RENOVATION OF THE JAPANESE CONSTRUCTION INDUSTRY: EVALUATION OF I-CONSTRUCTION FROM THE PERSPECTIVE OF CONSTRUCTION MANAGEMENT

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Japan's population is both decreasing and aging. The abundant labour force that has supported the economy will continue to decline, and improving productivity is becoming a challenge. The “i-Construction” initiative, which aims to drastically improve productivity in all construction production processes from survey to design, construction, inspection, maintenance and renewal, is an important measure, and the i-Construction Report was compiled by the Ministry of Land, Infrastructure, Transport, and Tourism in April 2016. Based on the rapid development of satellite positioning technology and Internet of Things, the report summarizes viewpoints for advancing i-Construction in three categories: "Turning construction sites into advanced factories", "Introduction of advanced supply chain management at construction sites", and "Regulation of construction sites, breaking stereotypes, and continuing "Kaizen"". As overarching policy from these 3 perspectives, "full utilisation of ICT (ICT earthwork)", "optimal overall deployment" and "levelling of construction time" were set. The main characteristic of this policy is that it lists the items to be tackled for each category. In addition, as a mechanism for promoting i-Construction, the development of a national promotion system, establishment of a public-private partnership consortium, utilisation of big data, collaboration with other outdoor industries, and overseas expansion is proposed. This study evaluates and analyses Japan's efforts from the viewpoint of construction management research and examines how construction management research is utilised in the policy practice carried out in Japan, and what is considered for the feedback from policy to research. In this paper, we re-evaluate Japan's i-Construction efforts from three perspectives, (1) the relationship between construction management methodology and i-Construction; (2) the relationship between i-Construction and the interdisciplinary and comprehensive nature of construction management; and (3) the relationship with digital platforms. In recent years, digital platforms have played an important role in dramatically improving consumer market access, and it is desirable to identify the key to their success, and to verify the points of attention that contribute to both practical use and research.

Keywords: i-Construction, Japan, project management

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INTRODUCTION

The population of Japan is both aging and declining. The abundant labour force that has supported the economy will continue to decline and improving productivity has become a challenge. The Ministry of Land, Infrastructure, Transport and Tourism (MLITT) compiled the i-Construction Report in April 2016 with the aim of drastically improving productivity in all construction production processes, such as research, survey, design, construction work, inspection, maintenance, and renewal. The i-Construction initiative has been a major means of solving the problems that the construction industry has faced since productivity improvement was taken up as a Japanese national policy. This includes: (1) Turning construction sites into advanced factories based on the rapid development of satellite positioning technology and Internet of Things (IoT); (2) Introduction of advanced supply chain management at construction sites; and (3) Regulation of construction sites, breaking of stereotypes, and continuation of "Kaizen" which is mainly aimed at improving awareness. This not only includes the utilisation of advanced technology, but also the improvement of existing awareness technological possibilities.

The opportunity to improve productivity at this time is attributed to the sluggish productivity caused by an excessive number of workers. After the bursting of Japan's economic bubble in the 1990s, construction investment continued in order to support the economy and minimize the economic downturn. As a result, public work projects designed to help the unemployed hired a large number of people, thereby creating a labour surplus. Therefore, improvements in productivity at construction sites, which lead to labour saving efficiencies, were postponed, and work at construction sites has been carried out manually since the late 1990s.

In contrast, it is estimated from statistics that over the next 10 years, 1.1 million workers will leave their jobs owing to the aging of society and other factors, and skilled workers will disappear from the construction industry over time. Few young people want to work in the construction industry, and construction workers aged 29 years or below account for only 10% of the total workforce. This is also evident from the graph of changes in the number of skilled workers. In the graph showing the age of construction business licensees, 30% of construction industry workers are aged 55 or over, and 10% are aged 29 or under. Despite the decrease in the number of older workers entering the workforce, young people are reluctant to work in such occupations.

In Japan, the civil engineering industry has depended on public investment. However, this public investment has decreased to a level of about 60% of its peak in 1996, and the business environment has not been stable, making it difficult for the construction and civil engineering industries, as a whole, to break away from public works. The focus of this report is the field of earthwork, where productivity improvement is currently lagging, and Japan's labour productivity is only about 80% compared with that of the United States.

Over the past 50 years, the mechanisation of tunnel construction has advanced and productivity has increased by a factor of ten. In contrast, there is still scope for improvement in earthworks and concrete works that have relied on human resources, where productivity is still constant or declining. The construction industry is destined to receive orders on a case-by-case basis. Before starting production, they receive orders for unique products and produce them at fixed prices. In addition, because the requirement to work outdoors is inevitable and the products to be produced are

attached to the site, it is sometimes necessary for the labour force to be located there. In the past, the cell production method had been promoted in the manufacturing industry because of the characteristics of labour-intensive production. This method should be incorporated into IoT technology to improve the productivity of the manufacturing industry now that innovation has made it easy to introduce IoT technology outdoors.

The research methods used in this paper were developed by listening to those who are actually promoting i-Construction through discussions at five seminars on system sciences of i-Construction held at the University of Tokyo, and by exchanging opinions among researchers on their position in construction management research. Therefore, in this paper, we first explain i-Construction, and then link it to previous research on construction management.

I-CONSTRUCTION VIEWPOINT

The i-Construction report aims to (1) make the construction site similar to a state-of-the-art factory; (2) introduce i-Construction, automatic operation, and mechanisation into the supply chain, including the procurement of materials, transportation of earthworks, and transportation of soil; and (3) break through the two Kisei (official regulations that are followed in practice) and make continuous improvements at the construction site, following the Plan-Do-Check-Act (PDCA) cycle, in order to incorporate i-Construction into the next site in an improved way. However, in addition to these three aims, it is also necessary to pay attention to the following caveats.

The first caveat is the improvement of safety. The construction industry still accounts for 40% of fatal labour and work-related accidents. Second, flexible measures should be taken to promote the introduction of rapidly advancing new technologies into the field. Existing technologies that were not introduced owing to regulations should be reviewed and the introduction of such technologies should be actively promoted. Third, overseas expansion should be considered with international standardisation of the i-Construction package, and its export. This also includes studying ways to better integrate concurrent engineering and front-loading bidding contracts.

Concerning point (1) above, specifically, various cutting-edge "Information Communication and Technology (ICT)"-enabled construction equipment, including drones, are being introduced in research, surveying, design, and construction work stages. It is a great advantage that one person can speedily perform a wide range of labour-intensive work with improved accuracy. Through the introduction of these devices, we hope to eventually turn the construction site into a state-of-the-art factory that will attract young people.

Regarding point (2), we aim to introduce an efficient supply chain that uses a flexible and integrated approach at all stages: research, survey, design, construction work, inspection, and maintenance. By utilising i-Construction, productivity will improve, the work site will become cutting-edge, and each process will not be divided, but rather introduced after integration.

Viewpoint (3) will be discussed later.

In terms of safety, which is a critical aspect, the number of fatal accidents in the construction industry is double that in other industries. The number of accidents caused by contact with construction machinery is second only to motor vehicle

crashes. The introduction of ICT in this area, to detect people and reduce fatal accidents by preventing their contact with dangerous equipment, is highly desirable.

Overall Optimal Deployment (Standardisation of Concrete Work Standards)

The introduction of overall optimisation is explained using the standardisation of concrete work standards as an example. First, regarding overall optimisation, there is a problem in applying the optimum design method and construction method. This involves the fact that concrete work is undertaken outdoors and is easily affected by weather conditions. In particular, it is stipulated that cast-in-place concrete, which is transported to the site, assembled with reinforcing steel and the concrete cast in a particular form, should be placed in an environment where the temperature is between 4 °C and 25 °C. Therefore, work during summer and winter is restricted, and it is also affected by rain. As a result, planned construction becomes difficult, and extra time is required for completion. In addition, there are problems such as the fact that a bridge requires work in high places and involves danger, and that the work environment and conditions are different for each construction site. The combination of factors is very complicated. Thus, skilled workers engaged in these activities also require different levels of a variety of skills.

On the other hand, there is a method of construction using ready-made concrete, called precast, which is manufactured in a factory. This can be produced more cost-effectively by standardizing products of the same size in large quantities. However, the opportunity to use these products in large quantities is currently very limited, and economies of scale that equalise the operation of these plants are unlikely to occur. The current problem is that it is difficult to reduce costs because the inventory produced at such plants becomes dead stock.

In addition, as standards for superior construction methods and new technologies have not yet been established, even if proposals for new construction methods are received, they are unlikely to be adopted. This is another current challenge. To solve these problems, the i-Construction report states that we are beginning with what can be implemented in the present circumstances and what may be implemented in the future. Based on the above problems, to improve the productivity of the entire concrete work process, the current positive characteristics are extracted, optimised, and incorporated into the stages of the supply chain.

It is necessary to develop innovative technologies and establish a mechanism to promote the full-scale introduction of overall optimisation, but it is very difficult to implement such methods through the initiative of the client. In contrast, the government encourages a shift to a system that may realise the concept of front-loading by utilizing private technologies that were not conceived before, such as receiving orders and holding technical competitions. Successful cases can be effectively distributed nationwide. At the same time, the standardisation of precast products and generalisation of technical elements are being considered. For overall optimisation, particular standards and parts are optimised to the maximum possible extent. For this purpose, the concept of civil engineering structures and design guidelines must be revised. As it is impossible to supplement the field standards and field requirements through pre-casting, the guidelines for civil engineering structure design should be reviewed first. In addition, quality regulations should be reviewed such that better-quality products can be delivered to the field. Specifically, the guidelines aim to standardise materials, indoor work for factory manufacturing of

items, the introduction of new technology, and especially the rationalization of quality inspection for items made in factories.

After improving each of these processes, we consider introducing supply chain management. This aims to introduce the concept of concurrent engineering and to improve each process of production, transportation, procurement, and assembly.

Levelling Construction Time

Levelling the construction time is also known as levelling the ordering period. This is mainly a target of the orderer and is basically the same as the standardisation of the construction time. Standardizing the construction time considers the weather conditions and the conditions required for laying the concrete such that an established construction period ends at the end of the fiscal year. This is largely the responsibility of the orderer, as the construction period is limited to the end of the fiscal year for the convenience of the orderer. (In Japan, a single fiscal year rule is followed, and orders are often placed at the end of the fiscal year to utilise the remaining budget). In particular, 70% of local governments that have a large gap in their busy schedules place orders for all public work projects. Even if only the MLITT is standardised, an overall optimisation would not be achieved unless the local government ordering procedures are standardised. To this end, a regional orderers council has been established, and the national government, local governments, and other ordering agencies work together to standardise construction periods and orders through the Ministry of Internal Affairs and Communications as necessary.

In addition, efforts are being made to ensure that construction need not be completed by the end of the fiscal year. Levelling is attempted by prolonging the construction period. Construction companies that are responsible for disaster response and maintenance in the region are expected to have a sustainable business environment in the future. To this end, projects should be constructed over a two- or three-year period, improving on the existing procurement mechanism of the single-year principle. In other words, a multi-year procurement mechanism should be considered to ensure a sustainable business environment. To reduce the number of construction projects scheduled for completion at the end of the fiscal year, the concept of a 2-year long project and a longer 10-year project are being implemented. Construction projects to be ordered from now on will be revealed to the industry such that management can continue to keep the future requirements in perspective. Standardisation is being carried out in a planned manner, with a view to formulate plans for the maintenance and renewal of infrastructure, placing detailed orders based on regional characteristics, and medium- to long-term standardisation.

Academic Evaluation of Construction Management

Next, we would like to provide an evaluation of i-Construction in Japan from an academic viewpoint of construction management. This is based on three viewpoints. The first aspect is the relationship between construction management methodology and i-Construction. The PDCA, a known engineering method, is used as an analytical method for construction management. This is an inductive extraction of technology in the field and part of the methodology is an accumulation of empirical knowledge. Furthermore, the methodology of business management advocated by Iriyama (2019; Page 788) is not unique to that field, and the argument that the analysis of business management using the methodology of economics, sociology, and psychology is mainstream in modern business management is also basically applicable to construction management. As claimed by Dainty and Leiringer (2019), new

directions are being explored in the study of construction management and economics (Koskela, 2017; Ivory, 2017; Bröchner, 2018; Volker, 2019). Koch *et al.,* (2019) also explored the application of various methodologies in social science. On a more unusual note, Tutt and Pink (2019) are exploring the application of ethnography to construction management. The positioning of i-Construction in Japan in the methodology of construction management, which is an interdisciplinary field, can be regarded as the combination of various management methods. In particular, dynamics based on academic consistency will not be sufficient in the course of policy formation; hence, it is important to re-evaluate them from an academic perspective in order to modernise construction management in Japan.

We have reviewed and further deconstructed the i-Construction report from a construction management perspective. Specifically, the i-Construction report is an excellent summary of the efforts so far to put productivity at the centre. However, it is different from the system and position used in construction management study. Therefore, compared to the textbooks (e.g. Pellicer *et al.,* 2014; Sherratt, 2015), there is a particular emphasis on productivity improvement perspectives, which can be seen from the fact that there is a chapter of the report entitled "Perspectives", and productivity improvement standpoints are always in mind when organizing efforts in the field. In contrast, in the two textbooks above, the former carefully explains the model and theory of project management, while the latter analyses the field, but due to its nature as a textbook, it lists in detail the points of caution for discussion on production management. These are aspects that are not mentioned in the i-Construction report. Furthermore, the two textbooks and the i-Construction report also emphasize a very forward-looking perspective, reminding us that construction management is a discipline of practice. However, this has advantages and disadvantages, and construction management research does not have its own methodology, but rather borrows methodologies from economics, sociology, management, and engineers. While this is something that construction management as a practical science cannot escape, it must be understood that the type of research presented in this report that firmly summarizes existing efforts is also important.

The second aspect is the relationship between i-Construction and the interdisciplinary and comprehensive nature of construction management. From a methodological point of view, i-Construction is a collection of various experience values; however, to date, interdisciplinary and comprehensive knowledge of construction management has been utilised. Specifically, Hiroshi Komiyama, a distinguished engineer and the president of Mitsubishi Research Institute, Inc., served as the chairperson of the committee for the planning of i-Construction. Two of the five members of the committee, Kazumasa Ozawa, a professor at the Graduate School of Engineering, the University of Tokyo, and Kazuyoshi Takeyama, a professor at the Faculty of Science and Engineering, Ritsumeikan University, were joined by academic researchers in construction management to complete the report for our study. This was beneficial in order to compile the experience of the interdisciplinary and comprehensive nature of construction management researchers. In addition, as pointed out in the aforementioned papers by Dainty and Leiringer, construction management has immense practical research potential. However, although the research results of construction management are not directly applied to i-Construction, the findings to date have been generated from the viewpoint of improving productivity, introducing total optimisation, and levelling construction timings (Hegazy and Saad, 2014; Lindblad and Guerrero, 2020). Among these, the need to change consciousness in the

construction industry is pointed out from the viewpoint of construction management as a significant contribution in the process. These are important achievements in construction management research and will provide momentum for further research. The emphasis is evident in the analysis of the text of the i-Construction report. We used simple text mining to analyse the i-Construction report. The list of the top 20 extracted words from the Japanese text mining is shown in Table 1.

Table 1

	Word	English	Frequency
1	建設	construction	158
2	生産	production	111
3	現場	site	102
4	施工	actual working	72
5	技術	technology	71
6	向上	improvement	62
7	導入	introduction	58
8	i-Construction	i-Construction	58
9	必要	necessary	55
10	ICT	ICT.	54
11	設計	design	45
12	活用	practical use	41
13	管理	management	41
14	労働	labor	39
15	工事	construction work	36
16	データ	data	35
17	維持	maintenance	30
18	基準	standard	30
19	検査	inspection	28
20	作業	work	28

Figure 1 shows a diagram of this co-occurrence network, in Japanese as well as English. This is a visual presentation of what i-Construction aims to achieve and what is needed to achieve it in relevant terms. Particularly prominent terms, such as ‘site’, ‘improvement’, typically indicate that it is an organized report referring to actual construction implementation.

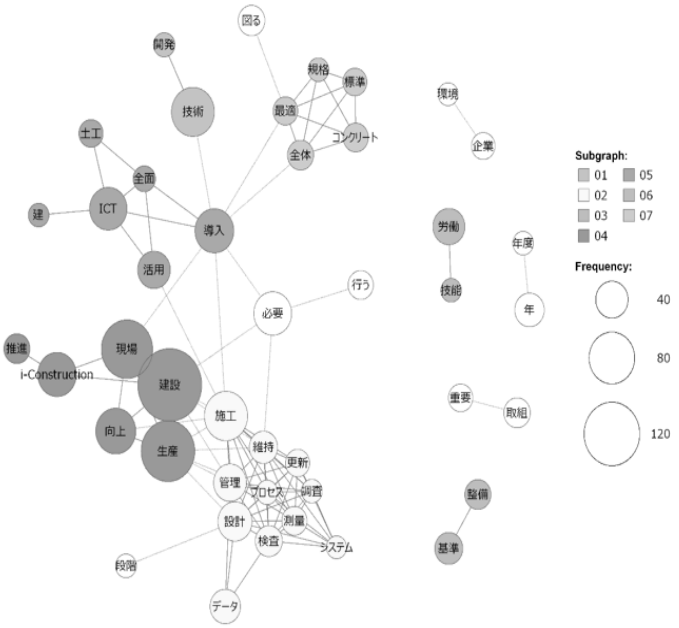

Figure 1

This can also be seen in the use of terms such as ‘construction work’ and ‘work’. Parallel to this, the terminology of ‘technology’, ‘introduction’, and ‘practical use’,

which is geared towards increasing productivity, is conspicuous, and vividly illustrates that the purpose of this report is to increase efficiency. It is also noteworthy that it specifies the conditions for productivity improvement, such as 'necessity', 'ICT', and 'standard'. The third aspect is the relationship with digital platforms. In recent years, digital platforms have played an important role in dramatically improving consumer access to the market and to business activities in the market. Relationships with Google, Amazon, Facebook, and Apple (GAFA) cannot be ignored in the construction industry, so we need to consider how we should leverage data. To date, there has been little research in construction management on improving the transparency and fairness of transactions on digital platforms (except for Lavikka *et al.,* 2018). However, it is also necessary to consider how to implement better measures based on the voluntary and proactive efforts of digital platform operators. For example, now that construction without Google Maps is no longer conceivable, it is necessary to think about how to respond to the further shift to a data society and how to channel the market.

From this point of view, ICT utilization and data linkage have been focusing on i-Construction in particular in recent years. MLITT established a plan to develop a "National Transport Data Platform" in May 2019, which would link a large amount of data held by the MLITT with data from the private sector. The aim is to improve the efficiency of operations, improve the sophistication of MLITT's policies such as smart cities, and create innovation through collaboration between industry, academia, and government. In this context, a platform is being built to link data on national land, and to utilize data on national land, data on economic activities, and data on natural phenomena such as weather.

CONCLUSION

In this paper, as Japan's population composition is an issue of increasing concern, we showed that i-Construction, which drastically improved productivity in all construction production processes such as research, survey, design, construction work, inspection, maintenance, and renewal was an important measure, and examined the i-Construction report compiled by the MLITT in April 2016 from the viewpoint of construction management.

In i-Construction, based on the rapid development of satellite positioning technology and IoT, the areas for advancing i-Construction were organised into 3 categories: "Turning construction sites into advanced factories", "Introduction of advanced supply chain management at construction sites", and "Regulation of construction sites, breaking stereotypes, and continuing 'Kaizen'". As top-ranking policies from these three perspectives, "Full utilisation of ICT (ICT earthwork)", "Optimal overall deployment (Standardisation of concrete work standards)" and "Levelling of construction time" were set. The characteristic of these policies was that they listed the items to be tackled for each perspective. In addition, as a mechanism for promoting i-Construction, it was proposed to establish a national promotion system, establish a public-private partnership consortium, utilise big data, collaborate with other outdoor industries, and expand overseas. After the compilation and publication of this report, the government created a road map each year since 2017, and progress was steadily advanced for each item, such as the utilisation of 3D data, levelling of construction time, open innovation by open data, and strengthening of the system through public-private cooperation.

This study evaluated this effort in Japan from three viewpoints. The first was the relationship between construction management methodology and i-Construction. The positioning of i-Construction in Japan in construction management methodology was seen to be an arrangement of various management methods in the engineering discipline. The second point of view was the relationship between the interdisciplinary nature and integrity of construction management and i-Construction. The interdisciplinary nature and integrity required in i-Construction was based on the knowledge of construction management to date in terms of human contribution and individual application cases. The third point was the relationship with digital platforms. The relationship with GAFA is not negligible in the construction industry, and it is necessary for construction management to examine ways to utilise data.
The main contribution of this research is that it is the first introduction of i-Construction in construction management research in Japan. It presents an evaluation and positioning of i-Construction and helps to provide material for future construction management research based on this knowledge. However, the limitation of this research is that only an introduction of the case in Japan is presented. It is also important to understand the situation further based on regional and temporal perspectives.

From the empirical perspective as seen in this paper, we have found that the business environment and companies that are built there make good use of the principle for the common good in construction. A different national context would also create opportunities to learn about and contrast approaches to governance, economic models, and the role that the construction industry plays in society. It is expected that this analysis will contribute to the progress of construction management research for the common good in the field of construction.

Postscript

Before concluding this paper, we would like to briefly describe the efforts of the construction-related departments of the MLITT of Japan in relation to new corona infections (COVID-19) as well as a review by the construction management research industry. It may not be directly related to the efforts of the Japanese construction industry to improve productivity, which is the subject of this paper. However, at this point, a paper that does not address this topic is not only meaningless but may also be called irresponsible.
The Government of Japan recognizes that countermeasures against the new coronavirus infection are a critical issue in terms of crisis management. In addition, it has promoted the implementation of basic infection control measures, such as the thorough avoidance of the "three densities", the maintenance of human-to-human distance, the wearing of masks, and hand hygiene, such as hand washing (hereinafter referred to as "the cluster"). On April 7, 2020, a state of emergency was declared. Subsequently, on May 25, 2020, the Government of Japan declared the state of emergency to be lifted. A certain transition period was established to gradually increase the level of socio-economic activity, while easing requests for self-restraint on going out and restrictions on the use of facilities. In this case, it is assumed that the "new lifestyle" to prevent the spread of infection, as described below, would take root and that the guidelines for the prevention of the spread of infection, etc., formulated for each industry, would be implemented.

The construction industry is beginning to see a downward trend in sales and orders due to a drop in private investment and the suspension of construction work by some

general contractors. The construction materials business is gradually improving with the resumption of domestic plant operations in China. Some general contractors have begun to resume construction at the end of May, after consultation with the clients.

It is considered that the information provided here will be updated and compiled as appropriate till the time of the report presentation.

REFERENCES

Bröchner, J (2018) Construction economics and economics journals, *Construction Management and Economics*, **36**(3), 175-180.

Dainty, A and Leiringer, R (2019) Maintaining a relevant construction management and economics research community, *Construction Management and Economics*, **37**(12), 693-696.

Hegazy, T and Saad, D (2014 A microeconomic perspective on infrastructure rehabilitation *Construction Management and Economics*, **32**(5), 433-445.

Iriyama, A (2019) *Management Theories of the Global Standard Diamond*, Tokyo [in Japanese], Available from https://www.diamond.co.jp/book/9784478109571.html [Accessed 30th July].

Ivory, C (2017 The prospects for a production management body of knowledge in business schools: Response to Koskela, why is management research irrelevant? *Construction Management and Economic*s, **35**(7), 385-391.

Koskela, L (2017 Why is management research irrelevant? *Construction Management and Economics*, **35**(1-2), 4-23.

Koch, C, Paavola, S and Buhl, H (2019 Social science and construction - An uneasy and underused relation, *Construction Management and Economics*, **37**(6), 309-316.

Lavikka, R, Kallio, J, Casey, T and Airaksinen, M (2018) Digital disruption of the AEC industry: technology-oriented scenarios for possible future development paths, *Construction Management and Economics*, **36**(11), 635-650.

Lindblad, H, Guerrero, J R (2020) Client's role in promoting BIM implementation and innovation in construction, *Construction Management and Economics*, 38(5), 468-482.

Ministry of Land, Infrastructure, Transport and Tourism (2016) *Report on I-Construction [In Japanese],* Available from http://www.mlit.go.jp/common/001127288.pdf [Accessed 29th July 2020].

Morgan, B (2019) Organizing for digitalization through mutual constitution: The case of a design firm, *Construction Management and Economics*, **37**(7), 400-417.

Pellicer, E, Yepes, V, Teixeira, J C, Moura, H P and Catala, J (2014) *Construction Management*, West Sussex, UK: Wiley Blackwell.

Sherratt, F and Farrell, P (2015) Introduction to Construction Management, London UK: Routledge.

Tutt, D and Pink, S (2019) Refiguring global construction challenges through ethnography, *Construction Management and Economics*, **37**(9), 475-480.

Volker, L (2019 Looking out to look in: Inspiration from social sciences for construction management research, *Construction Management and Economics*, **37**(1), 13-23.