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Anticipating Constraints on Upscaling from Urban Innovation Experiments

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Abstract: The upscaling of innovations from urban experiments is often assumed to be relatively easy, as if they can simply be 'rolled out'. In practice, however, upscaling is usually constrained by a range of factors in the wider context of the innovation, typically a context of interconnected and 'obdurate' urban socio-technical networks and institutions. Innovation studies have used the notion of upscaling from experiments most explicitly in studies of transitions, especially of strategic niche management (SNM) and transition management (TM). However, these studies have focused more on niche internal dynamics and future visions, respectively, and much less on constraints in the present socio-institutional context. This paper offers a conceptual contribution on 'constraints on upscaling', elaborating on how upscaling can be more effective when constraints on upscaling are first identified in retrospective systems analysis, and then anticipated in the design of urban experiments. Our focus is on innovation in urban mobility systems. After a conceptualization of 'constraints on upscaling', based on a review of the literature of transition, social innovation, geography and science & technology studies, we present a retrospective analysis of urban mobility in Maastricht (NL) in which these interrelated constraints can be recognized. Further, we analyze a pilot on electric bus mobility which was relatively successful in anticipating future constraints. Based on this, we offer some guidelines on how to anticipate upscaling in the design of urban experiments with socio-technical innovations.

Keywords: upscaling; urban experiments; obduracy; constraints on upscaling; mobility; socio-technical innovation

1. Introduction

Urban experiments with sustainable innovations (such as in Living Lab approaches) are often focused on small-scale performance tests and technology-user interactions, largely ignoring the wider socio-institutional context [1,2]. In order to deliver significant contributions to sustainability at the city level, the impact of urban experiments (i.e., projects devised to design, test and learn from an innovative practice in real-life contexts with a diversity of stakeholders) needs to go beyond the level of the building, street or small district at which the experiments are conducted. Thus, the innovation should be scaled up to the level of the socio-technical system (i.e., city or urban region). Upscaling from experiments is often misconceived as just the wider adoption of innovative products over time. Especially in 'smart city' initiatives, decision makers seek to 'roll-out innovations across the city' after successful real-life experiments at a small scale. For innovations produced by Urban Living Labs, it is even claimed that "*nobody will have to ask "But will it work in reality?", because it is already taking place in* *reality*" (Annex on 'Urban Living Labs' to the Calls of JPI Urban Europe, http://jpi-urbaneurope.eu/). In practice, however, upscaling is often constrained by a range of factors in the wider context of the innovation, typically a context of interconnected and 'obdurate' urban socio-technical networks. In this paper we develop an approach for upscaling of innovations from urban experiments that better anticipates such constraints in the socio-institutional context.

The notion of upscaling from experiments has received attention in innovation studies, most explicitly in studies of Strategic Niche Management (SNM) [3–5] and Transition Management (TM) [6,7]. Both SNM and TM attribute an important role to 'transition experiments', which refers to innovation projects in which actors in society learn about societal challenges and how to address those [8].

SNM and TM are related, policy-oriented frameworks focusing on interactions between learning processes (on various dimensions), social networks, and visions and expectations [8]. They presume that sustainable innovations are disadvantaged and require strategic support to protect them against premature rejection by investors, customers and users whilst the performance, price and infrastructures for these technologies develop [9].

Smith and Raven [10] developed a framework conceptualizing the construction of 'protective space' as consisting of three features: Shielding, nurturing and empowering. Shielding is about actively protecting new initiatives against an adverse selection environment. Nurturing refers to the activities geared to make the new initiatives strong enough to survive without support in the future. And finally, empowerment refers to intervention in the selection environment to support the production of conditions favorable to new niche technologies. To illustrate this, they give the example of governments implementing an investment support program for demonstration sites (ibid.). An analyst interested in shielding would question how such a support program came into place, who had lobbied for it, how, and so on. An analyst interested in nurturing would emphasize how the program enables further growth of the niche, such as how it enables learning, or draws in new entrants. Finally, an analyst interested in empowerment will question how the establishment of the program is used by niche advocates to argue for more enduring forms of institutionalization; mobilize the program as 'evidence' for maturing of the niche, and so on.

Although SNM studies have clearly contributed to an understanding of niche development, they are still primarily 'inward looking', and do not pay much attention to the system's environment [9,11]. There is need for niche development concepts to include more outward-oriented processes. TM studies on the other hand, are more outward oriented, but primarily in a forward looking sense. Proponents have developed a prescriptive framework, which suggests that policy makers can shape transitions (understood to follow an S-curve development) through four sequential steps [7]. (1) Strategic activities in a 'transition arena' aim at vision development and the identification of potential transition pathways. (2) Tactical activities develop more specific plans for concrete routes and build agendas and support coalitions for these routes, preferably with investment commitments. (3) Operational activities include on-the-ground activities like innovation experiments, demonstration projects and implementation activities, aimed at learning-by-doing. (4) Reflexive activities (evaluation of projects, monitoring of progress) should lead to adjustments in visions and the articulation of best-practices. In other words, transition experiments are mainly shaped by the future vision and transition pathways (step 1) [9].

Hence, both SNM and TM hold the promise of supporting upscaling from experiments, but largely seem to neglect how upscaling of the innovation interferes with the system's environment, the wider socio-institutional context. In this paper we seek to address this gap, focusing on innovation in urban mobility systems. We offer a further conceptual and empirical analysis of 'constraints on upscaling', elaborating on how upscaling can be more effective when constraints on upscaling (in the wider socio-institutional context) are identified in retrospective systems analysis, so experiments can be designed to better anticipate these. We take stock of the fragmented understanding of the context-related constraints on upscaling of (successful) innovations from experiments by reviewing literature on transitions, social innovation, and geographic and science & technology studies (Section 2).

Given the focus of this paper, our review also includes urban and transport studies. We then present a retrospective analysis of urban mobility in Maastricht (NL) in which many of these interrelated constraints in the socio-institutional context can be recognized (Section 3). Further, we analyze a pilot on electric bus (E-bus) mobility in Maastricht which was relatively successful in anticipating future constraints (Section 4). Based on this, we offer some guidelines on how to anticipate upscaling in the design of urban experiments (Section 5) and then conclude (Section 6).

2. Conceptualizing Constraints on Upscaling

The notion of upscaling of innovations from experiments has been used explicitly or more implicitly in a range of scientific fields, with some only referring to constraints, that is: to factors or conditions that hinder upscaling. Here we take stock of the rather fragmented understanding of the context-related constraints on upscaling by reviewing the most relevant fields. We start with those that use the term upscaling explicitly and then review fields that implicitly highlight constraints in the socio-institutional context, including insights on how to anticipate on these, when discussed.

Studies of socio-technical transition have referred to upscaling from experiments most explicitly. They generally refer to upscaling from innovation experiments or projects as not only the growing level of adoption (as in diffusion studies), but also the changing social and institutional context, or, in their words, the growing alignment of technologies, actors and institutions (For the argument in this paper it is not productive to flesh out the slight differences in defining upscaling, such as between Kemp & Grin [12], *the emergence of a set of new practices learned from practical experiments, with corresponding new structure and culture elements;* Van den Bosch [13], *all activities aimed at embedding the experiment in the structure, culture and practices at a higher scale level (the regime),* or Naber et al. [14], *four types of upscaling: (1) growing (i.e., the experiment continues with more actors), (2) replication (on other locations), (3) accumulation (i.e., linking to other experiments), (4) transformation(i.e., the experiment shapes wider institutional change in the regime)*). Transition studies have offered a wealth of cases of societal transformation, but to what extent do these elaborate how established socio-institutional contexts constrain upscaling from experiments? As Pel [15] notes, there are approaches that focus on large-scale transition pathways and evolutionary mechanisms, hinting at 'regime resistance' in more general terms, yet their system-dynamic insights tend to go at the price of abstraction, not going to the level of particular constraints on upscaling of a particular experiment. Geels [16], for instance, lists a number of lock-in mechanisms by which the automobility regime is stabilized, but offers no analysis of particular constraints of particular experiments. On the other hand, the more fine-grained analyses of system innovation 'in the making' tend to focus on niche developments, neglecting the bigger picture and lacking the explanatory power of the former.

Reviewing a decade of Strategic Niche Management (SNM) research, Schot and Geels [5] indicate that the attention to niche-internal dynamics has gone at the expense of understanding their external dynamics and today this still applies [9,17]. Like SNM, studies of Transition Management (TM) have argued that experimentation is key to stimulate upscaling [13]. Nevertheless, in TM studies experiments are mainly shaped by the future vision and transition pathways [8], neglecting (anticipation on) constraints on upscaling in the wider socio-institutional context. An exception is Van den Bosch [13] whose prescriptive guidelines for experimenting state that "*anticipating and learning about barriers and opportunities in dominant culture, practices and structure is part of the learning goals*", but why and how is not specified (as also observed by Porter et al. [18]). Therefore, we take this as a proposition to be further explored and will revisit it in the final section. We first turn to review other fields to understand how the established socio-institutional contexts can constrain upscaling innovation from experiments.

In literature on social innovation, the notion of upscaling is also important. Westley et al. [19] distinguish 'scaling up' from 'scaling out' and 'scaling deep' from the perspective of an organization that seeks to expand. 'Scaling out' refers to 'diffusion': the organization attempting to affect more people and cover a larger geographic area, whereas 'scaling deep' means further development in the own community (so taking geographic place as the main dimension of the scale of diffusion). 'Scaling up' is reserved for when "*an organization aims to affect everybody who is in need of the social innovation they offer, or to address the larger institutional roots of a problem* (ibid.)". However, social innovation studies do not address constraints on upscaling explicitly.

Transport scholars discuss how constraints on upscaling (from sustainable mobility experiments) can follow from the established urban context in which a mobility project takes place [20]. They explain how experts have importantly shaped the discourse and the associated conceptualization of transport problems and solutions among policymakers, researchers and lobby organizations over the past decades.

This expert-shaped way of thinking is reflected in established procedures and governance structures, and prohibits radical change in mobility governance in at least two ways (ibid.). First, despite experiments with bottom-up and participatory approaches, the governance of mobility systems remains strongly driven by technical expertise, involving only a subset of stakeholders and organized in a top-down manner. Second, the expert-driven tendency toward specialization and compartmentalization of mobility governance blocks the implementation of more coordinated and holistic approaches in real-world planning practice.

The idea that the compartmentalization of responsibilities represents a significant challenge to mobility governance is far from new [21–23] but becomes all the more problematic in those occasions where a wider range of stakeholders is involved in mobility governance. Banister et al. [20] conclude that "*it is not surprising that such fragmented institutional arrangements frequently produce public policy agendas lacking a clear direction (i.e., ineffectual, piecemeal, and convoluted policies), with overreliance on technical expertise, powerful pro-growth lobbies, and continued carbon lock-in*". In other words, their analysis expounds how the established transport planning context (also at an urban level) is at odds with the nature of experimentation (learning, evolutionary), hence constraining upscaling (from sustainable mobility experiments).

In the field of policy studies, Vreugdenhil et al. [24] discuss constraints on the effectiveness of pilot projects which can bear similarity with urban experiments. A key constraint is *limited representativeness*, which implies that the design, conditions and results of pilot projects are of only limited applicability to new projects and therefore the usefulness of the pilot projects in new situations is subject to doubt. Scaling up from pilot project conditions implies that the complexity of the problem increases (e.g., [25,26]). This constraint also points to the close intertwinement of upscaling and social inclusion: by including only a very particular set of actors in the development of an innovation, its representativeness and potential of using the outcomes of this project in new situations declines.

Literature of social inclusion also points to the importance of the local context, since various local factors—for example the quality of and access to infrastructure—can influence the extent to which individuals are exposed to risks and ultimately socially excluded [27]. It should thus be ensured that a diverse group of actors is involved in setting up and realizing local experiments. A threat of not working with a diverse group of actors at the design stage (e.g., working with the 'usual suspects') is that it tends to reproduce existing roles and power structures within the project. This represents a huge missed learning opportunity because urban experiments in particular can be an opportunity through which diverse sets of partners can renegotiate their roles in urban change [28], which may in some cases be a pre-requisite for upscaling.

Geographic work on the 'politics of scale' has extensively investigated the ways in which particular actor constellations (social movements, citizen initiatives, neighborhood organizations, environmental groups, etc.) have tried to strategically manipulate and change scalar relations [29]. Work inspired by Neil Smith's comments on 'scale jumping' [30] has investigated how social groups move to higher levels of organization in order to realize their interests. Interesting empirical work has been done on the role of urban protest movements and how their 'local' success depends on linking up with actors both in other cities and on other scales. As Köhler and Wissen [31] highlight, it is "*this complex interplay between institutions and processes on different spatial scales which influences and provokes the search for new forms and scales of resistance*". In other words, constraints on upscaling may be anticipated by strategically 'jumping scales' and developing *spaces of engagement* [32] in order to impact and transform the local regime.

Finally, over the past 15 years, an interesting body of academic work emerged at the intersections of Science & Technology Studies (STS) and urban studies (see Reference [33] for an excellent review of this work). In this field of research, scholars have identified a number of explanations for the failure of new, emerging socio-technical urban assemblages to scale up However, the term upscaling itself is hardly used in this literature. The distinction between upscaling, growth and change is not explicitly made (as it is in the transition literature). Such assemblages can for instance fail to scale up because specific actors resist incorporation into the larger network. A related reason for failing to scale up is that key actors do not care enough about the new urban assemblage "*to make the whole network coherent and hold it in place*" [34].

Another explanation for the failure to scale up discussed in this combined STS and urban studies literature is the notion of urban obduracy [35]. Obduracy refers to the resistance to change of large, embedded urban socio-technical assemblages. Once urban infrastructure is in place, it can be hard to change it. As a result of obduracy, it may be difficult to scale up innovations from urban experiments, to foster new practices or achieve institutional change. Hommels (ibid.) identifies three types of urban obduracy that may hinder processes of upscaling: (1) the situation in which technological frames of key actors clash and compete to such an extent that a deadlock in the negotiations about urban innovation emerges; (2) the situation in which social and technical elements are so firmly integrated and embedded in an urban assemblage that changing one element meets with resistance towards the whole assemblage; (3) the situation in which longstanding (cultural and planning) traditions and imaginaries (embedded in the reasoning of key stakeholders) keep influencing current decisions in a way that prevents more radical changes from happening. In *Unbuilding Cities*, Hommels argues that in order to allow upscaling of urban socio-technical novelty in cities, these three forms of obduracy need to be overcome.

To conclude, in reviewing various fields of literature, we have taken stock of a number of contextual factors and processes that hinder upscaling. In the next section, we present a retrospective analysis of the mobility system in Maastricht in which these interrelated constraints in the socio-institutional context can be recognized.

3. Identifying Constraints on Upscaling

To identify constraints on upscaling sustainable mobility experiments in Maastricht's current mobility system, we reconstruct key moments in its recent history (based on [36]) (We refer to 'sustainable mobility' as more public transportation, more cycling and walking, fewer cars, more intermodality, including bicycle sharing or car sharing; see Banister [37]). By 1960 there were four main mobility practices: Cycling was the largest in terms of total passenger km, just slightly larger than car mobility, and there was also bus mobility and walking [38].

The 1960's are remembered as years of population growth and unprecedented economic prosperity in most of the countries in Western Europe. Likewise, this period is associated with a car ownership surge. In the Netherlands, after the period of austerity in the 1950's, the annual wage increased by approximately 6% [39]. The purchasing power of Dutch society increased and owning a car also became available to the labor class; a privilege only granted to the high and upper-middle urban classes before the war [40].

Faced with increased traffic and limited parking capacity, urban planners in the 1960's and 1970's implemented car-accommodating strategies. The municipality of Maastricht, in cooperation with other stakeholders, began a policy process for the construction of parking garages and (over-ground) facilities in the 1960's. The first parking garage in Maastricht, commissioned in 1971, was situated below the Vrijthof, the main city square that for a long time had served as an open-air public parking. At first, all parties involved were pleased with the results: there was increased parking capacity and the square was cleared of cars.

Underground parking strongly expanded after that. The clearest indicator is perhaps the number of underground garages and places: Between 1970 and 2007 ten (public) parking garages were built with about 3700 public spaces in total, thereby doubling the total capacity in the city center of Maastricht to about 7300 places. Whereas in 1960 cycling was still the main mobility practice in Maastricht in terms of total passenger km, by the end of the 1970's, cycling had reduced to about 20% [38]. As Stankovic et al. [36] explain in more detail, the expansion of underground parking entailed a growing alignment of the cultural values of historic squares, urban car use, expertise of urban planners, traffic experts and parking operators, parking and traffic policies and regulations, and underground parking infrastructures. Whereas squares had always been treated as 'available parking space', at the end of the 1960's squares became assumed to be clean (and in the case of the Vrijthof even as the 'common room'), while sufficient urban parking capacity was also expected.

Challenges regarding lack of urban planning expertise and financial capacity for underground parking facilities at the municipal government were addressed through an exchange with a more experienced city (Delft) and a private investor. The traffic circulation plan and parking policy were increasingly adapted to underground parking and expertise to develop underground garages at the municipality was built up. Because of the large financial investments—literally sunk in specific locations—the city government engaged in long-term contractual agreements with investors and parking operating firms (initially 50 years, and after renovation in 2002 another 30 years (also applied in other public parking garages). By the end of the 20th century all this had resulted in a tightly aligned and obdurate socio-technical ensemble around car use and parking.

Although at first, in the early 1970's, practically everyone was pleased with the results of underground parking, in the course of time negative effects of the policy also started to manifest themselves. Faced with increasing congestion, noise and air pollution of in and outbound traffic in the following decades, the city government began to question the appropriateness of the decision made three decades earlier. Alternatives, however, are difficult to realize, as the urban assemblage around car use and parking in the inner-city had become increasingly obdurate. This became especially clear during the debate in 2001, when the Vrijthof garage construction showed cracks and actions needed to be taken for safety reasons. By then its 500 parking spaces were seen as "*indispensable for the parking balance in the inner-city*" (ETIL/BRO report in Accessibility plan 2001 [41]). Moreover, the long-term contractual agreements with the garage operator would not even allow this (without buying off the contract for significant sums of money).

The same sense of inevitability echoed in the discussion of (the successful) Park + Ride Noord after 2013, offering cheap parking in combination with a bus or train trips for the last few urban miles. For many transport experts, Park and Ride (P + R) facilities are seen as an element of sustainable urban mobility strategies when combined with shifting parking capacity to the border of a city (i.e., car constraining measures). P + R Maastricht Noord (with 400 parking spots) was instrumental to skim off car growth in the city center, but was not a stepping stone to shift parking capacity from the center to the periphery. The success of P + R-Noord should be credited mostly to public-private partnership Maastricht-Bereikbaar that managed to implement a dedicated bus transit when Dutch Railways (NS) withdrew (at a late stage) their commitment to stop an intercity twice an hour at the P + R facility (because NS said it was not profitable for them), and Veolia, the regional bus operator, did not want to fund a bus line alone either. Upscaling P + R, in the sense of shifting parking capacity from center to periphery, had not been considered explicitly in the planning of the initiative, mainly because there was only political support for one facility, which was seen as one project.

Next to P + R, development of another sustainable mobility innovation, bicycle sharing, (indirectly) highlights constraints on upscaling sustainable mobility initiatives. Shared bicycles are offered in Maastricht (150 bikes at the central train station), but these are part of a national scheme, and therefore this example shows the influence of national actors and developments. The bike rental system, called OV-fiets, was introduced in 2002 at the main railway stations, initially as a joint pilot initiative of Fietsersbond (the national bicyclists' organization) and Prorail under the MOVE program (benefit from national subsidy). The NS was also contacted by the two parties, and was neutral towards the initiative.

After the scheme grew to about 400,000 trips a year, NS took over the system in 2008, which it saw as a means of controlling the cost of accommodating bicycles, but only after accepting conditions that it would invest in growth and introduce automatic hire facilities. OV-fiets was initially not happy with being taken-over by NS, because they feared NS would adapt OV-fiets to their own benefits, e.g., not expanding to bus-stations or even discontinuing the system if not profitable enough (as they did with a train-taxi initiative a few years earlier) [42]. The system continues to grow rapidly: From 480,000 trips in 2008, it has grown to 1 million in 2011 and 2.4 million in 2016 in The Netherlands.

Nevertheless, the fact that all bicycles are rented out on most days, also in Maastricht, shows that the potential for growth is much higher and that national level management of supply is not effective for the local city. This has been so obvious to the owner of the Bicycle Repair & Storage at the Maastricht central train station that he has started to rent out simple bicycles for 5 euro a day.

Our analysis of car mobility and parking highlight two major constraints on upscaling sustainable mobility innovations in Maastricht. First, an obdurate urban assemblage emerged around car use and parking in the inner-city. In addition to the physical presence of eight underground garages, offering more than half of the number of parking places, there is the majority political view that underground parking is essential for preserving the parking balance in the city and that the operational contracts of the garages (with Q-park), most running till 2032, do not even allow to change this. Traffic circulation plans are adapted to the operation of the garages. Visitors expect to be able to park in the center, shop owners like cars passing by their stores, and urban planners have built up the necessary knowledge around developing over- and underground parking. The operational contracts can be seen as a strong glue that hold the pieces of the urban (car) mobility regime together, resisting change of the whole socio-technical assemblage, and only allowing 'add-ons' that leave the rest in place (see Figure 1 for a schematic representation of the elements that contributed to the obduracy of the urban assemblage around car use and parking). Without fundamental changes in this assemblage, however, car alternatives will likely remain 'plan B' for most travelers, with regard to comparison of travel time.

Second, our analysis showed the fragmented nature of public transport mobility. On the one hand, public transport (PT) operators in Maastricht (train, bus, OV-fiets) are large national or even multi-national firms that are primarily focused on their own business, while they are on the other hand often indispensable for the success of sustainable (and typically intermodal) innovations. They focus on short term profitability, which intermodal initiatives usually do not deliver, and, when this applies, either terminate an initiative (e.g., train taxi by NS, a (national) mobility service initiative operated by NS that they abandoned after a few years because it was not profitable enough, or leave pioneering options to others altogether (P + R Noord, OV-fiets)). Although travelers are likely to benefit from more seamless mobility (when a high frequent affordable service is offered), the creation of systems of intermodality requires cooperation from various transport actors, none of whom is strongly inclined to invest in it—the most significant intermodal innovations were initiated by actors outside the regime. In many cases national or provincial funding was necessary to enable urban mobility initiatives.

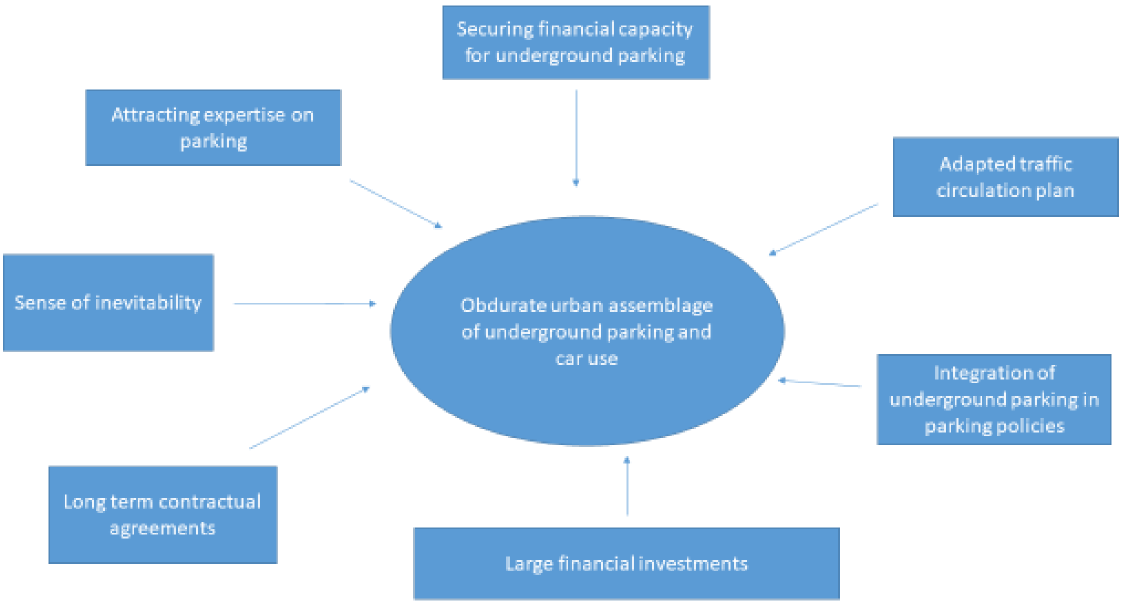

Figure 1. Schematic representation of the elements that contributed to the obduracy of the urban assemblage around car use and parking (in Maastricht).

4. Anticipating Constraints in the Zero Emission Bus Project (2012–2016)

Maastricht also offers an example case of an urban experiment that was relatively successful in anticipating constraints on upscaling. Recently a pilot project on electric bus mobility was organized in Maastricht in the form of one electric bus serving one particular line (for about a year, March 2015–Summer 2016) referred to as the Zero Emission Bus (ZEB) project. It was initiated by a regional foundation that believed in the public value of electric bus mobility and aimed to introduce it in Maastricht and expand it throughout the province (Limburg). More than only a test of technical functioning of an electric bus, the project aimed at learning how the electric bus would fit the schedule of operation (of Veolia), which relates to questions of to what extent the schedule would need to be adapted in the shift from diesel to electric mobility because of the shorter range of the latter, how many extra buses would be needed, when and where recharging would be most economical, what the new recharging infrastructure would look like, and what that would mean in terms of overall operational and infrastructural cost (and start a discussion who would need to bear these). Also, it included a question regarding what the implications would be for the tendering process for public transport by the provincial government (previously done every 10 years).

What were constraints on upscaling? First, there was a well-established practice of diesel bus mobility in Maastricht (and Limburg). The well-known cost structure of diesel buses, the concession requirements that were designed to optimize punctuality and minimize cost, diesel technology being well-known in terms of maintenance and performance characteristics, with no need of refueling (and associated infrastructure) during operation, together formed the main pieces of this fairly obdurate socio-technical assemblage. This is also reflected in the fact that dozens of experiments with electric and hydrogen buses across Europe from the 1990's onwards did not succeed to expand anywhere to a large extent. Second, bus operators compete sharply to win concessions from the provincial government. Price and punctuality are key indicators, the latter including penalty mechanisms in case of delays. This implies that these actors (i.e., different bus operators, the province) are fairly distant or even competitive to one another, entailing a level of compartmentalization and institutional fragmentation.

More specifically, there were a number of interrelated constraints. First, there was a financial-economic constraint. All interviewed stakeholders agreed that the main challenge to upscaling electric buses is a financial one: They are more expensive to purchase (about twice the price of diesels) and investments in a new recharging infrastructure are necessary. The municipality expressed the concern that if extra cost would be transferred to higher ticket prices, this would discourage urban public transportation. It argued that the 'other parties' should bear the extra cost. The operator and manufacturer agreed with this, but argued that the government as the concession provider should increase the importance of emission reduction compared to price stability and punctuality in the concession requirements.

This relates to the second constraint: Concession constraints. All three interviewees representing public transport operators showed considerable concern in relation to the uncertainty, duration and flexibility of the concessions. The financial investments are considerable and rather risky in light of the fact that concessions were generally covering a time span of 10 years. Secondly, the tight and inflexible performance requirement of concessions (including penalty mechanisms in case of delays) are not helpful for the introduction of a new technology which implies uncertainties in driving and charging times. For the province, however, tight performance requirements cannot be compromised (because passengers demand flawless services, they argue). These are political trade-offs between punctuality, price and emissions.

These uncertainties relate to another (third) constraint: Technological uncertainties. The shorter range of the electric buses obviously has an impact on the bus timetables, but it is unclear to what extent. How will the batteries operate in the more hilly areas, what about the available power to make a detour in case of road closures? Also, current time tables are so optimized that there is no time for hours of recharging. Other, more secondary, technical uncertainties relate to maintenance and life time of the batteries. Operator and manufacturer did not agree on who should bear the risk of these. Fourth and finally, there are constraints on available public space for recharging infrastructure. The municipality raised questions regarding additional structures needed in the city, and the effect of these structures on the quality of public space. Should it be one larger charging station or various smaller charging points? (See Table 1 for a summary of the constraints on upscaling we identified in this case.)

Table 1. Constraints on upscaling the E-bus.

Constraints Identified in Case Study of E-Bus
- Established practice of diesel bus mobility embedded in financial investments in infrastructure supporting diesel bus
- Adherence to established concession agreements around diesel bus and uncertainty about new concession agreements
- Technical uncertainties related to the E-bus and different visions of the merits of innovation
- Worries about available public space for recharging facilities

The pilot-project was part of a multi-stakeholder initiative aiming at a shift to electric bus mobility by 2025. After the pilot-project, the parties agreed that by 2019, there should be 30 to 35 ZEBs in Maastricht and by 2025, the Province of Limburg intends to have 250 ZEBs in operation (this means all buses). Although only numbers of buses are mentioned as (upscaling) target, it implies that electric bus mobility will increasingly be integrated in all sorts of public transport practices (scheduling, refueling, tendering etc.). The key stakeholders in the project were the municipal and provincial government (the latter being the concession provider of public transportation in the whole of Limburg), the former and successive public transport operators (Veolia and Arriva) and a bus manufacturer (VDL).

Did the project leadership anticipate upscaling of the innovation? Yes, because the project in Maastricht was part of a multi-stakeholder initiative that included a vision to shift to electric bus mobility by 2025, all of the constraints on upscaling discussed above were explicitly addressed and discussed in a series of meetings to anticipate and explore possible solutions. This resulted in the following lessons:

- “*The due renewal of concessions are the real trigger for the Province of Limburg to think about how to make a full-fledged ZEB plan become reality*” (interview with the province).
- The concession period should be lengthened to (at least) 15 years instead of 10 years (which was the length of the previous concession). This could bring the cost of electric bus mobility towards the level of diesel bus mobility (interview with Veolia).
- The bus operator needs some extra buses that can be used when electric buses are recharging or experience other problems (interview with Veolia).
- Arriva stressed the importance of cooperation and mutual support between the private and public sector: “*At this moment, we need each other*” (interview with Arriva).
- Veolia learned the need for cooperating with others within the initiative: ”*it is helpful because it gathers all stakeholders together to obtain and share experience of this growing business, instead of conducting separate projects*”. Veolia’s representative claimed that “*you need all kinds of parties in the discussion. And every party is really concerned. That is why the Zero Emission Bus Foundation was very helpful as a sort of mediator to get all parties together and then go on with the discussion. And at the end we all sit together to get experience on this business model. Otherwise, everybody is starting with ‘I only want to get involved if I get my cost’s back)’*” (interview with Veolia).
- A technical lesson learned was that it’s very important that ”*our bus can drive with one battery for more than 300 km or more than 350 km*” (interview with Veolia). (The E-bus used had a range of 200 km.)
- VDL, the E-bus manufacturer, expressed that they “*obtained useful experience while working together on the ZEB project*”, which helps to better estimate the risks of electric bus mobility. ‘”*If you know something is not a risk, then you don’t need to price it. Then you’re cheaper than your competitor*” (interview with VDL).
- The Municipality learned that they would like more studies on air quality improvement of electric bus mobility (Interview with the Municipality).

The project leadership (i.e., the board of the foundation ZEB) was especially interested in the development of a more integrative ‘Total Cost of Ownership’ (TCO) model, which made connections between the business models and roles of the various stakeholders to focus on the societal cost/revenue structure of electric bus mobility. This has been delivered. The TCO-model is available via a free web-application for stakeholders in the PT-chain, supported through the (established) mobility knowledge platform CROW. So although the ZEB will be discontinued as an initiative, the availability of the findings is secured.

The process that led to the public-private coalition (in the form of a Foundation for ‘Zero Emission Bus transport’) was unique in the sense that previously these parties would have a more distant or even competitive relation to each other (because of performance contracts or competition in tenders). This time they accepted the invitation of the ZEB foundation to join the visioning process and experiment and thus engage in an open dialogue on what would be needed to achieve a socio-technical shift to electric bus mobility, what each partner would need to change to make this happen, and what they would need to learn Probably, the fact that the province (who, as client, plays a key role in the concession procedure) joined the initiative, triggered other parties to follow. The members of the coalition would need to share the knowledge obtained, whilst accepting to make a small investment and risk of failure.

The Foundation was set up at a regional level, with connections to the ministry and especially two provinces, which teamed up with the large transport operators (in that area) and a Dutch electric bus manufacturer from the region. Together these parties set up two local experiments, one in Eindhoven and one in Maastricht. Lessons learnt at the local level were shared with the regional level (i.e., the level of two provinces).

The ZEB initiative was mainly executed by the three key stakeholders (authorities, public transport operators and manufacturer), but the steering group included a broader set of representatives from 'knowledge, financial and branch organizations', although it was not transparent how they were chosen. The local project in Maastricht mainly was a collaboration between the three types of stakeholders mentioned above (i.e., bus operators, manufacturer and authorities). Other stakeholders, such as bus drivers, passengers, and cyclists, were only marginally involved and consulted [43]. Figure 2 shows an overview of the various stages in the upscaling trajectory of the E-bus.

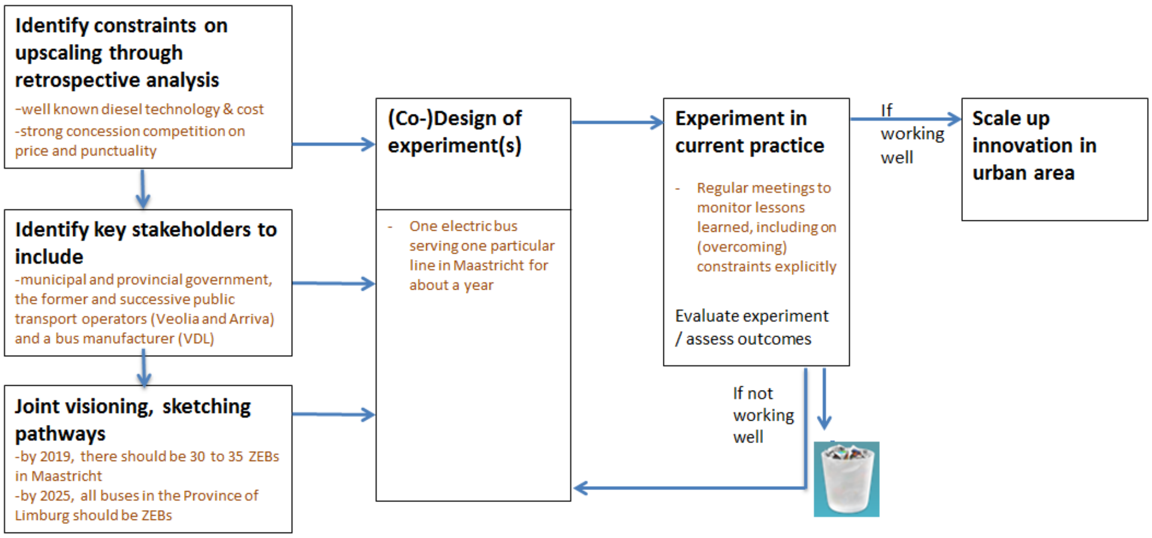

Figure 2. Upscaling trajectory of the E-bus.

5. Discussion: Anticipating Constraints on Upscaling

In this paper, by reviewing a range of scientific fields, we have taken stock of the factors, processes or structures in the socio-institutional context that hinder upscaling (Section 2) with the ultimate aim of advancing insights on how to anticipate constraints more effectively in urban experiments. Table 2 summarizes the findings in four types of constraints on upscaling, and also several ways to anticipate upscaling that were discussed in the literature.

The case study of an E-bus project in Maastricht helped to discuss ways of anticipating constraints on upscaling in a less abstract way. The project faced a combination of a fairly obdurate socio-technical assemblage around diesel bus mobility, and a group of fairly distant actors. It shows that much of the success of the local experiment depends not only on local actor relations, but local actors can 'jump scales' and engage with actors on higher scale levels shifting the local power balance in favor of the local experiment at the expense of vested interests. We saw the local government effectively teaming up with the provincial authority when put together in one coalition with international PT operators by a Foundation that believed in the public value of E-mobility. Also, collaborative development of a vision of electric bus mobility (that formulated, and thus at least suggested, their common interest) in this group of actors that usually is more distant or even competitive to one another, greatly helped to address the compartmentalization and institutional fragmentation of urban mobility governance.

More generally, strategies to reduce or cope with *fragmented established institutional arrangements* include the inclusion of representatives of the various institutional units and the inclusion of future users. In this first case, actors from established institutions are especially important, and need to become ambassadors of the innovation to position ('anchor') it amidst the established institutional structures—generally a complicated puzzle. What also helps is doing more experiments: Multiple successful pilots may well be needed to convince urban planners (and other future users).

The E-bus case also reflects a third type of constraint: Key actors such as provincial governments and the public transport companies had different views on the risks involved in investing in an electric bus system. The province in this case demanded a flawless service for bus passengers and considered the electric bus as a challenge in that respect. Private parties such as the public transport companies were initially put off by the financial risks of the electric bus system. These opposing views and priorities could easily have resulted in a complicated and slow negotiation process and could have limited the chances of successful upscaling. But, again, the stakeholders were placed together in a coalition by a Foundation that believed in the public value of E-mobility and the coalition addressed and negotiated all relevant doubts and concerns. They managed to overcome the differences in view points and developed a shared vision of electric bus mobility that highlighted their common interests.

More generally, the conflicting views on merits of the innovation (constraint #3, see Table 2) and the issue of ’obdurate’ urban assemblage (constraint #2) may be addressed by developing visions in a participatory way. This is a well-known element in SNM and TM literature. In cases joint visioning is not feasible because of sensitivities, it may be instrumental to deliberately frame the topic of the experiment in such a way to avoid immediate dismissal (e.g. as an air quality issue, instead of a mobility issue (see [44]). Further, regarding constraint #2, literature on behavioral change importantly remarks that upscaling is not just about local experiments ‘being picked up’ and supported by local governments, it is also about embedding the innovative activities in the daily practices of existing communities, such as schools or people working in the same company [45]. Fostering community engagement with collective ‘sense making’ and trials moves beyond the focus on individual behavioral change and is more likely to lead to structural behavioral change.

Table 2. Typical of constraints on upscaling and ways to anticipate.

Typical Constraints on Upscaling	Possible Ways to Anticipate Upscaling
1. Fragmented established institutional arrangements with expert-driven way of thinking and powerful lobbies [20,35] (E-bus mobility case)	- Highlight interrelatedness and organize (hence: invite) collaboration between institutional/departmental units (E-bus mobility case) - Include future users/relevant stakeholders (incl. policymakers) (E-bus mobility case) - Carry out multiple (successful) pilots to convince urban planners (and other future users) [24]
2. ‘Obdurate’ urban assemblage (infrastructural/technical, legal, financial; spatial, social etc.*)* [35] (E-bus mobility case)	- Scale jumping [30] - Develop vision in participatory way (TM literature and [46]) - Focus on behavioral measures that trigger structural change [45] (E-bus mobility case)
3. No consensus on the merits of the outcomes of the innovation experiment beyond those involved [34,35]	- Develop vision in participatory way (TM literature; [46]) (E-bus mobility case) - Frame the experiment in a way to avoid immediate dismissal [44]
4. Limited representativeness: results of innovation experiment are only limited applicable to large scale [24]	- Make explicit what is contextual and what is not [24] - Include future users (ibid) - Include a diverse group of relevant stakeholders [47]

Finally, strategies to reduce or cope with *Limited representativeness* (constraint #4 that we did not recognize in this case but may be significant in others) include the provision of explanations about the contextual dependency of knowledge [24]. Additionally, the inclusion of future users through open governance styles and co-financing arrangements increases their commitment. At the same time, the innovation can be tailor-made for further implementation, because users are involved in the design process. The inclusion of a diverse group of relevant stakeholders is useful to reduce the risk of reproducing existing power structures within the experiment and the risk of neglecting effects outside the locality of the project [27]. In terms of user involvement, the E-bus pilot did not perform very well. The bus drivers were just consulted through a questionnaire and passengers, cyclists, residents and tourists were interviewed only at the end of the pilot [43]. Although their attitudes towards E-bus mobility were generally very positive, suggesting broad societal support for upscaling, their views and contributions could have resulted in even better ideas on how to upscale E-bus mobility successfully.

6. Conclusions and Final Remarks

This paper started with the observation that in urban experiments, explicit attention for and anticipation of constraints in the experiment's larger socio-institutional context are generally lacking. Both SNM and TM hold the promise of supporting upscaling from experiments, but largely neglect how the upscaling of innovations interferes with its environment. In this paper we started to address this gap.

The paper offered a further conceptual analysis of constraints on upscaling with empirical examples, elaborating on how upscaling can be more effective when contextual constraints are explicitly identified in retrospective systems analysis, so experiments can be designed to better anticipate these. We offered a discussion of four types of constraints and ways of anticipating upscaling, which we made concrete for the case of urban mobility in Maastricht. We showed that upscaling (successful) innovations from urban experiments is not a matter of simply 'rolling out' (vehicles, smart app's, chipcards etc.) across the city and beyond, but involves changes in various components of the larger socio-technical system such as actor perspectives, capabilities (i.e., informal institutions), and regulation (i.e., formal institutions), in addition to the technological hardware (i.e., artifacts or infrastructure etc.).

The proposition that effective upscaling can be supported by the anticipation of the constraints in the design of urban experiments with socio-technical innovations was already hinted at by Van den Bosch [13]. This current paper offers an elaboration of this point, which is theoretically grounded in a review of relevant fields of literature and empirically in a retrospective analysis of the urban mobility system of Maastricht and a pilot on E-bus mobility in the same city. This both strengthens our confidence in these guidelines presented in Table 2, and provides a handle on how to operationalize them. The empirical examples showed how upscaling can be made more effective by (1) identifying the specific constraints on upscaling for a particular type of innovation in retrospective systems analysis, and (2) anticipating constraints by addressing them in urban experiments explicitly, e.g., through formulating joint learning goals. At the same time, there is much more work to be done. Which constraints on upscaling are the major ones is to a significant extent case or city specific and thus needs to be identified through a specific analysis of each local situation. More cases beyond Maastricht need to be assessed and compared in order to test the guidelines in our table in a range of different areas and cases. Meta-studies may deliver the identification of various types of upscaling, or types of urban transition pathways, which possibly could lead to further specification of guidelines for particular types of upscaling or innovations.

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Appendix A. Interviews

Dates of interviews.

- Veolia Transdev Limburg, 14/4/2016.
- Veolia Transdev Brabant, 14/4/2016.
- VDL, 21/4/2016.
- Municipality of Maastricht, 21/4/2016.

- Municipality of Maastricht, 21/4/2016.
- Province of Limburg, 13/5/2016.
- Arriva Netherlands, 27/5/2016.
- Maastricht Bereikbaar, 8/12/16 and 31/01/17.
- Municipality of Maastricht, 16/01/17.
- Arriva Netherlands, 16/01/17.
- Provincie Limburg, 24/01/17.

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