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Smaller is smarter: A case for small to medium-sized smart cities

Sławomir Nowaczyk [a,*], Andrea Resmini [a], Vicky Long [a], Vaike Fors [a], Martin Cooney [a], Eduardo K. Duarte [a], Sarah Pink [a,b], Eren Erdal Aksoy [a], Alexey Vinel [a] and Mark Dougherty [a]

[a] *Halmstad University, Sweden*
[b] *Monash University, Australia*

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Abstract. Smart Cities have been around as a concept for quite some time. However, most examples of Smart Cities (SCs) originate from megacities (MCs), despite the fact that most people live in Small and Medium-sized Cities (SMCs). This paper addresses the contextual setting for smart cities from the perspective of such small and medium-sized cities. It starts with an overview of the current trends in the research and development of SCs, highlighting the current bias and the challenges it brings. We follow with a few concrete examples of projects which introduced some form of "smartness" in the small and medium cities context, explaining what influence said context had and what specific effects did it lead to. Building on those experiences, we summarise the current understanding of Smart Cities, with a focus on its multi-faceted (e.g., smart economy, smart people, smart governance, smart mobility, smart environment and smart living) nature; we describe mainstream publications and highlight the bias towards large and very large cities (sometimes even subconscious); give examples of (often implicit) assumptions deriving from this bias; finally, we define the need of contextualising SCs also for small and medium-sized cities. The aim of this paper is to establish and strengthen the discourse on the need for SMCs perspective in Smart Cities literature. We hope to provide an initial formulation of the problem, mainly focusing on the unique needs and the specific requirements. We expect that the three example cases describing the effects of applying new solutions and studying SC on small and medium-sized cities, together with the lessons learnt from these experiences, will encourage more research to consider SMCs perspective. To this end, the current paper aims to justify the need for this under-studied perspective, as well as to propose interesting challenges faced by SMCs that can serve as initial directions of such research.

Keywords: Smart cities, small- and medium-sized cities

1. Introduction

The notion of "Smart Cities" (SCs) has many different definitions. The European Commission defines a smart city as "a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and business" [16]. Emphasis is placed on digital augmenting existing capabilities and on the concept itself having a reach that extends "beyond the use of digital technologies for better resource use and less emissions": the Commission not only establishes a direct connection between smart cities and the Digital

*Corresponding author. E-mail: slawomir.nowaczyk@hh.se.

Single Market,[1] and hence to sustainable socioeconomic development, but also between smart cities and general policy-making and governance issues, exemplified by “a more interactive and responsive city administration, safer public spaces and meeting the needs of an ageing population”.

In a recent program declaration for the Swedish Strategic Innovation Program (SIP) Viable Cities, the following was part of their view of the term (translated from Swedish): “The concept of “smart” refers to the necessary integration between socio-technical and natural systems that is necessary to exploit the opportunities that digitalisation brings to collaboration – to benefit people. It includes infrastructures, ecosystems, technologies, institutions and actors. “Smart” also means that information and communication technologies are used more for planning, decision-making, innovation and coordination. Behavioural factors as well as models and processes for governance, collaboration, financing and business models also have a significant impact.” There is no direct contradiction with the EU formulation, however, the focus is placed somewhat differently. We highlight this definition since it brings to the forefront important aspects that we agree with and, even though it does not consider the size explicitly, it is well-aligned with the key message of this paper.

The Smart Cities concept is inherently multifaceted and must be treated as such whenever studied, something that many research activities of today fail to account for and accomplish. Smart Cities are enabled by technology, but technology is not the central aspect. Following previous ideation [17], in this paper we discuss six key dimensions, namely the smart economy, smart people, smart governance, smart mobility, smart environment and smart living. However, in order to make the message clear and due to space considerations, we focus on some of them more than others. This does not necessarily reflect their true or objective importance, which will need to be analysed separately in the future, but rather the personal experiences of the authors and the narrative flow of this paper.

In recent years, the interest in Smart Cities research has been continuously increasing, and the technology progress continuously makes it more viable and economically justified [2]. This inaugural issue of the journal itself is a good example of such growth. Nevertheless, the focus of most of the work is on ultra-densely populated areas, in particular megacities (MCs). It is natural for such areas to attract the most attention, and to provide the most interesting study cases, at least superficially. Today, according to United Nations Population Division data, approximately 4.4 billion or 58% of the people live in urban areas. The urban population surpassed the rural population in 2007. According to Our World in Data,[2] however, only 24% of the world population live in agglomerations greater than one million people, i.e., large urban agglomerations. While this varies greatly by region, for example from 19% in the European Union through 46% in the United States up to 64% in Japan, it is still clear that the MCs are the minority and that Small and Medium-sized Cities (SMCs) deserve at least the same level of attention in the context of Smart Cities research. This paper intends to bring attention to this issue, and challenge the scientific community working on SCs to begin explicitly considering the SMC perspective more often. In the context of this work we are purposefully vague on the exact definition of SMCs, since we believe it is the intuitive understanding of the concept that is important at this stage. We especially do not consider any limits on how small a community of interest may be, and sometimes talk about “smart villages” as examples.

Highlighting this bias favouring large and very large cities is even more important since part of this bias has become embedded in the conversation around SC for historical reasons. Early and rather famous examples which have been long in the public eye favoured a “blank slate” site approach to location and were developed in close coordination with tech companies such as Cisco, Microsoft, or IBM. This meant huge investments, which in themselves pushed for larger rather than smaller interventions, but also the possibility to design both the built environment and the technological environment unencumbered by any need to fit into an existing, and complex, urban, social, and technical fabric. In this work we consciously refrain from formulating a strict definition of what exactly is considered an SMC and what is not; we believe such a statement, at this stage, would be premature, since the details will very likely depend on the specific challenge being addressed; they might be categorised according to certain distinct and unique characteristics, and perhaps differentiated based on additional context.

[1] The Digital Single Market proposed in 2015 is a political priority of the European Commission that seeks to move from the EU’s many national digital markets to a single one by improving access to a fair, reliable, and affordable digital environment while maximising growth potential.

[2] Ritchie, H. and Roser, M. (2018). Urbanization. Our World in Data. https://ourworldindata.org/urbanization.

This is for example the case of the Songdo International Business District in South Korea, built for a population of 500 000 with the help of Cisco on land reclaimed from the Yellow Sea [27], or of PlanIT Valley in Portugal, built for 225 000 and planned to run on its own central Urban Operating System [29]. This meant huge investments focusing on small areas, for relatively large populations, with the idea that the generic nature of the intervention could translate to smart city blueprints that could then be also reapplied mostly as-is to even larger cities [19].

The smart cities that we often read about have been "explicitly positioned as laboratories in which the praxis of the smart city can be worked out, with the resulting techniques to be applied just about anywhere, as scale-free, generic, turnkey 'solutions'" [19]. Such an approach clearly does not fit the diversified, stratified, and multifaceted nature of SMCs.

The ultimate goal of this paper is to encourage more research that considers the perspective of small and medium-sized cities, preferably explicitly, but at least implicitly. This entails two key aspects. First, we intend to justify the need for this perspective, in terms of both the needed effects and the fact that "one size does not fit all." We will do this primarily by highlighting several relevant differences between MCs and SMCs, and discussing how those differences affect research, development and implementation of SC solutions. Second, we are proposing a number of interesting directions to get started with such research, by highlighting the challenges faced by SMCs, especially the unique ones.

The rest of this paper is organised as follows. In the next section we discuss the background concepts of Smart Cities, highlight some of the current challenges in the field, and argue that SMC perspective can be beneficial. We follow with examples of case studies where the differences between SMCs and MCs are explicitly discussed in concrete contexts. Finally, we summarise our findings and provide discussion on future steps.

2. Background and problem definition

The very concept of Smart Cities arises from the dissatisfaction with the current design and operation of most, if not all, urban areas. Despite their many strengths, the cities of today also give rise to many serious problems. On the one hand, there is a push from new technologies that promise to be the "silver bullet" and solve all these issues. On the other hand, urban planning, architecture, and urban anthropology have been generally very critical of the technological push, and not the technological epiphany [51], that has so far driven smart city development.

In a talk given in Brussels for the European Commission High Level Group on Smart Cities, Dutch architect Rem Koolhaas [24] offered a scathing analysis. Koolhaas is particularly concerned with how what he calls the "smart city movement", a "very crowded field", casts itself in a saviour position by identifying "a multiplicity of disasters which they can avert" by means of the smart city, where "(a)pocalyptic scenarios are managed and mitigated by sensor-based solutions". He connects this approach to simplification, "(s)mart cities rhetoric relies on slogans", and to commercialization: "(e)verything saves millions, no matter how negligible the problem, simply because of the scale of the system that will be monitored". The result is that "(t)he citizens the smart city claims to serve are treated like infants[,] (...) fed cute icons of urban life, integrated with harmless devices, cohering into pleasant diagrams in which citizens and business are surrounded by more and more circles of service that create bubbles of control". Koolhaas suggests that "(s)mart cities and politics have been diverging, growing in separate worlds": they need to converge for this "confluence of rhetoric – the 'smart city', the 'creative class', and 'innovation'" to be transformed not into control but rather into real improvements. The discussion on citizen engagement in smart cities continued over the years, cf [38].

2.1. *Smart cities rhetoric*

Krivý [25] considers the smart city "a hegemonic notion of urban governance" that has supplanted planning and summarises three main arguments from literature against the smart city: its conceptual incompatibility with the informal character of a city; its "subject(ing) the city to corporate power"; and the fact that "it reproduces social and urban inequalities".

Starting from the perspective of geography and drawing on critical planning theory and actor-network theory, [48] describe the smart city phenomenon as "corporate storytelling". Focusing on IBM's registration of the trademark "smarter cities" in 2011, following their launch of their smarter city campaign in 2009 (now part of IBM's "smarter planet" initiatives), and building on Mandelbaum's conceptualisation of planning as "telling stories to build communities" [30], they describe the concept of smart city as a new "form of storytelling in the world of planning" that specifically mobilises and recycles two older tropes that they identify as the city as a "system of systems", and a "Utopian discourse exposing urban pathologies and their cure" [48].

Greenfield [19] identifies in "the idea of an instrumented environment capable of responding in real time to its users' needs" and in "the use of empirical data to guide the planned allocation of public resources" the two conceptual threads at the foundations of the modern idea of a smart city, but stresses how its notion "in its full contemporary form appears to have originated within (...) businesses, rather than with any party, group or individual recognised for their contributions to the theory or practice of urban planning." Greenfield also makes a distinction between "canonical smart cities", such as Songdo, Masdar, PlanIT Valley, and more recent smart city efforts characterised by "broader and far more consequential drive to retrofit networked information technologies into existing urban places". These use the same technologies, techniques and practices and are also built on "the notion that a usefully synthetic awareness of urban processes can be garnered from sensing devices strewn throughout the built environment", but do not profit from digital devices being a transformative element of the design of the urban fabric from the beginning [21]. They are either "bolt-ons" or a re-purpose of already-installed and available hardware.

Kitchin [23] considers problematic that "much of the writing and rhetoric about smart cities seeks to appear non-ideological, commonsensical and pragmatic", while critical scholarship, even if it is still "making vital conceptual and political interventions", presents gaps and shortcomings that "inhibit making sense of and refashioning the smart city agenda". According to Kitchin, these shortcomings are "the lack of detailed genealogies of the concept and initiatives, the use of canonical examples and one-size fits all narratives, an absence of in depth empirical case studies of specific smart city initiatives and comparative research that contrasts smart city developments in different locales and weak collaborative engagement with various stakeholders".

Colding and Barthel [7] provide "reflections that need to forgo any wider-scale implementation of the Smart City-model with the goal to enhance urban sustainability". They criticise current research and literature dealing with smart cities, maintaining that it "must better include analysis around social sustainability issues for city dwellers. Focus here should start on health issues and more critical analysis about whom the Smart City is for. Also, the literature must address issues of resilience and cybersecurity, including how Smart City solutions may affect the autonomy of urban governance, personal integrity and how it may affect the resilience of infrastructures that provide inhabitants with basic needs, such as food, energy and water security. A third major gap in this literature is how smart city developments may change human-nature relations".

2.2. Missing aspects

The above discussion clearly highlights several important aspects that are challenging and often missing, or at least insufficiently addressed, by the majority of contemporary SC research. While not all of these issues are directly connected with the size of the city, we will argue that at least some of them are well-aligned with the main message of this paper: the need for broadening the SC research perspective. In particular, an important direction for the future are improvements in the area of concrete and tangible benefits that come from the SC solutions. The ones driven (solely or primarily) by technology development tend to be the biggest offenders in this aspect. Unfortunately, "rhetoric [that] relies on slogans," lack of "real improvements," and solutions centred around the notion that gains will emerge "no matter how negligible the problem" are all, unfortunately, common today. We argue that, while considering the SMCs perspective to a larger degree will of course not magically solve all these issues, it is an important step forward, because at a smaller scale and complexity it is harder to obfuscate lack of true relevance.

The most clear of these examples is possibly Koolhaas' claim that "everything saves millions, no matter how negligible the problem, simply because of the scale of the system that will be monitored." This puts the size of the city directly in focus, and can be seen as a clear argument that there is a need for more diversity in the SC studies. There is a clear issue with today's overuse "of canonical examples and one-size fits all narratives," and in this paper we argue that bringing SMCs into the forefront of the research is an important future step for the SC community.

Another clear example of how the MCs focus turns out to be problematic is the "weak collaborative engagement with various stakeholders" aspect [23]. In a metropolis, the complex organisational structure and the sheer number of stakeholders makes it virtually impossible for any given project or initiative to ascertain deep enough buy-in from all of them. In a smaller city, however, it is significantly more feasible, just as is the "analysis around social sustainability issues for city dwellers" [7].

2.3. Paper rationale

In summary, given the critique above, there is a clear mismatch between the real needs of "the people" and much of today's development within the Smart Cities field. This is the key rationale for writing this paper – and it aligns very well with the message we want to convey in this text. We understand that the issues being raised are very difficult to address, and we by no means claim to offer the final and complete solutions. Nevertheless, the following paragraphs provide the justification why research in SMCs is important, and argue that several of the concepts that are being criticised, like "one size fits all" or the lack of concreteness of the solutions provided, can naturally be addressed easier within that scope [15].

In order to make the argument convincing, first, we define the need of contextualising it for small and medium-sized cities. It is natural to do in terms of the population living there, especially considering recent trends, as well as the sustainability aspects. The statistics demonstrating that the majority of urban population lives in small and medium-sized cities have already been mentioned in the Introduction, establishing that SMCs are important and SC development cannot exclusively concern megacities. The current approach is, ultimately, overly limiting, first of all in the societal needs aspect. It is not enough to solve the existing issues for huge cities only. In reality, a large percentage of the human population is living, and will continue to live, in medium density populated areas. From many perspectives, this leads to higher quality of life. It is well-established that neither an extremely high nor low population density is environmentally sustainable, with valid arguments for both solutions weighing in differently in different contexts [6,35,46], and a more balanced setup is needed.

Second, we explain the need to explicitly consider SMCs when developing the Smart City solutions; in other words, what is unique about them, compared to MCs? Why cannot the developments in the largest metropolis be directly applied across the board, so that the SMCs just use the same approaches as the bigger cities? In particular, the "big cities" perspective leads to "one size fits all" proposals, however, this is inherently flawed. While the argument can be made on universal solutions applicable to many MCs, due to their scale, the infeasibility of such propositions for the diverse, smaller communities is apparent. Instead, it is absolutely necessary to take advantage of specific, local conditions, and the unique requirements and challenges that come from being a SMC. Small and medium-sized cities normally do not have the same economic strength, knowledge and capabilities, which requires specific investigations and solutions. Smart cities as large, top-down efforts require sizeable investments, and have been criticised for unbalancing the relationships between technology (providers) and the needs of the communities they are supposed to serve. A network or federation of smaller initiatives presents a number of possible leverage points that, at least in theory, could offer a better fit for many parts of the world, especially those with a more diffusive model of urban development (plenty of smaller centres over a rather largish territory) and allow for more citizen-centric developments.

This paper aims to increase awareness of these issues, primarily by providing an initial formulation of the problem. Our main focus is on highlighting the needs and giving examples of specific requirements from small and medium-sized cities. We hope to initiate the discourse on the need for the SMC perspective in Smart Cities literature. The ultimate goal is to encourage more research that explicitly considers the perspective of small and medium-sized cities. The key result we intend to achieve is to stimulate future research in the SC area to become more diverse. This should be done partially by convincing the existing research tracks to become more inclusive, but also, by opening completely new lines of research, demonstrating that SMCs have inherently different needs from MCs and that they deserve to become first-class citizens.

2.4. Experiences from research in SMC context

The origin of this paper builds upon authors' own experiences regarding SC development in SMCs, as it resonates very well with the regional position that Halmstad University has. It also complements most current research and examples on smart cities that relate to megacities although most people live in small and medium-sized cities.

Compared to big cities and megacities, SMCs normally have their own specific conditions to consider, such as less economic strength, knowledge and capabilities, which requires specific investigations and solutions.

In order to highlight the multi-faceted nature of the current SCs research, and put it in the perspective of the differences between MCs and SMCs, we present below examples of current trends centred around the six core dimensions of Smart Cities [17]. Within each one we discuss examples of topics that, while far from comprehensive, give an overview of the recent directions in the respective fields. In all the cases our selection is necessarily done somewhat arbitrarily, while subjectively trying to maintain the coverage of key topics. Clearly, the complete body of work is far too large to be analysed comprehensively – in 2020 alone there were almost two thousand articles published with the "smart cities" phrase in the title (according to Scopus search).

The *smart economy* dimension focuses on entrepreneurship and innovation, as well as development of new, more sustainable business models. It particularly involves creation and maintenance of business and innovation ecosystems, where many different actors interact in increasingly complex ways. The key is ICT-enabled and advanced manufacturing, as well as a new way of delivery of services. The *smart people* dimension focuses on lifelong learning and continuously increasing human resources and capacity management. The primary goal is building a more inclusive society that improves creativity and fosters innovation. The *smart governance* addresses open and participatory platforms supporting the collaboration between the government and the stakeholders, in particular the citizens. The key aspect is increased transparency, enabled by ICT and e-government in participatory decision-making and co-created e-services. The *smart mobility* dimension focuses on transportation infrastructure, in particular the integration of different systems and modalities, primarily using ICT. The key concept is mobility as a service and developing more sustainable travel behaviour, mainly enabled by intelligent vehicles and traffic management. The *smart environment* primarily concerns the energy sector and attractive natural conditions. With the main goals of reduced rate of pollution, environmental protection and sustainable resources management, different solutions are targeting the circular economy. Finally, the *smart living* dimension aims for the higher quality of life of the residents. It includes aspects of, for example, good quality housing, as well as healthy and safe living.

Given that the point of this paper is to encourage more research that addresses the needs of SMCs, and in the light of the challenges discussed above, we now present the key findings from three concrete example cases where SMC perspectives have been successfully applied, while highlighting the benefits of doing so. These examples, described in more detail in the next section, serve the purpose of supporting the claims put forward in this paper, providing credibility, as well as demonstrating the feasibility and soundness of the ideas.

3. Discussion and findings

3.1. The question of size

The question of size has long been discussed in sustainability studies, tracing back to Schumacher's landmark book "Small Is Beautiful: Economics as if People Mattered" [42], which discusses problems such as balancing economic growth with human needs and wants. Points relevant to the discussion on smart cities and communities include:

a) Scale should be considered when activities and (personal) engagement are concerned. "(T)he more active and intimate the activity, the smaller the number of people that can take part, the greater is the number of such relationship arrangements that need to be established": additionally, "certain things can only be taught in a very intimate circle" [42, pp. 70–71]. Pursuing scale only can result in diminished personal involvement. This relates also to the so-called Socretian bottleneck in teaching, as well as social loafing, Ringelmann effect, etc.
b) Inclusion becomes problematic when a city (or any other community) is too big. This creates a problem of "drop-outs", people who cannot find a place anywhere in society [42, p. 75], resulting in a "dual society" without inner cohesion. This is relevant to today's smart cities as long as the user's individual resources and capabilities are concerned.
c) The bigger a unit or organisation becomes, the more difficult it is to keep a human touch. "Human touch" here means that any member (of a unit) can act freely as a moral being, even if the moral impulses are against

existing structure, rules and regulations. This is relevant to smart cities as long as the citizens' feedback is concerned.

d) Scale also introduces concerns related to the growth of bureaucratic structures and burdens, often a product of excessive size and the increase in rules and regulations necessary to keep organisations functional. Smaller units require less formal structure, can often self-administer (self-balance, self-adjust, and self-cleanse), be more cost-effective, and more humane [42, p. 156], [43, p. 13]. This is relevant for smart cities as long as the whole-parts administration (in a system) is concerned.

To summarise, Schumacher introduces a citizen perspective into the conversation on smart cities: it is not mass production that matters. Smart cities may be viewed as interactive systems of systems, as services. Schumacher's emphasis on inclusiveness and sustainability is relevant for smart cities as long as the variety of needs, capabilities, access to resources, and participation of citizens remains relevant. Schumacher [42] also discusses what the ideal size of a city should be, placing the upper limit around a half million inhabitants, since "above such a size nothing is added to the virtue of the city". What "critical size" should be considered in the smart city context has yet to be thoroughly discussed in terms of features, functions and benefits offered to citizens. The degree of autonomy enjoyed by smart devices and ambient appliances is also an important factor to consider.

The question of size appears to be less debated in studies on the data-driven economy than it is in sustainability studies, with a number of researchers from various fields implicitly supporting a "the bigger the better" position:

a) The economics textbook message about returns to scale – at the supply side – is essentially related to the decreasing average cost: while the fixed cost part is set, the higher the volume of production the lower the cost per unit. Digital technologies are often treated as important enabling tools in this direction of pursuit (efficiency).
b) Debates on platform economies are often related to literature on two-sided markets [37] and on network externalities. The economies of scale here are in the form of network externalities, namely a return to scale at the demand side: the more customers, the more use, which in turn, generates more customers. Typical example is online multiple-player computer games: the more gamers, the more attractive the game, the more resources spent on the improvement of the game, the better the game, then even more gamers.
c) Debates on the sharing economy, on peer production, and on open innovation commonly address the importance of community in knowledge production [4,52,53]. Implicitly, this brings in a "threshold size" past which any such community would become less efficient in creating and sharing knowledge. What this threshold is has not been discussed at length, nor has the relationship between distributed, peer-based knowledge production and peer expertise. For example, open source software communities benefit from engaging professionals, rather than laypersons.
d) Debates in Machine Learning argue that scale of data is good, but not necessarily the exact scope and context, which leads to certain dangers of trying to port systems to contexts in which they will not work correctly. Machine learning is a statistical technique. The statistical estimation becomes more reliable when the size of the underlying datasets increases, and the variation of the datasets decreases [31].

In the context of smart cities, if the supply side (technology/services) is ever to meet the demand side, including or perhaps even focusing on small and medium-sized cities and communities is a necessity, for the following reasons:

a) by treating smart cities and communities as a service rather than a product, a Schumacher-ian [42] human touch is increasingly needed. The main difference between services and products lies in the former being instantiated at use. While both need a "human touch", smart communities are a system service, in which many aspects from health care (nursing) to waste management (garbage handling) intermingle. This, in turn – as argued above – motivates an equal importance of SMCs compared to megacities, given that the supply side of typical smart-city-based-services must match the same relevant demand side from human residents, regardless of the size. At a scale appropriate to the problem at hand it is often important to ensure a human touch, as well as effective operation. A human touch here is synonymous with (the degree of) inclusiveness (of users);
b) there is no reason to assume that users in small and medium-sized cities/communities are less or more sophisticated than those in megacities. The sophistication of the demand (users), especially changing over time, has been argued as an important factor to pull innovation (see the concept of supply-push versus demand-pull)

[41]. The variety and the sophistication of demand are not necessarily derived from the scale. On the contrary, the demographic distribution is often the same across cities irrespective of the size. Consequently, the variety of the demand can be equally similar within cities in different sizes, which means that the need for "smartness" exists equally in both SMCs and MCs. Moreover, the feedback loop and the learning-by-doing (improvement in quality or decrease in cost due to experience) – important for smart cities – are more related to capabilities, rather than scales, of users;

c) compared to MCs, SMCs's lighter bureaucratic superstructures create less of a barrier to bottom-up engagement, as demonstrated in some of the applications and examples documented here. The power asymmetry between the different groups of stakeholders, a factor undermining efficiency in public–private relationships, is also lessened. Additionally, public values such as fairness and solidarity – important in smart cities' implementations – are typical of small and medium-sized communities.

The economies of scale derived from size do not exhaust the discourse on smart cities. While being cost-effective is certainly a factor, local engagement, local skills, local infrastructures, and local institutions – elements often discussed in relation to the "digital divide" [20] — are also important for a successful implementation. Small and medium-sized smart cities offer a more manageable opportunity to bring these to fruition.

3.2. *Key differences*

The personal interest of the authors on small and medium cities is motivated by who we are: the city of Halmstad, where Halmstad University is located, is one such city – thus, these circumstances are "in our DNA". This motivation, who we are and why it is important for us, is the primary catalyst, and we want to share our experiences with the rest of the scientific community. At the same time, we believe this position is somewhat unique, since there has not been so much research on small and medium sized cities before. This gives us hope that our perspective can be valuable for the broader community.

For the last two decades human and urban geographers have called for a focus on the small city [3], and small cities have already emerged as sites for citizen-engaged urban change and renewal, as in for instance the Transition Town movement [47] and the Slow Cities (Cittàslow) movement [33]. Scaling down smart technology experiments to the small city or urban precinct level has led to a Living Lab model for interdisciplinary collaboration, as for example in the Net Zero Precincts project at Monash University Australia [44]. The outcomes of such research and technology design experiments can be transferable to other cities or neighbourhoods or scaled up for larger urban contexts [26].

A crucial point for the discussion brought forward in this paper is a list, and explanations, of key differences between MCs and SMCs. In particular, which of those differences are relevant and affect Smart Cities solutions, in what way, and how the awareness of those issues can strengthen the research. The list here is certainly not comprehensive, as all the factors that affect SC solutions are not known, and especially how they differ between cities of varying sizes, but it serves as a starting point for further discourse.

Population and resources volume: with larger population comes larger budget, which makes up-front investment into solution development much more bearable. The key aspect here is the economy of scale argument brought forward above. More specifically in the Smart Cities context, additionally, the Big Data concepts [36] become more relevant at a larger scale. However, one can also expect differences in the population distribution – often, SMCs have a lower proportion of young people, since there tend to be fewer jobs. This can lead to more demand for social assistance to take care of the elderly, possibly socially assistive robots or health tech. Education levels can often differ, since with a lower proportion of University-educated people Smart Cities may face decreased acceptance of new technologies, and so on. Decisions in SMCs can be made by smaller groups more rapidly, with less red tape – it is easier to be a "big fish in a little pond." Also related, finally, is the generally lower crime rates.

Population density: the number of people that can be affected by any given solution differs quite a lot, as well as the variability in terms of available infrastructure, businesses, etc. A good example here is shared mobility, which faces serious challenges in smaller cities – one needs a lot of people in one area to guarantee a stable, matching distribution between supply and demand. Additional related aspects include, for example, SMCs having larger houses than MCs, since housing is less expensive; houses can be shorter, with fewer stories and flatter –

making them, for example, easier for a robot to move around in. Since SMCs have fewer events and stores offering specialised products and services, often more driving is required to visit those events or acquire those products. On the other hand, lower density means being more intimate. There can be an "everyone knows everyone" effect, characterised by less urban isolation and bystander effects, and the potentially greater importance of reputation. It might be easier to forge bonds, as there is a stronger sense of community and identity. Social technology should not replace people but seeks to support more and better interactions with humans.

Unmanageable complexity: on the other hand, solving anything in a megacity is very difficult, since many different and often conflicting perspectives must be taken into account. Getting a clear picture of the true priorities is difficult, due to generally lower engagement of the citizens, and the larger budget often attracts actors that are looking for quick profit, without really having long-term well-being of the city in mind. In an SMC, it may be a lot easier to at least get started in a smaller, simpler setup, and get an initial viable product working, before scaling up. Additionally, in a smaller city it is easier to be more relaxed, closer to nature (less stinky, loud, or dirty). It can be possible to "get away" and be alone, often in nature, faster. This is an opportunity for improved quality of life. Where MCs are striving to be self-contained and self-sufficient, small cities tend to be obviously and visibly implicated in regional networks, and in relations to their hinterlands – they are a way to connect with vulnerable and possibly excluded people living in rural and remote areas – who for example depend on the small city for shopping, hospitals etc.

3.3. Impact on smart city research

The next key question, then, is how do these differences affect the Smart Cities solutions, in particular their research and development? Why is the distinction between MCs and SMCs important? Given the above differences, it should now be clear that the small and medium-sized cities perspective needs to be considered in developing Smart Cities solutions. More specifically, in this section we present our conclusions on what are the key concepts to keep in mind for each of the six Smart Cities dimensions.

Smart economy: large cities tend to be more focused on entrepreneurship and innovation, with more startups, etc. – this culture makes it more natural to iterate and combine inventions, try out new things, and so on. On the other hand, the environment there is more "cutthroat", with slow starts and early sub-optimal decisions often having graver consequences; in smaller cities it is more difficult to create true business and innovation "ecosystems", solutions need to be more comprehensive and self-sustaining. Finally, the economy of scale is weaker, as is population density, which means less people benefiting from any given solution. Collaboration between many SMCs is a very promising direction to explore in the future.

Smart people: the need for lifelong learning is, in today's world, equally important regardless of the size of the city. Smaller and more tight-knit communities have the potential to provide activities and opportunities that take advantage of their local specific opportunities – at the cost, however, of the breadth and the necessity of more limited selection due to budget and resources constraints. Due to more informal interpersonal relations, SMCs tend to develop more inclusive societies that improves creativity and fosters innovation.

Smart governance: the government in SMCs is "closer to the people," which means less focus on what is trendy and marketed successfully; instead, more focus is put on what is actually useful and valuable. On the other hand, with fewer resources and less legislative power, in some cases SMCs cannot stand up to big players such as multinational companies. Those limited resources for investments in, e.g., infrastructure, ICT, etc. mean higher initial costs for any individual solution. On the other hand, there is an inherently higher transparency, which arises from citizens who are generally more active. The SC benefits are more directly targeting concrete people and the areas of life that are important for them, leading to more co-created services.

Smart mobility: the transportation infrastructure, and especially the integration of ICT into traffic management, is an important issue for many SMCs to be solved in the near future. In particular, with the ageing society and the focus on sustainable mobility, the dangers of exclusion for certain parts of the population are becoming more and more severe. Much of the development in mobility as a service concepts targets ultra-dense areas, and there is a serious danger of public transportation in SMCs not being able to fulfil the needs of the citizens.

Smart environment: the solutions for the environment are probably highlighting the diversity of SMCs the most. While large cities are often relatively similar and all face similar challenges (like traffic jams and pollution in city centres), managing environmental quality in smaller cities often varies a lot, for example considering irrigation, waste, lighting, weather stations and water supplies. Improving energy efficiency and the quality of the environment utilises new technologies, but the implementation of regulatory and cultural changes is equally crucial, since they need to facilitate the sustainable standards and practices. New urban planning standards improve efficiency and minimise the environmental impact.

Smart living: homes and living conditions also vary quite a lot between small and large cities. The key objective, to improve the quality of life of citizens, needs to follow an inclusive strategic approach – across all age groups and demographics. Improving social and digital inclusion, healthcare and care for the elderly, as well as safety, is easier in SMCs where the connection between municipal government and the stakeholders it serves is closer.

Small cities offer us the contexts in which to develop new and effective smart city moves towards sustainability, care and more. The Emerging Technologies Lab participates in two experimental projects which focus on small urban units, using design anthropology methods. Our Net Zero precinct's project at Monash focuses on the concept of the urban precinct which is part of our largest campus (precinct is a key concept used in Australia but not in all English language countries) to refer to an urban area, in which we will design and test new smart technologies and data for sustainable transition across the mobilites, energy and buildings sectors. In another project with the City of Melbourne, we work in a specific neighbourhood, focusing on the local to understand how to engage people with city data. Working at this level, in small urban areas or small cities has the advantage that it enables us to undertake interdisciplinary smart city research which is rooted in the relationship between people, technology and the specificity of place. This means we can both create meaningful local interventions which improve the way smart city technology is used and engage people, and offer templates for transferring and scaling up our methodologies. Working at this level also enables us to ask the important questions about ethics and responsibility, about where automation should stop (we should not just do it because we can) and how to build smart city communities.

3.4. Scalability

A critical issue for the Smart Cities is that different technologies and their properties scale in very different ways. A good example of this is telecommunications systems. In the hunt for ever greater bandwidth, the trend from 2G through to projected 6G systems has been to increase carrier frequency. This, however, leads to an inherent trade-off; the higher frequency of radio transmissions, the lower the range and the more susceptible signals are to interference from solid objects. In a large city, the population density can justify installing the large number of transmitters needed to get good coverage for a 6G system. But in a small town this would be a dubious economic prospect. Somewhere in between (a smallish city) we might find that it would be worthwhile for a single operator to install the technology but that a fully competitive market could be problematic.

These kinds of factors are problematic because consumers might reasonably expect that services which build on 6G should work everywhere, not just in big cities. It will be important for developers to ensure that applications degrade gracefully as a user goes out of 6G or even 5G coverage. In the larger picture, it is critical to build a comprehensive understanding of which factors make things easier as one grows bigger, and which factors make things harder. This is, of course, not just a technology question, but it affects all the different aspects of multi-faceted Smart Cities.

It is crucial that the scientific community working on Smart Cities identifies where the optimal point is, for any given task, challenge, solution or technology. Since this optimum point differs across different challenges, trying to develop every aspect of Smart Cities in a one-size-fits-all approach is going to be unnecessarily difficult. It is a much more promising proposition to develop initial versions of different solutions at a scale where they are the easiest to build, and once the initial versions are well-demonstrated and accepted, to scale them up, or down, as needed in different contexts.

To reiterate, SMCs tend to be less dense and therefore require more investment in infrastructure per inhabitant for many items, including utilities, broadband, telecommunications and so on. On the other hand, the price of land is cheaper. However, patterns of land use are also affected by zoning regulation and vary widely from country to country. For example, in many large cities in the USA almost all land outside a typical central business district is for single family buildings. This results in a sharp divide between dense and sparse areas of the city. These are just a

Table 1

A comparison of benefits and drawbacks of smart city models for small and medium-sized cities vs large cities

Benefits of small scale	Benefits of large scale
Allow for more active and personal engagement	Decrease average unit cost of building the solutions (i.e., economies of scale from the supply side)
Increased inclusiveness and cohesion of the community	Network externality effect (i.e., economies of scale emanated from the demand side)
Limited bureaucratic structures and burdens	Larger potential for sharing and platform economy
More potential for bottom-up engagement (i.e., civic tech)	Availability of Big Data for ML/AI models
Lower population density leading to tighter communities, with more of a human touch	Higher population density leading to greater potentials in supply-demand match
Decreased complexity of proof-of-concept solutions	More resources available for up-front investments
Simpler and cheaper to build infrastructure	Larger potential total savings due to scale
Drawbacks of small scale	**Drawbacks of large scale**
Single unitary authority may aim for optimum solutions but there is a risk for a lack of democratic debate	Competing or vested interests from big players and independent actors may lead to local optima but global sub-optimum
Harder to reach both economies of scale and scope in service provision (e.g., ML needs big and varied datasets)	Risk of digital divide (and/or drop-out) in user participation
Danger of developing solutions that are overly specific for local conditions and cannot generalise	Risks with administrative bureaucracy leading to services that are not tailored for the needs of individuals

couple of examples of factors that should be taken into account when developing truly inclusive and general Smart Cities solutions. The summary of this discussion can be found in Table 1.

We often talk about scale, especially in computing science, in terms of what happens when we make systems and problems and data bigger. All the time the question is "how does it scale up?" But it is not so often that computer scientists these days ask the opposite question, "how does it scale down?" We used to, in the whole process of going from large mainframes down to personal devices, but somehow in recent years we have just assumed that the problem of scaling down has been solved. However, in the process of transferring solutions from megacities to small and medium-sized cities, it is exactly that process which remains a challenge.

4. Applications and example studies

The examples that follow summarise the experiences and lessons learned from applying and studying smart cities in the context of small and medium-sized cities. As mentioned above, given the goal of the paper, these examples generally address the three aspects we want to demonstrate in this work. The first is the needs, potentially unique, of small and medium-sized cities; the second are the differences between megacities and SMCs; finally, the third are the challenges faced by SMCs where Smart Cities approaches can provide tangible benefits.

4.1. Intelligent robots in SMCs

Development of intelligent assistive technologies in general, and robot-based in particular, faces significant practical challenges. In several different ways the specific characteristics of SMCs (or even villages) make them very promising areas of deployment for the intelligent autonomous robots, since the problem space is relatively smaller in contrast to big metropolises. This makes it more feasible to deploy robots to autonomously assist humans in real-world applications. Two main applications of autonomous robots in small towns and villages are (i) outdoors for transportation and mobility, (ii) and indoors to help elderly people.

4.1.1. Outdoors transportation and mobility via autonomous vehicles and drones

Autonomous robots, that is autonomous vehicles (AVs) and drones, are the key enablers to tackle the mobility and transportation problems in the concept of smart cities. Some of our general thoughts on such AI in smart cities can be seen in a recent article [14]. Outdoor robots can contribute to smart mobility, smart living, and smart environment

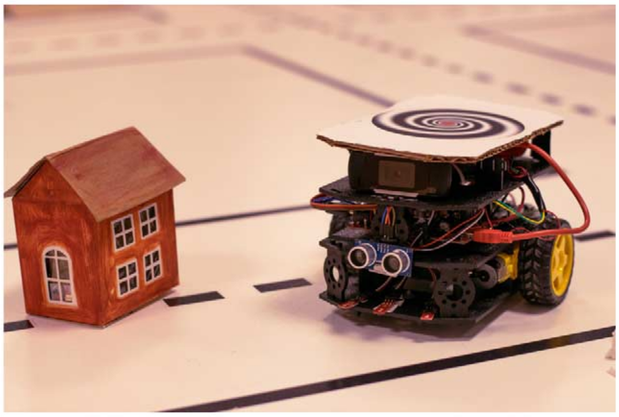

Fig. 1. Facilitating transportation in small towns with robots.

aspects. Conversely, although there is vast progress in the literature, robots still do not exhibit full autonomy, and the idea of SMCs could accelerate this progress by affording more easily solvable problems.

Residents of some SMCs must drive more to buy specialised products or, if located near an MC, to commute to the big city for work. It is important not to marginalise them. AVs should be considered not only to let people go from A to B, but also for the transportation of goods like delivery service. It is crucial to note that all the necessary elements (like 3D maps of the city, smart traffic lights, traffic control units, etc.) that support AVs can easily be set up for small smart cities, which is non-trivial for metropolises. Moreover, in small cities, the population density is lower, meaning there are more roads with less traffic and vulnerable road users, so that systems have a lower chance of injuring someone if they do not function perfectly.

As part[3] of the Swedish Knowledge Foundation's (KKS) SafeSmart project (Safety of Connected Intelligent Vehicles in Smart Cities Synergy), the Swedish Innovation Agency's (VINNOVA) Epic project (Emergency Vehicle Traffic Light Preemption in Cities) and the ELLIIT Strategic Research Network, we have been conducting speculative work in this area (see Fig. 1 for inspiration), which has been aided by the focus on small cities, and has provided various insights:

a) First aid for AVs. Emergencies are bound to occur when autonomous vehicles are deployed in real complex mixed-driving environments, but little research has explored how to recover afterwards, from accidents to crime and natural disasters. We have explored a speculative scenario of using a mobile robot inside an AV to conduct first aid, exploring how to detect emergencies, and examine and help victims, as well as lessons learned in prototyping, especially related to perception. The focus on SMCs is key to such exploration, because the complexity of the problem is reduced greatly. In a large city accident, many people could be injured, but triage, determining who to help and in what order, is even highly difficult for humans, due to high uncertainty and the high stakes involved; by focusing on small cities where we can expect fewer injured persons, we can avoid the great problem of how to autonomously conduct triage and were able to focus on a smaller problem of how we can detect people's state of awareness and health. Furthermore, larger distances and fewer medical staff make the problem more pressing in SMCs. Through our studies over several years, we were able to identify some challenges to perception, and obtain some positive preliminary results that suggest the promise of robotic first aid in AVs in the future, toward stimulating discussion, ideation, and further advances in the area [11].
b) Social media mining for drivers. Previous work on driver monitoring has focused on the short time that a driver is inside a vehicle and risks missing important health problems such as loneliness, depression, and sleep-deprivation that increase the risk of accidents. We propose a speculative scenario of providing continuous monitoring and care via a "robot" that interacts with drivers on social media, exploring potential challenges

[3] Embedded and Intelligent Systems (EIS), School of Information Technology, Halmstad University. https://hh.se/eis-en.

and solutions. For example, to address how to generate appropriate robot activities and mitigate the risk of damage to the driver, a hybrid neuro-symbolic recognition strategy leveraging stereotypical and self-disclosed information is described. Although loneliness can also be a problem in large cities ("urban isolation", related to the bystander effect), it is a problem which is strongly associated with more rural locations such as SMCs where distances between people can be large [50].

c) Teaching about AVs. Autonomous Vehicles promise to revolutionise our world, but training the next generation of researchers is a challenging task that traditional education strategies are ill-equipped to meet. We proposed a new pedagogical approach targeted toward AVs called "CAR" that combines Creativity theory, Applied demo-oriented learning, and Real world research context. In seeking to also address the smart people aspect of SCs, this work was facilitated by exploring the application of the approach to a university master's course in an SMC. MCs can have thousands of students in a class, making it difficult for students to interact much with teachers and researchers. By focusing on a small class and maintaining a high researcher and robot ratio (8 researchers and 10 robots, for only 20 students), we observed some highly engaged and successful interactions that suggested the feasibility and usefulness of the CAR approach, as well as some challenges (primarily in regard to presentation of research results). Some results can be seen in a short summary video, which shows the robots running ROS2 and Ubuntu on Raspberry Pi 4s, coordinating their movements in a small city mock-up[4] [45].

4.1.2. *Indoors assistance for elderly people via social robots and smart homes*

Why is the SMC perspective important for indoor healthcare robots? This perspective could make it easier to develop robots that could contribute to smart living and smart people. Small cities can have a greater need for assistance for elderly given the lower proportion of young people and fewer jobs. It is easier to design a robotic intervention, since they feature larger houses with less floors and staircases due to lower prices of land and housing, which makes it easier to deploy mobile robots; and events and projects can also be smaller, planned by just a few individuals, which makes it easier to coordinate (more control can be exerted over one's environment with less red tape). We expect the technologies to be more effective, since less pollution and more nature offers an important opportunity for rehabilitation, and improved treatment and quality of life; and it might be easier to forge bonds, as there is a stronger sense of community and identity (less urban isolation and bystander effects) – this is important because social technology should not replace people but seek to support more and better interactions with humans.

Previous work has mainly focused on robots in larger cities, in large hotels, hospitals, museums, airports. For example, the "Hen-na hotel" chain in cities like Tokyo[5] has translator robots at the front lobby since they expect visitors from many countries, large robot arms to store much luggage in lockers, and large dinosaur robots for entertainment near some entrances. This differs fundamentally from the small city view, in that the goal above is to be able to automate "shallow" interactions with many people while reducing costs (some hotels use a kind of vending machine with a touch screen instead of robots for automation), whereas our focus with SMCs is on exploring how to provide high value in close interactions with few people.

Challenges include social, healthcare, and practical aspects, which we have started to explore in the KKS CAISR (Center for Applied Intelligent Systems Research) and Sidus AIR (Action and Intention Recognition in Human Interaction with Autonomous Systems) projects:[6]

Social. In small and medium-sized cities, robots might have to deal with fewer people, but establish closer relationships. We have begun to explore how to achieve richer interactions that involve complex phenomena such as emotions (including enjoyment and affection) and creativity, see Fig. 2, but much more work remains to be done on how to establish good long-term relationships with trust [8,9]. Some observations included that:

a) Several typical patterns (norms) exist in how people seek to interact and perceive meaning in a robot's behaviours. People differ in how they interact with robots; some interact as with other humans, while others treat them as toys or machines. Robot behaviours can appear to be functional and/or emotional. Some important

[4] Cooney, M. (2020) DEIS 2020 project summary: COVID rescue robots. https://www.youtube.com/watch?v=qNJry218YMo.
[5] Henna Hotel. https://www.hennnahotel.com.
[6] Center for Applied Intelligent Systems Research (CAISR), School of Information Technology, Halmstad University. https://hh.se/caisr.

Fig. 2. Supporting close relationships with robots. Published with permission.

properties of communications appear to include complexity and specificity (monosemy), as well as balance between external and internal factors. Penalisation can be accomplished via user-driven self-disclosure.

b) Touch is vital for establishing affectionate relationships, and people will seek to touch even robots that they know can only perceive audiovisual communications like speech and hand gestures; typical touches like hugging can also be recognised not only haptically, but also kinematically or visually. A perception of sincere liking, and a balance between stability and variation in a robot appeared to affect how much a person likes it.
c) Large reactions, consistent internal intentions, and affordances that allow a person to help a robot, facilitate enjoyment in playful interactions.
d) Alternative modalities can be used to complement current approaches, like using thermal sensing to detect medicine intake, or gas sensors to use a person's breath to locate them unobtrusively.

Healthcare. Elderly can be more isolated in SMCs than MCs, as the distances are greater, and there are typically fewer large hospitals. This means that it might take emergency medical personnel more time to detect problems and help. To address this, we have explored the use of first aid robots in homes (as well as AVs), which could allow for telemedicine or autonomous inference of health state and interventions. This has involved also building a 50 m^2 smart home at our university called Halmstad Intelligent Home (HINT), which features a fully functional bathroom, kitchen, and bedroom, as well as patrolling robots [9,28]. Robots are not limited to use in emergencies but can also provide everyday assistance and companionship. For example, therapy robots can help elderly to exercise, since there are fewer healthcare personnel in the country than in big cities, and in general a growing shortage [10]. Open challenges include ethics, legal ambiguity about culpability, and how to create highly reliable systems, given that the risk of damage from faulty interventions can be large.

Our design ethnographic research with older people and smart home technologies in rural and regional towns in Australia has shown that certain smart home technologies benefit their independence and well-being but that these technologies need to be supported by a human support service. That means that we should see the use of smart home tech for older people in small cities as embedded in the community and in social services, rather than as a replacement for them. Our work emphasises the need to design smart home technologies with older people.

Practical. In general, an economical view should be incorporated to achieve sustainable development. SMCs are poorer than MCs, as there are fewer jobs. This leads to a challenge of how to introduce social robots and smart homes into poorer environments. This can be especially a problem in LMICs (Low and Middle Income Countries) which are defined as less than $3,955 GNI per capita by The World Bank Group. The largest problem is money to purchase equipment. Robots span a large spectrum from doll-like robots with limited mobility like Paro [54] to mobile manipulators, but typically none are cheap (Paro is about $5000 US). A simple smart home can be set up for several hundred US dollars with an inexpensive computer like a Raspberry Pi with a small screen, and some cheap sensors. Typical sensors are touch sensors (on furniture like chairs, sofas, and beds, and as doormats in front of doors), passive infrared sensors, and contact switches (on cupboards). Common communication protocols are Wi-fi, Zigbee, Bluetooth, etc. LoRaWAN can be useful even when distances between homes are large (or communication between a farmer's garden and their home). Other problems include electricity, mobility (there might not be floors), and internet (which devices like Google Assistant require). As part of this focus, we have explored the use of recognition using simple, inexpensive sensors for various tasks (e.g. simplified touch sensors, or gas sensors to infer location).

4.2. *Building smart villages and communities*

Smart people, as one of the key drivers at developing smart cities, have been characterised through different elements such as eagerness to learn and education, the development of human resources and contribution to social interaction in the urban environment, flexibility and adaptability [1,17]. These characteristics pertain to the people who live and work together to solve public and urban concerns. Below we demonstrate through two examples how SMCs as well as villages are beneficial for developing the "smart people" indicator of a smart city through the close collaboration between local stakeholders, people living in the same neighbourhood, academia, industry and city planners. In fact, we argue that building on already existing social communities in SMCs and villages is by nature beneficial for creating smart cities, since people are already engaged in solving problems and innovating new ways of creating the viable local living areas. These social communities are easy to find and approach in SMCs since they are bound together through geographical places where people share practical concerns regarding mobility, safety, social life, and local facilities. In Sweden, there is also a strong tradition of building local interest groups and communities in villages and neighbourhoods, to give voice to local values, ideas and interests in local government decision-making procedures. In the following two cases we will describe two examples where we have collaborated with such local stakeholders to design and develop technological solutions to local ideas with people instead of for, creating local engagement as we moved on. These examples are the smart village project in Veberöd and Design Ethnographic Urban Living Labs in the peri-urban area of Gothenburg and a smaller neighbourhood in Helsingborg, all of which are villages and cities in southern Sweden.

4.2.1. *Smart village Veberöd*

Veberöd,[7] with about 5500 inhabitants, is a village located in Lund Municipality, Skåne, Sweden. As a showcase of smart village, Veberöd has won many prizes from Swedish state-funded projects (e.g., from Vinnova), under the umbrella of "Civic Tech"[8] and "smart village". There are about 200 firms and non-profit organisations included in the Veberöd smart village network, circa 20 000 visits to its website per month, and 2700 downloads of its apps by 2020.[9]

The concept of "smart village" mainly embraces two components: a) Information and Communications Technology (ICT) is in use to provide benefits to rural communities; b) there is a collected community effort in a sense that the services provided are for-the-people and by-the-people. Two additional dimensions are included in modern smart-village debates: a) territory: a smart village is seen as an important tie between rural areas and cities in their close vicinity, to strengthen their relations; b) sustainability as a trajectory of development is a must.

Arguably, the "smart village" as a concept derives from Gandhi's vision of holistic rural development in India [49]. The focus of smart village development in the OECD peripheral regions is however different and Veberöd may serve as a case to illustrate this modern development. Ongoing smart village projects in Veberöd include:

a) "Digital tvilling" ("digital twin" in English), see Fig. 3, a sensor-based water consumption monitor system in the village: this is in collaboration with local water infrastructure system provider VA Syd. This monitor

[7] We acknowledge the help of data collection on the Veberöd smart village case from two students: Tim Malmgren and Joakim Wahlberg.

[8] Civic tech may be treated as a sibling concept of smart village here. Civic tech, with its primary focus on enhancing citizen-government links, also uses digital technologies as key tools.

[9] Many of the smart applications can be found in www.smartabyar.se; www.veberod.nu; www.södrasandby.com; www.byutveckling.se

Fig. 3. The "digital tvilling" in Veberöd village – a water consumption monitor system. Source: https://smartabyar.se/ (photo used with permission from Byutveckling AB).

system helps not only measure water consumption, but also detect errors in the pipeline system such as water leaking or holes. In Sweden, "the oldest water pipeline in operation is from 1870" and "20% of the water disappears from (water) pipe system [without being utilised] due to the fact that there are holes in the pipes", according to the interviewee. This brings the villagers the awareness of their water uses and helps the villagers to detect and report errors occurred in the infrastructure system. A 3D-based platform is under construction, also for helping error detection in other important infrastructure systems (e.g., holes in the road).

b) "Sense farm", a sensor-based water/moisture measurement system used in agriculture: this is used to measure moisture degree of the trees and plants, and measure cow's drinking water consumption in the village, to ensure a functioning ecosystem in agriculture.
c) "Smart aid", a smart (virtual) pharmacy: based on existing authentication apps – the widely used bank-id system in Sweden – this service (app) is a combination of functions of online-doctor, medicine ordering, and drone delivery of urgent medicine. This service is mainly served to build up a safety feeling for the elderly in the village, so they are not forced to move to the city close to hospitals. This is based on the fact that Veberöd is a minimum 37-minutes-driving-distance away from the nearest hospital in Lund (when there is no traffic jam).

There are also non-profit associations (and apps) such as "Unga Smarta Byar" ("young smart villages" in English), that are run "by the youth and for the youth" in Veberöd village. With a belief that "the world should not be governed only by [older] adults", it is aimed to function as a platform to collect the young villager's ideas in the effort of building up a better village. "Better" here, as they defined it, is "smart and sustainable". Mobile apps developed under this umbrella include "find my bike".

To summarise, the ongoing Veberöd smart village projects are aimed to use ICTs to build up village-wide apps (services) that make all the villagers connected, involved, engaged and benefited. Together, the villagers are ensuring their own sustainable development. Compared to smart villages in developing countries, Veberöd and similar villages in old industrialised countries face different challenges, for example a century old (water; roads) infrastructure system and an ageing population as mentioned in the Veberöd case. Error detection – of an ageing infrastructural system – and healthcare services are therefore important, arguably more acute than that in megacities as service facilities are often miles away. Consequently, ICTs are used to address these local needs – with a human touch – and meanwhile to revitalise the village with new dynamics.

4.2.2. Design ethnographic urban living lab in Gothenburg and Helsingborg

Design ethnography brings together the theory, methods and intervention of ethnography and design to create a collaborative approach that involves both citizens and stakeholders. It involves using ethnographic methods, interviewing people and following them in their daily lives and communities, sharing their experiences in the present and their imagined futures. It also means working with participants and stakeholders in workshops, to co-create knowledge, imagine future technologies and co-design prototypes and services. In our project AHA II,[10] we have developed a design ethnographic Urban Living Lab approach to exploring future mobilities. The Urban Living Lab innovation milieu can be seen as a network of supporting activities in smaller geographical areas. The approach brings together a collection of methods and techniques to support human-centred activities and perspectives to innovation situated in a real world context. The Urban Living Lab (ULL) approach is closely related to human-centred and co-design approaches to cross-sector development, integrating research and innovation processes in real life communities and settings [32].

Key in ULL is public engagement and co-learning and co-design activities with local stakeholders and citizens. In the AHA II project (see Fig. 4) we have established two ULL in two different SMC in Sweden, Helsingborg and Gothenburg, and in the first phase we learned more about local knowledge and values through engaging with citizens in the areas through ethnographic fieldwork such as interviews, participant observations in local activities, drive-alongs where we followed people who showed us how they move around in the areas and probing workshops. We also engaged with local stakeholders such as local community organisations and local building owners. During this fieldwork we discussed future mobility solutions based in these smaller residential areas with the people living there and engaged them in co-design workshops with developers at Volvo Cars, public transport experts and urban planners. In this way, the ULL became a locally integrated and engaged co-design hub and not simply a testbed for technology-driven innovation as is the case in many mega-city implementations of autonomous vehicles.

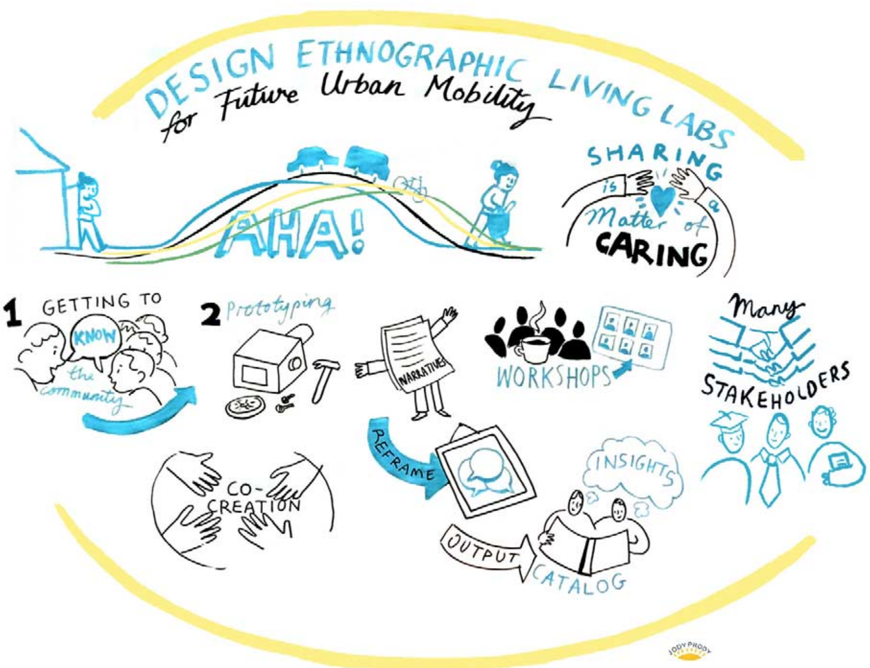

Fig. 4. Visualisation of the AHA II living lab. Published with the permission of JodyPrody.

[10]AHA II. https://aha2.hh.se/.

Through this approach we got an opportunity to re-frame technology-driven grand narratives transferred from generic smart mega city development of what problems and challenges new mobility solutions should target. One such example is efficiency in mobility. From a technical perspective, shared and combined mobility systems for transporting people aim to minimise the number of vacant seats in vehicles in order to reduce the number of used vehicles, using concepts such as ridesharing, carpooling, car-sharing, managed by a growing number of on-demand app-based services [12]. However, as was demonstrated through our work in the small city environment of our ULLs, sharing and combined transport is far from solely being a technically driven practice, since sharing practices are closely tied to relational and social dimensions of the context in which it is embedded. The AHA II project focuses on mobility within a mile from people's homes, and one of the primary insights was that the first mile of people's everyday travel is not a matter of getting the most time and cost efficient travel from A to B, but a matter of coordination and family logistics. Furthermore, the last mile is not always a problem that needs solving but rather an opportunity for sociability, exercise or quality alone-time – and holds central features such as popular shortcuts and informal meeting places. Within the last mile, people find close neighbourhood ties, or a pre-school, playground or a bus stop. These findings led us to the conclusions that smart technologies aimed at smaller places need to be engaged according to the logics of the social life of the smaller communities of people living there. It is only through understanding small city life, smart technologies can be implemented in line with the goal of smart cities.

As these two examples reveal, people, institutions and other stakeholders in smaller scale communities are often characterised by specific forms of existing social, political and economic connectedness which have implications for how smart tech might be applied. By learning how these local systems already work, what social values and ethics underpin them and how people learn and innovate within them, we can better understand which and how smart technology solutions will be suitable. As our examples suggest, it is necessary to treat smart technology solutions for small places differently to large smart city solutions since they address very different place-based community contexts.

4.2.3. Digital literacy initiatives part of smart city Habo

Twenty-nine percent of the population of Habo, a municipality of 12 000 located in Jönköpings county on the western shore of Lake Vättern, is under nineteen years of age, the highest percentage in all of Sweden [18]. "Read Ahoy!" was designed and set up in 2019 by Jönköping University in cooperation with Habo municipality and Habo Public Library to explore a "smart" digital / physical installation addressing the United Nations, Sustainable Development Goals sub-targets on "Early childhood development" and "Universal Youth Literacy" [34]. It was part of an ongoing series of joint initiatives and pilot projects involving academia, public bodies, and the local industry aimed at creating awareness of the challenges and opportunities of digital transformation and at laying the foundations of a smart city framework.

"Read Ahoy!" was based on a concept originally developed as a co-design information architecture exercise at UMIX 2014, a two-day hackathon hosted by the École Normale Supérieure de Lyon, France, with the idea of reinventing the children's library as an experience in blended space [5] to support personal discovery, playfulness, and serendipity through digital technology as a way to encourage children to interact with the space and the content of public libraries and create familiarity with the activity of mapping digital information on the physical environment. It was designed to fit the space of the children's space at the public library in Habo, and structured as a storytelling experience centring on a Viking crew on their way back to Birka, an important Viking Age trading centre; after a trade expedition, their ship was hit by a storm and much of its precious cargo of books washed overboard and floated in large boxes on the waves.

An animated audio video call to action asked children who interacted with the installation to help the crew return at least a few books to the ship and provided them with a treasure hunt-like screen map, randomly generated, that matched the physical position of the boxes in the library, and a series of keywords, such as "skog" (forest) or "slott" (castle), also randomly chosen and corresponding to titles or topics from the 200 books contained in the boxes. Children were then free to explore for books at will, and were rewarded with a "victory" video from the crew if they returned books containing matching keywords to the hold of the ship [40].

The narrative grounded the challenge in tropes familiar to Swedish culture (see Fig. 5) and gave children a playful setup and well-defined goals as they searched for books, allowing them to explore and make sense of information

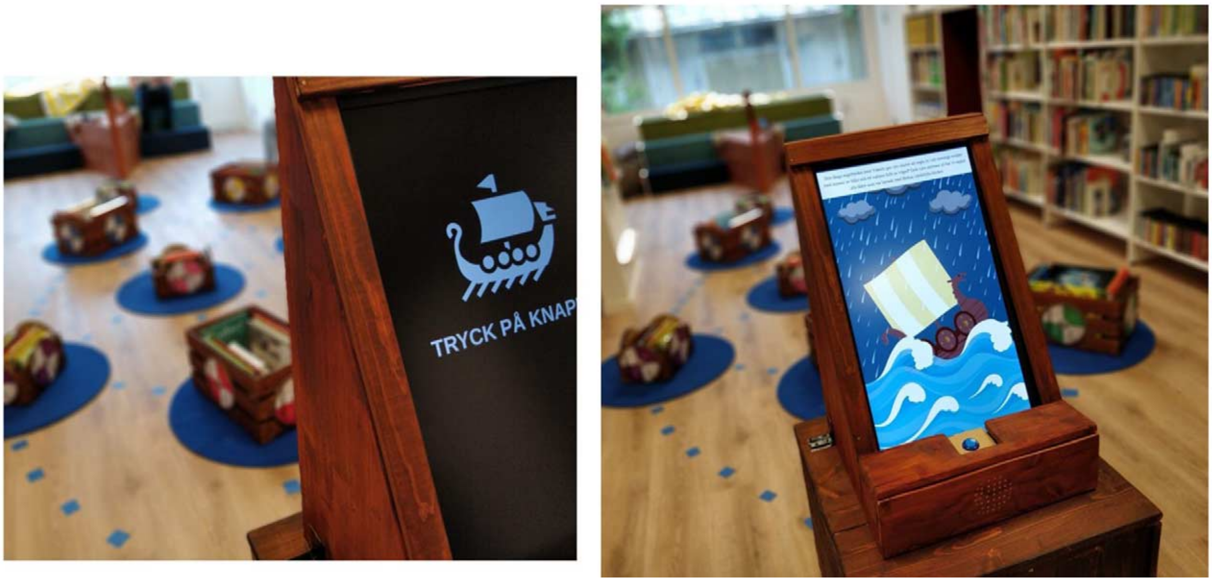

Fig. 5. Initiatives aimed at creating awareness of the challenges and opportunities of digital transformation "Read Ahoy!"

in a blended space, structurally recreating the way they customarily mix action in digital and physical space. Correspondence between narrative flow and the space of the experience was one of the primary design considerations, and the installation was set up as a three-part, linear succession of clearly identifiable areas containing custom-built rough wood Viking-looking props for the technology: the story box, a video installation which provided the audio / video narrative hook; the chests or boxes, filled with books and resting on the water, offering exploration; the ship, where books were to be taken and also hosting a video installation to salute children off.

"Read Ahoy!" was conceived to be a "a game-like interactive experience for children to play with information in a blended space" [40] while placing them in control. Children could spend as much time as they wanted going from box to box, sample any book that caught their attention, stop to read something, or just leave. Spatial, aural, and visual clues converged to structure the narrative, the digital map, and the library space into a blended space. Topologically, since the chests on the digital map occupied the same position the boxes occupied in physical space, children had to relate what they saw on the screen to the physical environment in which they were, correctly traversing the information seam connecting digital and physical space [39] to formulate an effective cognitive map of the area. The cognitive map could then be used to search for the book within the physical space.

Post-mortem interviews with library staff showed that the experience was engaging and well-liked: "children had been engrossed by the story and engaged by the search for the lost books". Parts of the narrative proved to be difficult to follow for the smaller children, with "choice of words, speed of enunciation, and the lack of a way to repeat parts of the narrative" suggested as necessary improvements. Most interestingly, interpreting the interplay between the physical and digital elements of the experience did not create any problems: mapping issues, when they happened, were again rather a consequence of language and literacy level mismatches. The material anchors [22] provided by the story box and the book chests worked effectively, and the children could "successfully relate the map and its physical embodiment in the space of the library, immersing themselves in direct search while going through the make-believe task of helping the crew" [40].

Importantly, library staff also reported that they had been pleasantly surprised of how extremely light in technology and heavy in narrative aspects and spatial engagement the installation was. This was seen as a positive characteristic and one that provides a lesson for the design of any type of smart environment approached from a user experience perspective: "the interplay of the different elements in the ecosystem and the environment itself, the topology of the blended space of action, should be used to create meaningful narrative pathways that support actors achieve their desired future state. In this process, all technology is a support layer" [40].

As this example indicates, SMCs allow experimentation with low-impact, low-resources, low-budget pilots that target specific aspects of the relationship between the smart city concept (or elements of it, such as digital literacy) and the experience that citizens have of them that would simply not be possible in other settings: the small scale at which these initiatives are run allows a degree of agility and flexibility in setting these up which would be problematic to achieve at the scale of large cities. Habo has been running a number of such smart cities pilots, ranging from the one presented here to sensor-activated smart lighting to the visualisation of relevant local information on large real-time displays in the main square: these have all contributed to lay the foundations for a more sound and human-paced approach, and for a vision of the smart city that is radically different from that of Big Tech. This is true for both decision-makers and simple citizens: in the example described here, children have successfully coupled information provided to them in a digital environment to act in physical space, obtaining a better grasp of what a smart environment is; but library staff and municipality administrators have also greenlit and directly worked with (or observed) a proof of concept illustrating how smart ambient technologies do not necessarily equate huge top-down investments, helping recalibrate efforts from pure technological pushes to technological epiphanies [51] primarily centred on people.

4.3. *Traffic light preemption*

While the previous examples highlighted the differences between MCs and SMCs explicitly, it is also important to acknowledge that not everything within the Smart Cities context is inherently as specific to one or the other. This final case demonstrates that certain aspects are more universal – especially when they address issues such as safety, where no compromises can be accepted, and where specific local conditions have no bearing on the core system requirements.

Scenarios where emergencies require specialised vehicles (i.e., police cars, fire trucks, etc.) might occur in cities and towns of any size. Whatever the size of the city, if there is an emergency, it is of vital importance to ensure that the emergency vehicles (EVs) are able to reach their destination as quickly and as safely as possible. One way of improving the response of emergency services is through the usage of a traffic light preemption system. In this case, it is our experience that the differences between SMCs and MCs are not as impactful as in some other situations. The main concept, including the method and the system design, are relatively universal, however, there still might be differences when it comes to the operational part, such as acceptance and deploying the system.

A traffic light preemption system, see Fig. 6, can be designed to work on different kinds of communication technologies, such as ITS-G5, Dedicated Short Range Communication (DSRC), or LTE-based. However, although the general idea is applicable for cities of all sizes, there are some peculiarities which a small city like Halmstad presents. For instance, traffic light preemption depends on specific devices and infrastructure to work. These devices include, at the very least, transceivers on both ends: the emergency vehicles and the road-side units (RSUs). A smaller city might not have as much funds to acquire, implement and deploy a system of this kind when compared to a bigger city, while at the same time, the number of devices needed is also much smaller. A small city will also be much less affected by traffic jams and other similar traffic disturbances that could negatively impact the response to an emergency scenario. This means that the benefit of implementing these communication-enabled devices all over

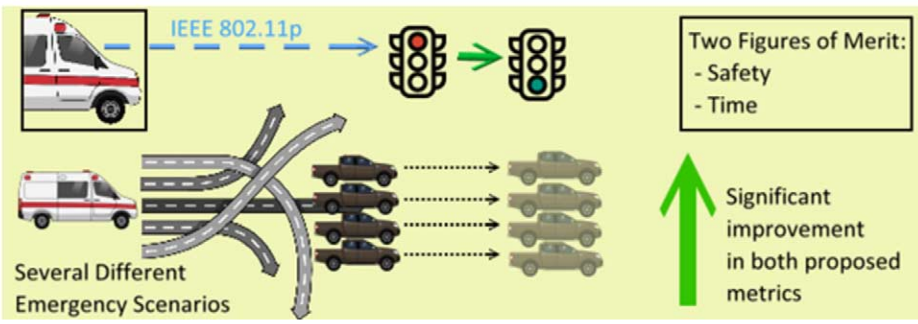

Fig. 6. Conceptual presentation of the traffic light preemption scenario.

a city would most likely not outweigh the costs of the deployment and maintenance of the system. Therefore, for a small city to benefit from a system that enhances the emergency scenario response, it is important to focus on key points of a city, such as arterial roads and high-capacity streets.

Another interesting aspect is when certain conflict scenarios, where more than one EV will try to preempt the same traffic light at the same time, are considered. In a small city, these scenarios are much less likely to happen for several reasons. A smaller city will probably have much less hospitals and ambulances, assuming it even has more than one medical facility. If there is just one medical facility, then the chances of a conflict happening are very remote. Similarly, a similar situation will be observed for police stations and fire departments as well. By analysing this factor, it is possible to say that conflict scenarios are much less likely to happen in a smaller city than in a bigger one. This makes the initial implementations of such systems significantly less complex, potentially leading to faster adoption.

To evaluate the different aspects and benefits of this kind of system, we are conducting ongoing research focusing on simulating traffic and emergency scenarios. The simulations focus on Laholmsvägen, in Halmstad, which is one of the main avenues in the city. The simulations were designed using two well-known simulators, SUMO and OMNeT++, for mobility and communications, respectively.

The two main objectives are to enable faster responses and increase overall safety of drivers and pedestrians. For that, we have two metrics, one to quantify the time improvement (trip times) and the other one to quantify the safety improvement (based on the time-to-collision metric). Different scenarios have been tested, with several different routes, traffic intensities and conflict scenarios, with several EVs requesting traffic light preemptions at the same time.

So far, preliminary results have shown that there is a significant improvement in the time metric, especially in traffic jam scenarios. The trip time improvement ranged from approximately 15% to over 48% with intense traffic [13]. Considering emergency responses are time-critical operations, it is possible to conclude that even a small city has room to improve its emergency response using an intelligent VANET system. It is worth noting that the selected avenue is a very important factor on the obtained results, since deploying a system of this sort in small streets with low density traffic would most likely impact the trip times less dramatically.

5. Conclusions

This paper presents an argumentation aiming to encourage more Smart Cities research directed towards small and medium-sized cities. This entails, specifically, both justifying the need and proposing interesting directions to get started. The key contribution is supported by examples and case studies established based on the experiences of the authors. These examples, complemented with review and analysis of existing literature, build towards the credibility and soundness of the overall claim.

Most examples of Smart Cities research today is based on, and primarily target, megacities. This is somewhat surprising, given that the majority of urban population lives in small and medium-sized cities. This paper addresses the contextual setting for smart cities from the perspective of such small and medium-sized cities. Building on three examples of concrete cases introducing "smartness" in practice, we discuss the multi-faceted (e.g., smart economy, smart people, smart governance, smart mobility, smart environment and smart living) nature of smart cities research. We focus on presenting and highlighting how the small and medium cities context has been applied in those cases, and what specific and unique effects did it lead to. We describe the mainstream bias towards large and very large cities, sometimes even subconscious.

Initiating a wider discourse on the need for small and medium-sized cities perspective in Smart Cities literature is a key contribution of this paper. As we highlight the importance of the topic, we present several unique needs and the specific requirements, as well as the differences between cities of different sizes. We hope that our argumentation will encourage more researchers to consider this important perspective.

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Conflict of interest

None to report.

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