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Mapping the Realities of Smart Urbanism: A Method to Promote Transdisciplinary Smart City Approaches

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Abstract. Smart urbanism is shaping the world's cities. Through the use of digital sensors attached to urban infrastructure, smart cities use data to make quantitatively informed decisions regarding city management and policy. Yet, whilst elements of the smart city exist in the empirically observable realm, the proposed benefits of smart urbanism emerge from an empirically unobservable reality. Therefore, the forces driving the smart city are essentially invisible to those who live within it. This paper adopts a perspective informed by the work of Martin Heidegger and critical realism, which respectively posit that the essence of technology is to reveal new entities and this simultaneously occurs across multiple domains of reality - arguing that the essence of smart urbanism is the experience of previously imperceptible events, which are revealed to achieve a set goal or vision. This paper proposes a systemic map centred upon a mnemonic, SMAARTEE, which stands for eight elements of smart urbanism - *situation, manifestation, actors, application, reveal, technology, events* and *experiences* - to be used to aid holistic smart city thought, in order to shape transdisciplinary practice.

Keywords. Smart City, Transdisciplinary, Transdisciplinary Engineering, Quadruple-Helix, Martin Heidegger, Critical Realism

Introduction

A simplistic definition of the smart city is "a place where traditional networks and services are made more flexible, efficient, and sustainable with the use of information, digital, and telecommunication technologies to improve the city's operations for the benefit of its inhabitants" [1]. However, the essence of smart urbanism is contested, with Luca Mora et al arguing there are two broad conceptualisations of the smart city. The first being a 'holistic' approach, which argues "that smart cities are described as the result of the balanced combination of human, social, cultural, economic, environmental, and technological aspects, which stand alongside one another" [2]. On the other side of the coin sits the 'techno-centric' approach which focuses "almost exclusively on the singular role of new technologies in developing integrated platforms of city services" [2]. Regardless of its interpretation, the smart city is a complex phenomenon which encapsulates not only the technological and governmental, but also the social, political and environmental spheres [3].

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There is a well-established tradition of multidisciplinarity within smart urbanism, with the 'triple-helix' organisational model – comprised of the public and private sectors plus academia - serving as an example of this [4]. However, this represents a techno-centric approach to the smart city. The omission of the citizenry in this conceptualisation has led to the establishment of the 'quadruple-helix' [5], with smart city projects identifying stakeholders who cover not only "citizens, businesses, universities [but also] third sector, health partners, emergency services, entrepreneurs, start-ups and public bodies" [6]. What emerges is an expansion in expertise and insight contained within a project. Whilst this may appear to be beneficial, additional complexities are added, especially concerning the potential for the emergence of "professional silos [which could] leave the lay community entirely outside [a projects] circle of understanding" [7]. The emergence of these silos is a significant issue which could prevent the realisation transdisciplinary smart city solutions, especially when concerning the "fusion and/or transcending of methodologies" [8] underlining any transdisciplinary approach. In short, for the transdisciplinary to exist, silos cannot.

1. Model Confidence: Theoretical Perspectives

Smart cities are practically invisible at street level, with Adam Greenfield arguing that "the average pedestrian is at best only liminally aware of the presence or operation of [IoT] sensors" [9]. To holistically interpret the smart city in a transdisciplinary manner, these hidden elements need to be 'revealed'. Martin Heidegger's 1953 lecture *The Question Concerning Technology*, presents a means to do this, with the philosopher's argument that "technology is no mere means [rather it] is a way of revealing" [10]. To apply this observation, take the analysis of a city's metabolism, with Hossein Shahrokni et al arguing that "the real-time monitoring, analysis, optimization, and visualisation of energy and material flows in cities may allow urban planners to obtain new insights into the flow of energy and material in cities" [11]. Without the application of sensory technology, a real-time analysis of a city's metabolism would be impossible, for the technology *reveals* the flow of energy and materials. This 'bringing-forth' of a city's metabolism "involves conceptualising a city [...] as an organism and tracking resources that go into the system and products and wastes that leave it" [11]. Viewing a city in this way also, in Heidegger's terminology *enframemes* it, with the utilisation of technology setting a framework in place for future development [10].

Whilst there are examples of technological acceptance and user experience research concerning smart urbanism [12], these only consider a small segment of the technological whole - that which is user or citizen facing. However, such approaches fall short of encapsulating the totality of the smart city. For, much of the value produced through smart urbanism lies in the collection, refinement and utilisation of data, which occurs beyond the perception of not only the citizenry, but also those who operate within the smart city milieu.

The concepts and theories of Roy Bhaskar and the 'critical realism' he pioneered are best placed to interpret this unseen element of the smart city, for the unique contribution of critical realism lies in an assertion that reality cannot be reduced to our experience of it [13]. To zero in on what is experienced is to focus on the tip of the metaphorical iceberg and not the majority submerged under water [14]. This viewpoint is suited for application in the smart city realm. For instance, consider the MotionMap app developed for the

Smart Cambridge project in the UK [15] where users access the app vis-a-vis a mobile device. Yet, the totality of the app includes not only the app itself, but also the data fed into it, its collection and refinement, plus the motivations behind the app's existence. This highlights Bhaskar's assertion that there are three domains of reality: the *real*, *actual* and *empirical*.

Smart city projects exist to achieve set goals or visions, with these drivers existing in the *'real'* domain - the "level [where]'causal mechanisms,' exist [through] the inherent properties in an object or structure that act as causal forces to produce events" [14]. In this example Smart Cambridge was devised to "transform the way people use the city's transport network [and] to reduce congestion and boost the local economy." [16]. This drive for economic expansion, particularly through enhancing journeys across the city, represents the causal mechanism for the smart city in Cambridge. These causal forces produce events which formulate the '*actual'* domain, where events take place independent of experience. It is within the actual domain where the entirety of urban reality exists, including the collection of data regarding public transport. In Cambridge, buses are fitted with GPS trackers to monitor movement [17], which transmit data to the 'Intelligent City Platform' [18] where it is combined with other city data captured by a network of IoT sensors [19] – all of which occurs beyond the perception of the citizenry. Finally, there is the *empirical* domain, exemplified by the MotionMap app itself. Thus, when viewed through a critical realist or Heideggerian perspective, the MotionMap app is not just a tool to make public transport easier to use, but rather, it is an element of a grand project envisaged to make Cambridge more economically competitive through the utilisation of data and the internet of things.

Taking this perspective, at a fundamental level, the smart city is not merely the use of digital infrastructures and data to achieve a set goal or vision, but rather is *the experience of previously imperceptible events, which are revealed to achieve a set goal or vision*. Whilst this paper argues that this original interpretation presents a fresh perspective of smart urbanism, it is also aware of the potential aloof and detached nature of its constitution. Speaking in such philosophical and broad terms runs the risk of non-interoperability with existing smart approaches, alongside the alienation of those who could potentially use it – thereby, imposing a 'professional silo'. According to Nils Wognum et al a key challenge within the formulation of transdisciplinary projects is the presence of "professional cultures and cognitive cultural differences [which] create subgroups among team members, challenging cross-discipline collaboration" [20]. Therefore, by deconstructing the essence of the smart city it is argued that holistic interpretations of smart urbanism can be built upon the back of it, in order to promote transdisciplinarity. What follows is a means of applying the above theories *in situ* to promote transdisciplinary approaches towards smart urbanism.

2. SMAARTEE: Smart City Analysis and Mapping Tool

What is proposed is a development based upon the work of Peter Checkland and his well-established soft systems methodology (SSM) [21]. A cornerstone of SSM is the CATWOE mnemonic - *Customer, Actor, Transformation, Weltanschauung, Owner, and Environmental constraints* - which concerns six elements to consider when constructing the root definition of a proposed system [21]. Whilst CATWOE is entrenched within systems engineering, it is limited when concerning the smart city.

Firstly, Checkland argues that within the SSM schema, a system requires input which is transformed into output [21], therefore, within CATWOE the transformative process is where technology fits in - presenting technology as a means to an end. As argued above, technology is more than a means to an end but is instead, a means of revealing previously concealed entities. Another issue with CATWOE in this context is a focus upon one transformation taking place, whereas within the smart city, multiple occur simultaneously, spanning the technological, political and social realms. Therefore, at a macro level, CATWOE can only work through 'black-boxing' smart city technologies [22] or by being used at a micro level when concerning specific technologies and their utilisation - potentially producing silos. Finally, the human elements of CATWOE - the 'customers', 'actors' and 'owners' - are all somewhat redundant distinctions within the smart city context, with the prevailing triple/quadruple-helix structures envisaging each stakeholder as a 'partner' [23].

Owing to the above shortcomings, what is proposed is a smart city specific mnemonic which encapsulates the various elements of smart urbanism, from its goal orientated and potentially transdisciplinary nature, to the inclusion of Heidegger and Bhaskar's work, to produce a holistic approach towards interpreting and devising a smart city project. This concept is called SMAARTEE and consists of eight elements: *situation, manifestation, actors, application, reveal, technology, events* and *experiences.* The purpose of a mnemonic such as this is "for aiding recall when it is not possible to provide oneself with external retrieval cues" [24] and with this in mind the above example was chosen to be 'retrievable' and does not identify the sequence upon which each element is used - which would spell SMATEERA (as set out below). Rather, each element when used in sequence, combines to make a map which can be used to visualise these different elements (Figure 1). SMAARTEE has been formulated to counter 'siloised' thinking and therefore, to aid transdisciplinary approaches and is envisaged to be utilised at numerous different times in a project's lifecycle and in several different ways. For instance, it could be used speculatively, in the early stages of a project, as a means of setting an approach, or conversely, it could be used reflexively to analyse a completed or near completed project. Owing to the "emergent behaviour and shifting goals" [25] of transdisciplinary engineering, it is also possible for the map to be used throughout the project as a means of documenting and categorising development. The map could also be used in a comparative manner, with different actors revealing their own interpretation of the smart city. The next sequence covers the elements which make up SMAARTEE and are presented sequentially as they appear on the map below.

Situation: Why is there a need for a smart city approach?

Smart city projects do not just appear out of thin air, rather they exist to achieve a set goal as part of a broader vision or strategy. These projects are frequently conceived under a larger umbrella vision, encompassing sustainable, economic and efficiency parameters [1], which influence specific smart city approaches and therefore, the orientation of the project. Smart city goals can encompass a range of drivers. For instance, they can be problem orientated and strive to enhance the city through easing a persistent issue - such as traffic and congestion [26] - or can also be used to achieve a set goal - such as net-zero [27].

Manifestation: What shape is the smart city project going to take?

There are three general approaches a smart city can adopt, from the production of information, to automating existing systems or transforming them [28]. The most straightforward approach concerns the production of information, embodied by Cambridge's aforementioned, GPS tracked, bus service [17]. With this information, the

project automatically provides updates at bus stops [29] - the automation of a service – and is trialling 'integrated ticketing', which enables passengers to pay with their phones [30]; a system transformed. Another consideration for a smart city project centres around whether there is a need to develop new infrastructure or a capacity to update legacy systems. For instance, digital sensors can be situated unobtrusively on pre-existing infrastructure which form the everyday experience of a city, such as bins, lampposts and busses [4]. However, such alterations may not be possible, or there may be a desire to refresh or renew sections of the city.

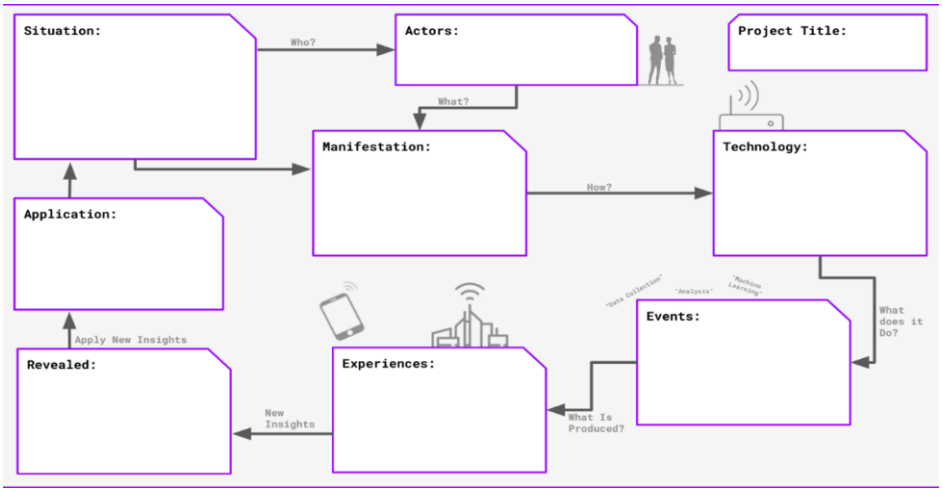

Figure 1. The SMAARTEE map.

Actors: Who is going to be involved with bringing the smart city to life?

Alongside the quadruple-helix, smart city projects need to consider how the citizenry and civil society are to participate. Paulo Cardullo and Rob Kitchin propose a 'scaffold of smart city participation' [31] where the least involved citizens are 'steered, nudged or controlled' as 'non-participants', whilst the forms of involvement which encompass 'citizen power', place them a position of 'leadership or ownership' to 'create' the smart city. Whilst on the surface, more public participation may produce a more holistic project, the reality is that many smart city projects require little involvement from the public sphere, such as the integration of smart traffic control systems [32]. Ultimately, there is an importance in strategically identifying the role the public should play to ensure that the unique insight provided by residents can be utilised in an impactful way.

Technology: Which specific technologies are to be used?

Within smart urbanism original insight is primarily revealed vis-a-vis technological means, yet there is often a 'black-boxing' of technology in the name of simplicity [22]. However, in the pursuit of transdisciplinary smart urbanism, to consider the realities of technology is essential. Therefore, breaking-down the 'technical' into its constituent parts; software, hardware, network connectivity, data storage, devices and platforms [33] is proposed. Whilst this clarifies the approach, it also acts as a guide to consider the complexities of a project. Rather than relying on a black-box perception of the smart city, a detailed analysis would consider the types of sensors (hardware), which computer

programs (software) and which IOT networks would be used (network connectivity and data storage), alongside data presentation (platform) and if devices are required.

Events: What events take place through the functioning of technology?

For example, when an oxygen sensor collects data, it is imperceptible to an observer, therefore, its functioning needs to be revealed. The 'events' element - named in reference to the critical realist argument that events occur regardless of experience - serves as a means of making explicit the hidden functioning of smart city technology. In a similar vein to the above unboxing of technology, by considering in detail the un-experienced elements of technology, a deeper and more holistic understanding of a smart city project can be accomplished.

Experience: What is produced by the technology to be experienced?

An important consideration for understanding a smart city approach, as it is this experience which produces the insights which are to be applied to the city. So, whilst a sensor may collect data, the experience of that functioning comes through a visual representation of what is analysed. This may be in the form of raw data sets or can be refined and published as a graph or a map.

Reveal: What original insights are going to be revealed?

The question is which previously imperceptible elements of a city would a project make visible? This could include, but is not limited to, phenomena such as air quality, traffic levels, infrastructure faults, public opinion, social media traffic, public transportation use, the popularity of public spaces or, as referred to above, a city's metabolism. A technology being utilised in situ may well reveal multiple essences which escape consideration before installation, however, by considering the use of technology in a 'revelatory' manner, the project will be in a better position to interpret what is revealed; expected or otherwise.

Application: How are the insights generated going to be applied to the city?

The final element concerns the application of insight. For instance, if a project develops a platform to manage the data produced by a sensor network, future smart city developments will utilise that platform. Another facet which influences the application of insight revolves around the potential of 'scaling-up' and expanding trial projects. Within the smart city context there are three means of scaling-up: roll-out, expansion and replication [34]. Therefore, when considering how to apply the insights produced by the smart city, it is of use to consider not only how this application will take place, but also potential impacts of the technology itself, and how these could frame city development going forward.

The proposed value within this approach is bound in the argument that any smart city project is an undertaking which spans numerous domains of knowledge, skill and, with a nod to critical realism, reality. Therefore, the SMAARTEE mnemonic and map serves as a means of prompting holistic interpretations of smart urbanism to be used in the implementation of any smart city project. This, as argued below, also serves as a base to implement transdisciplinary engineering practices.

3. SMAARTEE and Transdisciplinary Engineering

As argued within academic literature, "transdisciplinary engineering research is especially aimed at solving problems that require a vision beyond the immediate engineering task for their solution" [20]; the above SMAARTEE mnemonic and the below map are designed to facilitate the mapping of that vision. Yet, given the diversity

of stakeholders within a smart city project, there is potential for silos to emerge is prescient.

An important element of transdisciplinary approaches is “the integration or relationship of different forms of epistemics (ways of knowing)” [25]. Scholz and Steiner draw from ‘the architecture of knowledge’, arguing that *experience* produces *understandings*, which in turn, produce *conceptualisations* and subsequently, *explanations* of phenomena [25]. However, whilst the authors discuss the significance of all four elements, they “assume that the conceptual level is most important in transdisciplinary discourses [and that] conceptualization is a key level of discourse among stakeholders" [25]. For transdisciplinarity to emerge, a shared conceptualisation of the task ahead is required. The SMAARTEE map (Figure 1) has been envisaged to produce a holistic conceptualisation of the smart city, thereby ensuring all stakeholders are able to work from the same source.

However, maps “are very much an abstraction, a mental construction, and as such have become disassociated from the physical and social realities of lived experience” [35]. This is of relevance when considering the ‘post-normal’ scientific approach imbued within transdisciplinarity, for the ‘normal’ scientific view “postulates that - though the boundaries between science and practice have become blurred - scientists and practitioners have different primary objectives and reference systems” [25]. Yet, the ‘post-normal’ view posits that “in complex, real-world situations where facts are uncertain and values and interests form perceptions and decisions [do] not distinguish between science and practice knowledge [...] science becomes one (stakeholder) voice” amongst many [25]. Therefore, within the scientifically ‘post-normal’ realm of transdisciplinarity, the purpose of mapping is not to represent an absolute ‘truth’, but to conceptualise the various experiences and understandings of stakeholders to produce a holistic, transdisciplinary explanation of the task at hand. Thus, by deconstructing the smart city, the user of the SMAARTEE mnemonic or map has a means of experiencing the smart city holistically, not as a solely technological, governmental or social phenomena, but as a combination of all three. Therefore, a holistic conceptualisation of the smart city can be realised and, thus, a base upon which transdisciplinary approaches to smart urbanism can be built.

4. Conclusion

This paper is a component of an ongoing research project which seeks to further connect the realms of engineering and social sciences. An absent element of this paper is the testing and *in situ* utilisation of the SMAARTEE approach; this will follow in due course. Yet, the above pages demonstrate a novel means of holistically interpreting the smart city and enhancing the effectiveness of transdisciplinary smart urbanism. Therefore, to conclude, this paper has applied the work of Martin Heidegger and Roy Bhaskar as a means of deconstructing the smart city, arguing that the act of smart urbanism is *the experience of previously imperceptible events, which are revealed to achieve a set goal or vision*. This interpretation of the smart city was subsequently utilised to produce the SMAARTEE mnemonic and map.

The driving ideology behind the SMAARTEE approach is the translation of abstract philosophical works into a tool which can be used by any stakeholder within a smart city project. It is designed to function as a device to aid de-siloised thought and is envisaged as a means of conceptualising a unique holistic interpretation of any smart city project.

The purpose of the map is not to depict an objective reality or 'truth', but rather to bring-forth the broad church of expertise and viewpoints contained within a smart city project, and therefore, to reveal the complexities inherent within the development of smart urbanism. By experiencing and understanding the various elements conceptualised within SMAARTEE, holistic explanations of the smart city can be revealed. Thus, it is argued, that the SMAARTEE mnemonic and map sets the scene for the adoption of transdisciplinary approaches towards implementing the smart city - an environment where the collaboration and integration of divergent disciplines and expertise is deemed essential, yet, is a reality where professional and linguistic silos often proliferate.

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