994). This meant that key phases in the innovation process and key stakeholders were identified and documents were analyzed for indications related to (the ambition to) adopt and diffuse the innovation, references to

objectives of the various stakeholders, material related to the current and previous (lack of) collaboration between stakeholders and indications that the process was connected to broader symbolic frames concerning urban development and the reputation of the city.

The research started with a reconstruction of the construction of the LLS over time and an identification of the key actors. The reconstruction focused on the role of technology in the innovation process and participants' assessment of the value of technology. The respondents were asked to recount the origin and development of the LLS and about their current practices and the specifics of the various technologies used in the Living Lab. Finally, the respondents were asked to reflect on the value of this technological innovation for themselves and the other actors. The different types of value were reconstructed by categorizing their answers according to the type of value they (implicitly) referred to in terms of technology diffusion, realization of specific objectives, new collaborations, and legitimizing value to the broader environment. The data were first analyzed to check for factual inconsistencies in the recollection of historical events. Second, the data were used to identify the variety of stakeholders involved and their relations to each other and roles in the innovations process. Third, we applied the framework we had developed to assess the value of urban technological innovation. Fourth, we analyzed the interactions between the different dimensions to evaluate whether positive or negative interactions could be identified.

Case Description: Living Lab Stratumseind

Until recently, the reputation of the entertainment area of Stratumseind in the City of Eindhoven was very questionable. The entertainment area was weighed down by different forms of crime (like theft, vandalism, and violence). More in general, Eindhoven was appointed the city with the highest crime rates in the Netherlands, according to a monitor of a Dutch National newspaper. At the same time, it became clear that the economic viability of Stratumseind was also becoming more and more of a problem as the number of visitors was declining. In 2012, the mayor of Eindhoven, who is responsible for safety in the city, decided that action was needed. As a result, a biweekly consultation with stakeholders of Stratumseind was started. In the beginning, he chaired these meetings personally, which made clear to the other stakeholders that he thought it was something important. As a result of the consultations, the idea for a project Stratumseind 2.0 was born. This project soon became more extensive, focusing not on safety alone, but also on other relevant aspects of making Stratumseind more viable and attractive.

In parallel, ideas were being generated for the improvement of Stratumseind with light technology. This was rather obvious because, as stated before, Eindhoven is the home town of Philips which is one of the major lighting companies in the world. The Eindhoven University of Technology established the TU/e Intelligent Lighting Institute (ILI) in 2010

to investigate novel intelligent lighting solutions that will become within our reach by the large-scale introduction of LED technology, with a special emphasis on how these new solutions might affect people. For testing and implementing the ideas about lighting interventions, ILI needed a testing area. Stratumseind could provide such a testing area. Then the De-Escalate Project was formulated. This project combines fundamental research and technological innovation with a direct implementation and evaluation in the entertainment area of Stratumseind. A grant from the Netherlands Organisation for Scientific Research (NWO) was allocated and with the co-financing of Philips, the municipality of Eindhoven, and some other partners, the De-Escalate Project could take off in January 2014.

The idea of what later became the De-Escalate Project fitted the line of thinking in the Stratumseind 2.0 project. It also matched well with some other ideas that key stakeholders had with regard to the use of technology to solve some of the problems that Stratumseind was facing. In the period that the request for a research grant for the De-Escalate Project was pending, local government established the LLS to strengthen the technological component of Stratumseind 2.0. The "Living Lab" was established because quite a number of private organizations believed in the potential of technology for improving the area. They have provided hardware for free that was needed to install the basecamp. The Municipality contributed with financial means to invest in hardware and software, but most of their contribution was an in-kind contribution. This Living Lab is an urban laboratory in the sense that it has the objective of social learning in relation to a new sociotechnical configuration with the aim of generating both proprietary and public knowledge (Sengers et al. 2016).

At the moment of our study, the municipality was largely responsible for the LLS as it finances this project for about 50%. In total, the municipality invested about 200,000 euros in the LLS. The main reason why the municipality believes in this lab is because it thinks that it directly contributes to making Stratumseind more viable (one of the goals of the broader Stratumseind 2.0 project). Furthermore, the LLS fits the political agenda in the field of safety and security. Another reason why the Municipality is supporting the LLS is because of the fact that such a lab matches with the image of the city. For years, the slogan of the city was "Eindhoven. Leading in Technology." So a Living Lab with innovative technology can be used to strengthen this specific image. The Brainport region—Greater Eindhoven—was declared "world's smartest region" by the Intelligent Community Forum in 2011. This was used extensively for city-marketing purposes. In this way, the city can use the LLS as an example to show why the region is such a smart region.

A Multidimensional Assessment of the Case

Actor Analysis

We identified a variety of public and private actors in this process of urban technological innovation. These actors are sometimes consistently represented by one person (e.g., Eindhoven University of Technology, Philips), and also sometimes represented by persons with specific positions, perceptions, and considerations (e.g., City of Eindhoven, citizens, and businesses in the street). Our case description had the challenging ambition to capture this variety of perceptions and motivations but, at the same time, identify patterns.

A key actor is *local government*. Key persons are the managing civil servant (R1), the responsible civil servant (R3), and the alderman (R4). These persons, jointly representing the city perspective, originally conceptualized the situation as a safety problem but quickly broadened the scope to an integral urban problem. The local government stressed that the variety of problems is highly connected but no other actor takes responsibility for an integral approach (R3). For the local government, the project is important to not only improve the economic and social situation at Stratumseind but also to develop a solution that is in line with the image of the city (R2, R3). The city wants to be a city of technology and design and this project fits in perfectly. This vision is shared by all political parties in the City Council and for this reason the project is said not to serve electoral purposes. Surprisingly, the police are not a direct partner in the LSS (Kanters 2013).

A second set of actors include *citizens and businesses* in and around Stratumseind. Interestingly, they are not listed in the project manager's (long) list of partners in the LSS, but they are listed as groups with a stake in the Living Lab (Kanters 2013). No individual person was strongly involved in the process. The owners of bars form a diverse group with different economic positions. Overall, they view the decline in the number of visitors to the area as the main problem (Managing Civil Servant R1). The inhabitants of the neighborhood see noise and garbage as the main problems in the neighborhood (R9). They find good measurement of noise levels and limiting garbage in the street important (R1). The visitors to the area and also the owners of the bars basically want a safe, clean, and trendy place to go out (R8). Interestingly, there are no indications that they have problems with the safety measures that are being developed. According to Neighborhood Consultants R2, young people have few problems with measures that involve their privacy as privacy is not a major concern to them.

A third set of actors consists of the *technology producers*. The key technology producer, Philips, sees the need to have a real-life setting to experiment with its technologies and to build a convincing story to sell this technology as the key issue in this Living Lab (R1, R2). Other technology producers include Bosch security cameras, ViNotion (real-time video analyses and countings), Munisence (real-time sound sensors in two or even three dimensions), Tele-Event (wireless cameras, Wi-Fi points), Geodan (geographical information), and Coosto (real time social media sensoring) (Kanters 2013).

The fourth set of actors in this process of urban technological innovation is the *research institutes*. The key actor here is the Eindhoven University of Technology. The Eindhoven University of Technology has a similar perspective on the issue as Philips: they need a setting to conduct the research on the influence of light on behavior. For them, Stratumseind is primarily an interesting location for experimenting and developing new knowledge (R1, R2). Additional research institutes are Fontys University and Tilburg University (Kanters 2013). These institutes have been involved in research into user experiences and privacy regulation.

The final set of actors entails the *project and process managers*. The consultants for neighborhood improvement are important for connecting the Living Lab to other developments in the areas. They highlight that the LLS can contribute by (1) creating new connections between the various actors involved in improving the area and (2) improving the subjective assessments of the area by emphasizing the new and "cool" use of technologies in use (R2).

Adoption and Diffusion of Urban Technological Innovation

The perspective of adoption and diffusion of innovation focuses on the variety of technologies that is used and the integration of these technologies in coherent approaches. All network partners—and actually also the political and media environment—have high expectations of the value of technology for urban innovation (R1–R6; Kanters 2013). From the start, the media are very positive about the use of technologies in this street to enhance safety and improve urban quality. The use of all of these technologies is not questioned: although there is no empirical evidence that the suggested approach will actually make the street safer, cleaner, and livelier, all partners willingly participate in the project and "believe" in the technology (R1–R9). The objectives that are formulated are quite open and the general sentiment is that the technology will bring positive effects (Kanters 2013). This positive attitude toward technology could stem from the identity of Eindhoven as a city of technological innovation.

Stratumseind can be characterized as a Quantified Street: enormous amounts of data are being collected to generate not only more safety but all kinds of other outcomes such as more visitors and a higher consumption of food and beverages. This sociotechno practice illustrates Morozov's (2013) idea of "informationism." The dominant reasoning behind the approach is that more information will result in better urban governance. There is surprisingly little attention to the question of whether the safety problems—and all the other issues—are due to a lack of information. In the cybernetic perspective on governance information, gathering is seen as the key to success. The pilot projects seems to be about searching goals that fit the technological systems that are being deployed and they can therefore be characterized as a goal-searching network (Klijn et al. 2008). In line with this finding, the acceptance, adoption, and use of technology are high.

The story about the adoption and use of technology is dominant in the accounts of the participants and the media. Managing Civil Servant R1 proudly showed all the technology that was used in the Living Lab to demonstrate the vibrant dynamics. All actors seem to think that technology is "the answer": the collection of rich data about a variety of aspects will help to solve the problem. All partners support the use of new information, communication, and light technologies for making the street safer and more livable. Interestingly, even if it is not clear how exactly certain technological systems contribute to the quality of the street, the adoption of the technology is still seen as a sign of success as it confirms that Eindhoven is an early adopter of technology. In line with theories of diffusion of innovations and technology acceptance, the key question at this stage of the project is whether the technology is perceived to be useful and all actors indicate that they regard the technology as a useful tool for these complex problems (R1–R6).

In addition, the idea of the Living Lab is also that the lessons in Eindhoven can help to disseminate the use of new technologies for urban safety to other cities in the Netherlands and possibly even further (R1, R6). This highlights that a first technical success has been established—the use of a variety of technologies in the Living Lab—and that subsequent success of the experiment in Eindhoven is to be measured in terms of its adoption in other cities.

Instrumental Value of Urban Technological Innovation

To assess the instrumental value of urban technological innovation, we needed to analyze to what extent the individual objectives of the participants were realized. The research showed that the perception of the problem and the contribution of the LLS are quite different. These objectives differ first in their focus on improving the local situation (citizens, owners of bars) versus a focus on the development of knowledge and technologies that could be useful for cities all around the world (university, technology producers) (R1, R3, R6, R8, R9). Even the consultants for neighborhood improvement highlight that the project can be conceived as a pilot for developing a solution to be applied in various cities in the Netherlands (R2). A second difference in objectives we identified concerned the public and private interests. The owners of bars and also the citizens have a private interest in the improvement of the area whereas the local government and the police have a public interest in the street's vitality (R2). A third difference in objectives of partners concerned the focus on safety as an objective or a subjective problem. Whereas the managing civil servant highlights crime statistics (R1), the consultants for neighborhood improvement stress the subjective assessments and the need to improve the image of the street (R2).

This means that an assessment of goal realization needs to be broad. For the inhabitants, the use of technology is valuable when it makes the area more livable (Managing Civil Servant R1, Citizens R9) whereas it has value

for Philips when the Living Lab results in a good "business case" for selling technologies (Independent Project Consultant R6). For the owners of bars, the technology is valuable when they sell more beer and the price of the real estate goes up whereas the quality of the street is a key concern for local government (R1, R3, R5). The consultant for neighborhood improvement highlighted that the technology is valuable when people think that the street is safer whereas the project manager wants the use of technology to result in lower crime rates (R2). These objectives are broadly conceived as complementary, and contradictions between these objectives have not been mentioned.

At the moment, there were no clear indications about the extent to which these objectives were realized. It seems too early to assess this value of urban technological innovation as the Living Lab has only recently started. A broad variety of indicators will be collected both through the Living Lab (Managing Civil Servant R1) and through the scientific analysis of this project (Principal University Investigator R7). A concrete plan in terms of key performance indicators, targets, deliverables, timeline, and so forth is lacking: the objectives have been formulated in a rather loose manner in policy plans and should be regarded as arguments for supporting the Living Lab rather than specified outcomes. This is in line with our previous observation that the collaboration is to a large extent a goal-searching network. This could mean that the instrumental value will be reconstructed post hoc to legitimize previous efforts in a process of urban technological innovation.

Urban Technological Innovation as a Platform for Collaboration

There have been two driving forces behind the growing collaboration around the technological innovation. The first one was political: the mayor of Eindhoven stressed that he wanted to improve the safety situation in the street and called upon all other actors to collaborate with him. According to Senior Civil Servant R3, "An official invitation from the mayor is not something other actors easily ignore." The political focus pulled the variety of actors together and stimulated them to discuss and develop collaboration. Top-level political support also meant that personnel and financial resources were made available. The second driving force was research: the Eindhoven University of Technology obtained funding for research into the effects of light on public situations through the so-called De-Escalate Project (Principal University Investigator R7). This money stimulated other actors to develop the LLS as a testbed for light technology and a range of other technologies (Neighborhood Consultants R2, Senior Civil Servant R3, Contact at Philips R6).

The second driving force shows that the technology presents an occasion for different stakeholders to start collaborating on improving the street. Actors who had not collaborated before have started working together in the Living Lab. Concrete problems were secondary: they came to be connected

to the idea of investigating the potential of light technology for influencing people (R7). It should be noted that it seems unlikely that technology by itself could drive this collaboration. The money that became available for research on technological innovation through the funding that the Eindhoven University of Technology received from the National Science Foundation was an important driver for this new process of urban collaboration (Neighborhood Consultants R2).

This open collaboration has been quite successful in crafting a coalition of actors willing to work on improving the street (Neighborhood Consultants R2). Other collaborations were already being set up but the Living Lab formed a reason for the Eindhoven University of Technology and Philips to join the project. In addition, the interaction between the other actors has been strengthened by the technological project. In that sense, the technology can be regarded as a vehicle for generating collaborative innovation in the area. This collaboration has resulted in a broad range of nontechnological efforts—spillover collaborations—such as efforts to attract other businesses to the street, new activities, and improvements to the ambience on the street by painting buildings. All these activities could have taken place without the technology but the technological aspect has helped to craft and build trust in collaborative efforts among actors with widely different perspectives and interests (Senior Civil Servant R3).

One should not conclude, however, that the technology only facilitates collaboration: certain frictions between the various actors about the technologies are now starting to emerge. These conflicts focus on the ownership over and benefits of the technology. The innovation process is largely carried out through user innovation (von Hippel 2005): the lead user—in this case the manager of LLS—tinkers with available technologies to make them useful for smart safety governance (R1). Consequently, the manufacturer—most importantly, Philips—manages to appropriate the outcome and uses these to sell the innovation. The main source of funding for the LLS is money from the university's De-Escalate Project combined with funding by local government (R7). Additional funding is obtained through a provincial funding scheme for neighborhood improvement (R1, R2). The gains of the neighborhood improvement, however, are likely to go to the owners of the bars in the forms of higher value of the real estate (Neighborhood Consultants R2). These interests form a potential risk to the networked collaboration.

The analysis highlights how in spite of partly contradictory interests, collaboration between various actors emerged around the technology. Private parties, such as Philips, have been able to either obtain ownership of ideas or obtain value without providing a financial contribution. They have been able to use the local government's explicit intention to improve the street to their own end and the local government is not used to asking anything in return for this type of support (Senior Civil Servant R3). At the same time, local government has an interest in improving the neighborhood and there is no direct reason why this should not be paralleled by private gain. This situation,

however, may result in problems when it is seen as "unfair" and the manager of LLS already indicated that he felt that this was beginning to be the case (R1). These specific issues have hardly been discussed in the dynamics of developing good solutions but they are becoming more prominent now the solution is actually being implemented. This shows that the technology has stimulated collaboration but now it is being implemented, issues related to the ownership of technology threaten to undermine this collaboration.

The Socially Constructed Success of Urban Technological Innovation

To assess the symbolic value of urban technological innovation, we looked at the institutional dynamics in the process to understand whether and how the innovation is framed as a success or failure. The collaboration started without formal rules but still the actors in the collaboration work with institutional rules for governments, companies, or academic researchers that influence their behavior. Government rules focus on the political and democratic nature of practices and the role of (privacy) legislation. Conformity with data regulations, for example, is of great importance to government. These democratic rules also highlight that government should be open to citizen participation. Informal government rules highlight the importance of the media environment. It is crucial that government engagement is supported by popular representatives and positively reported in the media (Senior Civil Servant R3, Alderman R4).

At the same time, (informal) private-sector rules focus on profitability and proper functioning of guiding the behavior of private actors. These rules limit the engagement of private actors, such as the breweries, in a collaboration that does not result in direct economic gain. Free rider behavior is seen as economically rational behavior. The rules about the responsibilities of technology producers toward those that test and redevelop their technologies are more disputed (Managing Civil Servant R1). At the same time, the bar owners and the technology producers seem to have an interest in visibility. The high number of publications in newspapers with explicit attention for Philips are a form of free publicity and it may attract more people to the street and therefore generate business for the bar owners (Senior Civil Servant R3, Alderman R4).

In parallel, knowledge production rules focus on the contribution of insights into the general academic body of knowledge. Rules for academic knowledge production, such as publications in academic journals about the outcomes, guide the behavior of the knowledge partners. At the same time, researchers are increasingly expected to produce research that is valuable for society and networked research generates relevant new insights (Principal University Investigator R7). And even though individual researchers are reluctant to talk to the media as they do not see this as their main role, for the

Eindhoven University of Technology, media attention is quite important (Principal University Investigator R7).

A common theme in all these rules is the symbolic value of urban technological innovation: the idea that the Living Lab is a success just because it is "new," "innovative," and "unique." In terms of the media logic (Altheide and Snow 1979), the LLS forms a "nice story to tell." For government, technological innovation is successful if it generates the impression that government is working hard and smart in improving the city (Alderman R4). For the technology companies, there is a similar symbolic value: public technology can boost the reputation of these companies (Contact at Philips R6). For the citizens and owners of bars, it may improve the image of their street (R8, R9). And also for the researchers, the symbolic value is of great importance for supporting their research and future access to funding. This analysis highlights that the fact that the use of technology for improvement of the street was *seen* as successful was important to government, private companies, researchers, and inhabitants.

Overview and Interactions Between the Dimensions

The assessment of the value of urban technological innovation on the different dimensions of our sociotechnical framework is summarized in Table 2.

This overview clearly highlights the different dynamics in the innovation process of the LLS. The technological and symbolic values drive the process forward: technology is perceived as useful and publicly framed as a success. The collaborative capital is positive at the moment but some risks have been identified for the near future. The instrumental value is at this stage not yet determined. These dynamics are often mutually reinforcing: the success of the technology results in the realization of a variety of objectives, generates a platform for collaboration and, in parallel, the success generates symbolic value through extensive media coverage. There are, however, also some indications of tensions between these dynamics. R5 highlighted that the overemphasis on technology may have a negative effect on the spillover collaborative value.

It is interesting to note that some types of value of urban technological innovation can quickly be realized—adoption of technology, a platform for collaboration, and the symbolic value of the innovation—whereas the actual

Table 2. Analysis of Urban Technological Innovation in Living Lab Stratumseind.

Perspective	Empirical Observations of LLS	Theoretical Analysis of LLS
Technological	LLS is successful as a wide set of technologies is used to monitor and improve the street	Perceived usefulness is established in the case and results in technology adoption
	The broader impact of LLS will be assessed on the basis of the diffusion of the use of technologies to other cities	Perceived usefulness in other cities—required for diffusion—has not yet been established
Instrumental	The success of LLS cannot yet be established as specific objectives will only be realized over time	Expected fulfillment of individual objectives drives participation in the innovation process
	Few specific targets have been formulated: instrumental value may be constructed post hoc on the basis of outcomes	Long-term commitment depends on the actual contribution to (shifting) objectives
Collaborative	Technology has been a vehicle for developing a new collaboration between a wide variety of actors	Relational benefits are realized and move the innovation process forward
	Issues related to (ownership of) technology may form a risk to the collaboration as diverging interests are starting to emerge	Relational costs form a risk to the further development of the innovation
Symbolic	Media framing is of great symbolic value to the different actors collaborating in the Living Lab	Socially constructed success of LLS drives the innovation process forward
	The technology has resulted in positive framing in the media because it is "new," "innovative," and "unique."	Public construction of LLS as a success provides a positive incentive for collaborative innovation

Note. LLS = Living Lab Stratumseind.

realization of the objectives of the different stakeholder can only be assessed after a long period of time. This means that the motivation to continue with the innovation—stamina—is to be realized through these short-term dimensions. This confirms the idea that certainly the short-term legitimacy of an innovation largely depends on the way this technology is being framed (Meijer 2015).

In the short term, there is a positive interaction between the symbolic value and the other types of value. The striking finding is that everybody wants the public image of the street to be positive as this will enhance the legitimacy of government, strengthen the image of companies, generate more

funding for researchers, and boost the prices of housing for inhabitants. The positive image thus strengthens technology diffusion and adoption (technical value), the realization of objectives such as subjective safety and value of real estate (instrumental value), and incentives to collaborate in the Living Lab (collaborative value). As the Thomas Theorem states, when things are perceived to be real, they are real in their consequences (Thomas and Thomas, 1928).

The long-term value of this type of innovation still remains to be established but interesting potential frictions for the collaborative effort have been identified. Ownership over the technology and profits of the collaboration have remained open to facilitate a goal-searching process but now constitute possible barriers for developing the collaboration into a more structured form. Institutionalizing the innovation will be a challenge and requires new strategies for managing the diversity of instrumental values (Contact at Philips R6).

Conclusions

We set out to develop a sociotechnical framework for urban technological innovation and build this framework on the basis of the literature on technological and social innovation. The empirical analysis of the LLS in Eindhoven (the Netherlands) illustrates the value of the framework that we developed for studying urban technological innovation. The key contribution to the literature is that technology should be understood in terms of not only the adoption of technology and the realization of specific objectives but also its value for collaboration and its symbolic value for the community. Technology is not only an innovation in itself or instrument for realizing objectives but also a platform for collaboration and a symbol that provides community value. The different dynamics of urban technological innovation need to be taken into account when this type of innovation is being studied.

Our research of the LLS also resulted in some interesting conclusions about the dynamics of urban technological innovation. Early technical and symbolic values were key to the continuation of the process. We found that technological and symbolic values are more easily produced than instrumental value and we concluded that short-term collaborative value was also produced fast but is put at risk by new debates about ownership and benefits of the technology. The idea that the different types of values reinforce one another was confirmed and symbolic value was identified as an early driver of legitimacy for the innovation process. At the same time, there were some indications that too much emphasis on technological and symbolic values might undermine collaborative value in the long run by ignoring potential conflicts in ownership over the technology (see the literature on open innovation, for example, Dahlander and Gann [2010], for an in-depth discussion of these issues). The capture of value from the innovation by private actors also raises ethical question concerning the potential “abuse” of public effort and money for private gains (Mazzucato 2013). A further understanding of the interactions

between the socially constructed short- and long-term values of innovation will enrich the polemic debate about smart cities.

This analytical perspective sheds new light on the evaluation of the smart city projects that are carried out all over the world. On the basis of this sociotechnical assessment framework, these projects need to be analyzed in terms of not only their technological and instrumental values—do they make use of the newest technological options and do they produce more sustainable, inclusive, and wealthy cities?—but also their collaborative and symbolic value—do these project craft new urban collaborations and do they generate legitimacy for innovative solutions to complex urban problems? The current literature on smart cities is often either highly positive about smart cities (Schaffers et al. 2011) or highly critical (Greenfield 2013), and the framework presented in this article helps to systematically analyze the benefits and drawbacks of smart cities.

Although the management of urban technological innovation was not the key focus of the research, the analysis provides some interesting insights. Managing urban technological innovation requires a strong understanding of the social construction of technologies as an interplay between technological features, individual objectives, collaborative capital, and symbolic value. The analysis shows that symbolic value may be beneficial to the dynamics in the early phases, and that a goal-searching approach proved beneficial to the development of collaborative value. At the same time, in line with strategic niche management (Hoogma et al. 2002), long-term institutionalization of the collaboration and a focus on the realization of instrumental goals is needed. The management of urban technological innovation is initially not only about achieving instrumental value through collaborative action but, to a large extent, about generating the shared imagination that is needed to drive the process forward. At a later stage, initial enthusiasm needs to be linked in a timely manner to the long-term dynamics of institutionalized collaboration and embedding of technopractices in organizational routines.

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