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Meaningful Transfer: Tech-Knowlogical Interdependencies in the Digital Built Environment

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This paper engages with ideas of tacit and explicit knowledge, how it is created, transferred, and ultimately translated in contemporary discourses of the digital built environment. The aim is to open a more critical and original dialogue in the digital built environment by (a) interrogating digital innovation as it strives to utilise relatively distilled information to enhance the sustainable design, construction and operation of the built environment and wider urban areas, (b) representing the rights of those whose knowledge is created and transferred in the digital built environment and (c) by further understanding the context of knowledge creation, and thus maximising its potential for scaling up sustainability objectives. The paper considers the conceptual and methodological tools that may help to focus more novel analysis of knowledge production and transfer in the digital built environment. The paper considers three conceptual positions that have hitherto been considered either in isolation or only tangentially connected to each other: (1) Science and Technology Studies (STS), in order to understand how society and technology is intertwined and importantly to form a meaningful backdrop for engagement with knowledge; (2) Organisational Theory (OT) and the concept of “pipelines,” in order to understand how organisations—and more broadly cities—can meaningfully capture and utilise knowledge when transitioning to digitally enabled sustainable futures; (3) Aspects of Actor Network Theory (ANT), in order to understand how knowledge travels and gets translated and institutionalised in new domains. Furthermore, we also use the same conceptual positions to argue how following knowledge can help individuals and society navigate the digital built environment. Our findings suggest that smart technology is a “social prosthesis,” and only works because humans make up for its deficiencies.

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INTRODUCTION

The aim of this paper is to open up a new engagement with ideas of explicit and tacit knowledge in order to examine how it is created, transferred, and ultimately translated in contemporary discourses of the digital built environment. At the moment, the ability of smart technology (in the urban environment) and property-based technology (in the built environment) to deliver social and environmental sustainability remains *little more than an article of faith in many cases* (Evans et al., 2019: 558). The underlying argument in this paper is that, in part, this is due to the (only) partial transfer of knowledge, often only explicit, binary and codified (captured as information and data)—and importantly the absence of softer tacit knowledge that often

operationalises data and information. Without the anchoring coordinates of tacit understanding, it can be argued that data and information only obliquely represent the respective phenomena under investigation—whether that be the outputs of an experimental urban initiative, movement around a building or an automated valuation model—and thus risking misinterpretation, misrepresentation and poor adoption and application in practise. By largely ignoring tacit forms of knowledge creation, transfer, and translation—in favour of data and information-based reflections of this same phenomena—the agency-orientated political reality of knowledge is often disguised and inflected. This decontextualization disregards and distorts how knowledge (and the power held within) is expressed and appropriated through the urban and built environment (Livingstone, 2003).

In order to improve on this situation, our aim is to open a more critical agenda in relation to knowledge in the digital built environment to (a) interrogate digital innovation as it strives to utilise relatively distilled information to enhance the sustainable design, construction and operation of the built environment and wider urban areas, (b) represent the rights of those whose knowledge is created and transferred in the digital built environment and (c) by further understanding the context of knowledge creation, transfer and translation, maximise its potential for improving and scaling up sustainability objectives. The ensuing discussion posits an alternative perspective to the linear and rational flow of data and information that often masquerades as knowledge production and transfer. The central argument in this paper is that it is not sufficient for smart technology (alone) to only capture explicit information via the sensor-based internet of things, algorithm-based reflections of human activity or building information modelling. Building on the arguments of Collins (2021) in relation to artificial intelligence, this is because smart technology, in its various guises, is only an adequate “social prosthesis”—it is a tool to help improve the use of buildings and their urban environment, but it is not able to mimic human activity exactly. This is because building use is a polymorphic action. In other words, day-to-day decision making can only be executed successfully by a person or organisation who understands the social context within which they make such decisions (Collins, 2010.) This is in contrast to mimeomorphic actions that can be mimicked in the same way in all situations.

This is because the use of buildings, and wider urban areas, rests upon continual nuanced and context bound decision making. In the same way that driving a (non-autonomous) car into traffic demands eye contact with other drivers and a knowledge of the relative rules of the highway code, day to day building use decisions involve complex tacit interactions with colleagues and knowledge of business values. In focusing on the “tacit,” our objective here is to examine how the increased generation, transference and harvesting of “data” and “information”—regularly seen as objective resources to improve the performance of the built environment—has the potential to ignore context specific knowledge. Ignoring, as it could, the human experience of information and associated knowledge in

society (Trencher and Karvonen, 2019) and how *collective values are infused in and practised through the built environment* (Karvonen, 2020: 421).

We contend that this gap in knowledge is in part down to the difficulty of isolating and describing the knowledge process. In its tacit form, knowledge is often unspoken, and awkward to recount and capture. In this paper, we counter this situation by developing a conceptual framework to better understand how and on what basis this “smart knowledge” is often partially transferred. In doing so, the paper addresses the following research question: *How can greater recognition of knowledge creation, transfer, and translation help to understand the techno-politics of the digital built environment?* In order to reflect upon this question, the methodological approach of this paper is inherently conceptual, with the aim of suggesting theoretical perspectives that can help to focus the critical analysis of knowledge production in the digital built environment. The paper considers three conceptual positions that have hitherto been considered in isolation or tangentially from each other when relating to the generation of knowledge: (1) Science and Technology Studies (STS), in order to understand how society and technology is intertwined and to importantly form a backdrop for engagement with explicit and tacit knowledge; (2) Organisational Theory (OT), in order to understand how organisations—and more broadly cities—can meaningfully capture and utilise particularly tacit knowledge when transitioning to digitally enabled sustainable futures. (3) Engaging with aspects of Actor Network Theory (ANT) in order to understand how knowledge travels and gets translated in new domains.

While STS and ANT have a common lineage, they typically examine the role of actors. In this paper we instead focus on the movement and interaction of knowledge, aided by the third element of organisational theory. By following knowledge, it is possible to understand where and how it originated, what Healey (2013) describes as origin storeys, and to then better recognise how knowledge can be transferred and captured in new domains.

This engagement has utility on several fronts. While the adoption of technology may seem to intuitively align with objective information and key performance indicators (KPIs), its actual utilisation, interpretation and adoption is implicit and qualitative and often inherently unspoken—taking place in communities of practise. This process is very difficult to monitor through KPIs that are designed to capture quantifiable direct impacts. Focus in this area is important because uncritical knowledge transference has the potential to decontextualise and even deterritorialise context specific knowledge and reposition it in different contexts beyond its original zone of creation—creating new, more diffuse, and potentially inaccurate knowledge assemblages. The focus on *measurability* results in *insufficient recognition of what cannot be measured coupled with excessive stress on the readily measurable and codifiable aspects of performance* (Addis, 2016: 444). Currently, tools in the digital built environment (for example digital sensors and automated machine learning models) achieve their effects through the sheer quantity of data that they connect, mine and/or hurl at the problem or task in question.

However, knowledge has a depth and dimension that needs to be unearthed. Understanding how knowledge is generated and subsequently transferred (often only partially) into new digital domains will illuminate how this process is bound up within and contextualised within socio-spatial processes, governance and built environment design, construction, and management. This genealogical perspective is relatively rare, with only a few analyses available of how knowledge is formulated and deployed over time, space and by agents or stakeholders in this context. Consequently, the experimental method outlined in this paper has the potential to sit alongside the traditional KPI performance methodologies adopted by organisations, cities, funders and governments to form a more nuanced description/characterisation of activity, best practise and adoption strategies.

The remainder of this paper is structured in the following way. The next section sets out the emergence of the digital built environment and the relative silence in relation to tacit knowledge, in favour of explicit data and information. It then gives a grounding in explicit and tacit knowledge, setting out the value in examining this position for the built environment. The paper proceeds to consider the conceptual and methodological tools that can help connect the tacit domain into the digital built environment. The paper concludes by summarising the argument and by setting out some additional research possibilities in relation to knowledge transfer in the digital built environment in two main areas: (1) the potential for enhanced examination of knowledge, particularly tacit knowledge production and transference, to help scale up the adoption of sustainable digital innovations; and (2) the potential methodological strategies available for understanding and capturing tacit knowledge. The paper ends with an appraisal of limitations, in view of the positions adopted and developed in this paper.

THE DIGITAL BUILT ENVIRONMENT

Over the last 20 years, the concept of the smart city (Batty et al., 2012) has gained purchase within society and economies as information and communication technology and software enabled technologies have either been used to stimulate economic development or to assist city management (Kitchin, 2014). The global shift in relation to digital technology—what Schwab and Davis (2018) calls the “fourth industrial revolution”—has altered the way we live, work, and relate to one another. There is now a palpable enthusiasm to increase urban knowledge through the application of big data, ubiquitous sensing, geospatial and social network analyses, algorithms, machine learning, and artificial intelligence (Karvonen, 2020: 418)

The built environment, as a living and/or working space, as an asset, or an industry, forms a significant part of the wider digital transformation of the city, and is the point of departure for this paper. In recent years, the built environment has begun to be radically transformed by data and software innovations. The digital built environment, in many ways the physical part of the smart city and urban domain [as distinct from but connected to humans and organisations as the social and behavioural domain], has begun to transform itself through construction technology.

Smart buildings are increasingly ubiquitous, aided through new construction technologies such as Building Information Modelling (BIM), digital twins, city information models, 3D printing and robotics. In addition to the management of the bricks and mortar element of the built environment, the conveyancing of the built environment, as an asset, has also been disrupted by smart innovation (Baum, 2019). This has primarily been driven through the platform mediums of fintech, the distributed algorithms of blockchain, but also through automated methods of valuation that are likewise reliant on computer algorithms (Tagliaro et al., 2021).

The wider digital urbanism has begun to question these innovations. In recent years, the city and related infrastructure has been a lens for science and technology (STS) scholars to explore the interrelationship between knowledge, technology, power, and politics (Foley and Miller, 2020). Other scholars have understood this situation through the lens of volunteered information (Sui and DeLyser, 2011), as well as through a platform understanding of urban society (Fields et al., 2020; Stehlin et al., 2020). However, in digital built environment studies (broadly including construction management, quantity and building surveying, and real estate management) the smart city and the harvesting of information for the digital built environment is typically considered as an untrammelled good for society, the economy, and the environment [provided data protection laws are not violated]. The increasing ubiquity of information is viewed as a neutral conduit to more sustainable and efficient buildings and operation. However, the move to digitalize the built environment can have profound and long-lasting impacts on the politics of sustainable urban development—particularly on the assemblage and transference of knowledge into new domains and platforms.

In this sense, the gathering and transference of information is not seen as a neutral conduit but rather as a liminal space where territorialised context specific knowledge is gathered, turned into information, and often reappropriated in new domains and locations. This process has its own politics that often goes unexplored. What has been termed the urban techno-politics (Karvonen, 2020) recognises that the urban built environment and digital technology exist in a connected synergy (Graham and Marvin, 2001; Rutherford, 2020) which co-evolves (Guy and Karvonen, 2011; Farias and Blok, 2017). In recent years, this understanding—often seen through the lens of Science and Technology Studies (STS)—sees cities as *messy sociotechnical achievements that are simultaneously discursive, material, temporal, spatial, and infused with power dynamics* (Karvonen, 2020: 418). We aim to extend this critical analysis into the digital built environment, connecting debates that are ongoing on the periphery of the built environment (techno-politics) and organisation studies (particularly the transfer of tacit knowledge) into the relatively theory neutral digital built environment.

REJECTING THE LINEAR: THE TACIT DOMAIN

Digital built environment advocates often see themselves as *creating technologies, techniques and visions that are scientific,*

objective, common-sensical and apolitical (Kitchin, 2014). Reminiscent of modernist ideals of a better life achieved through economic progress, the idea that society is achieving ever higher levels of digital control, even a (positively connotated) revolution, over the built environment shapes much of contemporary thought and practise in the digital built environment (ARUP, 2017). In a certain sense, the advent of data and technology has moved the understanding and management of the built environment forward, celebrating technological expertise (Baum, 2019). However, we can also see it moving back towards a tradition of positivism and uncontested “truth” where interpretation and causality is not needed because we have [or rather, deemed to have] real-time “total” information control (Canali, 2016). Academics and practitioners in the digital built environment often consider their research pragmatic and non-ideological. However, this runs the risk of the digital built environment becoming a pre-resolved end in sight—and thus obviating discovery, chance, and change. It is this simplification and potential overstatement of progress that obscures the *adequate social prosthesis perspective*—namely, that the real potential of the digital built environment is reliant upon the incorporation of socialised tacit knowledge.

A central argument in this paper is that *knowledge production, transference and translation is a missing link between how the smart cities learn and transform into successful digital built environments*. This argument is linked to the observation by Evans et al. (2021) that there is a gap between the process of experimentation in the city and work focusing on learning. This argues that *moving from a project to changing business as usual relies on how lessons from experimentation are captured and embedded into organisations* (Evans et al., 2021: 172). However, while learning and knowledge are often used interchangeably and relate to one another, they are nonetheless different. Indeed, learning, knowledge, information and data are often considered part of one fuzzy whole. For this reason, the assumption that learning automatically equals knowledge and widespread adoption can often be forced. While there is lots of learning going on, this does not necessarily result in knowledge that can be readily transferred into organisations or wider society. Learning is the process, as well as potentially the platform, through which someone or something develops understanding. Knowledge itself relates to the output of this learning, whether it is explicit, tacit, personal or group orientated. Ultimately (at least in most setting and for most processes), it is this product (the desired and agreed outcome), not the process as such or at least purely in itself, that needs to be transferred within organisations and institutions in order to scale up activity and to transfer best practise into new domains.

Broadly speaking, the digital built environment is good at transferring explicit information that can be codified, but not so good at doing the same job for the tacit underpinning—that is, the unspoken daily actions that characterise building use. This problem can be seen in the increasing adoption of Building Information Modelling (BIM) in the construction and building management sectors. Such models utilise explicit knowledge to track and control construction/building related material—but they do not gather the tacit knowledge that

underpins many of these activities (Addis, 2016). Addis (2016) indicates that knowledge management systems themselves are inherently objectivist and regularly preclude the possibility of tacit knowledge. At best, human information is represented in process models, workflows or agent-based models that simulate the actions of autonomous agents—but which give little emphasis to agency (McCann and Ward, 2012). Similarly, the intensive apprenticeship with urban experimentation that has been taking place in recent years is difficult to transfer into unfamiliar contexts or organisations. It is of course possible to record objective information in databases, and records of successful projects and codified instructions and the information will largely hold meaning in different contexts. This type of information then translates well into objective KPI systems. However, it is not possible to do the same with tacit information, which is arguably the unspoken language of experimentation and innovation. It is of course possible to attempt a description of how projects have taken place, but each time this information is transferred there is the risk associated with meaning leakage and misinterpretation—that is, that the societal context of personal and group orientated tacit knowledge gets lost.

In this paper, the focus is on tacit knowledge (often generated over decades) that helps built environment professionals, owners, tenants, users and their connected communities of practise, navigate and make sense of building use and its life-cycle. During their careers and day-to-day lives, built environment professionals, owners, tenants and users accumulate tacit knowledge in relation to their material local domains and institutional practise. It is this information that is not captured when contemporary property technologies monitor footfall, computer use, building warmth (including temperature but also psychologically, with connexions to productivity) and wellbeing. What is captured is an information-based trace of the process of daily activity, but not the underlying rules that govern this behaviour and which would make any replication (at last in principle) possible. This paper concerns itself with who may lose (out on), and what may be lost, if incomplete information is translated as a complete picture of activity and “let loose” in specific situations (Healey, 2013).

Polanyi (1958) first introduced the idea of tacit knowledge and went on to contend that *we know more than we can tell* (Polanyi, 1966: 20). His argument was that expertise and human activity *is deeply personal and difficult to communicate verbally or in writing and was more reliant on intuition* (Muldoon-Smith and McGuinness, 2020: 3). Collins (2010, 2021) has since developed this argument, arguing that “strong” tacit knowledge is embedded in a process of socialisation. What we know as “knowledge” is thus a “mirror” which reflects the external as it is but is actively constructed in the flow of practical endeavour (Healey, 2013). The present authors are aware that the division between tacit and explicit knowledge is not clear cut. Collins (2010), Nonaka and Takeuchi (1995) and Maskell and Malmberg (1999) have established that explicit and tacit knowledge are interdependent, complimentary and dialectically interwoven (Malmberg and Maskell, 2002). However, this paper makes use of a simple dichotomy between tacit and explicit knowledge in order to develop a more complex interpretation of knowledge in the

digital built environment. This relates to how knowledge can be interrogated to understand the complex politics inherent in the digital built environment and to understand how tacit knowledge can be more faithfully leveraged in this domain. For this purpose, the paper makes use of the following knowledge typology originally outlined by Lundvall and Johnson (1994) and Zook (2004). Knowledge can be considered on the basis of:

- Know—what (broad knowledge about facts which is similar to information);
- Know—why (an understanding of scientific principles);
- Know—how (context-specific expertise);
- Know—who (the density and strength of social networks).

The first two categories are comparable to Polanyi's, 1958 fact-based knowledge and Collins (2010) relational and somatic knowledge. They will be returned to in the conclusion, where we contend that these knowledge categories are those most regularly captured by the various property and smart city technologies. The latter two classifications relate to the tacit domain, and particularly collective knowledge (Collins, 2010), that underpin and support the social prosthesis perspective. More specifically, this is with reference to the tacit domain's context and the networks within which the knowledge is created, transferred and ultimately translated. It is this tacit knowledge that is taken up in the proceeding sections, where the theoretical positions outlined here all offer resources for understanding the transference of tacit knowledge into the digital built environment and wider smart city domain. All three positions have evolved in opposition to a rational positivistic understandings of society, and therefore present useful critical perspectives to the regularly atheoretical perspective in the digital built environment.

SOCIAL TECHNICAL SYSTEMS

(Karvonen, 2020: 419) argues that *generating and disseminating new knowledge about cities is a significant challenge* and that *an urban STS perspective compels us to examine how this knowledge informs decision-making processes*. Yet, tacit knowledge is relatively under-theorised in socio-technical conversations. It has stronger roots in organisational studies and knowledge management (Seidler-de Alwis and Hartmann, 2008; Holste and Fields, 2010), by now classic work in economic geography into knowledge economies and relational perspectives (Gertler, 2003; Bathelt et al., 2004) and, quite recently, architecture (Dortheimer and Margalit, 2020). (Bathelt and Glückler, 2005: 1545) have argued—in line with the institutional and also relational turn in economic geography—that *resources are relational in that their generation, interpretation, and use are contingent, and that this depends on the particular institutional structures and social relations, as well as on the knowledge contexts and mental modes of the agents involved*. They also contend that *some type of resources, such as power and social capital, are also relational because they cannot be possessed or controlled by individual agents—but rather that they are built and mobilised through day-to-day social practises. Individuals or groups—they state—may appropriate the returns, but not the resources themselves*.

In most of these disciplinary spheres, the appreciation of tacit knowledge is seen as relatively “old hat”—yet it is strangely missing in many subject areas and has only taken root in distinct areas. Polanyi (1958) originally used tacit knowledge to help understand the human factor in scientific experimentation in the lab. While his ideas—and that of those that build on him—have evolved over time, the principles remain the same. Tacit knowledge has the same capacity to understand and problematise urban techno-politics in the wider urban lab—and by extension the digital built environment.

In many ways Polanyi can be seen as one of the originators of STS, focusing on the social construction of science. Yet, he is afforded little space in the growing literature around this subject. Most historical studies start with Fleck's 1935 “Genesis and Development of Scientific Fact” and Kuhn's 1962 “Structure of Scientific Reason,” before quickly moving onto Latour's 1987 research into the laboratory. Yet ideas of tacit knowledge, and knowledge more generally, have a role to play in understanding how successful experiments in the urban lab can be scaled up and adopted on a larger scale. These same ideas have the potential to inform those charged with designing, constructing, managing and using the built environment about how they can contextualise the typically binary data that they gather. By drawing a distinction between tacit knowledge and more codified knowledge, including explicit data and information, there is potential to connect the politics of knowledge production and transference into contemporary digital urbanism and built environment domains. We argue that most research in the domain of digital urbanism focuses on the system or the platform for knowledge generation, rather than its transference and translation. This echoes the findings of Evans et al. (2021) who indicate that, in the context of the municipal organisation, there is considerable challenge in learning, understanding and rolling out new knowledge associated with innovation (Doren et al., 2016; Dijk et al., 2018; Gopakumar, 2020).

Initial learning has been considered, particularly through urban experimentation, via various formulations of urban, living, city and building labs (Hajer and Versteeg, 2019; Scholl and Kraker, 2021), and more recently at the municipal scale (Evans et al., 2021) in relation to how cities transform through adoption of initial innovation into customary practise. However, there is less engagement with the type of knowledge that is generated (either individually or as a group) within this process and how better understanding of this might aid this wider transformational process. While the traditional STS perspective is useful in understanding how social and technical worlds connect, as well as the power dynamics between agents and the process of enabling transformation, it pays less attention to the generation and movement of knowledge. It also does not pay particular attention to—using the perspective of Graham and Marvin (2001)—how the digital built environment can become splintered when knowledge is gathered, concentrated, and even re-grounded in new locations.

(Karvonen, 2020: 418) indicates that *the city serves as an object of study to reveal how humans and technologies co-evolve*. By extension, a focus on tacit knowledge can help to understand how humans and technologies co-evolve through developing

and transferring knowledge. It can also help to reflect upon not only who is included in this process, and how their experience and expertise is taken forward, but also which elements of their contribution is transferred, and which parts are absent. While there is some emphasis within STS on networks (primarily through the work of Latour, 2005), increasingly these are viewed as technological ones: presumed and taken for granted, and which enable the transference of knowledge. There is less emphasis on the composition of these networks, what knowledge goes into them, how it circulates, flows, and accumulates as well as how, ultimately, the knowledge is received—and indeed interpreted—at the other end by willing actors who want to utilise insights for better building performance or upscaling innovation.

In this sense, we are asking STS and traditional thought in the domain of tacit knowledge to move beyond its situational focus *in-situ* and extend a little towards the scale of the structuring analysis seen in political science (Jessop et al., 2008; Storper and Scott, 2016). The proceeding section discusses a means of retaining the situational focus of STS but moving beyond its spatial fix on the ground (Karvonen and van Heur, 2014) into the network and ultimately to include the other end of the network where knowledge is received, interpreted and translated. It does this to try and connect the often-small scale area of experimentation and/or knowledge creation into the wider geography of organisational adoption and delivery. It does so by focusing on the ideas of “pipelines” as meaningful zones of analysis.

PIPELINES OF KNOWLEDGE TRANSLATION

In the digital built environment and contemporary smart city, there is a considerable focus on information extraction and capture. However, there is less focus on how information is exchanged, nor is there much focus on the medium and complexity of transference and translation. The result is that the extraction and capture process is almost taken as a smooth extraction. This evokes, and feeds into, the mechanistic and objective narration associated with explicit, codified information. However, this ignores less tangible information—that is: context specific knowledge, the rules of the game, sometimes considered as expertise, which is not easily collected via sensors, algorithm, database, or model. This type of knowledge cannot be accounted for by improved workflow documentation or better use of technology (Addis, 2016). In this sense, knowledge development is simply assumed to happen anyway, bound up within the process of innovation (Evans et al., 2021). For this reason, we favour an alternative position of knowledge co-production. This can be considered on several fronts: between groups of people who create knowledge, between humans and technology, and finally between knowledge creator and knowledge receiver. It is this final point where the importance of pipelines is (particularly) helpful.

The notion of “pipelines” was put forward by Bathelt et al. (2004) when considering the knowledge economy in economic geography, in order to conceptualise how local tacit

expertise could be transferred successfully to other locations and organisations—as an alternative to the notion of spatial fixity assumed in agglomeration and clustering. Building on parallel work from Owen-Smith and Powell (2004) into the biotechnology industry, Bathelt et al. (2004) build on the notion that the tacit knowledge held within local innovation does not necessarily need to be fixed in location or developed and transferred via close proximity to other organisations. With careful development, “pipelines” can help transfer tacit knowledge meaningfully into new contexts. We consider that this largely metaphorical position is a useful tool for understanding how local innovation can be upscaled into larger organisations and different locations (Grandin et al., 2018; Evans et al., 2021). While there is plenty of good practise in relation to partnership working, co-production, collaboration and demonstration, innovative projects rarely become the norm. With the potential to alleviate the tension between implicit knowledge and objectivist perspectives of knowledge management found in construction management (Chen and Mohamed, 2010; Addis, 2016), McFarlane (2011) proclaims that *the city is a machine for learning*.

Taking this forward, “pipelines” are a potential means of distributing this learning, as knowledge, and STS scholars can help to unpack the intricate sociotechnical inner workings of this movement. However, in taking this approach it is important to note that the very use of the pipeline/conduit narrative has the potential to evoke simplistically linear, even physical, notions of knowledge extraction between producer and receiver. This is not the intention in this paper; rather, we consider knowledge pipelines to be complex sociotechnical networks made of institutions and communities of practise where continual tensions exist between the creation, transfer and exchange of knowledge.

Intentionally, a contrast is drawn here between the locally specific situation where tacit knowledge is developed, and then transferred by investing in the development of channels of communication—to domains separate to the location of initial creation. This is because knowledge transfer, particularly in the tacit domain, does not happen rationally and smoothly. Rather, it takes place through a gradual, and typically unconscious assimilation of ideas and understanding through practise—evoking the messy socio-technical achievements hinted at earlier in the paper. It is for this reason that organisational change theorists have put so much emphasis on developing and retaining tacit knowledge (Argote and Ingram, 2000; Kikoski and Kikoski, 2004), and that pipelines have been forwarded as a means of demonstrating how explicit codified and tacit knowledge can be transferred locally and globally (Bathelt et al., 2004).

However, the creation of pipelines demands careful consideration. While knowledge creation is largely organic, even automatic, echoing the ephemeral learning process illustrated by Evans et al. (2021) *that just happens*. Pipelines need to be developed more circumspectly with the emphasis on what Bathelt et al. (2004) call “joint interpretive context” to facilitate (a) the transmission of knowledge and (b) the translation of knowledge. In (traditional) economic geography the focus is (mostly) on the firm. In the digital built environment and

with regard to the smart city, the focus has always been wider, including any organisation or institution that is utilising digital information and/or looking to scale up innovation. In each case, different organisational or institutional regimes need to place resource into appreciating the context surrounding knowledge creation but also the means of translating and operationalising the knowledge once received in order to bridge cognitive distance (Owen-Smith and Powell, 2002).

Figure 1 describes this situation.

The Knowledge Creation Zone describes where agents involved in urban innovation or building use develop knowledge in a discrete domain. The Zone of Transference describes the interface between this initial zone and the connecting pipeline for knowledge transference, as organisations seek to capture knowledge. The Zone of Translation describes the interface point where knowledge enters an organisational entity. Finally, the Zone of Knowledge Use describes where this knowledge is deployed. The authors contend that it is in the pipeline, and particularly in the respective interface zones of transference and translation, that new enquiry should take place. It is the Zone of Transference that is often presumed to collect all meaningful knowledge from the initial creation point, but that filters this knowledge through decision making and prescribed use of technology, often ignoring tacit knowledge. While it is the Zone of Translation that receives this knowledge and disperses it into an organisation. It is in these locations where the techno-politics is perhaps most intense, where power and decision making has most influence, gains credibility, is most hidden, and has the potential to shape the built environment of the city (Foley and Miller, 2020). In other words, by following the transfer of knowledge we can be drawn deeper into, and closer to, the politics of the digital built environment where it is possible to reveal the way society and organisations are structured, to include and preclude certain positions. In doing so it may be possible to provide a counterpoint to objectifying knowledge production, recognising that knowledge is not only data and information—rather each element is different because of the context of initial creation and consequent use.

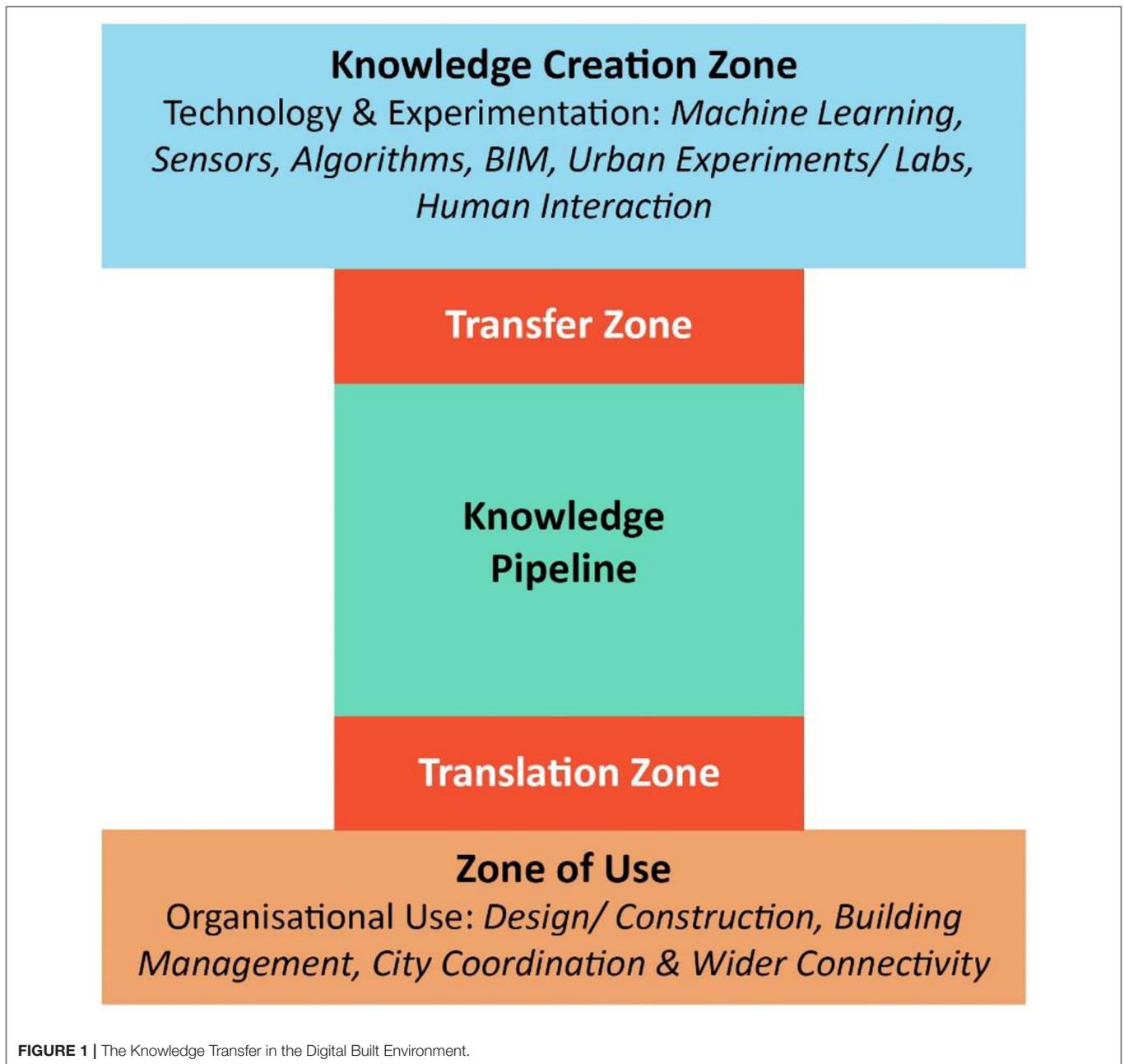
In this sense, understanding the value of knowledge and isolating its creation is only one part of the puzzle. A relatively unexplored challenge resides in perfecting the receipt and translation of information—what Cohen and Levinthal (1990) call “absorptive capacity,” where knowledge once transferred through the pipeline is then further exchanged within departments, organisations and contexts, far removed from the initial pipeline. In this sense, *absorptive capacity can be seen as a mediating variable between the firm’s environment and its organisational adaptation* (Bathelt et al., 2004: 44). The next section adapts Actor Network theory to propose a method of following knowledge through these notional pipelines. The conclusion revisits pipelines, and argues for policy, financial and academic focus to develop the infrastructure to support this process.

KNOWLEDGE NETWORK THEORY

Actor Network Theory (ANT) has emerged as a potential means of understanding the formation and flow of ideas in scientific

knowledge (Healey, 2013). While ANT has been used quite readily in STS studies, it has received less attention in the digital built environment and digital urbanism. Callon et al. (2009) focuses on how ideas, techniques or knowledge flow or “translate” from the zone of creation to new, wider, contexts. This perspective fits well with the transference and translation zones introduced in the previous section. In the main, ANT has been used to understand how ideas and innovations become prevalent through initial enrolment, translation and eventual mobilisation. ANT scholars follow actors involved in networks in order to understand the power dynamics of innovation. We propose using ANT slightly differently, in order to follow knowledge rather than actors. That is, to understand the transference process; but also to understand where knowledge is lost, broken, or distorted after its original creation. This can be seen in response to Evans et al.’s 2021 argument that *cities do learn, but often implicitly and without a clear methodology or dedicated resources for capturing learning*. It can also be seen in parallel to the arguments of Healy (1974), Freeman (2012) and McCann and Ward (2012) who examine how the cobweb of social economic conditions, stakeholders and institutions reverberate and bounce back and forth between each other to formulate, transfer and sustain policy practise. Only in this case, we propose using ANT to examine and reveal the cobwebs of knowledge creation. ANT, in combination with the previously presented knowledge pipeline, makes it possible to infer how innovation in the digital built environment can be improved and scaled up. Importantly, as a conceptual device it can be utilised at the individual project level (to understand and capture the dynamics of knowledge), at city level (to scale up and help transfer knowledge) and at the intra/intercity/national level (to aid city to city and country to country learning). This has also been characterised as “organised anarchy” with respect to technological search processes and knowledge flows at and through international trade fairs (Bathelt and Gibson, 2015).

Broadly, there are two domains associated with ANT. The first uses ANT to critique the assumptions and power dynamics in scientific knowledge. This has the potential to get at the nub of how urban knowledge is being assembled and institutionalised through processes of digitalization. The second is more practically focused on the *significance of non-humans in social life where relations are always mediated and transformed and even enabled by nonhumans of diverse kinds, whether objects, materials, technologies, animals, or eco-systems* (Nimmo, 2011: 109). This perspective suggests a hybridity or “generalised symmetry” of socio-technology where humans and nonhumans are interrelated, and the materiality of technology has agency (Latour, 2005). This latter aspect can be directly related to the current concern with smart digitisation and the partial extraction of knowledge by non-human techniques which is increasingly part of everyday life. In addition, the concept of the pipeline can be readily connected into the network ideas embedded in ANT, where entities acquire meaning through interaction with other entities and technologies within networks. This perspective, therefore, gives us a method to understand the creation of knowledge, its transference through pipelines and its translation upon receipt at the culmination of the pipeline.



When working with ANT as a methodological tool, the intention is to follow the network in order to trace the circulation and interaction that establishes reality (Law, 1991; Murdoch, 1995; O’Neill and Whatmore, 2000; Latour, 2005; Ruming, 2009). The study of these relations enables us to follow the creation of knowledge, to understand which elements are being transferred and which are being left behind by human and nonhuman actors and ultimately how they are translated into, and within, new contexts. In doing so, it enables us to develop an understanding of how orders and hierarchies of knowledge, and ultimately society is held together (Latham, 2002; Gabriel and Jacobs, 2008). In this perspective, institutional systems (for example: smart

city dashboards, project repositories and Building Information Models) should be understood through the way that they *act as constraints on the flow of activity in particular situations, and as products of this flow over time* (Healey, 2013: 1516). The ANT perspective contends that society, knowledge and technology are entangled, and places emphasis on the devices that *connect and effectively transmit agency and power from one part of the network to another* (Jones, 2009: 314). It is this aspect of ANT that can be applied to the partial flow and accumulation of knowledge in the digital built environment due to technological device and constraint—highlighting the preclusion of tacit knowledge. More positively framed, the ANT perspective also has the utility to

follow knowledge through pipelines in order to analyse and potentially improve the devices and techniques in the joint interpretive context—allowing us to scrutinise and improve the circuits of knowledge (Featherstone and Venn, 2006; McCann, 2008; Healey, 2013) that have the potential to facilitate successful transmission of tacit knowledge and better operationalise the adequate approximations of smart technology.

CONCLUSION

The arguments in this paper attempt to interrogate how knowledge, often incomplete and partial (but regularly taken to be complete) flow through and into the delivery of the digital built environment and wider smart city agenda. We expose this situation by engaging with both explicit, and particularly, tacit knowledge, that is the unspoken component of knowledge that cannot be codified but which develops over time as part of an accretive symbiosis with explicit knowledge and human practise. In response to our posed research question: *how can greater recognition of knowledge creation, transfer and translation help to understand the techno-politics of the digital built environment*, we argue that an engagement with tacit knowledge makes it possible to examine how knowledge flows through and into the management of the digital built environment and wider smart city. We argue that much of the knowledge currently being accumulated in digital built environment is explicit codified knowledge—that is, data and information that is readily transferable through automated sensors and algorithms but that simplifies many of the complex interactions between human and building. It can be argued that the digital built environment only partially understands human activity through media such as blockchain and automated algorithms. And it can thus also be argued that this is largely ignoring the tacit knowledge that often accompanies human action on the ground.

This means that we must question how meaningful the current transfer of knowledge is in the digital built environment, and what can be done to improve this transfer process. We argue that *smart technology is only an adequate social prostheses* that can help society (in this case building managers, landlords, investors, tenants and wider city managers) to improve the performance of the built environment. In other words, it should be considered a tool that can help achieve more sustainable practise, rather than as a panacea or common-sensical solution to the same issues (Kitchin, 2014). It can be contended that much of digital built environment practise currently translates information gathered from humans as mimeomorphic activity—that is, as one which can be readily mimicked. We contend that, in contrast it is actually polymorphic, i.e., reliant on the tacit kernel of socialised human knowledge to facilitate and operationalise meaningful activity and make up for the deficiencies in explicit knowledge transfer.

In response, we propose the largely metaphorical concept of “pipelines” to suggest how knowledge accumulation could be improved in the digital built environment. Focus on, and a deployment of pipelines, suggests a means of transferring the “buzz” of local knowledge generation into new domains

(Bathelt et al., 2004). In the largely automated digital built environment, pipelines in the main do not exist. We contend the new attention should be given to how pipelines can be converted from a largely metaphorical device into systematised process that can exist alongside existing smart city and property related technology initiatives. These same pipelines have the potential to be the conduit for transferring the knowledge gained in small scale urban experiments into wider institutional environments—helping organisations assimilate knowledge and learn.

In considering tacit knowledge, it is worth noting some limitations in this paper and future directions for subsequent research. In order to examine the research question, the paper has taken a broad view of several distinct academic subjects. The paper does not claim to offer an in-depth understanding of the digital built environment (see Neely et al., 2019, for a more detailed account), digital urbanism (see Karvonen et al., 2019, and Fields et al., 2020, for a detailed account), tacit knowledge (see Collins, 2010, for a detailed account), the knowledge economy (see Bathelt et al., 2004, 2018; Bathelt and Li, 2020 for a more detailed account) or ANT (see Callon et al., 2009, for a more detailed account). Rather, we attempt to present a set of conceptual tools that can be used to understand the transfer of knowledge in the digital built environment. In this sense, the paper should be viewed as a staging post for research into knowledge creation, transference and translation in the digital built environment. Also, in casting the digital built environment as largely atheoretical, we have perhaps been unfair to many of the digital innovations seen in the design, construction, management and use of the built environment. Considerations of smart cities and digital built environments clearly have scope to radically improve the operation of the built environment and wider urban areas. Yet, despite these caveats, we consider that the material in this paper provides a perspective through which the tech-knowledge interdependencies in the built environment can be better understood.

One avenue for taking this initial staging post further is by incorporating principles and learning from the field of human computer interaction (HCI). Traditionally, HCI has largely concerned itself with computer and mobile phone application interfaces to refine user experiences, but it has increasingly expanded its reach to consider how systems can be designed to fully accommodate human relations. (Johanssen et al., 2019: 77) set out why *tacit knowledge is very important in the development of high-quality software, and how the identification as well as the externalisation of tacit knowledge matters both during the design time and run time of a long-living and continuously developing system*. Challenges arise from the *difficulties of detecting deviations between explicitly elicited requirements and implicitly derived requirements*. Nonetheless, McKenna (2020), Stephanidis et al. (2019) and also Komninou and Kakderi (2019) argue that HCI has the capacity to transform the way society interacts with smart environments, and that there is greater need to compliment algorithmic logic with citizen engagement and collaborative action. This position has a clear alignment with the joint interpretive contexts within pipeline design and the demand to calibrate the collection of tacit, as well as codified, knowledge in the digital built environment. Increasingly

data and information are seen as the key asset in the digital built environment, as a mode of understanding how tenants, people, society and buildings perform. As automation becomes more prevalent, the human nature of activity is given less emphasis. Yet, the impact of human interaction is ingrained in the creation of knowledge in the first place, as well as its transference, final translation and interpretation in the operational domain. This means that human activity, tacit knowledge in this instance, must be given primacy alongside data, information, and technology in software, sensor and algorithm design. Rather than considered to be separate resources, this human computer interaction (HCI) must be seen as symbiotic—evoking many of the central tenants of STS. Hui et al. (2017) make similar observations about what requirements need to be thought about in the process of building smart homes in smart cities—particularly those that utilise Internet of Things based technologies. Of course, in times of an (energy and) climate emergency, retrofitting is an important dimension, and Lilley et al. (2017) show that engaging (social) tenants—including in their lived practises and every-day use—is as important and may be as (or more) difficult than the actual building design and technical installation for an increased energy performance of buildings.

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In combination with HCI, we propose the further adaptation of the traditional ANT approach to follow the translation of knowledge into specific cases studies in the digital built environment. ANT, due to its focus on the messy assemblage of knowledge and technology, has the potential to bring to the surface partial accumulations and blockages in knowledge transference and connexions and relations within individual contexts. This interaction could help drive academic and policy focus towards improving the operation of the zones of transference and translation described in this paper. By considering how knowledge pipelines can be better designed, it may be possible to prime the joint interpretive context between small and larger organisations to fully scale up the power of tacit knowledge. Of course, technology deployment and intensive experimentation is important, but we argue that transmission of consequent best practise and insight is often overlooked or only partially transmitted. Stimulating pipeline development could aid adoption and better use of data and information.

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The paper is joint authored by KM-S, LM, and RK. All authors contributed to the article and approved the submitted version.

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