

A Systemic Exploration of Drivers for and Constraints on Construction Productivity Enhancement

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Abstract

Purpose: This paper seeks to investigate the complex interdependence of the factors in driving or hindering construction productivity at the industry, project and activity levels in a systemic manner.

Design/methodology/approach: A mixed-methods design, which combines a critical literature review, an interview-based survey with 32 industry experts and five focus group meetings (FGMs) participated by 109 representatives of a wide range of industry stakeholder groups, was employed to identify the drivers for and constraints on construction productivity enhancement in Hong Kong and explore the interrelated insights into the drivers and constraints.

Findings: The study conceptualised and validated a systemic framework for examining construction industry productivity, and developed three causal loop diagrams (CLDs) for illustrating the dynamic structures that underpin the complex systems of the drivers and constraints.

Research limitations/implications: Although the scope of the study was limited to Hong Kong, the results could be interpreted for critical learning in other urban contexts.

Practical implications: The systemic perspective of construction productivity and the CLDs of the drivers and constraints support the systems thinking of industry stakeholders in the formulation of holistic strategies for long-term construction industry productivity enhancement.

Originality/value: The study conceptualises construction productivity from a systemic perspective and provides empirically supported CLDs to facilitate future investigations into the complex system of construction productivity.

Keywords: Construction productivity; productivity growth; system dynamics; industry development; causal loop diagrams; systemic framework

Article classification: Research paper

Introduction

The construction industry makes a significant contribution to global gross domestic product (GDP); therefore sustaining construction productivity is essential to economic growth (Barbosa et al. 2017). Productivity is often defined as the ratio of product output to input resources (Goodrum and Haas 2004). Within the construction context productivity is estimated by the quantity of output as well as the quantity of the intermediate, capital and labour inputs which are required to produce the output (Chau 1993). Research on construction productivity concerns three levels: industry, project and activity (Chia et al. 2014) pertaining to the project based nature of the industry.

The construction industry has achieved substantial improvements by adopting new construction methods, materials and technologies (Goodrum and Haas 2004; Goodrum et al. 2009). Despite these improvements, labour productivity decline has been reported in multiple economies (Green 2016; Teicholz 2013). While the construction industry in Hong Kong performed well in terms of gross value during the past few years (Zhan et al. 2016), its productivity declined primarily due to high construction cost (Pan et al. 2016), and severe skilled labour shortage (Ho 2016). The Hong Kong Construction Industry Council (CIC 2015) has alleged that it is imperative to enhance productivity for the industry to stay competitive.

Construction productivity is influenced by multiple factors including drivers that enhance construction productivity such as offsite construction approaches (Eastman and Sacks 2008), and constraints that hinder construction productivity enhancement such as rework (Palaneeswaran et al. 2008). In line with Porter's (1998) assertions on productivity growth and the systems dynamics (SD) perspective (Serman 2004) the literature seems to imply that construction productivity could be understood as a complex system where multiple drivers and constraints interact with each other and evolve over time. The dynamic complexity of labour

productivity in construction projects has been analysed through SD modelling (Nasirzadeh and Nojedehe 2013). Nevertheless, investigation into the structure and dynamics of the overall construction productivity system is limited in the literature.

This paper addresses the research need through a mixed-methods study seeking to fulfil three objectives: (i) to identify the drivers for and constraints on construction productivity enhancement; (ii) to reveal the important drivers and significant constraints within the context of the Hong Kong construction industry; and (iii) to explore how the drivers and constraints evolve and interact with each other. A critical literature review helps to construct a systemic framework for examining the complex system underpinning construction productivity. The framework is subsequently validated through analysing the data obtained from an interview-based survey and five focus group meetings (FGMs) participated by industry stakeholder groups of the Hong Kong construction industry. The analyses develops three causal loop diagrams (CLDs) of drivers and constraints revealing their dynamic impact on construction productivity enhancement.

Drivers for and Constraints on Construction Productivity Enhancement

Productivity growth of a regional industry is driven by a system formed by a wide range of attributes concerning production and demand conditions, supporting industries, company strategies and rivalry, which could be shaped by the regional government's industrial policies (Porter 1998). In order to identify the factors that affect construction productivity, the relevant construction management literature (e.g. Yi and Chan 2014) and consulting reports (e.g. Barbosa et al. 2017) were reviewed. The analysis of the review was guided by the political, economic, social, technological, legal and environmental (PESTEL) analytical framework, which has been applied extensively in examining construction business environment (e.g. Zhao and Pan 2015).

The review found that political factors are primarily reflected by government policies

which catalyse construction industry development (Crescenzi et al. 2016; Hussain et al. 2017). Legal factors mainly concern regulatory requirements that govern the industry's practices (Ling and Ng 2011). Economic factors such as economic fluctuations affect construction cost, and ultimately the industry's productivity (Chia et al. 2014). Technological and environmental factors are manifested by rapid technological advancement (Pan et al. 2008; Papadonikolaki et al. 2015) and sophisticated demand for sustainable built environments (Pan 2014). These are the two major forces that drive smart and sustainable design and construction (Barbosa et al. 2017; Sezer 2015), meanwhile impel integrated project management and administration (Hanna 2016). Social factors such as aging population and negative societal perception of construction lead to labour shortage that challenges site operation efficiency (Ho 2016).

Building upon the major themes identified by the review, the systemic framework (Figure 1) is constructed to contextualise the PESTEL factors in the built environment and society, and structure them under five strategic aspects, namely, *policy formation*, *regulatory requirements*, *planning and design*, *project management and administration*, and *site construction*, and at industry, project and activity levels. As discussed below, the review shows the co-existence of drivers and constraints in the five strategic aspects.

[Insert Figure 1]

Policy formation: Government policies are developed to enhance construction productivity in both developed and developing economics. The major policies include developing construction workforce through training, encouraging innovation, applying new construction technologies and methods, and strengthening collaborations of construction supply chain (Barbosa et al. 2017; Green 2016). Whereas slow local authorities' approval were identified as the key constraint that hinders productivity improvement (Kadir et al. 2005).

Regulatory requirements: The impact of regulatory requirements on construction productivity could be positive or negative according to the literature. On the one hand, the implementation

of health, safety and environment (HSE) regulations leads to less accidents and consequently less absenteeism, hence has a positive influence on productivity (Choudhry 2017). On the other hand, the implementation of the requirements might save time through clarifying work uncertainty and ambiguity, but they consume time and resources without guaranteed tangible outcomes, thereby resulting in a mixed influence to productivity (Chang and Ibbs 2006).

Planning and design: Lean construction principles have been widely used to develop production planning and control systems for productivity improvement (Howell et al. 2011). Building Information Modelling (BIM) (Papadonikolaki et al. 2015) and offsite technologies (Pan et al. 2008) are making radical changes in project planning and design. Waste and inefficiencies could be further eliminated through adopting standardised design, offsite prefabrication, and automated construction processes (Pan et al. 2018; Pan and Sidwell 2011). However, the initial high application cost could affect productivity negatively (Pan and Sidwell 2011).

Project management and administration: Contract environment, management systems and strategies, experience and motivation, scheduling, manpower management, working conditions have been identified as key factors which may drive or hinder project productivity depending on specific contexts (Rojas and Aramvareekul 2003). Collaborative procurement approaches have gained popularity due to their capacity of achieving better value for money and benefit project productivity (Hanna 2016).

Site construction: Previous research suggested that factors including systematic flow of work, supervision, site layout, direction and coordination, material and equipment management, foreman competency, training, and on-time payment; all impose significant impacts on site work productivity (Dai et al. 2009). The possible causes for productivity decline were reported to include inadequate training for workers and managers, fewer younger workers entering the construction industry, more safety procedures, increased complexity of projects, greater time

pressure on project completion, and greater fragmentation of the work process (Kazaz et al. 2012).

Systems Dynamics Approach to Examining Drivers and Constraints

SD is an objective-oriented simulation methodology that models complex systems, in which multiple influencing factors interact with each other and change over time (Forrester 1992). SD Modelling has a capacity to simulate processes involving changes over time and allowing feedback loops, thus are widely used in public and private sectors for the design and analyses of policies and strategies (Sterman 2004). SD has been applied in construction productivity research for developing CLDs, flow diagrams, and governing equations (e.g. Nasirzadeh and Nojedehi 2013). From the SD perspective any fragmented identification of drivers and constraints would introduce theoretically flawed assumptions and fail to effectively tackle the fundamental issues with productivity, thereby leading to less robust strategies. Therefore, this paper employs the SD perspective to reveal the complexity of drivers and constraints that affect construction productivity.

Methods

Research design

A mix-methods design, which combines a critical literature review, an interview-based questionnaire survey, and five focus group meetings (FGMs), was used to achieve the research objectives and ensure validity and reliability of the findings (Zou et al. 2014).

In this research, the literature review was undertaken to identify the drivers for and constraints on construction productivity enhancement. The review was guided by a socio-technical systems approach (Pan and Ning 2014), and explored and evaluated both technical and institutional factors affecting construction productivity. PESTEL framework was adopted to provide the initial coding categories for ensuring the comprehensive inclusion of drivers and constraints in the broad construction business environment. The five major themes derived

from the process of coding and analysis were used as the five strategic aspects to construct the systemic framework.

Scopus was chosen to identify the articles, given the search engine's effectiveness in supporting literature review of construction productivity research (Yi and Chan 2014). Key words of "productivity" "productivity & construction" and "productivity & construction industry" were used to undertake title/abstract/keywords scan of articles published in the top-ranked construction management journals defined by Chau (1997); as well as other journals from 2008 to 2017. The titles and abstracts of the 1387 articles derived by the scan were further reviewed to identify 155 articles that are closely relevant to the research issues of this study; attention was especially paid to the articles of large numbers of citations. Further, 11 highly cited articles published between 1997 and 2007 by the authors who have reported extensively about construction productivity studies were also included in the scope of the review. In addition, 15 industry literatures including government documents, consulting papers and industry reports were also reviewed.

The identified drivers and constraints were then verified through face-to-face semi-structured interviews with 32 industry experts carefully selected from the Hong Kong construction industry. During the interviews, the interviewees were asked to respond to a survey on the drivers and constraints. The analyses of the interview transcripts and completed survey questionnaires helped to identify the important drivers for and the significant constraints on productivity enhancement within the context of Hong Kong construction industry.

Five FGMs were held after that to synthesise the findings from the interview-based survey and also to explore the interdependent nature of the drivers and constraints. The five strategic aspects (see Figure 1) were respectively adopted as a theme of each of the FGMs. A total of 109 participants attended the FGMs. The analyses of the FGMs records helped to reveal the insights into the drivers and constraints and their impacts on productivity.

The interviewees and FGM participants represented different stakeholder groups including government agencies, clients, developers, contractors, consultants, and suppliers (see Table I). Three selection criteria were used to select interviewees and FGM participants from the industry stakeholder groups, i.e. 1) held senior management positions in their respective organisations, 2) had over 15 years of working experience with the construction industry, 3) was involved in at least one construction project, by the time of this study. Academic scholars and researchers specialized in construction productivity research were also invited to participate in the FGMs.

[Insert Table I]

The interviews and FGMs were audio-recorded with prior permission of the participants. The transcripts of the audio-recordings were analysed using QSR NVivo 10 analytical software to yield meaningful themes and insights. The SD perspective was applied in the analysis of FGM transcripts to depict the key drivers and constraints underpinning each strategic aspect, as well as the interrelationships among them.

Design and analysis of interview-based survey

The interview-based survey was designed under three parts. Part 1 collects information of the interviewees and their affiliated organisations. Part 2 asks open-ended questions about the drivers and constraints in the five strategic aspects. Part 3 derives the relative importance of the drivers and the relative significance of the constraints identified through the literature review. The interviewees were asked to rate the importance and significance of drivers and constraints respectively using a five-point Likert scale (with the scale from 1 for “not important / significant” to 5 for “very important / significant”).

A pilot study of the survey was carried out with three experienced researchers and two industry specialists to review the appropriateness, structure, readability and validity of the

survey questions (Neuman 2011). Their feedback was incorporated to revise the survey questions. The revised interview-based survey was then emailed to the interviewees before the interviews with ethics clearance. This approach provided the interviewees with necessary cognitive background on the drivers and constraints as well as their underlying institutional and socio-technical issues, which helped to effectively engage them in the discussion during the interview (Willis 2005).

The completed questionnaires were analysed quantitatively to validate the qualitative analysis of the interview transcripts. The Relative Importance Index (RII) was utilised to identify the relative importance of the drivers and the significance of the constraints. The RII is a process where weight is given to each type of response as per the judgment of the respondents, and has been widely used by researchers in the field of construction and project management (Gündüz et al. 2013).

The quantitative data collected through the questionnaires were analysed using SPSS 20.0 statistical software. The RII for each option was calculated using the following equation (Gündüz et al. 2013):

$$RII = \frac{\sum W}{A \times N}$$

where W is the weighting given to each driver and constraint by the respondents (ranging from 1 to 5), A is the highest weight given (i.e. 5 in this case), and N is the total number of respondents. The RII value ranged between 0 and 1, the higher the RII value, the more important/significant were the drivers and constraints. The RII value of 0.60 is the demarcation point. The RII value of less than and/or equivalent to 0.60 (≤ 0.60) is considered "not important", and that larger than 0.60 (> 0.60) as "important/very important".

Results and Analyses

Important drivers and significant constraints

The average RII index values of the drivers and constraints in the five strategic aspects are over 0.60 (see Table II). The results suggest that all five aspects were perceived to be fairly important for construction productivity enhancement. This finding supports the suitability and relevance of the constructed systemic framework for examining construction productivity (Figure 1). The three most important drivers and the three most significant constraints in the five strategic aspects are presented in Table II in descending order. The detailed analyses in relation to the five strategic aspects are presented below.

[Insert Table II]

For the policy formation aspect, the RII values indicate that ‘initiatives on labour training’ (RII=0.86) is the most important driver, followed by the drivers ‘flexibility in labour and capital markets’ (RII=0.81) and ‘transparent policies regarding construction industry’ (RII=0.74) (Table II). In contrast, the RII values indicate that ‘ageing workforce’ (RII=0.90) is the most significant constraint in the policy formation aspect, followed by the constraints ‘slow local authorities’ approval’ and ‘impeding environmental sustainable construction’ with their RII values of 0.82 and 0.70, respectively. The interviews revealed that at the time of this research the Hong Kong construction industry was facing a skilled labour shortage and an ageing workforce. The industry was demanding radical changes through promoting new sets of skills, knowledge and capabilities in order to improve performance and competitiveness. There was an urgent need to train non-active and semi-skilled workers, and attract young people to join the industry.

For the aspect of regulatory requirements, the RII values indicate that ‘qualification of contractors (e.g. category A, B, C and P for public works)’ (RII=0.77) is the most important driver, followed by ‘meeting the legal, quality control, aesthetic and functional requirements’

(RII=0.69) and ‘implementation of health, safety and environment (HSE) regulations’ (RII=0.68). In contrast, the RII values show that ‘restriction on labour importation’ (RII=0.87) is the most significant constraint, followed by ‘compliance with new sustainability standards’ (RII=0.70) and ‘stringent HSE requirements’ (RII=0.65). The respondents commented that consultants and contractors’ technical capability and past performance should be assessed during tender evaluation stage. Further, labour importation might need to be considered as a short-term strategy to ease labour shortage. In line with the literature, compliance with HSE regulations was perceived as a driver and/or a constraint depending on specific construction contexts.

For the planning and design aspect, the RII values indicate that ‘improved buildability’ and ‘increased collaboration between project partners’ (RII=0.90) are ranked as the most important drivers, followed by ‘effective planning and scheduling’ (RII=0.89) and ‘integration of design with supply chain’ (RII=0.82). In contrast, ‘frequent changes in design’, ‘incomplete design’, and ‘inaccuracies in the design’ are ranked the highest (RII=0.85) as the most significant constraints, followed by ‘bad working order planning’ (RII=0.80) and ‘architectural and engineering errors and omissions’ (RII=0.77). The interviewees welcomed the buildability assessment methods, which might be pilot tested on public sector projects by the Government for improving construction efficiency. They also supported the application of the New Engineering Contract (NEC) to improve project collaboration.

For the project management and administration aspect, ‘good coordination with multi-layer sub-contractors’ (RII=0.89) is ranked the highest as the most important driver in this aspect, followed by ‘effective and efficient supervision system’, and ‘good management control of project team’ (both RII=0.88), and ‘good communication networks’ (RII=0.85). In contrast, ‘coordination problems between site personnel and the engineer or architect’ (RII=0.87) is ranked the highest as the most significant constraint, followed by ‘inaccurate

working methods' (RII=0.84), and 'unclear instructions to workers' and 'poor field management' (RII=0.80). The interviewees argued that as the industry heavily relied on sub-contracting, good coordination and effective supervision were fundamental for smooth delivery of projects to enhance the productivity and efficiency of projects.

For the site construction aspect, 'better management of concurrent operations at site' and 'the use of automated production' (RII=0.84) are ranked as the most important drivers, followed by 'quality of craftsmanship' (RII=0.82), and 'quality control and quality assurance practices' and 'effective labour time utilisation' (RII=0.79). In contrast, 'lack of skilled craftsmen' (RII=0.87) is ranked as the most significant constraint, followed by 'rework' (RII=0.86), and 'incompetent foremen' and 'waiting for design interpretation/engineering information' (RII=0.81). Most of the interviewees opined that skilled workforce, offsite construction as well as new technologies, methods and material can all enhance productivity of the industry. They urged the industry to adopt automated production technologies for managing severe challenges of skilled labour shortage and an ageing workforce.

Interrelationships between the drivers and constraints

The findings derived from the interview-based survey suggest that the drivers and constraints relating to the aspects of policy formation and regulatory requirements focus more at the industry level, while those factors relating to the aspects of planning and design, project management and administration are primarily related to the project level, and those factors relating to the site construction aspect are associated more with the activity level. While the discussions of FGMs revealed that actually all the factors interact across the three levels to impact construction productivity.

The insights into the interrelationships between the different drivers are depicted in Figure 2. For example, the FGMs revealed that at the industry level, policy incentive and regulations would drive the industry to adapt new construction technologies and methods (e.g.

BIM and prefabrication). Electronic submission of designs would allow smooth submission and reduce conflict between public and private sectors. At the project level, early contractor's involvement, closer coordination and fairer risk allocation enabled by NEC contracts would enhance productivity. '3S' concept (standardisation, simplification, and single integrated element) applied during the design stage would facilitate offsite construction. The adoption of offsite technologies and automated production would reduce labour intensiveness of site operations thereby improving the productivity at the site level. The findings derived from the FGMs support that the drivers in the five strategic aspects and at three industry working levels are interlinked with each other in enhancing productivity.

[Insert Figure 2]

Similarly, the FGMs also revealed that the interdependence between the constraints could reinforce their negative influence on productivity (Figure 3). At the industry level, the lack of productivity measurement standards was perceived as a fundamental constraint that had caused difficulties for effective productivity evaluation. Funding approval delays by the Legislative Council of Hong Kong affected the continuity of some major public infrastructure projects and slowed project progress. Other constraints at the industry level such as skills shortage, lack of continuity of construction work, stringent statutory requirements, long planning approval processes and insufficient incentive for new technology application were also interconnected with each other and reduce the productivity of project delivery. Site productivity was decreased by over dependent on old techniques, delay in payment and high construction waste. Low retention rate of skilled labour and lack of skills training affect site work quality.

[Insert Figure 3]

The analysis on the interrelationships between the important drivers and significant constraints in the five aspects and at the three levels disclosed the systemic nature of construction productivity enhancement (Figure 4). The findings suggest that workforce

development, infrastructure planning, planning and design, project collaboration and management, and regulatory compliance could be potentially improved by leveraging the drivers and reducing the impact of the constraints. The FGMs revealed that the lack of certainty and continuity of infrastructure development clouds the stakeholders' vision about future market evolution and thus causes difficulties in longer term planning for skilled workforce development. The impact of stringent statutory requirements on productivity is dynamic phenomenon depending on the resource allocation for meeting such requirements. Increasing labour market flexibility and training initiatives could ease skills shortages and improve quality of craftsmanship. Incorporating buildability into design solutions would increase design accuracy and minimise variation orders. Further control of sub-contracting layers could improve collaboration and coordination, thus achieve smooth operations on site.

[Insert Figure 4]

Discussion

The important drivers and significant constraints identified by the study are in line with the findings of previous construction productivity studies (e.g. Dai et al. 2009; Palaneeswaran et al. 2008; Rojas and Aramvareekul 2003). The analyses on the interrelationships between the drivers and constraints derived three CLDs, which unveil the insights from the construction context about the complex system and significance of innovation that underpin productivity growth being asserted by Porter (1998). The findings imply that the persistent challenges such as skills shortages and high construction cost could be resolved by upgrading both production and demand conditions through innovation. Joint forces of multiple drivers could be leveraged to amplify the impact of smart construction technologies, develop high-qualified human resources and cultivate sophisticated local demands for prefabricated construction.

Conclusions

The paper has identified the important drivers and significant constraints, which concern

construction productivity in Hong Kong, and explored the interdependence of these factors in driving or hindering productivity enhancements. The paper concludes that the overall productivity of the construction industry should be perceived as a latent entity, which is underpinned by a complex system of the five strategic aspects, i.e. policy formation, regulatory requirements, planning and design, project management and administration, and site construction, operating at three levels of focus, i.e. industry, project and activity. A wide range of drivers and constraints were found to co-exist and interlink to each other within that system. The interdependencies between the drivers and constraints were observed to evolve over time and contribute to the elusiveness of construction productivity in its measurement and prediction. From a systemic perspective, single factor productivity, which may help to address specific issues such as labour productivity within a given context, would fall short to elicit insights into the macro context in seeking for effective solutions.

Recommendations

The findings reveal the rationale underpinning construction productivity enhancement in Hong Kong, and suggest that holistic strategies must be formulated to leverage the drivers and deal with the constraints systemically. To highlight, construction productivity measurement standards need to be developed to pave a foundation for objective productivity evaluations. Policy solutions are required to stabilise the supply of public infrastructure projects in order to provide the industry with a clear vision for workforce mobilisation. Labour training should strategically focus on upgrading technological competence of the workforce. Smart and sustainable construction should be promoted by more integrated policy incentives and regulatory guidance, and facilitated by better project collaboration and management.

Future studies

The authors have planned to develop SD models based on the three CLDs for simulating the evolution of drivers and constraints over time in succeeding study phases. The generalisability

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of the findings could be improved by future research into a wider context. For example, the systemic framework could be applied to examine the drivers and constraints in other regions. The CLDs also provide guidance for future SD investigations into the relationships between the drivers and constraints within a project context.

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Table I. Profile of participants

No.	Major stakeholder group	Interview	1 st	2 nd	3 rd	4 th	5 th
		based survey	*FGM	FGM	FGM	FGM	FGM
Frequency							
1	Government agencies	10	3	3	3	3	2
2	Clients	3	-	-	2	1	-
3	Contractors/developers	11	1	4	2	2	6
4	Consultants	7	1	-	4	5	1
5	Institutions**	1	13	11	14	11	11
6	Suppliers	-	-	1	4	-	1
Total		32	18	19	29	22	21

* FGM: Focus group meeting. 1st FGM focused on the theme of ‘policy formation’. 2nd FGM focused on the theme of ‘regulatory requirements’. 3rd FGM focused on the themes of ‘planning and design’. 4th FGM focused on the theme of ‘project management and administration’. 5th FGM focused on the theme of ‘site construction’.

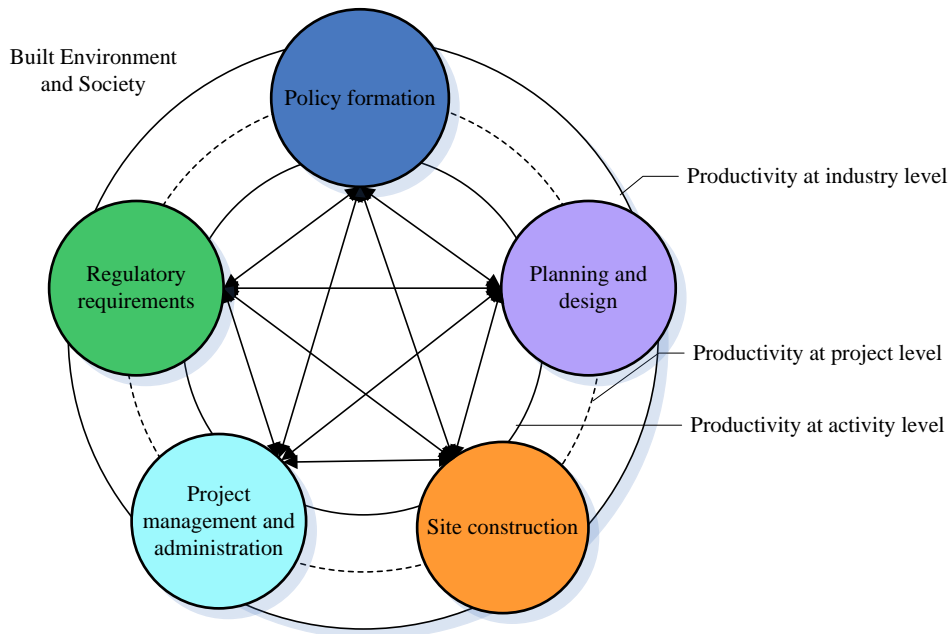
** Institution: Include professional institutions and educational institutions.

Table II. Importance level of drivers for and significance level of constraints to enhancing construction productivity in the five strategic aspects

Strategic aspects	Drivers			Constraints		
	Average RII#	Top three drivers	RII*	Average RII	Top three constraints	RII*
Policy formation	0.74	<ul style="list-style-type: none"> • Initiatives on labour training • Flexibility in labour and capital markets • Transparent policies regarding construction industry 	0.86 0.81 0.74	0.70	<ul style="list-style-type: none"> • Ageing workforce • Slow local authorities' approval • Lack of certainty and continuity of infrastructure development 	0.90 0.82 0.70
Regulatory requirements	0.67	<ul style="list-style-type: none"> • Qualifications of contractors (e.g. category A, B, C and P for public works) • Meeting the legal, quality control, aesthetic and functional requirements • Implementation of health, safety and environment (HSE) regulations 	0.77 0.69 0.68	0.65	<ul style="list-style-type: none"> • Restrictions on labour importation • Compliance with new sustainability standards • Stringent health, safety and quality requirements 	0.87 0.70 0.65
Planning and design	0.75	<ul style="list-style-type: none"> • Improved buildability • Increased collaboration between project partners • Effective planning and scheduling 	0.90 0.90 0.89	0.71	<ul style="list-style-type: none"> • Frequent changes in design • Incomplete design • Inaccuracies in the design 	0.85 0.85 0.85
Project management and administration	0.79	<ul style="list-style-type: none"> • Good coordination with multi-layer subcontractors • Effective and efficient supervision system • Good management control of project team 	0.89 0.88 0.88	0.67	<ul style="list-style-type: none"> • Coordination problems between site personnel and the engineer or architect • Inaccurate working methods • Unclear instructions to workers 	0.87 0.84 0.80
Site construction	0.77	<ul style="list-style-type: none"> • Better management of concurrent operations at site • The use of automated production (e.g. automated bar bending, precast concrete components and façade, RFID-integrated logistics) • Quality of craftsmanship 	0.84 0.84 0.82	0.67	<ul style="list-style-type: none"> • Lack of skilled craftsmen • Rework • Incompetent foremen 	0.87 0.86 0.81

#: Average RII index values of the drivers and constraints in the five strategic aspects.

*: RII index values of the three most important drivers and the three most significant constraints in the five strategic aspects;



- *Policy formation* involves developing strategies to deal with policy issues and taking both the effectiveness and the viability or acceptability of proposed actions into account (Hussain et al. 2017).
- *Regulatory requirements* refer to restrictions, licenses and laws applicable to the construction industry imposed by the government (Ling and Ng 2011).
- *Planning and design* and *project management and administration* govern the issues at the project level (Howell et al. 2011).
- *Site construction* refers to a place where a building is being built or repaired, and covers under activity level study (Sezer 2015).

Figure 1. A systemic framework for examining construction productivity

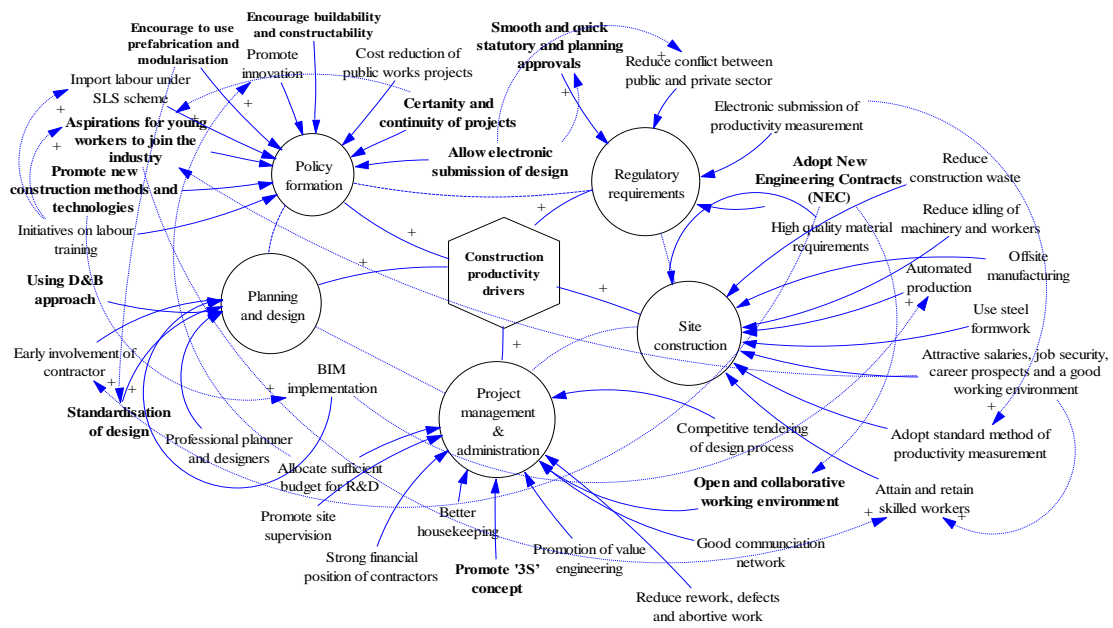


Figure 2. Key drivers for enhancing construction productivity

Note: Dotted arrows represent direct influence on other factors and bold text represents important factors. Relationships between drivers were verified in Focus Group Meetings

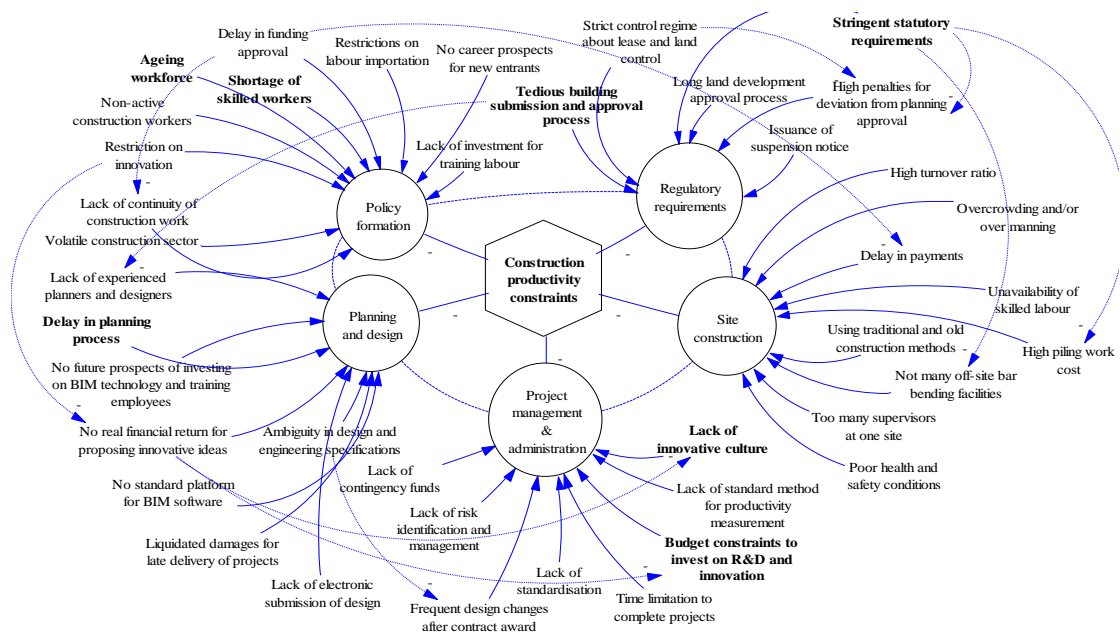


Figure 3. Main constraints for enhancing construction productivity

Note: Dotted arrows represent direct influence on other factors and bold text represents important factors. Relationships between constraints were verified in Focus Group Meetings

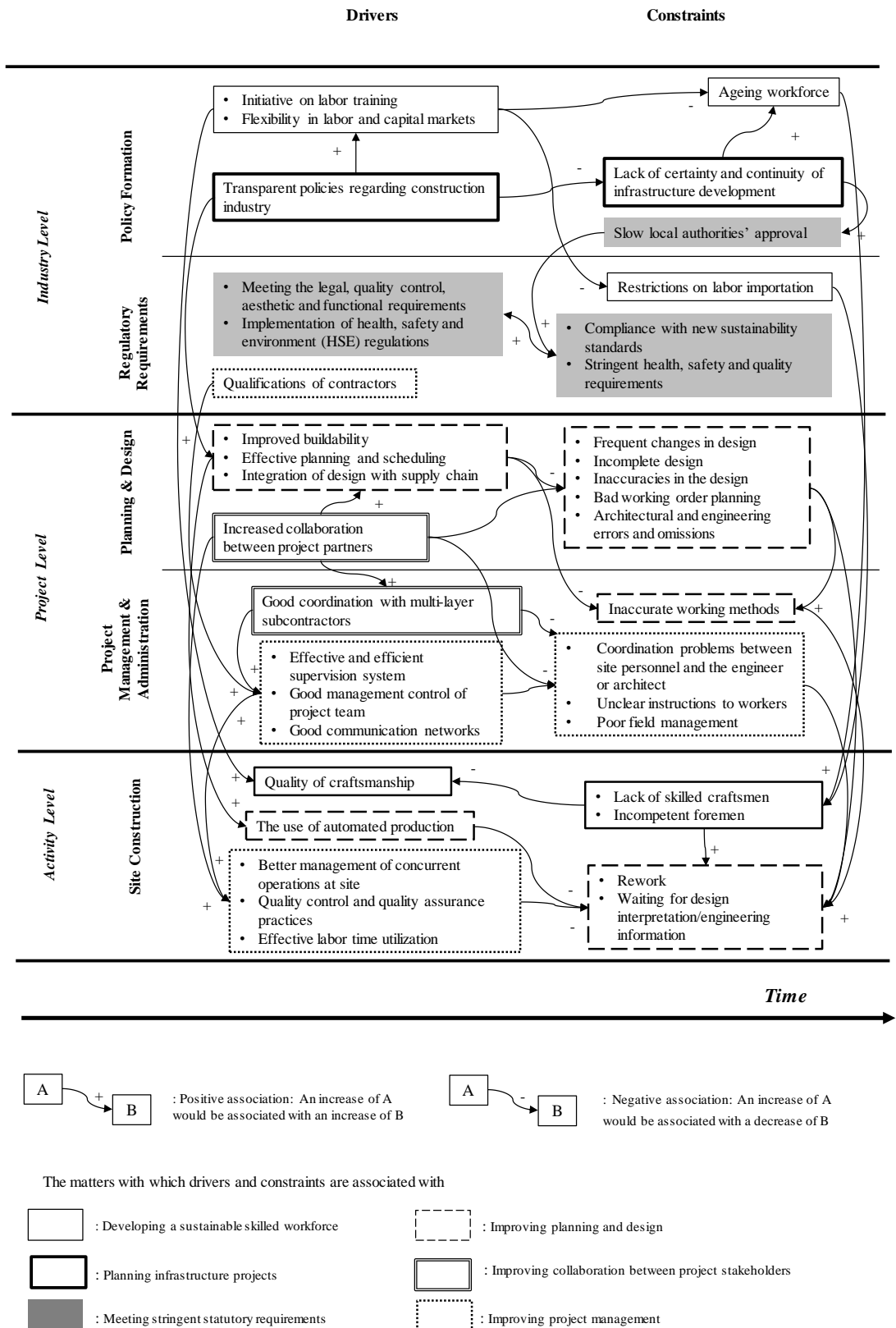


Figure 4. Interactions between drivers and constraints underpinning construction productivity enhancement in Hong Kong