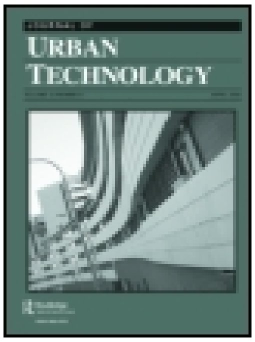

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Smart City Pilot Projects: Exploring the Dimensions and Conditions of Scaling Up

Willem van Winden & Daniel van den Buuse

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Smart City Pilot Projects: Exploring the Dimensions and Conditions of Scaling Up

Willem van Winden and Daniel van den Buuse

Amsterdam University of Applied Sciences, Amsterdam, The Netherlands

ABSTRACT
In many cities, pilot projects are set up to test new technologies that help to address urban sustainability issues, improve the effectiveness of urban services, and enhance the quality of life of citizens. These projects, often labelled as "smart city" projects, are typically supported by municipalities, funded by subsidies, and run in partnerships. Many of the projects fade out after the pilot stage, and fail to generate scalable solutions that contribute to sustainable urban development. The lack of scaling is widely perceived as a major problem. In this paper, we analyze processes of upscaling, focusing on smart city pilot projects in which several partners—with different missions, agendas, and incentives—join up. We start with a literature review, in which we identify three types of upscaling: roll-out, expansion, and replication, each with its own dynamics and degree of context sensitivity. The typology is further specified in relation to several conditions and requirements that can impact upscaling processes, and illustrated by a descriptive analysis of three smart city pilot projects developed in Amsterdam. The paper ends with conclusions and recommendations on pilot projects and partnership governance, and adds new perspectives on the debate regarding upscaling.

KEYWORDS
Smart cities; governance; technology management; urban technology; innovation projects; upscaling

Introduction

In recent years, many cities around the world have witnessed a proliferation of pilot projects that aim to test or develop new solutions to address urban sustainability issues, improve the effectiveness of urban services, and enhance the quality of life of citizens. These projects, often labelled as "smart city" projects, come in many forms, sizes, and types and vary in their degree of technical and organizational complexity. Helped by a growing supply of (inter)national funding opportunities, city administrations have been actively initiating, promoting, and supporting these projects, reflecting the belief of urban policymakers and other stakeholders that technology might help to make the city more livable, sustainable, competitive, and inclusive while improving public services (Townsend, 2014; Hollands, 2008).

A wealth of funding opportunities for smart city projects has become available in recent years. Europe's Horizon 2020 program provides €18.5 billion in subsidies for clean energy,

CONTACT Willem van Winden w.van.winden@hva.nl Amsterdam University of Applied Sciences, P.O. Box 1025, Room 07A08, 1000 DB Amsterdam, The Netherlands

green transport, and climate actions, implying significant funding opportunities for smart-city-related research (most of it to be conducted in collaboration with local authorities and companies). Also, the European Regional Development Fund (E.R.D.F.) regulation requires that a minimum of 5 percent of the funds be allocated to sustainable urban development, which amounts to a minimum of €16 billion between 2014 and 2020. The smart city equally appeals to the private sector. Multinational enterprises (MNEs) in the information and communication technology (I.C.T.) industry have discovered the potential of smart city technology as a high-growth business opportunity. These firms offer a great number and variety of solutions, ranging from energy-efficient and carbon-neutral solutions for city logistics, building management, and public street lighting, to big data analytics tools and dashboards for optimization of public services. Accelerated market growth is expected in the next few years. As an indication, Deloitte (2015) expects the global smart cities market to grow from US$400 billion to US$1.5 trillion by 2020. To explore and exploit new business opportunities in this sector, many of these firms have set up city-centric programs, of which Cisco's "Smart & Connected Communities" and I.B.M.'s "Smarter Cities" are prime examples. Moreover, these companies engage in local pilot projects and partnerships with a number of urban stakeholders, including housing corporations, local authorities, grid owners, and energy companies to test or demonstrate innovations in real-life contexts.

The growing interest from city administrations, businesses, research institutes, and all kinds of other urban stakeholders in smart cities has led to a great number of pilot projects in recent years. However, many of them remain small and experimental, and fade out after a (subsidized) demonstration phase; as a consequence, the impact of solutions developed in these pilot projects on urban development often remains limited (Vilajosana et al., 2013). There are obvious cases where scaling does not happen. Some pilots are merely set up to offer inspiration, demonstrating a future possibility or solution without claiming immediate commercial viability. Such projects are typically run in a protected/shielded situation with regards to funding and/or regulation. Other pilot projects end because they fail in terms of technology, feasibility, a lack of demand/interest or otherwise, and scaling in whatever form makes no sense.

Nevertheless, the lack of scaling is widely perceived as a major problem that needs to be addressed by policymakers on all levels. The European Innovation Partnership on Smart Cities and Communities (E.I.P.-S.C.C.) reflects that scaling and replication are considered to be important, and promotes sharing viable business models, financial tools, and procurement instruments in order to make smart city projects economically sustainable instead of dependent on temporary subsidies or grants. Similarly, the requirements for receiving funding from the European Union (E.U.) for projects is oftentimes conditional on the inclusion of dissemination/replication activities (roadshows, handbooks, toolkits, or online tools enabling other cities to draw lessons and replicate projects).

Despite these policy concerns, the issue of upscaling solutions from pilot projects has been sparsely addressed in the growing literature on smart cities. Many recent papers have focused on defining and conceptualizing smart cities on a higher level of abstraction (De Jong et al., 2015; Gil-Garcia et al., 2015; Höjer and Wangel, 2015; Albino et al., 2015), or analyze mega greenfield smart city projects such New Songdo in South Korea (Shwayri, 2013, Halpern et al., 2013) and Caofeidian International Eco-City in China (Joss and Molella, 2013). Some contributions offer typologies of smart city initiatives, mostly based on the domains to which they apply, including economy, mobility, environment, people, governance, and living (Giffinger et al. 2007). Only a few studies zoom in on the more concrete level of smart city initiatives, projects, and business models (Bakıcı et al., 2013; Hielkema and Hongisto, 2013; Mulligan and Olsson, 2013; March and Ribera-Fumaz, 2016), or address the issue of scaling in related fields (May et al., 2015; Van Leeuwen et al., 2015). In this paper, we aim to fill this gap, and make a more thorough analysis of the factors and conditions that affect the scaling of smart city projects. Our focus is primarily on pilot projects in the field of energy and mobility, in which both public and private stakeholders collaborate to develop smart city solutions.

Our objective for this paper is twofold. First, we want to refine and unravel the rather broad concept of scaling. While the importance of upscaling is widely recognized, the concept remains fuzzy, undefined, and undifferentiated. Second, we intend to better understand the conditions and requirements that drive or hinder upscaling processes in various types of smart city projects. Our analysis intends to enhance insights in scaling processes, and may also help to design pilots in such a way that their upscaling potential is maximized.

This paper is structured as follows. The next section clarifies and refines the notion of upscaling based on existing definitions and descriptions, and presents a typology of upscaling in smart city pilot projects. The section after that identifies and discusses a number of factors and conditions that play a role in scaling processes, drawing on insights from an interdisciplinary theoretical framework. That is followed by a section that contains an illustration of upscaling processes, based on an analysis of three smart city pilot projects in Amsterdam. The final section discusses the findings, draws conclusions, and derives some policy recommendations and avenues for future research.

Dimensions of Scaling and Smart City Project Types

There is no single or agreed definition of upscaling. International organizations such as the World Bank and the World Health Organization (W.H.O.) have adopted definitions of upscaling that can be applied to a broad number of domains. The World Bank (2005: 16) notes in relation to upscaling that "implicit in the concept of scaling up is the need to go beyond business as usual, to embrace new technologies, new institutional arrangements, and new approaches." Upscaling in this respect includes spatial dimensions (geographically enlarging projects, practices, or programs, and reproducing benefits from one local context more broadly); intertemporal dimensions (deepening the impact of projects or programs by expanding their duration and continuity); and dimensions related to influencing the (inter)national institutional environment to accommodate upscaling processes (World Bank, 2005). Hartmann and Linn (2008: 8) adopt a broad definition for upscaling in line with the World Bank, and define it as "expanding, adapting, and sustaining successful policies, programs, or projects in different places and over time to reach a greater number of people."

In the context of health services, the W.H.O. (2009: 1) describes upscaling as "deliberate efforts to increase the impact of health service innovations successfully tested in pilot or experimental projects so as to benefit more people and to foster policy and program development on a lasting basis," which are "backed by locally generated evidence of programmatic effectiveness and feasibility obtained through pilot demonstration or experimental projects". Although this W.H.O. definition is developed specifically in relation to health services, the element of local development and testing of solutions in pilot projects, before scaling them up beyond this local context, is also relevant for other domains.

Other classifications and descriptions of upscaling from the field of development studies are relevant for other domains as well. Uvin (1995) identifies four broad directions for upscaling, which include: quantitative upscaling, which means reaching more people in the same area, or expanding the geographic area in which a solution is applied; functional upscaling, which constitutes expanding the scope of activities; political upscaling, which entails influencing the (local-level) political agenda and institutional frameworks to better facilitate the process of scaling up; and organizational upscaling, which includes enhancing organizational capacity (either by internal capacity-building or via external collaboration with partners) to accommodate the broader diffusion and implementation of solutions (Uvin, 1995). These four directions of scaling are rather similar to the dimensions of upscaling identified by the World Bank (2005) and provide insight in the broad directions for scaling up solutions beyond the (local) context in which they have been developed.

Another distinction between upscaling typologies relevant to a broader set of domains is developed by Cooley and Kohl (2005). They make a distinction between expansion, replication, and spontaneous diffusion: Expansion involves bringing a pilot to scale within the organization(s) that developed it; replication, in their definition, means scaling up by others than the organization that originally developed the initial pilot or model intervention (for example through franchising as one model); and spontaneous diffusion, involving the spread of good ideas or practices largely of their own accord.

Based on these definitions of upscaling of international organizations, and building on the classifications of scaling identified by Cooley and Kohl (2005), we propose three types of scaling for smart city solutions: roll-out, expansion, and replication (See Table 1). We speak of *roll-out* when one of the pilot project partners uses the pilot's test results to scale up the developed product, service, or solution (market roll-out), or apply the lessons of the experiment within their own organization (organizational

Table 1. Scaling types

Scaling Type	Description	Manifestations	Examples
Roll-out	Bringing a smart city solution to the consumer or business-to-business market, or applying the solution in the entire organization	Market roll-out Organizational roll-out	Smart energy meters introduced in consumer market; system for car sharing implemented in municipal organization
Expansion	Add more partners, users, or functionalities to a smart city solution, or enlarging the geographic area in which the solution is applied	Quantitative expansion Functional expansion Geographic expansion	Add functionalities or partners to a tourist smart card system; enlarge the geographic area of a smart lighting solution
Replication	Replicate (exactly or by proxy) the solution in another context by the original partners involved in the pilot project, or by others.	Organizational replication Geographic replication	Replicate a tested vehicle-to-grid system in a new part of the city; replicate a smart traffic light solution in another city

roll-out). This type of scaling applies to manufactured smart city products or service innovations. We define *expansion* as the type of scaling that happens when the pilot project is not closed or dissolved, but is rather expanded with new partners or users to the project, or by enlarging the geographical area in which the project operates. This type of scaling is relevant for smart city projects such as mobility platforms, tourist smart cards, energy exchanges, online neighborhood communities. The third type of upscaling that we identify is *replication*, the most complex type, which can apply to all types of smart city solutions that are tested and developed in pilot projects. With replication, the solution that has been developed in a pilot project is replicated in another context, which can be in another organization or part of the city, as well as in another city altogether. Hence, replication can be done by the original pilot partnership but also by others, and the replication can be exact or by proxy.

A smart city project can be subject to several types of scaling; for example, a smart card solution for tourists can be expanded (by adding more partners) or replicated (in another city). Also a distinction must be made between scaling of the project itself (which is the case in expansion and replication) or scaling of particular products/services that were developed in the project (as is the case in roll-out). In the latter case, the project served mainly as test environment, and is dissolved in the scaling stage. Our empirical analysis of smart city pilot projects in Amsterdam will further illustrate these three scaling types and their characteristics. In the next section, we will take the next step and identify, drawing from a variety of literatures, a number of requirements and conditions for upscaling.

Conditions and Factors That Affect Scaling

Several literatures offer clues on what drives upscaling processes. In this section, we identify the following drivers and enabling conditions: prospects for economies of scale, the management of ambidexterity, knowledge transfer mechanisms and incentives, regulatory and policy frameworks, data exchange and system interoperability, and (lack of) standards to measure return on investment of smart city projects. Each of these factors are described in more detail below, and will be connected to the three types of upscaling at the end of this section.

Prospects of Economies of Scale

Successful pilot projects will be scaled up more easily when there is a prospect of economies of scale (leading to lower unit costs and/or higher profits), and an incentive to capture them. Economies of scale imply that fixed costs (including the costs of research and development [R&D] and pilots) can be spread out over a larger volume (O'Sullivan and Sheffrin, 2003). This mainly applies to the roll-out type of scaling, in which a single firm or organization is able to capture the benefits of scaling. In this respect, Hartman and Linn (2008: 19) note that where commercial firms have a market incentive for upscaling, public and not-for-profit organizations have a tendency "to move from one new idea to the next, from one project to another," rather than to scale up.

In the last decades, a traditional supply-oriented view on economies of scale has been enriched by a network perspective. In a growing number of information-intensive sectors (and relevant for many smart city solutions), the value of a product or service increases with the number of people who use them; examples are mobile phones and social media applications. These economies are referred to as *network economies* or demand-side economies of scale (Shapiro and Varian, 1999). To capture such network economies, developers of smart city products or services have an incentive to build a large user base in a short period, taking initial losses for granted. Moreover, a large user base offers scope for auxiliary services that further enhance the value of the product. For example, when more people drive electrical cars, there is a bigger market for charging stations, or specialized repair services. The recent emergence of digital platforms (such as Uber, Airbnb, and Kickstarter) has added a new dimension to network effects. In platforms, network effects are two-sided: the growth of supply and the demand side of the platform (for example, riders and drivers in the case of Uber; suppliers and users of local renewables in the case of a local energy platform) must be well balanced to create value for both sides.

If one side of the platform is underdeveloped, the scaling process stalls. To prevent this, a scaling strategy could be to subsidize growth in the start-up phase (in the case of Uber, the firm gave free rides to do this). In this regard, Choudary et al. (2016) discuss the typical "chicken-and-egg" problem: users won't come to a platform when it has no value to offer, and there is no value if there are no users. Many platforms fail to take off because they do not solve this dilemma. This platform perspective on scaling is highly relevant as many smart city solution have platform characteristics: mobility platforms (where traffic information is exchanged), energy platforms (that intermediate between supply and demand of renewable energy), and all sorts of smart city applications in the realm of the sharing economy.

Management of Ambidexterity

Scaling requires an adequate management of the transition from the pilot/testing phase of a project to the exploitation phase. From an organizational perspective, the literature on ambidexterity offers important insights. A central tenet here is that explorative activities such as innovation and R&D (or: the pilot stage of a smart city solution) require different competencies than activities related to large scale production and exploitation (the scaling phase). Organizations face the challenge of striking a balance between exploration and exploitation (March, 1991, and many others).

A balanced approach of pursuing both exploration and exploitation, i.e., ambidexterity, is essential for performance. Organizations that focus on exploration to the exclusion of exploitation bear the costs of experimentation but gain little of its benefits, whereas an over-focus on exploitation will hollow out a firm's competitive performance in the longer run. Scholars have discussed how organizations can achieve and manage balance (Lavie et al., 2010; Lavie and Rosenkopf, 2006; Andriopoulos and Lewis, 2009; Raisch et al., 2009). Most accounts argue for some form of separating exploration from exploitation (Stettner and Lavie, 2014): This separation can be temporal, where a firm manages transitions between exploration and exploitation over time (Eisenhardt and Brown, 1997); or it can be organizational (Benner and Tushman, 2003), enabling a firm to maintain distinct activities while engaging in internally consistent tasks within separate organizational units dedicated to either exploration or exploitation (O'Reilly and Tushman, 2008; Smith and Tushman, 2005). In a similar vein, Ries (2011: 261) discusses the challenge of connecting innovation teams in companies with the mainstream company operations. Isolating the innovators from the parent company rarely leads to sustainable innovation and scaling, as operational managers will strongly resist the innovations "sprung upon them." He argues for creating an "innovation sandbox" in which the innovation team can work independently, but remains in close contact and accountable to the parent organization. Samoff and Molapi Sebatane (2001) also find that upscaling is hampered when vested interests within an organization accept a small pilot but perceive scaling it as a threat.

In the context of upscaling smart city solutions from pilot projects, the concept of ambidexterity has significance; smart city pilot projects inherently involve exploratory activities, set up to test new technologies or innovative concepts. If we follow the analogy and frame the process of scaling as the transition to the exploitation stage, the literature suggests performance will be enhanced by separating the two stages; scaling up requires different competencies, and this must be accounted for. For each of the different manifestations of upscaling, organizations should therefore take a balanced approach to their exploration and exploitation activities, and arrange a connection between the innovation team and operations/senior management.

Knowledge Transfer Mechanisms and Incentives

Knowledge transfer within and between organizations is often necessary for scaling to happen (Tamer Cavusgil et al., 2003; Du Plessis, 2007; Seidler-De Alwis and Hartmann, 2008; Foos et al., 2006), especially for the replication type of scaling. Replicating a successful smart city solution developed in context a to context b requires that the know-what and know-how (tacit or explicit) is transferred from place to place, but also needs a contextualization of knowledge. Especially the transfer of tacit knowledge, which is "encoded knowledge and resides in the firm's system" that is "difficult to interpret and transfer (i.e. uncodified) from one firm to another" (Tamer Cavusgil et al., 2003: 7), is key in the replication process. Replicating a project in another cultural context requires an adequate accommodation to cultural values and social-interaction patterns, and often implies a re-configuration of the partnership. The simpler the institutional framework and the less complex the relationships between actors, the swifter and more successful replication can be achieved (Binswanger and Aiyar, 2003).

Large companies often are able (and have financial incentives) to organize effective knowledge transfer mechanisms. In the smart city domain, MNEs like I.B.M. or Cisco have developed global smart city programs that help them capture the benefits from their presence in many locations and their existing relations and contracts with cities across the world. These companies deploy internal knowledge transfer mechanisms, enabling them to apply lessons from pilot projects effectively, and sell smart city solutions to a large number of cities (Söderström et al., 2014; Paroutis et al., 2014). However, many smart city projects are run by municipal authorities and smaller, local players, who do not have an international network of offices, and lack the competencies and financial incentives to replicate solutions elsewhere. In such cases, knowledge transfer is more difficult to organize, and good pilot results are often not disseminated. The European Commission—a big funder of smart city projects—recognizes the relevance of knowledge transfer as a condition for replication, and stipulates that project proposals must have work packages on knowledge sharing and dissemination in order to facilitate replication. In the recent Horizon 2020 "smart cities and communities lighthouse projects" call, leading cities are invited to develop smart city solutions with replication potential for "follower cities," that must be part of the consortium from the outset; Consortia must make explicit how the knowledge transfer is organized between contexts, and dedicate substantial resources to it (EC, 2013, 2017).

Regulatory, Legal, and Policy Frameworks

Regulatory, legal and policy frameworks play a conditioning role in scaling processes of smart city pilot projects. Scaling up solutions—especially of the roll-out and expansion type—will be easier in cities with high ambitions in the smart city realm (for example reducing CO2 emissions, increasing the use of renewables, reducing energy consumption, public service digitization, etc.). However, in many cases, public funding is a bottleneck. Vilajosana et al. (2013) find that many municipal governments are cash strapped and have often only piecemeal funding (often external) available for small projects; Scaling is particularly difficult when the pilot relies on expensive technology and other resources (Hartman and Linn, 2008).

Regarding energy-related smart city projects, Vilajosana et al. (2013) note a lack of consistent policy frameworks on key issues, such as feed-in tariffs and carbon pricing; scaling and replication across national borders is hampered by large variations in rules, legislation, and incentive schemes. Also, public procurement policies and regulation can affect scaling, positively or negatively. On the one hand, a local or regional public administration can act as a launching customer when a pilot project results in a good solution, and thus contribute to the scaling of it. On the other hand, public procurement rules can also imply that companies that participated in a successful pilot cannot take for granted that they will win the big order in the scaling stage.

Some pilot projects fail to scale up because they are, for the sake of experimentation, shielded from real-world legislation and market forces. In the literature on transition management and strategic niche management (Kemp et al., 1998; Truffer et al. 2002; Hoogma et al., 2004; Smith et al., 2005; Coenen et al., 2010), pilot projects are framed as playing out in "protected niches," which can be defined as "protected spaces created by specific actors —companies, policymakers or citizen groups—with the strategic aim to test and develop a technology and to prepare it for further diffusion" (Truffer et al. 2002: 113). Niche development occurs through experiments in concrete places (e.g., though pilot projects in cities). At the same time, local experiments tend to add up to a "global niche" through the exchange and sharing of lessons and insights across locales (Geels and Raven, 2006; Raven and Geels, 2010). This leads to the articulation of common/shared problem agendas, expectations, theories, and success narratives, articulated and circulated by intermediary actors such as industrial lobbies, policy networks, user groups, and not-for-profit organizations, thereby influencing new experiments and funding programs for research and innovation (Carvalho, 2015). In this approach, scaling does not unfold at the project level but rather is a long-term process where pilots may fail (due to overprotection or shielding) but play their part to achieve a system transition.

Data and Systems Interoperability

Many smart city projects rely on data exchange between organizations, and interoperability of I.T. systems. This is especially relevant for multi-stakeholder platform-type projects in which data exchange and sharing is a key element. Here, scaling (particularly of the expansion type) is hindered when there are no (or not yet) widely accepted technical standards. Walravens and Ballon (2013) note a lack of transversal and interoperable technological platforms to manage the huge amounts of data generated in smart city contexts. In addition to technical compatibility issues, the willingness of partners to engage in inter-organizational data sharing matters as well. For data sharing on smart city-related platforms, such as Geographic Information Systems (G.I.S.), Nedović-Budić and Pinto (2000: 461) identify that "the nature of the coordination process is key to establishing an atmosphere of trust and mutual collaboration and for the overall success." Trust inherently matters in inter-organizational exchange relations (Zaheer et al., 1998) and is an important condition for partner organizations to share their data.

Standards to Measure Return on Investment

Many smart city technologies are at an immature stage, and it is unclear or uncertain what they will deliver in terms of return on investment. They typically hold promises of costs savings and efficiency improvements, but there are high margins of uncertainty, especially in the domain of clean energy solutions where returns depend on fluctuating energy prices, feed-in tariffs, and unpredictable policies, subsidies and regulations. Vilajosana et al. (2013) signal a dearth of appropriate and systematic methods to identify return on investment of smart city technologies. For the private sector, all this "translates into a certain immaturity of the market," which in turn is enhanced by the complexity of relationships with the public sector (Vilajosana et al. 2013: 129), resulting in low capital investments.

Summing Up

Table 2 presents a synthesis of the findings and insights discussed in the last sections. The two heading rows repeat the three types of scaling identified in section 2: roll-out, expansion, and replication. Next, the table summarizes the factors and conditions that affect upscaling, as discussed in the last section. Given the large diversity in smart city projects, the scaling dynamics are contingent on the type of smart city solution/innovation that is being tested (a product/service, a process innovation, a platform-type innovation, or a more systemic innovation); also, as discussed, the weight of the requirements varies between the three types of scaling (roll-out, expansion and replication).

An Illustration of Scaling Dynamics: Three Cases from Amsterdam

To illustrate the dynamics of scaling, this section presents an account of three smart city projects developed in Amsterdam. The first case is Climate Street, a pilot project that illustrates the roll-out of product and service innovations, although broader expansion and replication were initially envisioned. The second case is Energy Atlas, in which expansion

Table 2. Scaling types and conditions

Scaling types	Roll-out	Expansion	Replication
	Bringing a smart city solution to the market (market roll-out), or applying it in the entire organization (organizational roll-out)	Adding partners or users to a smart city solution, enlarging the geographic area, or adding features	Replicating (exactly or by proxy) the solution in another context (organization, geographic area), by the original pilot partnership or by others.
Mainly applies to	Product and service innovations	Projects, platforms, process, and system innovations	Projects, platforms, process, and system innovations
Examples	Smart meters and displays tested in the pilot are now produced at large scale by private company	Mobility app covers wider urban area and also offers parking solutions	Traffic light solution that gives green light to emergency services is replicated in another city
Scaling up a smart city pilot project requires:			
Prospect of economies of scale -Supply-side economies of scale -Network economies	X	X	X
Effective knowledge transfer mechanisms and incentives			X
Effective management of ambidexterity	X	X	X
-Separation between exploration and exploitation -Alignment between pilot team and senior management			
Enabling regulatory, legal, and policy frameworks	X	X	X
-Vision and ambitions of public authorities -Procurement policy and regulation -Public funding for scaling -Preventing overprotection of the pilot			
Data, standards, and systems interoperability		X	X
Standards to measure returns on investment	X	X	X

and replication of an information-based platform on energy data is central to the upscaling process. The third and last case is Cargohopper, a sustainable city logistics solution using electric vehicles, which has been replicated in several cities. For each case, we discuss the process of upscaling in more detail.

Methodology

For this study, we adopted a qualitative research approach based on a multiple case analysis. Evidence was collected through a documentation study combined with semi-structured face-to-face interviews with project leaders and stakeholders of smart city pilot projects, and representatives from the Amsterdam Smart City platform. All selected projects were in an advanced development stage or finalized at the time of our evaluation, to allow a thorough analysis of upscaling in the project. The three cases presented in this paper (Climate Street, Energy Atlas, Cargohopper) were selected on the basis of theoretical sampling from a set of 12 Amsterdam Smart City pilot projects, which were evaluated between November 2014 and April 2016. A total of 37 interviews were conducted with participants in these 12 smart city projects. Interviewees included representatives of the city administration, multinational enterprises (MNEs), small- and medium-sized enterprises (SMEs), grid management firms, and utilities involved in one of the selected projects. Interviews lasted between one hour and two hours and were transcribed into detailed interview reports. These results were triangulated with secondary sources such as internal evaluation documents, press releases, and personal communications between project partners (for further details, see van Winden et al., 2016). Each case discusses different types and mixes of upscaling processes in smart city projects, and identifies some of the underlying dynamics driving or hindering this process. Although all three projects relied to some extent on subsidies in their pilot stage, they are not excessively "shielded" by legal or regulatory protection, which would have reduced the chance of upscaling from the outset. All three forms of upscaling (roll-out, expansion, replication) are illustrated by one of the cases presented in the next section.

For each case, we briefly describe the history, rationale, and development process, and identify the key organizations in the partnership. Inherent to our focus on upscaling of smart city solutions from pilot projects, we identify how the upscaling process unfolded in each specific project and what drivers and barriers were faced.

Climate Street

Climate Street is an illustrative case that demonstrates (a) the co-existence of multiple types of scaling from one pilot project; (b) the significance of ambidexterity in the roll-out process; (c) the difficultly of replication in the absence of knowledge transfer incentives; and (d) the importance of securing public funding after the pilot stage.

Launched in 2009, Climate Street was aimed at turning a busy street in Amsterdam's city center into a living lab and showcase for smart products and services, to show how to make a high street more sustainable in all respects. Climate Street was envisioned as a beta lab: a platform for all sorts of experiments that would enhance sustainable urban development. The number of activities was very broad from the outset: retailers in this street were invited to apply a broad range of smart city products that would reduce energy use or waste (product innovations), and various experiments were set up in the fields of waste collection, logistics, and innovative street lighting (process innovations). For technology companies and utilities, the project leadership positioned the street as an interesting living lab where they could test new products that could later be commercialized (or "rolled out" in our terminology). In some cases, the project management team actively approached companies, inviting them to test their products and services there; in other cases, companies approached the project management, to inquire about the possibility of testing their products and services in Climate Street. The city was the main funder of the program, and helped to set conditions for realizing urban innovations: permits, solving legal issues, access to civil officers with the right skills and competences.

The partners in the pilot project had different roles and interests. Various city departments involved in the project saw the Climate Street as a unique lab to learn how to work with local retailers, having them adopt cleaner technologies, and thereby contribute to the city's ambitions regarding emission reduction. The lessons could be disseminated to other retail streets. Moreover, the city administration used the street to experiment with alternative urban services (in the field of garbage collection and street cleaning), expecting that lessons learned could be applied in the municipal organization at large (a case of organizational roll-out). Retailers hoped that applying new technologies would help them achieve saving on their energy bills, and/or increase the sustainability of their businesses. The technology companies and service providers hailed the pilot project to be a unique living lab to test their new products and concepts in a real-life setting, and then roll them out in a later stage (market roll-out). Thus, the partners, implicitly, had different expectations and ambitions regarding the scaling of the Climate Street project. Also, the city administration envisioned the project as a demonstration to be replicated in other cities.

All envisioned forms of upscaling turned out to be rather problematic. To the knowledge of the project leader, the only roll-out success was realized by Quby, a start-up firm that tested a smart energy display in the Climate Street project. The test was successful, and the solution was bought by Eneco (a major electric utility in the Netherlands) that sold over 100,000 energy displays to date. In this case, exploration (pilot project) and exploitation (roll-out in the market) were explicitly separated and performed by different organizations. In terms of replication of the concept, the city administration considered the Climate Street project as an example to be followed (replicated) by other streets in Amsterdam, and possibly beyond. To enable other cities to set up a similar project, a consultancy agency was hired to write a document titled "blueprint for sustainable shopping streets," a handbook and source of inspiration for other high streets based on the experiences in the pilot project. While it is unclear to what extent this blueprint has been used for replication, the project had a broader impact: due to the effective communication of the Amsterdam Smart City platform, Climate Street attracted wide attention from professional media and local governments, nationally and internationally, and many delegations made study visits to learn from experiences in Climate Street. It is beyond the scope of this study to assess whether these visits have played a role in replication, but at least some degree of knowledge transfer took place.

While Climate Street was initially envisioned as a permanent lab for experiments that would contribute to sustainable development in the city, this failed to materialize due to a lack of public funding after the pilot stage and ended in 2012. The project was unable to reach the point of being financially self-sustaining through contributions of private partners. Hence, Climate Street reflects the importance of commitment and ownership among project partners as a condition for successful upscaling.

Energy Atlas

Energy Atlas is a platform-type smart city innovation, in which key public and private players in the local energy system decided to share their data and create an online interactive platform (the 'Energy Atlas') that reveals data on real energy, water, and sewage use on the level of the building block for the entire city of Amsterdam. The Energy Atlas helps to identify the geographic locations in the city with the highest potential for adopting new energy solutions. The case includes both expansion and replication in the upscaling process, and demonstrates that: (a) the vision and ambitions of public authorities can be an important enabling factor in scaling processes; (b) knowledge transfer and learning mechanisms are crucial for wider dissemination of smart city solutions; (c) system interoperability is key to facilitating effective data sharing between different organizations; and (d) that alignment between the pilot team and senior management of parent organizations is important in the design and scaling stage.

In its initial development stage, the project was supported by European funding from the TRANSFORM project, executed between January 2012 and August 2015, in which six European cities collaborated with the aim of reducing carbon emissions (Van Warmerdam and Brinkman, 2015). The Amsterdam city administration was the driving partner in the project: it led and managed the project from the outset and organized the process of partner engagement and data integration. Participating utilities and housing corporations in Amsterdam agreed to provide their data for free on the condition that the platform would be open and would not reveal energy use on the level of individual clients. It was a key challenge for the partners to cluster information on clients in such a way that it would be impossible to trace back individual use. Despite many technical, legal, and data issues, senior management of the partner organizations backed the project, as they realized the value of sharing data in the Energy Atlas platform. The project partners, as well as experts in the energy sector that we interviewed, consider the Energy Atlas developed in Amsterdam a great success. It is internationally unrivalled, especially because it gives up-to-date and real (rather than projected or estimated) data on a wide variety of energy consumption and production in the entire city. The Atlas now floats without European subsidies, and the local partner management boards have committed to continuing to feed the platform with data, and keeping it technically up to date. In scaling up the Energy Atlas developed in Amsterdam, the planned process of expanding the number of partner organizations willing to share relevant energy data in the platform will enhance the functionality and usability as a decision-making tool even further.

Replication of the Energy Atlas beyond the context of Amsterdam was a central ambition of the project partners from the outset. To this end, knowledge sharing was facilitated by a "Replication & Exploitation Campaign," aimed at transferring the tools and lessons learned about energy transition to other cities. Three organizations, Accenture, the Austrian Institute of Technology, and Macomi, developed an online "Decision Support Environment" (DSE) for urban energy planning, which enables partner cities to simulate scenarios, and helps to design and assess interventions in the energy system. In addition, handbooks and masterclasses were developed to transfer the lessons on energy transition that were developed in the project. A key incentive to stimulate this widespread knowledge sharing came from the conditions related to the European funding on which the project relied, as well as the open data vision of the project leader in Amsterdam. In addition to sharing knowledge externally, one of the interviewees identified that consultancy firm Accenture (who played an important role in the development of Energy Atlas) also uses its experiences and lessons learned in Amsterdam to advice other cities on this topic. This illustrates how multinational firms can leverage internal knowledge transfer mechanisms to use experience from pilot projects in one local context and use these experiences in their activities in other contexts.

Our interviewees indicated that replication in other cities remains difficult. The value of the Energy Atlas critically depends on detailed geo-spatial and energy data inputs that must come from a variety of local partners, including different utilities, housing corporations, and municipal departments. Thus, replicating the Atlas elsewhere requires the formation of new local coalitions, involving high communication and transaction costs. Data issues can also be a complicating factor. Given that this information is embedded in the systems of different partners, a limited degree of system interoperability and compatibility between existing data sets can potentially be a hindering factor in this process. The developers of the tool in the pilot project in Amsterdam identified a set of legal, economic, and data quality challenges for open energy data and recognized their "limited success in getting the right data at the right level of granularity," arguing that data owners often face technical difficulties and do not perceive the value behind opening of their data (Accenture 2015: 17). Existing knowledge and experience in working with relevant systems to develop an Energy Atlas, such as GIS, can contribute to a successful development process. Amsterdam's Energy Atlas could draw on existing databases and maps, while many cities (especially smaller ones) lack the expertise of such systems.

The replication ambition for the Energy Atlas was not confined to the consortium that initially developed it, as many municipalities in the Netherlands expressed their interest to somehow replicate the Energy Atlas as well. Inspired by the Amsterdam example, the association of Dutch municipalities is currently developing a national version of the Energy Atlas. It is supported by the national government, and the Amsterdam team acts as advisor.

Cargohopper

In the Cargohopper project, a private logistics company developed and tested a sustainable solution for inner city deliveries using electric transportation. The solution was first piloted in the city of Utrecht, and was then replicated in Amsterdam in collaboration with the city administration. It demonstrates that (a) firm-level internal knowledge transfer is important for replication; (b) effective management of ambidexterity is needed to move from exploration to exploitation; (c) prospects of economies-of-scale can be a prerequisite for a scalable business model; and (d) local-level regulations—in this case a strict regime to ban diesel trucks from the city center—can be a driver of sustainable innovation.

The logistics company Transmission was the initiator of the project. This company, with various establishments across the Netherlands, developed the idea for the Cargohopper as a response to the growing number of Dutch cities that had introduced bans of large diesel trucks from inner city zones (labelled as "environmental zones"), in order to limit pollution and congestion. The Cargohopper solution consists of two interrelated components: an electric freight vehicle and a smart distribution system. The electric freight vehicle has the features of a "road train" with separate carriages, and delivers shipments to businesses in the city's central area where no diesel trucks are allowed. In a distribution center (located at a facility just outside the zone), shipments are processed, bundled, and loaded onto the electric freight vehicle. These shipments are bundled by address into separate carriages, allowing efficient delivery to businesses based on the proximity of delivery addresses in the same area. Amsterdam's city administration allowed Cargohopper to operate within the environmental zone in the city center for the delivery of goods, and partially subsidized the development of the first electric vehicle. For lead project partner Transmission, the pilot project created an opportunity to replicate the Cargohopper concept in Amsterdam and prepare it for further growth to other cities (i.e., exploitation), after an initial stage of experimentation with the concept in the city of Utrecht (i.e., exploration). At present, multiple Cargohopper vehicles are operational in Amsterdam, as well as in other Dutch cities.

Replicating a smart city solution developed in a specific local context requires that both tacit and explicit knowledge are transferred to a new context efficiently. In the case of Cargohopper, where lead project partner Transmission was responsible for the replication process, the transfer of knowledge from the pilot team to senior management and other teams in the organization was an essential part of the replication process. The case also highlights how economic and technical conditions can influence the potential for upscaling to other cities. The prospect of economies-of-scale when replicating the Cargohopper is an important prerequisite; there is a need to have a minimum threshold of clients in a city using the delivery service to develop a viable business model. Achieving scale advantages is especially relevant in the case of commercial transport, given interviewees suggested that a (more sustainable) solution should not impose significantly higher costs for businesses using the service compared to existing modes of (less sustainable) transportation. This potentially makes the service less attractive to smaller cities, in which achieving scale advantages could prove to be difficult. In terms of technical standards, several factors can pose limitations on replicating Cargohopper, including the maximum driving range, driving speed, and cargo load. While these specifications fit with the infrastructure of Amsterdam's city center, these specifications may prove to be problematic for major cities that are more spread out over a larger geographic area. If technical standards can be sufficiently adapted to fit with the geo-spatial context to which it is replicated, the solution becomes more attractive to a broader variety of cities. Interoperability between systems of different transportation firms also complicates the upscaling process: in this case, Transmission can only handle freight which is part of the firm's own system due to a lack of interoperability with the systems of other transportation firms. Obviously, competition and diverging interests between firms offering these commercial services also affect this process.

Finally, Cargohopper also shows that legal and policy frameworks can be an incentive for sustainable innovation. In this case, such incentives included stricter regulation for vehicles allowed to operate in the environmental zone in the city center, combined with partial subsidies for the development for the first electric Cargohopper vehicle. The full-electric vehicle design, and underlying distribution system just outside the environmental zone, were developed in response to this local-level regulation.

Discussion and Conclusions

Smart city technologies hold the promise of improved urban services and more livable and sustainable cities. European cities have set up a growing number of smart city pilot projects, in which various stakeholders apply new technologies to address urban challenges or improve service provision. In the last decade or so, European, national, and local public funding for such initiatives has grown, and also the private sector is increasingly interested in investing in smart city projects. Recently, there has been a growing concern among policymakers and funders about the impact of these pilot schemes, mainly because of the low rate of upscaling; many projects fade out after the pilot project ends and/or when the project subsidy dries up and fails to make a substantial impact.

In this paper, we have made an attempt to analyze the process of upscaling in more detail, both theoretically and empirically. We identified three upscaling types: roll-out, expansion, and replication, each with its own dynamics and specificities.

Next, we presented a framework (based on a study of various literature) containing conditions and requirements for scaling processes to take off. These include: the prospect of reaching economies-of-scale; the presence of knowledge transfer mechanisms and incentives; management of ambidexterity in exploration-exploitation activities; the presence of enabling regulatory, legal, and policy frameworks; interoperability between systems, data, and standards; and the inclusion of standards to measure returns on investment. Finally, we provided a descriptive analysis of the upscaling process (or the lack of it) in three smart city projects developed in Amsterdam, one of the most active cities in this field.

In the empirical analysis of smart city pilot projects in Amsterdam, we illustrated the impact of the conditions and requirements on upscaling processes in several ways. The first case, Climate Street, demonstrates the importance of organizational ambidexterity in the roll-out process, and shows how the absence of knowledge transfer incentives for partner organizations in a pilot project can hinder replication. The case also reflects how a lack of funding can hinder the upscaling process; the pilot ended prematurely because of a lack of funding and commitment by partner organizations, while it was envisioned to turn the project into a permanent urban lab for experimentation with smart city technologies. The second case, Energy Atlas, reflects how knowledge sharing and learning mechanisms are important for the development and wider dissemination of smart city solutions. It demonstrates, in a multi-stakeholder setting, the importance of having a strong link between a pilot project team and the parent organization, as well as an explicit common interest and commitment to move the project forward. In terms of sharing data, which is a crucial aspect of most smart city platform innovations, the case also showed that system interoperability is a key factor for partners to open up their data sets. The third case, Cargohopper, reveals that internal knowledge transfer mechanisms in the firm are important to replicating a solution from one locale to another, and confirmed that the prospects of economies-of-scale can be a prerequisite for replication; without sufficient scale, the solution developed in the pilot project is not commercially viable. Additionally, the Cargohopper case suggests that effective management of ambidexterity is needed in order to move from exploration to exploitation.

Overall, we conclude, in line with Hartman and Linn (2008), that the design of the pilot project has an impact on its upscaling potential. Hartman and Linn (2008: 16) state in this respect that a pilot project must be set up with a clear vision on how scaling processes will take shape (in any form):

> pilots should be designed in such a way that they could be scaled up, if successful, and so that key factors which will be necessary for a scaling up decision—with what dimensions, with which approach, along which paths, etc.—are already explored during the pilot phase.

Our study also demonstrates that upscaling is a multi-layered process, and different types of scaling might follow from a single pilot project. For both policymakers and practitioners, taking the potential path(s) for upscaling into account in the design stage of the pilot project is, therefore, important for the wider diffusion of smart city solutions.

Understanding the scaling process of smart city solutions requires insights into the subtle interplay between the project level and the individual organizational/firm level. Many smart city projects are collective ventures of different organizations, each with different rationales, ambitions, and perspectives regarding upscaling. Partners may enter a project for a variety of reasons: to test how consumers react to new products; to demonstrate technical feasibility of a solution on a small scale (the technology companies in Climate Street case); to share data in an integrated platform to enable cities to reach sustainability ambitions, improve urban services, and use energy more efficient (as was the case in the Energy Atlas case); or to develop and test a prototype version of a solution in a real-life urban environment, which fits with stricter environmental regulations (which occurred in the Cargohopper case).

Private partners may also join a project to (re)establish close relations to the local government (especially relevant for companies that have the local government as an important client), or from a corporate social responsibility perspective and/or to improve its corporate image. While such partners may have a clear motive for participating in a smart city pilot project, we also found that other projects do not scale because of a lack of incentives; they are often formed by coalitions of small local players who have no incentive to replicate the success elsewhere. The inclusion of mechanisms and incentives in pilot projects to maximize the upscaling potential for solutions, either via a roll-out, expansion, or replication process, should therefore be carefully considered by policymakers.

Our study puts the emerging policy orthodoxy about scaling as the holy grail of project success into perspective. Even in the absence of upscaling, pilots generate lessons and insights that might benefit ensuing projects—if captured, documented, and shared appropriately. On a higher level of abstraction, the transition management literature highlights the value of sequences of experiments, including failed ones, as part of the process of newly emerging narratives and agendas, influencing established regimes. Our interviews with local project leaders and other stakeholders revealed significant project-to-project learning processes, where tacit knowledge from former projects is infused into new ones. Moreover, a project can be successful without upscaling in other respects as well: Energy Atlas is seen by its local stakeholders as a success, the local initiators maintain and fund it without intending to expand or replicate it elsewhere. It evolved from a pilot project to a useful and stable platform. These findings suggest that a single-sided focus on scalability could reduce or impede more fundamental experiments that may not scale immediately but function as small building blocks in a process of systemic and more fundamental changes, and entail important learning processes. Policymakers need to be aware that the changes they are pursuing in society with their funding will take time and require the accumulation of many projects.

Most smart city technology projects are not only technical, but involve social, cultural, political, institutional, and behavioral changes that are very context sensitive. In this respect, there are reasons to be doubtful about the effectiveness of dissemination and replication activities (producing handbooks, toolkits, or online tools) so typical in E.U.-funded projects, because the required knowledge is tacit; a project's success is highly contingent on local coalitions and conditions. Finding more effective ways for disseminating tacit knowledge would therefore enhance the upscaling potential of pilot projects. Yet, from the accumulation of local experiments in pilot projects across different cities, and the exchange of lessons and insights across different local contexts, a broader adoption of scalable solutions for sustainable urban development can develop.

Scaling is difficult for small and local players. Technology MNEs such as I.B.M. and Cisco, as well as other international service providers (Accenture in the case of Energy Atlas), are able to apply lessons learned or replicate solutions in cities, namely by combining their local presence in various cities with internal knowledge transfer and ambidexterity. They manage to transfer solutions from one place to another and capitalize on their investments (achieving scale economies). Start-ups and SMEs lack such networks and competencies, and have much more difficulty effectively scaling up smart city solutions. This explains why so many applications and solutions never outgrow the local or even parochial level, unless adopted and scaled up by a larger player. The case of Climate Street is illustrative: the successful roll-out of the energy display only happened after the start-up company was taken over by a larger player that managed to sell the displays on the national market. Further research is needed on the role of multinational firms in smart city pilot projects and the wider diffusion of solutions developed in these projects.

Smart city projects are fascinating new arenas where different urban stakeholders (public, private, and civic) engage in coalitions and innovate together, and more research is needed to study the dynamics in this arena of upscaling where different interests meet and collide. For a start, our research suggests that project participants rarely openly discuss each other's upscaling perspective and ambitions during the pilot project's formation stage, nor do they build in mechanisms that ease the transition to the upscaling phase. When the pilot ends, this puts a strain on the upgrading stage which become a project of its own. This finding resonates with insights from the business literature that longer-term competitiveness relates with ambidexterity; a firm's ability to find a good balance between exploration (developing new knowledge and competences associated with R&D and innovation) and exploitation (implementation, scale production, refinement). Hence, specific attention to upscaling potential and achieving longer-term impact beyond the pilot project presents an important opportunity for future research on smart city projects. Pilot projects, after all, are designed for the exploration stage. Also, given the substantial degree of context sensitivity in the upscaling of smart city pilot projects, further empirical research in different geographic contexts beyond Amsterdam would further enhance understanding of upscaling processes in smart city pilot projects.

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Notes on Contributors

Willem van Winden is a professor of urban economic innovation at Amsterdam University of Applied Sciences. He is strategic advisor to Urbact, Europe's largest exchange and learning program promoting sustainable urban development, and lead expert of EUniverCities, a network of European cities and universities.

Daniel van den Buuse is a lecturer-researcher on the business and economics faculty at the Center for Applied Research on Economics and Management at Amsterdam University of Applied Sciences. He is also an external PhD candidate at the University of Amsterdam Business School.

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