# Construction Sector Transformation: Developing a New Learning Paradigm

Ricardo de Matos Camarinha [1(✉)], Jack Goulding[2], and Camaren Peter[3]

[1] BIMTEC Consultancy, Doha, Qatar
rcamarinha@bimtec-eng.com
[2] Unisearch Ltd, Manchester, UK
jack@unisearchuk.com
[3] University of Cape Town, Cape Town, South Africa
camaren.peter@gsb.uct.ac.za

**Abstract.** Architecture, Construction and Engineering (AEC) has historically reported low levels of productivity and performance, especially when compared with other sectors and industries such as automotive, aviation, manufacturing and ICT/telecoms. This is particularly concerning, given that this sector is a significant contributor to many countries Gross Domestic Product (GDP). Acknowledging this, and the fervent need to improve productivity as part of AEC's digital transition to Industry 4.0 – the so-called Construction 4.0 - this paper explores some of contributory forces affecting this journey. One aspect of this transition is the examination of industrialisation, or indeed the level of technological sophistication applied to this sector, including the 'success' indicators used. A historical reflection on the industrialisation process is presented, including traditional industrialisation approaches from Late Industrialisation. Developing economies undergoing late industrialisation are seen as unique because they did not base their material development on inventions, but rather on the basis of learning – i.e., using 'borrowed' technology. From this literature, a qualitative [explorative] research approach was adopted based on the principles of Critical Realism. Findings from this were then applied to four focus groups with 23 industry professionals. Research findings highlighted that AEC was not industrialised *per se*, but simply modernised. Moreover, that access to modern techniques and technological sophistication were insufficient to support sector transformation through such conduits as industrialisation, knowledge management or indeed innovation. Findings also indicate the need to more purposefully align transformational thinking to socio-economic transition models, principally those underpinned by grounded learning paradigms aligned to key industrial policy institutions.

**Keywords:** Industrialisation · AEC · Economic development · Technology · Innovation

## 1 Background

During 2016 and 2017, the Architecture, Engineering and Construction (AEC) sector represented 6% of global GDP, with a total yearly market of $10 trillion [1, 2]. Despite


A. Gomes Correia et al. (Eds.): ISIC 2022, LNCE 306, pp. 369–379, 2023.
https://doi.org/10.1007/978-3-031-20241-4_25

this, while productivity in manufacturing, retail and agriculture has grown by as much as 1,500% since 1945, construction productivity has barely increased at all, regardless of its strong relevance for national and global economies [2]. In comparison with the automotive industry, a study by Cambridge Econometrics [3] shows that the steady decrease in car prices was driven by the economic efficiency of a 'single market', but was also highly influenced by the technological improvements introduced by lean production in the manufacturing environments and platform sharing technologies. The latter entails using common architectures across as many models as possible, within and across factories or brands. Likewise, in AEC, several firms have introduced a number of technologies over the last decades to support communication, collaboration and execution [4]. These technologies largely target the processes of information management and the automation of fabrication, somewhat like those used in the manufacturing industry but in a much less extensive way [5]. However, the introduction of innovative technologies into the construction process has not always translated into meaningful improvements in efficiency or productivity.

## 2 Industrialisation

Industrialisation is typically understood to be a modernisation movement through the development of technology, machinery and other innovations [6]. However, it is also described extensively in literature as a process of economic development [7–9]. Yet industrialisation can also be considered a social process [10], which is why the analysis of AEC in this proposal considered extensive research within the fields of sociology and economics of industrialisation, specifically in terms of late industrialisation and emerging economies. Scholars seem to largely approach the industrialisation of construction from an operational perspective, rather than discussing its socioeconomic drivers in a complex setting. As an example, Koskela, *op. cit.* [11], argued that industrialisation is a process for eliminating or reducing the on-site activities in construction. While industrialisation does include this objective, this viewpoint may introduce important limitations. Other studies have attempted to include cultural perspectives, awareness of offsite solutions and adequate business models [12–14], which suggests that an expanded study of the phenomenon of industrialisation is required.

Modernisation and industrialisation are often incorrectly used interchangeably, despite their explicit connection. A set of differences set both apart. Firstly, it is important to note that modernisation is a collective phenomenon of changes in society (e.g. social, economic, cultural, physical, technological, aesthetic), which enable industrialisation [15]. Secondly, while industrialisation is often measured in terms of economic factors such as income per head or household, there is no equivalent metric to measure the modernisation phenomenon [15]. In appreciation of this, Inkeles [16] argued that it is too restrictive to frame development from an industrialisation perspective, therefore development should be defined as a broad process of technological, economic and social change. It is possible for a certain economic sector, institution or even country to become involved in a process of modernisation, but not become industrialised [15].

For decades, many scholars have attempted to frame a concise picture of the conditions that enable industrialisation, mainly through macroeconomic research. However,

alternative studies consistently challenge its understanding by considering new dimensions such as sociology and anthropology. Bruland et al. [17], inspired by the extensive work of Maxine Berg, introduced some of these recent history-altering learnings, i.e.: (i) the industrialisation phenomenon was not limited to Britain and relates to a long-term economic change dependent on global forces, including technological innovation, reliable knowledge and most importantly a demand market; (ii) industrialisation was an 'open' process overlapping with the preindustrial (protoindustrialisation) period, enabling organisational change and product design; (iii) only a few innovations or new technologies were, in fact, relevant to the process; (iv) economic growth was very slow and undramatic for many decades; and (v) the process was not exclusive to the factory but engaged consumers and material goods at the beginning of a consumer revolution.

Amsden [8] described the process of late industrialisation as an alternative path to industrialisation, in contrast to the 'natural' path of the first three Industrial Revolutions. This theory of industrialisation challenges mainstream economics, which is based on Adam Smith's theoretical framework on the centrality of free markets and limited government participation [7], showing that there is no 'one-size-fits-all strategy'.

Late industrialisation, as the term suggests, is a much younger phenomenon than Adam Smith's traditional industrialisation economic context. Whereas in the original phenomenon of industrialisation countries developed economically by means of innovation in products and processes [18], in late industrialisation, development is driven by borrowing technology or 'learning' from more developed economies [19]. Countries such as South Korea, in a post-war setting, had to narrow the large skills gap between themselves and the advanced economies. They did this by addressing the specific problem of knowledge in the context of industrialising when deprived of the "competitive edge of novel technology" [9]. To substantiate this, and in contrast to the laissez-faire principles of Adam Smith, Amsden focused on the importance of governments' role in late industrialisation.

According to Amsden [8], learners do not innovate, hence they need to compete based on low wages and offering improvements on the shop floor. Amsden [19] further clarified that there are two potential models for late industrialisation: (i) an institutional model based on labour-intensive exports supported by institutional measures driving basic exports, as well as the development of comparative advantage in more advanced exports against other economies. This is motivated by stimulating competitiveness, which requires knowledge transfer and learning to mitigate the technological gap with those developed economies, which naturally developed technologically in the early process of industrialisation; and (ii) a market-oriented model simply based on resource allocation and economic efficiency through the establishment of comparative advantage based on low wages, while ignoring that this differential may be compensated by the advanced technology of the competing economies. In the latter model, factors like work culture, infrastructure and others are arbitrarily ignored.

Empirical evidence from East Asia casts doubt on the economic theories that show low wages to be a competitive advantage against the higher productivity of more developed countries, leaving us with the institutional option where government intervention is not only required but welcomed [19].

Successful latecomer governments, as an example, assisted the private sector to build professionally managed, large-scale modern corporations in mid-technology industries, influencing the price of foreign currency, credit and labour, and deliberately getting them wrong. This resulted in a dramatic social transformation that helped the East Asian 'Tigers' to develop, in less than 20 years, a manufacturing market global share of almost 11% [9]. Importantly, this *visible hand*, also included government subsidies with imposed performance standards, controlling economic trade, and continuously transforming the process. This was executed with a great focus on developing human resources, motivating literacy and surpassing other industrialised countries by almost all indices of educational attainment [18]. In summary, the role of the government can influence the 'natural' evolution of institutions that typically ignore international variables, waste time and do not make use of the experience of other markets (Kalantaridis, *op. cit* [20]).

## 3 Methodology

This research follows a mainly qualitative approach. In doing so, it explores the social phenomena of the industry, by examining people's experiences alongside a theoretical framework [21]. This places a compelling reference to the epistemological and ontological nature of AEC as a general scientific field. Ontological research in the field of construction, such as in this study, are not new, however these kinds of projects are still far from mature and have mostly derived from the IT domain [22]. Holt and Goulding [23] identified ontological works dealing with production, knowledge management, supply chain modelling and construction informatics.

Furthermore, the approach presented here is concerned with a critical realist view of the industry in the ontological domain and draws, as an example, on the ideology of Lawson [24]. Lawson extensively discussed how the world's housing problems have been approached with decisions made 'in the dark', i.e. without taking into consideration the composition, structure and dynamics of their reality. As such, this research methodology is utilised to analyse the "social phenomenon by revealing the causal mechanisms that produce them" [25]. Mingers called this process of reasoning 'generative causality' [26, 27].

Critical realism critiques the reductionism through which has resulted in economic development in silos, disregarding the relationships of 'nature' and 'society'. Importantly, Bunge (*op. cit.* [25]) further explains that this line of thought depicts the reality construct arranged in a multi-level system. This opposes the reduction of reality to the empirically observable. It also introduces important concepts such as bottom-top emergence as nowadays widely accepted in describing complex systems [28, 29] and following the principles of system thinking [26, 30]. This philosophical construct is becoming influential in a range of relevant disciplines for this study, such as geography, economics, sociology and organisational theory [27]. Examples of other multi-level approaches include the multi-level perspective (MLP), an established framework used in the analysis of sociotechnical transitions [31, 32]. In our formulation (Fig. 1) the L1, L2 and L3 levels represent: (i) the social construct of the sector and its products; (ii) the macroeconomic landscape; and (iii) the operational setting of the sector.

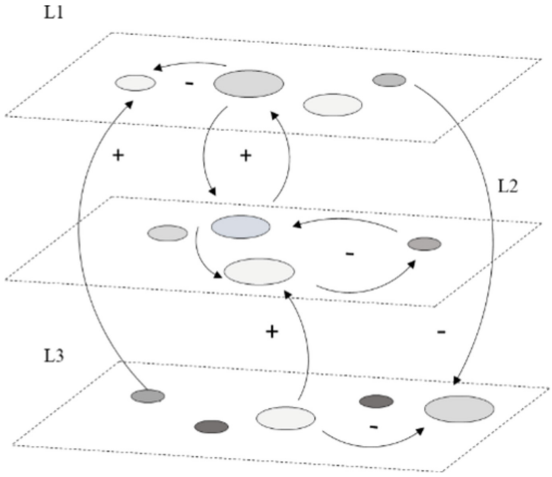


**Fig. 1.** Abstract depiction of AEC's structural levels and relationships

### 3.1 Research Design and Data Collection

The research adopted a cross-sectional design, and drew on secondary data (literature review) as well as primary data through four focus groups. The 23 participants were selected taking into consideration their: (i) industry role; (ii) years of experience; (iii) type of organisation; and (iv) geographic experience. There was a clear intention, through purposive sampling, in promoting diversity amongst the group mix [33]. In specific cases, participants were also acquired through snowball sampling but assigned to different discussion groups.

### 3.2 Data Analysis and Saturation

The data collected in the focus groups were transcribed as accurately as possible, followed by a qualitative data analytic process based on an interpretative cyclical coding procedure [34]. The coding process was used as a heuristic to help connect the data to ideas [34], producing a comprehensive summary of the data as a whole [35]. The decision to conduct four focus groups was supported by the findings of Guest, Namey and Mckenna [36] to define an adequate saturation level. In this work, after four focus groups a saturation level of 95% was reached.

### 3.3 Research Limitations

Although this work observes and depicts the AEC as a global sector, the reader may note that the context of the research may impact its findings, limiting generalisability and repeatability. Nevertheless, the diversity of the focus groups participants intentionally attempts to mitigate this caveat.

## 4 Findings and Discussion

The research shows that the AEC features properties of multi-level complex systems. The broad nature of the research allowed the codification of 73 codes distributed across six themes: sociology of construction; industrialisation theory; macroeconomics; construction management; manufacturing; innovation and technology. Through these, we observed mechanisms that support defining the industrial setting and improved productivity in the so-called industry. The following points summarise the most relevant discussion points, while highlighting important key findings.

### 4.1 Construction Modernisation and Industrial Drivers

Industrialisation can be defined by a transition to an economic environment that is characterised by improved efficiencies, productivity, and consequent growth typically motivated by technological sophistication. Moreover, informed by theories of late industrialisation and development economics, this study indicates that an iterative process of industrialisation initiates a context of protoindustrialisation, motivating the alignment of social structures. This means that individuals who are collectively organised are able to improve the working environment and encourage the iterative adoption of new technologies. Nevertheless, this sophistication ladder also requires macroeconomic support outside the workshop environment, creating a market landscape that regulates the required supply-demand conditions to motivate a required volume production industrial environment, towards economies of scale and comparative advantage.

While the participants of the focus groups share a common understanding of this ideal industrial environment, they also agree that the so-called construction industry (in this paper referred to as AEC) does not display the traits of having undergone industrialisation despite its access to more sophisticated tools and techniques. This is in alignment with the argument of Wrigley [15], who contended that an economy can be modern without being industrial. Empirically, industry indices do not reflect outcomes such as the 'hockey stick' which illustrates the economic divergence of economies undergoing industrialisation [37]. To some extent, this incomplete industrialisation process resembles some subtle differences that enabled the First Industrial Revolution in England but not in France, when the latter had more sophisticated technology but lacked a culture of improvement amongst the artisans, i.e. those creating the revolution in the workshop. As Marc Brunel, a French-British engineer, remarked, it is one thing to invent, but another thing to make the invention work [38]. Following this analogy, it is proffered that AEC still needs to develop an improvement culture to make use of innovations.

### 4.2 Social Learning

The macroeconomic drivers of low productivity and poor quality have been widely discussed at both supply and demand sides of the equation [39]. On one hand, this research observed that the end-user, whether they are private or public, is often ill-informed about the product being procured, yet they often play proactively an active role in all stages of the process. Nevertheless, traditional expert-based project management demands contractual arrangements based on cost and time, often compressing the early

stages of design and prototyping, limiting the power and the ability of the project to succeed [40], as opposed to a product developed in an industrial setting.

On the other hand, the supply side can be considered somewhat unregulated and fragmented, with very low barriers to new entrants and in several regions, affected by informality, which typically addresses with better immediate results the needs of particularly underprivileged communities. Informality is suggested to be a 'self-organised' complex system, with informal markets creating a layer of substitute products that undermine the required social transition which could motivate industrialisation. Governance and leaders have not been able to create incentives to alter a culture of resistance, and hence embrace innovation. Generative mechanisms show that a lack of incentives increases conservativism, and exacerbates a lack of value proposition. This is mainly explained by the inability of the end-user to regulate the market on the supply side, which given the conceptual construct of the built project is focused on the long-run asset value, rather than valuing a commodity in the short-term. A free-market economy expects that consumers possess the ability to rank market products based on their suitability to meet procurement criteria. Moreover, AEC is defined by local features, most of which are linked to regional factors of business models, but has been influenced by the economic phenomenon of globalisation and in both actors and materials has traits of a global sector. Beyond the local and global realms, it has been suggested that phenomena also occur in a metaphysical realm, in which themes such as sociology, anthropology and economics define important factors related to the economic definition of the construction products. Those are the satisfaction of primal needs, individual and cultural identity, aspirations, and political intent. However, it was widely accepted in the group discussions that in AEC the diversity of needs and the impact of local and cultural aspects – which shape social knowledge - create a hurdle that is still difficult to overcome in an industrial setting.

### 4.3 Institutional Learning

Late industrialisation and development economics describe economic development strategies in which the protagonist's attributes of not only technological sophistication but also policy and institutional sophistication are highlighted [18, 41]. Without exception, when thinking about undergoing a development process such as industrialisation in AEC, it is fundamental to acknowledge that the private sector requires regulation, in particular in an economic sector in which informality is ever-present. The focus groups discussed the low barriers to entry for companies in construction – in terms of financial inputs and qualifications (knowledge). Funds and incentives are often controlled by employers and construction companies are left without resources to develop and manage knowledge. Findings from this research noted that whilst some organisations were able to undergo an industrialisation process, implementing advanced capabilities of manufacturing and robotification, however in the competitive market, due to the lack of regulations to protect their investment, they often found themselves in isolation due to the lack of institutional knowledge of the public and governing bodies.

Similarly, it was also observed that the private sector played a critical role in the innovation of the industry, albeit that these efforts seem to fall short if not followed by a general development at the macroeconomic level. Several participants contended that the

role of governance is dependent on political intent, resonating with the state-led development programs described by Amsden [7, 8, 19]. Governmental institutions have a key role in establishing (directly/indirectly) a learning ecosystem by shaping market conditions, competition, and regulations to increase the level of specialisation required for industrial processes. Thus far, informality, fragmentation and underinvestment characterise AEC [2]. While acknowledging the limited participation of governments, examples of modern movements attempting to change the course of events have been reported – cf. The United Kingdom.

### 4.4 Learning and Operations: The Role of Data

Amidst the transition to Industry 4.0, technology will undoubtedly help organisational transition, particularly its 'enabling' role [42, 43]. Though, it is also important to note that technology diffusion (and the process that this entails) is equally important. Where this can be viewed through various prisms, including: individual, organisational, environmental and technology perspectives [44–47], this has been examined for several years, and the dynamics of technology diffusion in AEC is not new (*cf.* [48–51]). However, it is also important to recognise that AEC is not known for being able to accumulate collective knowledge [52]. Such contribution is proposed as an alternative 'organising' process, bottom-top, which is legitimised and structured by technology and data – ergo a learning platform. This relates with Moore, Ridell and Vocisano [53] phenomenon of social innovation (entrepreneurship) at the micro-level, requiring diffusion to affect the upper levels through systemic change. Such a decentralised approach, interlinked by information structures also aligns with a needed 'demodernisation' of the sector, 'unlearning' from failed attempts of global transformation. A global system is required for efficiency and sustainability - meeting (and respecting) cultural and individual needs – purposefully connecting micro, meso and macro levels (Fig. 1).

## 5 Conclusion

While undergoing a global economic transformation motivated by Industry 4.0, the AEC sector remains characterised by low productivity indices. This paper discussed several determinant factors for the development of the sector through a sustainable industrialisation route. At its core, is a learning paradigm which needs to be addressed by governments and leaders. Learning gaps are observed at micro, meso and macro levels of a reality construct that is complex in nature; and inter alia, has not really changed over centuries. Change requires reshaping roles and techniques, a bottom-top revolution. This also necessitates creating adequate information structures to support continuous collective learning. This study contributes to the wider body of knowledge by reframing the development of the AEC industry through the lens of socio-economic development – proffering that the sector could benefit from industrialising on the basis of learning – at social, institutional and organisational levels.

## References

1. WEF, BCG: Shaping the future of construction - a breakthrough in mindset and technology. World Economic Forum, Geneva, Switzerland (2016)

2. Barbosa, F., et al.: Reinventing construction: A route to higher productivity. Mckinsey Global Insititute (2017)
3. Cambridge Econometrics: Consumer prices in the UK: explaining the decline in real consumer prices for cars and clothing and footwear, Cambridge (2015)
4. Girmscheid, G.: Industrialization in building construction: production, technology or management concept? In: Understanding the Construction Business and Companies in the New Millennium, pp. 427–441. Technical Research Centre of Finland (VTT) & Association of Finnish Civil Engineers (RIL), Helsinki, Finland (2005)
5. Richard, R.B.: Industrialised building systems: reproduction before automation and robotics. Autom. Constr. **14**, 442–451 (2005)
6. Musa, M.F., Yusof, M.R., Samsudin, N.S., Muhamad Halil, F.: Adopting industrialisation in the construction environment: meeting the requirements of sustainability. Sci. Res. J. **13**, 45 (2016)
7. Seguino, S.: How economies grow: Alice Amsden and the real-world economics of late industrialisation. Cambridge J. Reg. Econ. Soc. **10**, 99–110 (2016)
8. Amsden, A.H.: Asia's Next Giant - South Korea and Late Industrialization. Oxford University Press, New York (1992)
9. Amsden, A.H.: Editorial: bringing production back in — understanding government's economic role in late industrialization. World Dev. **25**, 469–480 (1997)
10. Simandan, D.: Industrialization. In: Kitchin, R., Thrift, N. (eds.) International Encyclopedia of Human Geography, pp. 419–425. Elsevier, Boston (2009)
11. Bjornfot, A., Stehn, L.: Industrialization of construction: a lean modular approach. In: 12th Conference of the International Group for Lean Construction, pp. 3–5, Helsingør, Denmark (2004)
12. Goulding, J.S., Rahimian, F.P., Arif, M., Sharp, M.D.: New offsite production and business models in construction: priorities for the future research agenda. Archit. Eng. Des. Manag. **11**, 1–22 (2014)
13. Lessing, J., Brege, S.: Business models for product-oriented house-building companies: experience from two Swedish case studies. Constr. Innov. **15**, 450–472 (2015)
14. Lessing, J., Stehn, L., Ekholm, A.: Industrialised house-building: development and conceptual orientation of the field. Constr. Innov. **15**, 378–399 (2015)
15. Wrigley, E.A.: The process of modernization and the industrial revolution in England. J. Interdiscip. Hist. **3**, 225–259 (1972)
16. Inkeles, A.: Industrialization, modernization and the quality of life. Int. J. Comp. Sociol. **34**, 1–23 (1993)
17. Bruland, K., Gerritsen, A., Hudson, P., Riello, G.: Reinventing the economic history of industrialisation: an introduction. In: Bruland, K., Gerritsen, A., Hudson, P., Riello, G. (eds.) Reinventing the Economic History of Industrialisation, pp. 3–22. McGill-Queen's University Press, Montreal, Canada (2020)
18. Kim, L., Dahlman, C.J.: Technology policy for industrialization: an integrative framework and Korea's experience. Res. Policy. **21**, 437–452 (1992)
19. Amsden, A.H.: Diffusion of development : the late-industrializing model and Greater East Asia. Am. Econ. Rev. **81**, 282–286 (1991)
20. Klarin, A., Ray, P., Sharmelly, R.: Industrial modernization and business strategies in transition economies. In: Australian and New Zealand International Business Academy Conference (ANZIBA), Brisbane, Australia (2018)
21. Silverman, D.: Introduction. In: Silverman, D. (ed.) Qualitative Research, pp. 3–14. SAGE Publications, Los Angeles (2016)
22. Zhou, Z., Goh, Y.M., Shen, L.: Overview and analysis of ontology studies supporting development of the construction industry. J. Comput. Civ. Eng. **30**, 1–14 (2016)

23. Holt, G.D., Goulding, J.S.: The "ological-triad": considerations for construction management research. J. Eng. Des. Technol. **15**, 286–304 (2017)
24. Lawson, J.M.: Critical Realism and Housing Research. Routledge Taylor & Francis Group, New York (2006)
25. Danermark, B., Ekstrom, M., Jakobsen, L., Karlsson, J.C.: Explaining Society: Critical Realism in the Social Sciences. Routledge Taylor & Francis, New York (2002)
26. Mingers, J.: The contribution of critical realism as an underpinning philosophy for or/ms and systems. J. Oper. Res. Soc. **51**, 1256–1270 (2000)
27. Mingers, J.: Systems Thinking, Critical Realism and Philosophy. Routledge Taylor & Francis Group, New York (2014)
28. Cilliers, P.: Boundaries, hierarchies and networks in complex systems. Int. J. Innov. Manag. **5**, 135–147 (2001)
29. Heylighen, F., Cilliers, P., Gershenson, C.: Complexity and philosophy. Complex. Sci. Soc. **14**, 117–134 (2012)
30. Peters, L.D., Pressey, A.D., Vanharanta, M., Johnston, W.J.: Constructivism and critical realism as alternative approaches to the study of business networks: convergences and divergences in theory and in research practice. Ind. Mark. Manag. **42**, 336–346 (2013)
31. Geels, F.W., Schot, J.: Typology of sociotechnical transition pathways. Res. Policy. **36**, 399–417 (2007)
32. Sorrell, S.: Explaining sociotechnical transitions: a critical realist perspective. Res. Policy. **47**, 1267–1282 (2018)
33. Gill, P., Stewart, K., Treasure, E., Chadwick, B.: Methods of data collection in qualitative research: interviews and focus groups. Br. Dent. J. **204**, 291–295 (2008)
34. Saldaña, J.: The Coding Manual for Qualitative Researchers. SAGE Publications, London (2009)
35. Wilkinson, S.: Analysing focus group data. In: Silverman, D. (ed.) Qualitative Research, pp. 83–100. SAGE Publications, Los Angeles (2016)
36. Guest, G., Namey, E., Mckenna, K.: How many focus groups are enough ? Building an evidence base for nonprobability sample sizes. Field Methods **29**, 3–22 (2017)
37. Ocampo, J.A., Rada, C., Taylor, L.: Growth and Policy in Developing Countries. Columbia University Press, New York (2009)
38. Kelly, M., Mokyr, J., Gráda, C.Ó.: Could artisans have caused the industrial revolution? In: Bruland, K., Gerritsen, A., Hudson, P., Riello, G. (eds.) Reinventing the Economic History of Industrialisation, pp. 25–43. McGill-Queen's University Press, Montreal (2020)
39. London, K.: Construction Supply Chain Economics. Taylor & Francis, New York (2008)
40. Gruneberg, S., Francis, N.: The Economics of Construction. Agenda Publishing Limited, Newcastle (2019)
41. Park, J.-D.: Re-inventing Africa's Development: Linking Africa to the Korean Development Model. Palgrave Macmillan, Cham (2019)
42. WEF, BCG: Shaping the Future of Construction: Future Scenarios and Implications for the Industry (2018)
43. Forbes: The world's most innovative companies, 2021 Ranking. https://www.forbes.com/innovative-companies/list/
44. Rogers, E.M.: Diffusion of Innovations. The Free Press, New York (1962)
45. Peansupap, V., Walker, D.H.T.: Factors enabling information and communication technology diffusion and actual implementation in construction organisations. Electron. J. Inf. Technol. Constr. **10**, 193–218 (2005)
46. Jeyaraj, A., Sabherwal, R.: Adoption of information systems innovations by individuals: a study of processes involving contextual, adopter, and influencer actions. Inf. Organ. **3**, 205–234 (2008)

47. Hameed, M.A., Counsell, S.: A meta-analysis of relationships between organizational characteristics and IT innovation adoption in organizations. Int. J. Innov. Manag. **18**, 1–32 (2012)
48. Lees, T., Sexton, M.: An evolutionary innovation perspective on the selection of low and zero-carbon technologies in new housing. Build. Res. Inf. **42**, 276–287 (2014)
49. Ozorhon, B., Abbott, C., Aouad, G.: Integration and leadership as enablers of innovation in construction: case study. J. Manag. Eng. **30**, 256–263 (2014)
50. Shibeika, A., Harty, C.: Diffusion of digital innovation in construction: a case study of a UK engineering firm. Constr. Manag. Econ. **33**, 453–466 (2015)
51. Lindgren, J., Widén, K.: Diffusing building information management – knowledge integration, mechanisms and knowledge development. Archit. Eng. Des. Manag. **14**, 347–362 (2018)
52. Hall, D.M., Whyte, J.K., Lessing, J.: Mirror-breaking strategies to enable digital manufacturing in Silicon Valley construction firms: a comparative case study. Constr. Manag. Econ. **38**, 322–339 (2020)
53. Moore, M., Riddell, D., Vocisano, D.: Scaling out, scaling up, scaling deep. J. Corp. Citizsh. **58**, 67–84 (2015)