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Smart City Configurations: A Conceptual Approach to Assess Smart City Practices and Outcomes

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***Abstract*—This paper proposes a novel conceptual framework as analytical tool to support the systematic and methodical investigation of smart city instantiations. Integrating existing fragmented perspectives, we propose three analytical dimensions (*integration, automation and adaptivity*) to describe the relationships between four foundational smart city aspects (*technology, people, institutions and material environment*). Together dimensions and foundational aspects create *smart city configurations* (SCCs). SCCs enable the systematic description, assessment and comparison of specific smart city instantiations. SCCs can further help to make transparent the basis for policy decisions and implicit assumptions of decision-makers aiding the legitimacy, explainability and accountability of smart city efforts.**

***Index Terms*—smart city, smart city configurations, methodology, framework**

I. INTRODUCTION

The combination of challenges resulting from urbanization and their technological solutions converge in the concept of smart cities, loosely defined as *“places where information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems”* [1]. However, despite the fact that the notion of smart cities has come to dominate the thinking about urban management, the debate has burgeoned without a solid conceptualization of the phenomenon. Indeed, it is a widely cited criticism that smart cities lack definitional precision [2].

This contributes to confusion amongst urban policy makers who want to make their city ‘smart’ [3], while it also allows the label to be used like a floating signifier, conveniently shifting shape when encountering criticism [4]–[6]. Consequently, smart cities are like moving targets, and analyses of smart cities have focused on a wide variety of aspects without being clear whether these relate to the concept of smart cities as such, or to the wider social, political and economic contexts in which smart city projects are rolled out.

This paper aims to close this gap by proposing a pragmatic framework for analyzing smart cities, their practices and outcomes. Integrating and extending on previous definitions and smart city concepts our framework proposes three analytical dimensions: *integration*, *adaptivity* and *automation* to describe the relationships between four foundational smart city aspects: technology, institutions, material environment and people. Together they allow to describe smart cities in terms of *smart city configurations* (SCCs). SCCs operate on the notion of ‘smart city families’ with features that can be systematically described. SCCs move beyond the conceptualization of ‘smartness’ as a singular *quantitative expression* of simply ‘more or less’. Instead, they offer an alternative perspective of *qualitative descriptions of interrelations* amongst foundational city aspects. This conceptualization is formal in the sense that substantive objectives of smart cities, encompassing the control of urban challenges such as sustainability and public safety, are not a fixed part of it, but rather seen as domains of application [7] to which the dimensions can be applied.

In this way, smart city configurations afford to systematically reflect on, describe and compare instantiations of smart cities, whether existing, potential or ideal. This, we believe, is a marked difference to previous definitions of smart cities, where substantive objectives have always had a major role in defining what the smart city is. In their place, our approach offers a conceptual framework that can serve as an analytical tool to support the systematic, methodical investigation of specific smart city instantiations. It further affords the study of instantiations and their relationship with specific outcomes such as citizen wellbeing, security, mobility, etc.

In the remainder of this paper, we describe the development and makeup of our framework, followed by an example on how we envision it to function as an analytical tool in future smart city research.

II. REFLECTING ON CURRENT SMART CITY DEFINITIONS

Definitions of smart cities are many and diverse. However, the common feature of these discussions is the central role for information and communication technologies (ICTs) and the sophisticated analysis of digital data to make urban management and planning more rational and evidence-driven [3]. Especially early conceptualizations emphasized the prevalent role of technology [8]. One widely cited definition envisions the smart city as: *“the urban center of the future, made safe, secure environmentally green, and efficient because all structures – whether for power, water, transportation, etc. – are designed, constructed, and maintained **making use of advanced, integrated materials, sensors, electronics, and networks which are interfaced with computerized systems*** *comprised of databases, tracking, and decision-making algorithms"* [9] (emphasis added).

These early approaches emphasize that advanced sensing technologies be implemented throughout the city's built environment for urban management purposes, invoking the vision of a top-down managed city that "senses and acts" [7]. Here, **'smart' is primarily understood in terms of technology, implying automatic computing principles** [10]. The meaning of 'smart' thus centers on qualities of speed, intelligence and neatness as applied to technology [11].

These early approaches were criticized for not considering the role of citizens and organizations and for failing to explain how and why ICTs improve cities. Accounting for these criticisms, later approaches have shifted the attention to the roles of public and private institutions and citizens in collectively realizing smart city visions. This shift implies a move from techno-centrism to a more sociotechnical perspective, acknowledging the embeddedness of technologies in organizational and social contexts, as well as the mutual influences and interdependencies between social structures and the use of ICTs [8]. Accordingly, smart city discourse and practice has shifted from adding ICTs to urban space and services to engaging citizens and public and private organizations to experiment with technologies and urban data. This is hoped to contribute to the development of applications relevant to citizens [12], and to more innovation in urban governance led from 'the bottom-up' [13]–[15]. This change in perspective is embedded in a more recent definition, which conceives of smart cities as places where: *"**investments in human and social capital** and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, **through participatory governance**"* [16] (emphasis added).

By incorporating social and organizational aspects and allusions to community empowerment into the definition of smart cities, 'smart' is no longer uniquely viewed through the prism of technology, but more 'holistically' as sociotechnical systems where various urban matters of concern – notably economic growth, sustainability and quality of life – are linked to technological solutions [17]. This perspective thus views **smart cities through a lens of desirable preconditions and expected positive outcomes** across a wide range of parameters from governance to citizens' daily life.

As an alternative way to understanding smart cities, numerous scholars have proposed **conceptualizations in terms of dimensions**. The key dimensions or characteristics identified by these authors typically concern technological, physical, social and organizational characteristics, and can thus be seen in light of attempts to view smart cities 'holistically'. At the most basic level the dimensions of smart cities have been described as comprising *technology, people and institutions* [18]. Other scholars have sought to further specify and untangle these rough categorizations. Table I provides an overview of common attempts to conceptually define smart cities through dimensions. As this overview demonstrates, dimensional approaches share a common view that several aspects need to act in concert to create the notion of a smart city. These aspects can be summarized into the four foundational components: technology, institutions, material environment and people.

TABLE I
DIMENSIONS FROM 'HOLISTIC' APPROACHES

Nam & Pardo, 2011 [10]	technology (infrastructures of hardware and software), people (creativity, diversity and education), institutions (governance and policy)
Albino et al., 2015 [3]	a city's networked infrastructure that enables political efficiency and social and cultural development, an emphasis on business-led urban development and creative activities for the promotion of urban growth, social inclusion of various urban residents and social capital in urban development, the natural environment as strategic future component
Chourabi et al., 2012 [19]	management and organization, technology, governance, policy context, people and communities, economy, built infrastructure, natural environment

While these 'holistic' definitions acknowledge the copresence of technological and social systems, understanding technology as *driver* of social change is still rooted in a somewhat reductionist, techno-deterministic 'tool view' of technology [20]. Alternative conceptualizations view technology and social elements as intertwined, meaning that the demarcation between technology as artefact and the social as context dissolves [21]. This perspective seems especially apt in the context of smart cities where technology becomes imbedded not only in the physical fabric of urban environments, but in the fabric of daily social practices and where **mutual adaptation** is implied [10], [22]. This is also reflected in newer approaches in urban sciences which are grounded in cybernetics [23] and the ideas of real-time dynamism and data-driven management [24]. The cybernetic basis has also been used to analyze the opportunities and limits of the information-based functioning of smart city projects [25], [26] and the consequences of smart cities for citizenship [15], [27].

Reviewing past and current definitions illustrates the fragmented nature of perspectives from which smart cities have been addressed. While older perspectives foregrounded the role of ICTs and the primate of **automation**, newer perspectives focus on the need to reflect on the **integration** of disparate **foundational aspects** (technology, people, institutions and material environment), while others emphasize the results of their integration in terms of positive outcomes. Cybernetic approaches specifically stress the **dynamic and adaptative nature** of smart city systems. In essence, these various approaches find disparate answers to the question of 'what makes a smart city smart'.

Missing currently is an integrative perspective that allows to describe, assess and compare 'smartness' in a qualitative as well as quantitative manner across the range of possible smart cities instantiations. Specifically, dimensional approaches lack a comprehensive view about the **interrelations** between the smart city aspects they describe. This complicates necessary discussions about which systems contribute how much and in which way to a notion of urban 'smartness'. Even more critically, it leads to a dearth of possibilities to empirically investigate expected as well as unintended outcomes of smart city implementations. To overcome this common weakness of smart city efforts, we need better tools to understand 'grey shades', sub-system contributions and effects of design variations. In the following section, we present our framework of smart city configurations as an instrument to systematize smart city discussions and assessments.

III. SMART CITY CONFIGURATIONS

As indicated above, we conceptualize the makeup of smart cities as a combination of four universal components, namely technology, institutions, material environment and people:

- *Technology* encompasses the various elements of ICTs such as hardware, software, sensors, data, etc.
- *Institutions* encompasses the organizations involved in/affected by smart city efforts, governance, laws, policies, etc.
- *Material environment* encompasses the built infrastructures such as buildings, streets, lights, signage, etc. as well as planned and unplanned nature (gardens, parks, rivers, animals, etc.)
- *People* encompasses individuals as well as collectives such as specific social or demographic communities, personal and professional relationships, etc.

These four general aspects result from an integration and extension of existing smart city definitions (see Section II). Relevant to note is the *equal importance* of the four aspects, and thus of the material, institutional as well as social fabric of cities next to the technological component, in our approach. This is borne out by various failures which over-emphasized technology while missing institutional and social support [28]. A good example is Rio de Janeiro, where the IBM-led construction of a control room was characterized by too much (US biased) standardization, insensitive to the local context [29]. Hence, acknowledging that technology alone cannot provide 'smartness' in an urban environment without strategies and human efforts aligned with this vision, means that all four aspects need to be an integral part across smart city efforts.

Still, the four aspects (technology, institutions, material environment and people) will relate to each other in disparate ways across each smart city instantiation. For instance, depending on the ambitions of smart city planners one or the other aspects may be emphasized to achieve the wished-for outcome. Smart cities will thus articulate themselves in numerous combinations of these four aspects, creating instantiations that are more or less alike. Following Wittgenstein's concept of 'family resemblance' [30] we refer to such groups of dissimilar, albeit overlapping instantiations as **smart city families**. A smart city family contains an open number of cases that possess similarities in the way the four generic aspects relate to each other, while it is likely that no feature is identical across all instances. Smart city families make it possible to cluster instantiations – whether envisioned or real – into conceptually similar groups with the benefit to guide empirical assessments. This concept of smart city families is built on the expression of a fixed set of features so they can be empirically described and assessed.

The question is which framework can be used to conceptually describe and empirically assess similarity of smart city instantiations. We propose to base such assessments on the analytic description of interrelations amongst the four fondational aspects that constitute smart cities. For this we put forward the notion of **smart city configurations** (SCCs). With SCCs we refer to *the particular arrangement of smart city components that constitute a specific smart city instantiation*. SCCs serve the purpose to provide the necessary empirical tool to reliably describe and study individual instantiations as well as compare disparate instantiations, may they be potential or real. Most importantly, SCCs are a viable instrument to empirically investigate whether resemblances are relevant and productive in creating the expected positive outcomes such as improved mobility, health, housing or environment, as well as the range of unexpected outcomes that are likely to occur. This means, that we develop a systematic approach of describing smart cities in a consistent, testable and repeatable way. In the following section, we describe our analytical framework that underpins the notion of SCCs.

IV. PROPOSING DIMENSIONALITY AS EFFICIENT DESCRIPTOR OF 'SMARTNESS'

Much of the past and current discussion around 'what makes a city smart' has been either about defining 'markers' of intelligence such as speed or efficiency, or about defining outcomes that can be used as indicators for the successful applications of 'smartness' (smart mobility, smart energy, etc.; [31]). We take a different approach by aiming to define the nature of smart urban systems based on a small number of overarching characteristics that act together to create an expression of 'smartness'. These characteristics are presupposed as dimensions to accommodate the widest possible range of variations in features across smart city instantiations. Not all aspects of a city may be part of a smart city strategy or effort. Dimensions allow for this fact to be expressed explicitly both quantitatively and qualitatively. Using a small and fixed set of dimensions instead of varying qualitative descriptions as common in many definitions (see Section II) has further the crucial benefit to afford the direct comparison across instantiations. In our view, dimensions offer a more efficient and effective way to describe, assess and compare smart city instantiations than any other system including the use of static definitions. Our framework thus suggests to move from prescription of what a city 'should be like' to qualify as a smart city to a tool for describing actual instantiations that allows to conclude 'how much' and 'in which ways' – based on concrete, specific and replicable analyses.

We propose three analytical dimensions that together create an effective and efficient framework leading to SCCs. The three analytics dimensions have all individually been proposed as part of previous smart city definitions (see Section II). What our approach offers is a consolidation of these diverse thoughts to make them analytically accessible and productive within the same framework.

A. Analytical dimension 1: Integration

Integration describes the way the foundational basic aspects (technology, institutions, material environment and people) are combined. More precisely, the integration dimension describes the degree to which aspects operate separately from each other or in concert. The dimension is located between the two extreme points of 'complete independence' versus 'complete entanglement' (the latter referencing the sociomateriality perspective, e.g., [32], [33]). Relevant qualities this dimension captures are:

- *Location:* Which aspects are (or can/should be) integrated, and which aspects (can/should) remain separate?
- *Stability:* How stable is the integration/separation (e.g., consistent, periodically, event-based, random)?
- *Position:* Where across smart city processes does integration/separation occur (e.g., integration at the stage of inputs, partial separation during processing of information, total separation in terms of impact/outputs)?
- *Extent:* How complete is the integration/separation (none at all, partly, total)?

Integration can exist on all scale levels of a system. For instance, integration can exist between individual algorithms (e.g., those that control sound recognition and lighting levels in parks) or between large infrastructures (e.g., managing water and electricity flows). Integration may potentially also be possible across cities (e.g., achieving long-term goals of healthier living through integration of air-pollution measures and actions across several municipalities). Table II provides illustrations for the integration dimension. For ease of presentation, we limit these examples to relationships between two aspects, although more complex interrelations between three or even all four are equally likely. The initials T, I, M and P stand for technology, institutions, material environment and people, respectively.

TABLE II
ILLUSTRATIONS FOR THE INTEGRATION DIMENSION

Aspect	Integration examples
T<>I	Drug sensors in wastewater guide police to potential hotspots
T<>M	Heat sensors change climate controls to preserve energy
M<>P	Crowd behavior in nightlife area affects status of road barriers

Outlining the concrete extent and nature of integration across aspects further allows to ask important follow-up questions such as: What are the reasons for these specific choices and who determines such integration/separation choices (humans, system, laws/regulations, events, etc.)?

B. Analytical dimension 2: Adaptivity

Adaptivity is one of the most central features of smart cities in most definitions and descriptions (see Section II) and also has a central place in our framework. Adaptivity is defined as the ability to change and adjust; often this may happen in reaction to inputs and feedback, although adaptation is equally possible as result of specific rules or may even happen proactively. The two extreme points of the dimension range from 'no adaptivity' (i.e., no adaptation at all) to 'complete adaptivity' (i.e., the aspect or system transforms entirely up to being unrecognizable).

Adaptivity is often discussed in the context of software systems. However, we argue that in the context of smart cities adaptivity needs to be envisioned in a much broader sense, as also made clear by previous conceptualizations of the concept, especially in the context of a cybernetic perspective [23]. For instance, the integration of ICTs such as sensors into the built environment (and in some future visions even people) has the purpose to create improved living conditions. The latter encompasses housing, streets, green places, etc. just as much as people's behaviors, policies and regulations. Thus, adaptivity is a feature located at all levels from single subsystems (e.g., a specific stop light) to the overall eco-system within and beyond a smart city instantiation. In consequence, we propose to capture the following relevant qualities as part of this dimension:

- *Location:* Which systems are adapting (individual subsystems, multiple aspects, the whole urban eco-system)?
- *Target:* What is the location of the adaptation (within the same aspect/system, another aspect/system or both)?
- *Trigger:* How are adaptations prompted (reactive, proactive, event-based, rule-based, from outside/within a specific aspect, etc.)?
- *Speed:* How fast are adaptation happening (real-time, delayed, continuous, sporadic, long-term, etc.)?
- *Intentionality:* Do these adaptations represent intended or unintended/unexpected changes?
- *Extent:* How much adaptation is happening/envisioned/possible (none at all, some, complete transformation)?

Table III provides illustrations for the adaptivity dimension.

TABLE III
ILLUSTRATIONS FOR THE ADAPTIVITY DIMENSION

Aspect	Adaptivity examples
T	Adaptive lighting, self-configuring IoT devices
I	Data-based crime prevention programs, personalized city services
M	Smart landscape management, adaptive connected cars
P	Changes in peoples' energy consumption, safety behaviors, etc.

C. Analytical dimension 3: Automation

Automation is a feature of the way processes and interactions between smart city components are organized. Automation in a smart city context is generally thought of in a technological sense (e.g., decisions taken by algorithms instead of humans). However, if we take the ambition about the equal importance of all four basic components (see Section III) seriously, then this focus purely on the technology aspect is reductionistic. In fact, automation is equally a feature in human thinking and social decision making (e.g., through heuristics, biases, gut-feelings, etc.; [34]). Although tempting we therefore refrain from phrasing the two extreme ends of this dimensions as ‘human controlled’ versus ‘machine controlled’. Instead, we use the more neutral ‘entirely deliberate’ versus ‘entirely automatic’.

Further, our framework uses a broader perspective on automation, where automated processes are possible across all four basic smart city components owing to the ambition that our framework captures the full potential of smart cities, including ideal or visionary instantiations. For instance, it is entirely possible to envision automated changes in the layout of streets or the automated creation of housing units. Thus, while it may currently still be a bit of a stretch to think of the material environment as capable of total automation, our framework is equipped to capture such possibilities.

Automation helps to create efficiency in that processes do not have to be consciously re-produced again and again. At the same time, a high degree of automation is often problematized as resulting in ‘black boxes’ which limit a system’s transparency and accountability as well as the possibility for reflective thought [35]. Accordingly, the relevant qualities captured in the automation dimensions are:

- *Location:* Which systems are (meant to be) automated (individual sub-systems, multiple aspects, the whole urban eco-system)?
- *Processes:* Which processes are (meant to be) automated (decision-making, data collection, adaptation, etc.)?
- *Control mechanism:* Are mechanisms in place/planned to control and/or intervene in automated processes (e.g., through humans on the loop, control by other ICT systems, through institutional rules, laws/regulations, groups that make enquiries such as journalists/activists or combinations thereof)?
- *Extent:* How much automation is happening/envisioned/possible (none at all, partial, complete automation)?

Table IV provides examples for the automation dimension.

TABLE IV
ILLUSTRATIONS FOR THE AUTOMATION DIMENSION

Aspect	Automation examples
Data collection	Proximity marketing using brand-based mobile apps
Decision making	Housing allocation, matching peer-to-peer lenders
Adaptation	Self-repairing cities
Single systems	Autonomous buses, automatic rubbish collection

D. Linkages between the three analytical dimensions

Above we describe the three dimensions separately. Yet, as the explanations and examples imply, we do not perceive the three analytical dimensions as entirely independent from each other. For instance, the degree and nature of automation in the technology component can affect the level and shape of its adaptivity; similarly, a high degree of integration between institutions and people (e.g., through participatory or self-governance) may facilitate their adaptivity. However, analytically the separation is a crucial element to enable the systematic description and diagnostic, as will be illustrated in the next section.

V. SAMPLE ILLUSTRATION OF THE ANALYTICAL FRAMEWORK

The following is a short illustration of our framework applied to the smart city initiative “Stratumseind 2.0” in Eindhoven, the Netherlands. The analysis uses the information about the initiative provided by Meijer and Thaens [26].

Stratumseind is an important nightlife area in Eindhoven. The street contains over 50 pubs, cafés, discotheques and bars attracting huge visitor numbers. The objective of Stratumseind 2.0 is to use smart technologies to improve the safety, as well as livability of the area. As smart city initiatives go, Stratumseind 2.0 is thus small in scope centering on one street and limited in focus, namely safety, mostly by reducing aggression by street visitors.

A. Identifying foundational aspects (TIMP)

Starting our analysis, we draw out the four smart city aspects relevant in this instantiation in Table V.

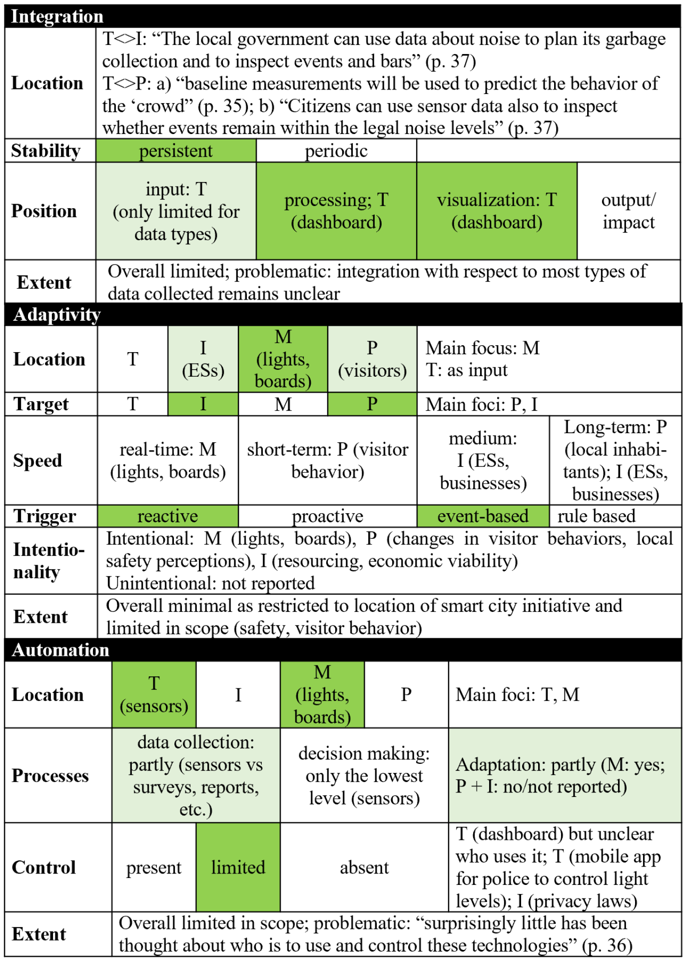
TABLE V
ILLUSTRATIONS FOR THE AUTOMATION DIMENSION

Technology (T)	Cameras for people counts, light sensors, wireless noise detectors, mac-address readers, social media web crawlers and sentiment analysis, data on mobile phone locations (purchased from providers)
Institutions (I)	Local municipality, police, universities, businesses (bar owners, technology providers)
Material environment (M)	Street lighting, interactive displays on the street with visitor information (e.g., ‘pub advisor’)
People (P)	Visitors, local inhabitants

As the above overview indicates, the core information stems from various ICTs. Additional information comes from non-technical sources: a weekly digital survey about neighborhood inhabitants’ perceptions, police reports about incidents, data from parking garages about traffic flows and number of visitors with cars, Municipal Cleaning Department information about amount of waste and glass collected per day, information about beer consumption from local breweries and overview of planned events from the public events calendar. Improvements in visitor aggression is meant to be achieved real-time through changes in light intensity and color and display boards and medium-term by measuring effects of interventions which should lead to improved planning of emergency services (ESs).

B. Smart city configuration for Stratumseind 2.0

Figure 1 presents the SCC analysis in a simple visual form which allows to easily showcase the configuration of the smart city instantiation Stratumseind 2.0. The SSC for Stratumseind 2.0 demonstrates that this smart city instantiation uses a limited set of mechanisms to achieve its goals: integration and automation are primarily located in technology (sensors) and material environment (light, boards), while adaptivity in these aspects is reactive and event-based (based on signals of possible aggression). The main targets for adaptivity are people (specifically visitors, short-term) and institutions (specifically emergency services, mid- to longer-term). The analysis further highlights that unintended effects or consequences were not directly considered (or not reported) which should caution decision-makers about probable gaps in their thinking and the captured information. The SCC analysis also highlights gaps and challenges such as the lacking clarity of how various datasets and data streams are integrated and how control is achieved.



Integration				
Location	T<>I: "The local government can use data about noise to plan its garbage collection and to inspect events and bars" (p. 37) T<>P: a) "baseline measurements will be used to predict the behavior of the 'crowd" (p. 35); b) "Citizens can use sensor data also to inspect whether events remain within the legal noise levels" (p. 37)			
Stability	persistent	periodic		
Position	input: T (only limited for data types)	processing; T (dashboard)	visualization: T (dashboard)	output/ impact
Extent	Overall limited; problematic: integration with respect to most types of data collected remains unclear			

Adaptivity					
Location	T	I (ESs)	M (lights, boards)	P (visitors)	Main focus: M T: as input
Target	T	I	M	P	Main foci: P, I
Speed	real-time: M (lights, boards)	short-term: P (visitor behavior)	medium: I (ESs, businesses)	Long-term: P (local inhabitants); I (ESs, businesses)	
Trigger	reactive	proactive	event-based	rule based	
Intentionality	Intentional: M (lights, boards), P (changes in visitor behaviors, local safety perceptions), I (resourcing, economic viability) Unintentional: not reported				
Extent	Overall minimal as restricted to location of smart city initiative and limited in scope (safety, visitor behavior)				

Automation					
Location	T (sensors)	I	M (lights, boards)	P	Main foci: T, M
Processes	data collection: partly (sensors vs surveys, reports, etc.)		decision making: only the lowest level (sensors)		Adaptation: partly (M: yes; P + I: no/not reported)
Control	present	limited	absent		T (dashboard) but unclear who uses it; T (mobile app for police to control light levels); I (privacy laws)
Extent	Overall limited in scope; problematic: "surprisingly little has been thought about who is to use and control these technologies" (p. 36)				

Note: Cells in dark green indicate main foci/fully realised aspects; light green indicates secondary foci/partial expression; white cells indicate that this value is not present/expressed

Fig. 1. Smart City Configuration for Stratumseind 2.0 (based on [26])

This illustrative analysis is based on only one source to fit within the limited scope of this paper and is thus naturally restricted in the detail we can provide. However, even this limited example already affords a foundation for a structured empirical description of Stratumseind 2.0. Looking at the specific configuration of Stratumseind 2.0 allows to understand the explicit and implicit assumptions about how design decisions are linked to the intended outcome of better safety in this area. Equally importantly, it allows to highlight the areas that remain opaque and under-developed. In a second step, the analysis also provides a basis to systematically test its assumptions, for instance, by changing specific elements of the current configuration and assessing their effect on the functioning of sub-systems or overall expected outcomes.

With the in-depth information city planners, system operations, engineers, etc. tend to possess, of course much more comprehensive SCCs can be created. In terms of the analytical details, while we believe that the qualities captured in each dimension (location, target, etc.) are useful, others can and should be added where appropriate. The same applies for the categories used for the analysis. For instance, depending on the granularity needed, automation control mechanisms may be assessed in much more detail or simply as present/absent. This means, SCCs are very flexible and easily adapted to the specific analytical context and purpose they are employed for. In the same regard, using the same categories across SCCs allows the direct comparison of instantiations within and across smart city families. In this respect a useful exercise may be the creation of parallel SCCs by disparate stakeholder groups to investigate possible mis-alignments in perceptions, expectations and assumptions about the structure and functioning of a smart city instantiation.

VI. CONCLUSION

The smart city configurations (SCC) approach proposed in this paper provides a new conceptual lens to capture the phenomenon of smart cities. The development of SCCs was driven by the need to make smart cities analytically accessible. The proposed combination of smart city configurations as a theoretical angle and the three analytical dimensions as an empirical guiderail enables the systematic description, assessment and comparison of smart city instantiations, including a systematic way to analyze and compare their function and effects, something current definitions and conceptualizations cannot deliver.

Many of the reviewed literatures try to prescribe how a smart city 'ought to look like', while often offering very different visions (see Section II). This is unhelpful when aiming to understand how variations in smart city features potentially enable or hinder intended outcomes. We see our approach in the sense of a toolbox for city planners, managers and researchers that can be applied to actual as well as imagined smart city instantiations. It further provides a methodology to understand variations in smart city families and their impact.

Our approach is purposefully value neutral: 'more' integration, adaptivity or automation is not linked with 'better' or 'smarter'. Instead, 'smartness' is a composite of features across our three analytical dimensions that needs to be described quantitatively and qualitatively. This avoids a seemingly common fallacy of 'more is better' and instead forces a detailed engagement with the real-life complexity of smart city instantiations.

As an analytical tool, SCC analyses can help to make transparent the basis for policy decisions and implicit assumptions of decision-makers (e.g., why and how specific integration choices should lead to improved mobility, health, education, etc.). Explicitly outlining the mechanisms expected to lead to improved outcomes allows to validate propositions in terms logic, feasibility, possibility to manipulate/steer the outcome variables or to check for gaps in assumptions. Such transparency is a crucial prerequisite in retaining the legitimacy of smart city efforts [36], aiding their explainability and accountability. In practical terms, detailing (existing or future) smart city configurations in this way offers an important decision support tool to guide design choices and strategies.

Currently, our approach exists as proposal and certainly requires testing and validation to understand its challenges in real life. Also, there are crucial aspects that our approach cannot answer directly, e.g., are there 'ideal' combinations of features, which smart city configurations are good or bad examples of 'smartness' or is there a threshold that differentiate 'smart' versus 'non-smart' cities? These are conceptually as well as practically relevant questions that do not find easy answers. However, what SCCs offer is a concrete and practical instrument to investigate these important questions.

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