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CONSTRUCTION IN THE PLATFORM SOCIETY: NEW DIRECTIONS FOR CONSTRUCTION MANAGEMENT RESEARCH

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An emerging aspect of digital transformation in industry relates to the rise of digital platforms. While examples such as Uber and Airbnb are well-known, technological platforms that seek to coordinate demand and supply-side actors in the architecture, engineering and construction (AEC) sector are also developing. Examples include Wikihouse, Sidewalk Labs, and Bosch IoT Suite. Although there is a growing body of scholarship reviewing the concept of 'platforms', far less attention has been paid to reviewing studies of digital platforms in the AEC sector. This systematic review of 18 studies seeks to address this deficiency. The findings show that the focus has hitherto centred on engineering platforms, with researchers adding greater functionality to platforms in order to yield efficiencies in the production process. Current endeavours tend to be laboratory-based, with prototypes still to be tested in the real-world. In contrast to reviews in management and organisational studies, scholars of platforms in construction do not pay as much attention to the power of platforms as a strategic organising principle for coordinating markets. The review thus proposes a number of possible directions for construction management researchers to examine the strategic potential for platforms to drive competitive advantage in the AEC sector.

Keywords: digital platforms, disruptive innovation, strategy, systematic review

INTRODUCTION

Over the past two decades, technological platforms from the high-tech information technology sector have proliferated. Examples of these platforms can be found in retail (e.g. Amazon), transport (e.g. Uber), hospitality (e.g. Airbnb) and social media (e.g. Facebook). Recent statistics (see www.statista.com) show how powerful these platforms have become in coordinating markets across the world: for example, in 2019, the ride-sharing platform Uber generated over US$14 billion in net revenue connecting more than 100 million monthly users globally; despite the controversies surrounding data and privacy infringements, the number of Facebook users keeps growing, linking more than 2.5 billion monthly active users in the 4th quarter of 2019 and generating over US$70 billion in revenue that same year. According to Cusumano *et al. (*2019), this 'platformania' is evident in the market value of seven

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platform leaders - Microsoft, Apple, Amazon, Google, Facebook, Alibaba and Tencent represent a total valuation of ~US$5 trillion in 2018.

By contrast, the Top 500 engineering design firms generated just over US$101 billion in 2018 for projects undertaken around the world (ENR, 2019). Indeed, the architecture, engineering and construction (AEC) sector is well known for lagging behind in digital transformation (e.g. the European Commission, 2019). Nevertheless, platforms have also begun to emerge in the AEC sector (see Mosca *et al.,* 2020). Examples include Wikihouse that aims to simplify (and make accessible) the design, manufacture and assembly of high-performance homes (www.wikihouse.cc/About), Sidewalk Labs as part of Alphabet Inc. (parent company of Google) that uses digital technologies to transform the urban environment (www.sidewalklabs.com), and Bosch Internet of Things (IoT) Suite, an open-source IoT-based platform that connects in excess of 10 million devices worldwide (www.bosch-iot-suite.com).

The emergence of digital platforms has heralded a promising era where these instruments lead to disruptive innovation. Platforms that connect users on the demand-side and providers on the supply-side can help address failures in the market, while the rise of the sharing economy can help democratise the production process. Yet, while the term 'platform' has become ubiquitous in the business world, until fairly recently, the workings of digital platforms have not been paid sufficient attention in the field of management and organisational studies (Gawer, 2014). A number of critical reviews of the concept of 'platform' have since been undertaken to clarify what platforms are, what they do and their effects.

At a very basic level, platforms form the ground or launchpad for driving actions. In computing terms, a platform is the operating system that form the basis for other entities (e.g. software) to run. Thus, for Bogusz *et al.,* (2018), a digital platform is "one digital artefact that mediates as digital entrepreneurs build their venture". It is through this technological entity that value creation happens by facilitating providers on the one hand, and users on the other (Leong *et al.,* 2019). Such entities, as Dolata (2019) explained, can be characterised as "digital, data-based, and algorithmically structuring socio-technical infrastructures that exchange information, coordinate communication or organize work, offer a wide range of services, or distribute digital and non-digital products" (p. 183).

Platforms are not just stable structures that simply act as intermediaries that broker relationships between demand-side users and supply-side providers. Scholars have begun to recognise that platforms go beyond facilitating two-sided benefits to consider how platforms dynamically shape and are shaped by network-level, multi-sided innovation effects (see Gawer, 2014). That is, for platforms to thrive, the platform owners must constantly grow its pool of users; to do so, platforms must not only attract more parties on both sides, but also develop integrative dynamic capabilities (Helfat and Raubitschek, 2018) and innovate themselves to in turn drive innovation among and across the parties to stimulate complementary innovations, which in return increases the value of the platform (Gawer and Cusumano, 2014). To illustrate this virtuous cycle, take Uber as an example. Its success was initially based on attracting more users to its platforms, both passengers and drivers, some of whom also play the dual role of a passenger and a driver. As it evolved, Uber used its digital infrastructure and algorithmic capability to diversify its offerings by attracting other complementary products such as Uber Eats, its restaurant/take-away delivery service.

Thus, in a platform society, social and economic relations are increasingly mediated through an ecosystem of interconnected digital platforms (de Waal *et al.,* 2017). In this ecosystem, processes of datafication to capture and circulate value representations, the commodification of value propositions to translate into tradeable entities, and the curation of value offerings to provide mass personalisation are the core mechanisms of the platform infrastructure (van Dijck *et al.,* 2018). As Grabher and van Tuijl (2020) noted, platform organisation serves to disrupt traditional production-based industrialisation by driving paradigm shifts in four main areas: A shift in value from one that revolves around ownership of assets to the ownership of access, a shift in governance from decisions surrounding make-or-buy to decisions to employ-or-enable, a shift from managing the back-end (supply side of making things) to managing the front-end (demand side of making matches), and a shift in labour from jobs to gigs.

To date, the concept of platforms has been reviewed mainly in business-to-customer (B2C) contexts - for instance, in healthcare (e.g. Islind *et al.,* 2019), financial services (Kazan *et al.,* 2018), (social) media and gaming (e.g. Rietveld *et al.,* 2019) - far less attention has been paid to reviewing platforms in business-to-business (B2B) contexts (Grabher and van Tuijl, 2020).

The construction sector is one such candidate for examining how platform organising works (or not) in a B2B context. This article therefore seeks to address this deficiency by systematically reviewing how platforms in construction have been studied. In so doing, this review finds that current studies on platforms-based organising in construction have tended to focus on engineering greater functionality of platforms, often based on building information modelling (BIM). In so doing, current studies ignore more strategic concerns of market coordination through digital platforms. Thus, this article concludes with future directions for construction management research to study the full range of problems and prospects of platforms as a disruptor to the status quo.

SYSTEMATIC REVIEW OF PLATFORMS IN CONSTRUCTION

Unlike conventional narrative reviews, systematic reviews which originated from the medical and health sciences is a thorough and transparent way of mapping and evaluating the evidence in a particular topic area (Tranfield *et al.,* 2003). Figure 1 below illustrates the process used to systematically review all the relevant studies on digital platforms in construction.

Two databases were consulted for the searches on 17 March 2020, including Web of Science and Scopus. The following keywords were used in the subject topic, title and abstract fields: (“platformi*” OR “digital platform*”) AND (“construction” OR “building” OR “built environment”). The choice of selecting “platformi*” as opposed to “platform*” was due to the fact that choosing the latter yielded results that had little to do with digital platforms, e.g., ‘oil and gas platforms’. Therefore, given how scholars who study the development of digital platforms outside of construction have recognised the importance of their dynamic evolution and the process of platformisation (Islind *et al.,* 2019), a choice was made to include a keyword search of “platformi*”. The initial search yielded 516 hits, including 197 hits on Web of Science and 319 hits on Scopus. By limiting the search to peer-reviewed journal articles published in English, the sample was then reduced to 113 articles on Web of Science and 148 articles on Scopus.

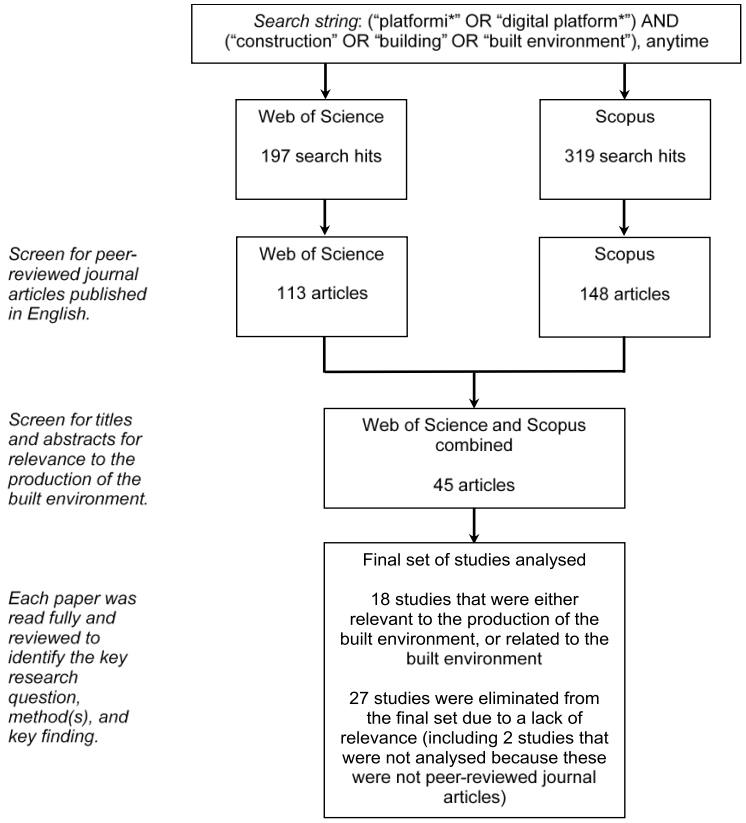

Figure 1: Process flowchart for the systematic review

A screening process was then undertaken by scanning through the title and abstracts of each article to establish relevance to construction and the production of the built environment. Those that were not directly related were eliminated, as were those that were found to be duplicated across both databases. This resulted in 45 studies selected for full review. Each of these 45 studies was then read fully to analyse the research question, method and key finding contained in each study. Through this process, a further 27 studies were eliminated; 25 of these studies were found not to relate specifically to the production of the built environment whilst 2 studies were not published in peer-reviewed journals. The remaining 18 studies - 12 that are directly associated with the production of the built environment and a further 6 that are related to the built environment more generally - therefore constituted the final sample of studies analysed for the review presented here.

RESULTS

Tables 1 and 2 below summarise the research questions, methods and findings of the 18 studies analysed in this review. Thirteen studies were published since 2018, indicating that digital platforms represent a nascent object of study in the field. The analysis reveals distinct interests between studies that are directly associated with the production of the built environment (Table 1) and studies that are related more generally to the built environment (Table 2). The former tends to be about technical developments (8 out of 12 studies), whereas the latter is more concerned about engagement with networks of end-users and citizens (4 out of 6 studies). Moreover, the central platform for studies connected with the production of the built environment is building information modelling (BIM) (7 out of 12 studies), whereas platforms that capture end-user or citizen experience tend to be the object of concern in more general studies about the built environment.

Tool-based focus: Designing functionality for production efficiency

Unsurprisingly, when it comes to studying platforms for the production of the built environment, the focus has been tool-based. Researchers have mainly considered how platforms can better support integration of information between the phases of design, construction and asset/facilities management. For example, using agent-based modelling, Fioravanti *et al.,* (2018) regarded BIM as the central platform that can be enhanced by introducing relational rules and goals that can enable better collaboration, communication and coordination between design and construction management and facilities management. Similarly, Di Tonno (2019), building on the Plan-Do-Check-Act cycle, also viewed BIM as the central basis for integrating project monitoring with information and communication technologies and enterprise resource planning during the operational life of a built asset.

Table 1 Summary of studies connected with the production of the built environment.

Authors (Year)	Title	Research question	Method	Key finding
Mahalingam, A., Yadav, A. K. and Varaprasad, J. (2015)	Investigating the role of lean practices in enabling BIM adoption: Evidence from two Indian cases	How do (lean) practices shape the adoption of BIM?	Comparative case studies of two metro projects in India	When BIM is adopted first as a tool, it is hardly used for decision-making. However, when BIM use is led by the (changing) coordination of practices, then BIM is used actively in decision-making.
Di Ludovico, D. and Fabietti, V. (2018)	Strategic environmental assessment, key issues of its effectiveness. The results of the Speedy Project	How can a digital sharing tool dedicated to addressing the Strategic Environmental Assessment directive be created to enable cross-border sharing of knowledge?	Reflections on the EU-funded SPEEDy (Shared Project for Environmental Evaluation with Dynamic governance) Programme 2007-2013	The platform is used to share information about the directive and experiences of making strategic environmental evaluations. The platform has potential to develop into more inclusive ways of engaging citizens to gather intelligence about the urban context.
Baydar, G., Komesli, M., Yilmaz, A. and Kilinç, K. (2018)	Digitizing Lefebvre's spatial triad	How can Henri Lefebvre's ideas about the spatial triad be used in the development of a digital platform?	Development of a digital platform in two social housing projects in Izmir (Örnekköy and Uzundere settlements), combining architectural and planning information with perception data from stakeholder interviews	The digital platform can capture information about how the residents is interacting with the built and urban environment, and could potentially be used for decision-making.
Fioravanti, A., Novembri, G. and Rossini, F. L. (2018)	A theoretical framework to align lean construction techniques in the 4.0 building industry	How can lean construction techniques be aligned within Construction 4.0 developments?	Review and conceptual framework by using agent-based modelling	BIM is the central platform that can be enhanced by introducing relational rules and goals through agent-based modelling, which in turn can enable better collaboration and linkages between Facilities Management and Design and Construction Management.
Saygi, G., Agugiaro, G. and Hamamcioglu-Turan, M. (2018)	Behind the 3D scene: A GIS approach for managing the chronological information of historic buildings	How can holistic understanding of historical changes be applied beyond geometric, spatial and physical representations of historic buildings?	Using Geographical Information System (GIS) approach, the authors develop a digital 'container' as a 3D digital model for the archiving of a building's chronological information	A prototype was created that can help heritage specialists be more efficient in their future investigations.
Di Tonno, C. (2019)	Smart models for new management of the building process	How can a quality-driven SMART platform be developed to manage the building process in a Construction 4.0 context?	Reflection on platform development	BIM as the central basis to integrate ICT, ERP, Planning and Monitoring software, and project monitoring in the Plan-Do-Check-Act cycle
Fadli, F. and AlSaeed, M. (2019)	Digitizing vanishing architectural heritage; The design and development of Qatar historic buildings information modeling [Q-HBIM] platform	How can a sustainable and interactive archiving platform be created to capture information about Qatari built heritage?	Review to identify aspects of sustainable urban preservation, site analysis and interviews with experts and societal actors	A digital platform was produced to capture preservation policy, tools and processes.
Li, Y., Ding, R., Cui, L., Lei, Z. and Mou, J. (2019)	The impact of sharing economy practices on sustainability performance in the Chinese construction industry	What internal sharing practices with project stakeholders and external sharing practices with unfamiliar companies are generated through the use of digital platforms?	Questionnaire survey of 208 respondents from the Chinese construction industry	Firms are likely to share knowledge within their project networks than with unfamiliar firms from outside their network.

BIM can act as the central platform for enhancements in technical functions or features. One example of added functionality is the use of BIM as a conduit to link the cyber and physical worlds. For instance, McMeel (2019) conceptualised a platform ecosystem that combined augmented reality with robotics. Ness *et al.,* (2019) developed a prototype that facilitated data exchange that can enable circular building processes in which reusable building component can be identified, tracked and managed. Others have proposed a life-cycle information transformation framework (Succar and Poirier, 2020). Furthermore, functionalities that allow the capture of building information beyond the technical have also be introduced, e.g., in adding geographic information to facilitate better coordination between architects and

urban planners (e.g. Baydar *et al.,* 2018), or historical information to support preservation of heritage buildings (e.g. Fadli and AlSaeed, 2019). What these studies have in common is the assumption that these added technical functions are able to facilitate better integration between different professional stakeholder groups. That said, a recent survey by Li *et al. (*2019) suggests that platforms only serve to support engagement between stakeholders who are already familiar with one another rather than with parties who are less familiar but who would bring about more creative ideas.

The tool-based approach is also problematic for a number of reasons. First, 10 out of the 12 studies relating to the production of the built environment are researcher-led, rather than practice-led. Thus, these are conceptualisations of frameworks and models that are developed in the 'laboratory', rather than trialled and tested in the real-world. The utility of these tools is therefore questionable at this point. Second, and more critically, Mahalingam's *et al. (*2015) comparative study of two metro projects in India showed that when the focus lies squarely on tools, then project participants are not likely to use these actively in everyday decision-making. Rather, project participants must first radically transform their practices and bring in new players in order to stimulate fresh questions and perspectives; only then will the usefulness of the platform (e.g. in visualisations of new, unfamiliar perspectives) be put to work.

Table 1 Continued.,

Authors (Year)	Title	Research question	Method	Key finding
McMeel, D. (2019)	Robots and AR: Towards a platform economy for construction	How can platform economies disrupt the construction sector?	Review of Platform 'Igloo', a collaboration between the Centre for Advanced Composite Material and the Faculty of Creative Arts and Industry in Auckland, New Zealand	A design platform was created using parametric design (in Grasshopper), and with augmented reality to help implement robotics in creating the structural elements for the 'Igloo'.
Ness, D., Xing, K., Kim, K. and Jenkins, A. (2019)	An ICT-enabled product service system for reuse of building components	How can a cyber-physical data exchange system be developed so that reusable building components may be identified, tracked and managed?	Developing an ICT-based data management system that connects RFID, BIM and Cloud-based data platform	The prototype developed was validated in an example of an internal glazed system. It is speculated that clients can be assured of the quality and performance of reused components.
Rashid, M. M. and Antlej, K. (2020)	Geospatial platforms and immersive tools for social cohesion: The 4D narrative of architecture of Australia's Afghan Cameleers	How can the application of 4D modelling of the past of lost architectural heritage sites in remote central and Western Australia be applied along with Linked Open Data (LOD) to disseminate new knowledge through digital platforms and VR/AR experiences to audiences regarding Muslims in Australia?	Case study of the Afghan Cameleer	A prototype was created to facilitate meaningful and engaging easy-to-use VR/AR experiences to enable better appreciation of historic heritage assets of the Afghan Cameleer.
Succar, B. and Poirier, E. (2020)	Lifecycle information transformation and exchange for delivering and managing digital and physical assets	What are the foundational concepts for an open access digital platform for defining, managing, and integrating project and asset lifecycle information?	Design Science Research	The Lifecycle Information Transformation and Exchange (LITE) framework was developed. Rather than to focus on product or production, the LITE framework takes a lifecycle approach to information requirements, capturing information of physical and virtual assets, and of intent and delivered. This is to be validated in practice.

Beyond the tool: Broadening participation and involving the unfamiliar

When reviewing the 6 studies that are more generally connected with the built environment, the focus moves away from the usefulness of the tool to examining how platforms can be used to better engage with a broad range of users. These platforms either captures user experiences of the built environment (e.g. Chan and Cope, 2015; Abdelmonem *et al.,* 2017), or about capturing the requirements of users and citizens (e.g. de Waal *et al.,* 2017; Bakardjieva, 2019). Thus, while the focus of the 12 studies relating to the production of the built environment emphasised more the design and

construction aspects, 5 out of the 6 studies in this category emphasised the role platforms can play in enhancing the use and experience of the built environment.

Table 2: Summary of studies relating more generally to the built environment

Authors (Year)	Title	Research question	Method	Key finding
Chan, S. and Cope, A. (2015)	Strategies against architecture: Interactive media and transformative technology at the Cooper Hewitt, Smithsonian Design Museum	How does the introduction of digital platform help transform and reinvent the museum (and museum experience) itself?	Self-reflection by the Director of Digital and Emerging Media at the Cooper Hewitt Smithsonian Design Museum	Introducing new digital platforms is not just a technical proposition, but one that involves new organisational practices (e.g. of customer-facing and budgeting).
Shah, K. (2016)	Creation of cultural heritage inventories: case of the historic city of Ahmadabad	How can cultural heritage inventories and documentation act as critical tools for heritage conservation and management in historic cities?	Case study of historic city of Ahmadabad	Documentation should not be just about the physical artefact of heritage assets, but linked to contextual and cultural information about the urban environment.
de Waal, M., de Lange, M. and Bouw, M. (2017)	The hackable city: Citymaking in a platform society	To what extent can new platforms be opened up by citizens, who has access to the data they aggregate, under what conditions, and who governs these platforms and decides on the rules encoded in their algorithms?	Reflection on the 'Hackable City' project, in collaboration with Amsterdam and Utrecht	Seven steps were found: issue framed by an involved stakeholder, then visualised through online campaigns and by manifestations of public space, before engaging the public (often through social media), then tools are introduced through which publics can ideate, learn and exchange upon the issue, pool resources or act upon it, before attempting to institutionalise temporary interventions. Trust is built through social events, rather than through reviews of online platforms.
Abdelmonem, M. G., Selim, G., Mushatat, S. and Almogren, A. (2017)	Virtual platforms for heritage preservation in the Middle East: The case of Medieval Cairo	How can digital models pay attention to the human aspects of city life, the intangible heritage to which people can actually relate to?	Investigating how a cultural-feed can be built into digital platforms of Virtual Heritage in Medieval Cairo	Computer-generated visual interpretation of history and culture plays an increasingly influential role in shaping public perceptions of the past, are therefore subjective and in many instances inaccurate. Contours of historical understanding should be integrated within a generation's impressions of the past.
Bakardjieva, M. (2019)	A tale of three platforms: Collaboration, contestation, and degrees of audibility in a Bulgarian e-Municipality	What kinds of participation do digital platforms make possible, and what specific features proved instrumental in shaping participation and its effects?	Three digital platforms used to engage with civic society in the Bulgarian city of Stara Zagora were evaluated.	Where platforms are used in a collaborative manner, then there needs to be a link between citizens and those in power to make a difference. Where platforms are used in contestation, then it is important that legal arguments are made.
Honic, M., Kovacic, I., Sibenik, G. and Rechberger, H. (2019)	Data- and stakeholder management framework for the implementation of BIM-based material passports	How can a semi-automated BIM-based materials passport be developed, and what data- and stakeholder management framework can support this?	A BIM-based digital tool for capturing materials in existing buildings has been created and validated in a case of an office building.	There needs to be links made to eco-indicators, catalogues of building and construction elements, and product declarations, alongside a framework to connect AEC organizations, industry (product manufacturers) and regulative bodies.

Instead of affording production efficiencies, the focus of studies to date that are more generally related to the built environment has been geared towards extending the network of players and enabling knowledge co-production and sharing. Thus, these studies tend to be much closer to studies of platforms in management and organisational studies, where attention is paid to examine network-level effects as the platform is used by a growing number of users. Within this group of studies, dynamics of competition and collaboration also feature. For example, when comparing between different digital platforms used to shape citizen participation, Bakardjieva (2019) found that the effectiveness of platforms to engage is dependent on its legitimacy; in collaborative settings participants must feel that their voices matter to those with the power to make a difference in decision-making, whereas in contested settings platforms must demonstrate a legal basis for engagement. Platforms are thus not just digital instruments that broker relationships, but also an entity that dynamically evolves in an ecosystem - comprising both digital and physical elements - that shape and are shaped by user engagements (de Waal *et al.,* 2017).

FUTURE DIRECTIONS

While there have been a growing number of reviews on digital platforms in management and organisational studies (e.g. Gawer, 2014; Helfat and Raubitschek,

2018; Grabher and van Tuijl, 2020), far less has been done to review the concept of platforms in the AEC sector. The aim of this article has thus addressed this gap by presenting a systematic review of 18 studies relevant to the (production of the) built environment. The review found that studies on digital platforms in the AEC sector have mainly focussed on engineering better functionalities in platforms, often utilising BIM as the central basis for adding new technical features with the explicit or implicit intention of integrating multiple stakeholders across the whole life cycle of the built asset. This quest for integration is not new, and platforms are emerging as a new organising tool for facilitating better communication and coordination.

However, by treating platforms as a tool, current research in the AEC sector fails to consider the full potential for platforms to dynamically shape and be shaped by the market. It is here that previous reviews from management and organisational studies can provide some clues for possible future directions for construction management researchers interested in examining the workings of platforms to radically transform the AEC sector (see also Thomas *et al.,* 2014). Here, three possibilities are proposed. First, future research could shift the attention away from the constant drive to introduce, update and refine new features of enhancing platform functionality to examining how platforms (and especially platform leaders) create, sustain and grow the number and range of users engaging with the platforms and related innovation capabilities. In so doing, future research can find a balance between the current skewed focus on engineering more functional platforms and the currently-lacking analysis of the dynamics of platform ecosystems and the markets, thereby paying more attention to questions around the dynamic capabilities of platforms (Gawer, 2014; Helfat and Raubitschek, 2018) as they occupy a more strategic position in the ecosystem of incumbents and disruptors in the AEC sector.

Second, by moving towards a more strategic orientation, attention is also turned away from questions of production efficiency to the creation and curation of value. In a recent study of gaming platforms, Rietveld *et al.,* (2019) found that it is not always the 'best in class' that thrives in the platform ecosystem. Rather, it is about the kinds of value that sustains and grows complementary solutions for the users on all sides and the platform owners. Thus, the mindset needs to shift from finding the most technically optimal, to asking what kinds of (added) value platforms bring in engaging with different and novel players in the AEC sector, and to what (better) impacts.

Third, and finally, while platforms tend to be regarded as (more or less) stable entities in existing research in the AEC sector, there is a need to examine more processually what platforms do in everyday practices. Islind *et al.,* (2019) point to the idea of platformisation, as opposed to platforms, to stress the importance of understanding platform development as a process rather than an end-goal. In so doing, there is a need to examine the boundaries and boundary work involved within platforms, between platforms and users, and among users (Leong *et al.,* 2019) as the platform society orchestrates the AEC markets of/in the future.

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