**Initiatives that enable Singapore contractors to improve construction productivity**

**ABSTRACT**

**Purpose**: This study examines the initiatives that would enable contractors in Singapore to improve the level of construction productivity.

**Methodology**: A two-pronged research method was employed: questionnaire survey with contractors (109 responses received) and in-depth interviews with 12 subject-matter experts. The questionnaire covered questions such as the current and future improvement measures.

**Findings**: The results show that the top three motives for achieving high productivity (increase profitability; on-time deliverly; and enhance corporate competitiveness) are underpinned by profit maximization. Factor analysis revealed several categories of productivity improvement strategies. Among these, only Site Operations category is under the control of contractors. Other important categories include Government’s Initiatives and Design Factors.

**Research implications**: While contractors are the producers of built products, their productivity is very much dependent on other factors and other parties. The long-standing exhortation to contractors to improve productivity is necessary but not a sufficient condition to improve it.

**Practical implications**: Recommendations are provided for the government, designers, contractors and other stakeholders on what can be done to improve productivity.

**Originality**: This research adds to knowledge by showing that contractors’ top motives for high productivity relate to self-seeking behaviour to maximise profit. Prior to this study, productivity improvement is considered the responsibility of contractors. This study shows two other stakeholders also hold the key to productivity improvement – government and designers. Government controls the supply of foreign labour, has the capacity to offer incentives and has the muscle to enact regulations to improve productivity. Consultants’ upstream designs must be buildable.

*Keywords*: Construction productivity; strategies; motives; initiatives.

Manuscript type: Research paper

**Introduction**

Many governments such as those of Australia, Ireland, New Zealand and the UK have formulated policies and implemented initiatives to enhance the level of construction productivity. In Singapore, it is recognised that there is a need to increase construction productivity in order for the construction sector to play its part in increasing overall productivity in the economy, enhancing national competitiveness and address the acute shortage of Singaporeans willing to take up careers in the industry (Ministry of Manpower, 2014). Increasing construction productivity in Singapore is challenging due to some unique features such as a high reliance on foreign/ migrant workers (constituting 70 - 80% of the workforce) who may not be highly skilled, and challenges exist due differences in language, work ethic and attitudes (Ministry of Manpower 2019).

The aim of this study is to examine the initiatives that would enable contractors in Singapore to improve the level of construction productivity. The specific objectives are to: determine the reasons or motives for construction firms to improve productivity; identify the strategies that are effective in improving construction productivity; and recommend ways forward to enhance the productivity performance of construction companies.

**Literature review**

*Productivity*

Productivity measures output produced based on the inputs used in the production process and many types of metrics on productivity are produced (Forsythe, 2018). Total factor productivity (TFP), partial factor productivity (PFP) are often used for the construction industry (El-Gohary and Aziz, 2014; Azman et al., 2019). Measuring productivity is challenging (Hwang and Soh, 2013). In construction, productivity can be considered at the task, process (stage), project, company or industry levels. This paper considers the concept at the macro, industry level.

*Factors affecting construction productivity*

Extensive studies have been undertaken to identify and explore the factors which affect construction productivity, and these are summarized in Table 1.

Table 1. Factors affecting construction productivity

| Factor | References |
| --- | --- |
| Planning & scheduling | El-Gohary and Aziz (2014); Naoum (2016); Yi and Chan (2013) |
| Coordination and communication | Haas (2009); El-Gohary and Aziz (2014); Naoum (2016); Yi and Chan (2013) |
| Management control | El-Gohary and Aziz (2014); Naoum (2016); Yi and Chan (2013); Vogl and Abdel-Wahab (2015); Hwang et al. (2020) |
| Labour union agreements | Yi and Chan (2013) |
| Restrictive work practices | Yi and Chan (2013) |
| Absenteeism | Yi and Chan (2013) |
| Turnover/ Sales volume | Yi and Chan (2013) |
| Delay | Yi and Chan (2013) |
| Availability of skilled workers | Haas (2009); El-Gohary and Aziz (2014); Yi and Chan (2013); Gao et al. (2020) |
| Workers’ education and level of skill | El-Gohary and Aziz (2014); Yi and Chan (2013); Won et al. (2021) |
| Workers’ age | El-Gohary and Aziz (2014); Won et al. (2021) |
| Experience and training of workers | Naoum (2016), Javed et al (2018); Oheuri et al. (2018) |
| Incentive programmes | El-Gohary and Aziz (2014) |
| Insurance and medical care for workers | El-Gohary and Aziz (2014) |
| Supervision of workers | Durdyev and Mbachu (2011); El-Gohary and Aziz (2014) |
| Regulations, permits, codes and standards | Haas (2009); Yi and Chan (2013); Sverikauskas et al. (2014); Vogl and Abdel-Wahab (2015); Barbosa et al. (2017 |
| Climate and weather | El-Gohary and Aziz (2014); Yi and Chan (2013); Vogl and Abdel-Wahab (2015) |
| Contracts | Haas (2009); Yi and Chan (2013); Barbosa et al. (2017) |
| Owner characteristics | Yi and Chan (2013); Vogl and Abdel-Wahab (2015) |
| Financing | Haas (2009); Yi and Chan (2013) |
| Automation, use of equipment, technology, tools & machinery | El-Gohary and Aziz (2014); Yi and Chan (2013) Vogl and Abdel-Wahab (2015); Dai *et al.* (2009); Zhan & Pan (2020) |
| Information system | Yi and Chan (2013) |
| Design and production information | Dai *et al.* (2009); El-Gohary and Aziz (2014); Naoum (2016); Yi and Chan (2013); Barbosa et al. (2017); Bohme et al (2018) |
| Project scale | El-Gohary and Aziz (2014) |
| Materials | Dai *et al.* (2009); Haas (2009); El-Gohary and Aziz (2014); Yi and Chan (2013); Vogl and Abdel-Wahab (2015) |
| Changes/ Variation | El-Gohary and Aziz (2014); Liu *et al.* (2010); Naoum (2016); Yi and Chan (2013); Bohme et al (2018)  |
| Buildability and constructability | El-Gohary and Aziz (2014); Naoum (2016); Yi and Chan (2013); Vogl and Abdel-Wahab (2015) |
| Subcontractors | Haas (2009); El-Gohary and Aziz (2014) |
| Work environment | Naoum (2016); El-Gohary and Aziz (2014) |
| Procurement method | Vogl and Abdel-Wahab (2015); Naoum (2016) |
| Team integration | Haas (2009); Naoum (2016); Barbosa et al. (2017) |
| Standardisation, prefabrication and off-site production | Vogl and Abdel-Wahab (2015); Barbosa et al. (2017) |
| Rework | Durdyev and Mbachu (2011) |

A team of researchers in Hong Kong conceptualized a systemic framework for examining construction project productivity. Javed et al. (2018) presented causal loop diagrams showing: key drivers for enhancing productivity; main constraints to enhancing productivity; and interactions between drivers and constraints underpinning enhancement to construction productivity in Hong Kong. The work was further developed by Zhan et al (2020) who identified three system boundaries (tangible versus intangible parameters, construction versus post-construction processes, and contractors versus client) for productivity evaluation. Thereafter, Zhan and Pan (2020) designed and tested a Total Factor Productivity enhancement framework that supports industry stakeholders in effectively formulating and implementing construction productivity enhancement strategies.

Lim and Alum’s (1995) survey of 67 contractors revealed that the main issues faced in improving construction productivity in Singapore are difficulties in the recruitment of supervisors and workers, and a high rate of labour turnover. Some 25 years later, Ofori et al.’s (2020) investigation revealed that the top barriers to improving productivity are delays in providing information to contractors, poor skills of workers and inadequate planning.

*Improvement measures*

Many studies on conducted on measures to improve productivity and the findings are summarized in Table 2. Some proposals are outlined below.

Table 2. Improvement measures for increasing construction productivity

|  |  |
| --- | --- |
| Improvement Measure | References |
| Reshape regulation | Barbosa *et al.* (2017); Singh (2010) |
| Restructure the contractual framework to reshape the industry’s dynamics | Barbosa *et al.* (2017) |
| Rethink design and engineering processes | Barbosa *et al.* (2017); Singh (2010); Low et al. (2015) |
| Improve procurement and supply-chain management | Barbosa *et al.* (2017); BCA (2010, 2015) |
| Improve on-site execution | Barbosa *et al.* (2017); Javed et al (2018) |
| Apply digital technology including automation | Barbosa *et al.* (2017); Abid et al (2018); Zhan & Pan (2020) |
| Apply new materials | Barbosa *et al.* (2017) |
| Reskill the workforce | Barbosa *et al.* (2017); Durdyev and Mbachu (2011); Singh (2010) |
| Adopt prefabrication based on off-site production of components | Barbosa *et al.* (2017); Gao et al. (2018) |
| Reduce rework | Durdyev and Mbachu (2011); Javed et al (2018) |
| Adopt appropriate methods of construction; adopt productive technology | Durdyev and Mbachu (2011); Oheuri et al (2018) |
| Ensure buildability | Durdyev and Mbachu (2011); Javed et al (2018) |
| Improve on co-ordination | Durdyev and Mbachu (2011); Singh (2010); Javed et al (2018) |
| Improve supervision | Durdyev and Mbachu (2011); Singh (2010) |
| Performance monitoring and control | Durdyev and Mbachu (2011); Javed et al (2018); Hwang et al. (2020) |
| Financial management | Singh (2010) |
| Predict demand | Singh (2010) |
| Improve work scheduling | Singh (2010) |
| Ensure right crew mix | Singh (2010) |
| Training, workforce development | Huang *et al.* (2009); Singh (2010); Javed et al (2018); Oheuri et al (2018); Ugulu & Allen (2018); BCA (2010, 2015) |
| Improve quality of materials | Singh (2010); Javed et al (2018) |
| Provide right equipment, technology adoption, higher capital investment | Singh (2010); BCA (2010, 2015) |
| Industry reform | Huang *et al.* (2009) |
| Apply industry best practices | Huang *et al.* (2009) |

Project management is considered as a major influencing factor on construction productivity. The aspects highlighted include: good planning, realistic scheduling, appropriate co-ordination, reduction of work flow changes from the plan and appropriate control (Yi and Chan, 2013; Huang *et al.*, 2009). Better planning strategies include Last Planner System (LPS) (González *et al.*, 2008) and collaborative project management (Fulford and Standing, 2014). Early contractor involvement is found to improve productivity through reducing variability, reducing cycle time, minimizing steps and increasing output flexibility (Low et al., 2015).

Technology related to tools, machinery, material and information technology has also played an important role on productivity (Yi and Chan, 2013). Design for manufacturing and assembly (DfMA) would be adopted more readily in Singapore when there is clear reduction in construction time, there are site constraints and storage limitation (Gao et al., 2018).

Enhancement to human resource management such as comprehensive training and knowledge transfer programmes need to be developed and frequent feedback should be provided to the workers. Won et al. (2021) found that workforce diversity in terms of workers’ skill and education, and age and experience have an impact on productivity in Singapore.

With data from 53 Singapore-based companies, Hwang et al. (2020) found that planning and communication are the most critical management strategies to improve productivity. Low et al.’s (2016) productivity research in Singapore focused narrowly on organizational learning in labour efficiency initiatives, BIM, and buildability and constructability appraisal systems as a way to increase productivity in construction. The leadership should communicate productivity improvement ideas and emphasize the importance of productivity for everyone (Huang *et al.*, 2009). Hwang et al. (2017) found that the most critical factors that affect the productivity of green building construction projects in Singapore are workers’ experience and skill, technology, design changes, planning and sequencing of work.

Government policies that affect productivity include regulations such as environmental requirements (Yi and Chan, 2013). Gao et al. (2020) investigated a unique scheme in Singapore where the Government incentivises employers to train their workers to possess multiple skillsets.

*Knowledge gap*

Previous studies conducted in many countries had already covered factors, initiatives and strategies for productivity improvement (see Tables 1 and 2). The strategies to improve productivity in other countries may not always be applicable to Singapore. For example, Zhan and Pan (2020) and Zhan et al. (2010) proposed frameworks to craft strategies to improve productivity in Hong Kong. However, Hong Kong’s situation is different from Singapore because Hong Kong relies on local labour and one of its findings is to build a sustainable construction workforce. Singapore, on the other hand, relies predominantly on foreign/migrant workers, characterized by high turnover as these workers return to their home countries after projects are completed or when they have earned enough.

In the last 25 years, several studies on productivity improvement in Singapore had been conducted. These may be divided into studies that focused on some narrow or specific issues and research that are wide and covered many factors that affect productivity. The narrowly focused research to improve productivity include implementing early contractor involvement strategy (Low et al, 2015), ensuring organizational learning takes place (Low et al., 2016), embracing high level of buildability through DfMA (Gao et al., 2018), adopting critical management strategies (Hwang et al., 2020), equipping workers with multiple skills (Gao et al., 2020), and ensuring workforce diversity (Won et al., 2021). Hwang et al.’s (2017) survey of 32 professionals found that technical factor is the main difference between green and traditional projects in productivity improvement. In terms of barriers to productivity improvement, Lim and Alum (1995) started the investigation and some 25 years later, Ofori et al. (2020) identified a different set of barriers. These studies did not address the broad strategies that the different stakeholders might adopt to boost productivity.

In recent times, the Singapore Contractors Association Ltd (SCAL) and Singapore Chinese Chamber of Commerce and Industry (SCCCI) commissioned a study on construction productivity in Singapore covering contractors’ views on industry-level productivity, causes of low productivity, practices adopted to improve productivity (SCAL and SCCCI, 2017). While this study covered a wide variety of factors, the limitation is that it provided general findings with descriptive statistics such as frequency count, percentage and means.

The literature review shows that although productivity studies had been conducted outside Singapore, these may not be relevant to Singapore which has unique characteristics such as a small construction market, a construction industry that is heavily reliant on migrant workers from Asia, and a state-led construction productivity program (Sweet, 2014). Most of the studies conducted in Singapore are narrowly focused on one or two issues, while SCAL and SCCCI’s (2017) study contained general findings and descriptive statistics only. The knowledge gaps are that there has been no in-depth study on the motives to improve productivity, no systematic examination of the corporate strategies that construction firms in Singapore have adopted to improve productivity, and no critical examination on which strategies suggested by the government are effective in improving productivity.

There is a large volume of literature on the factors which hinder efforts to increase construction productivity. These studies usually offer generally plausible recommendations. The current study seeks to find out what motivates contractors in Singapore to take measures to improve the levels of productivity on their projects. It then examines the particular strategies and actions adopted by the construction firms to improve productivity. The findings will help to identify the segments of the government’s program that work, and guide the formulation of policies and the adoption of corporate initiatives to enhance productivity.

**Research methods**

A large research programme on construction productivity in Singapore had been done and the outcome is a report of general findings and descriptive statistics such as frequency count, percentage and means (SCAL & SCCCI, 2017). This paper reports on the productivity improvement strategies part of the research programme, and takes the data analysis to a deeper level.

The investigation adopted a two-pronged research method: a survey and in-depth interviews. The survey was conducted to gather information, using a structured questionnaire, from a large group of respondents, and thereafter, aggregate the responses and conduct statistical analysis. The in-depth interviews were conducted to validate and explain the statistical results.

A questionnaire was developed based on extant literature. The complete questionnaire can be found in SCAL & SCCCI (2017, pp. 166 – 172). In the questionnaire, one section asked for information on corporate practices on productivity improvement adopted by the contractor. Another section sought respondents’ opinions on possible future improvement measures. The questions included the following: support from stakeholders, government efforts, labour management, technology, planning and corporate management. The final section asked respondents to indicate some basic personal particulars and those of their companies. There was a mix of answers required from respondents such as: “yes” or “no” answers; several options for selection; and 5-point Likert Scale. The Likert scale was anchored as follows: 1 = of least use/importance; 2 = not useful/important; 3 = neutral; 4 = useful/important; 5 = very useful/important.

A pilot test of the questionnaire was conducted in three meetings with the members of the Productivity and Innovation Committee of the Singapore Contractors Association (SCAL), who are subject matter experts, to validate the appropriateness of the questions. Their suggestions, which included the trimming of the length of the questionnaire, delineation of the period of the productivity programme the study should cover (to begin in 2000) and inclusion of particular questions, were adopted to improve the questionnaire.

The population comprised contractors operating in the construction industry in Singapore. 3032 E-mails were sent to all relevant members of SCAL and SCCCI who are operating in the construction industry. 305 sets of questionnaire were sent to Ordinary, Associate and Trade (OAT) members of SCAL. With a population of 3337 (being 3032 + 305), the sample size should be minimum 94 to achieve 95% confidence level and a 10% margin of error. In this study, a total of 109 valid responses were collected, giving an adequate sample size.

In-depth interviews were conducted to validate and explain the results collected from the questionnaire. The 12 subject-matter experts were carefully selected senior practitioners in construction companies. The majority work in local construction companies, and are from top management. This indicates that the interviewees are experienced and well suited to inform the research. They were asked 12 open-ended questions such as their views on construction productivity and ways to measure it, and main obstacles to and drivers of construction productivity improvement. Details are shown in SCAL & SCCCI (2017, p. 165). These interview questions may provide insights on why some strategies are more effective and what can be proposed to help the industry.

After the questionnaire responses were processed, the mean importance ratings were calculated for variables measured on the 5-point Likert scale. The formula for calculating the mean importance rating is given in Eq. 1.

|  |  |  |
| --- | --- | --- |
|  | 1(n1) + 2(n2) + 3(n3) + 4(n4) + 5(n5) |  |
| x̄ = |  | ………Eq. 1 |
|  | (n1 + n2 + n3 + n4 + n5 ) |  |

where:

x̄ is the mean importance rating of a specific variable, and

n1 , n2 , n3 , n4 , and n5 are the number of respondents who indicated on the 5-point Likert scale, the level of importance as 1 , 2, 3, 4, and 5 respectively.

One sample t-test was conducted using IBM SPSS Statistics 26 software. The null hypothesis is that the variable is not a motive for achieving high construction productivity, or the variable does not lead to productivity improvement. The hypothesized population mean (μ0) was set at 3 (mid-point of the 5-point Likert scale). For each question, the null and alternative hypotheses were:

* Null Hypothesis H0: μ ≤ 3. The decision rule was to accept H0 when p ≥ 0.05.
* Alternative Hypothesis H1: μ > 3. Reject H0 and accept H1 when p< 0.05, t-value is positive and conclude that the variable is a significant motive or significant strategy to improve construction productivity.

Factor analysis was conducted using IBM SPSS Statistics 26 software. With the many significantly effective strategies to analyse, factor analysis was chosen because it is a variable reduction technique which identifies latent constructs and the underlying factor structure of a set of interrelated variables. Factor analysis helped to detect the strategies that may be inter-dependent and to group them into a smaller number of categories or factors. Exploratory factor analysis was adopted because there is no need to impose any preconceived structure on the outcome, no need to predetermine the number of existing factors or the relation between factors and items (individual variable/strategy) (Hair et al., 2010).

As factor analysis requires the data to follow normal distribution and satisfy the sample adequacy, the distribution of variables was examined prior to factor extraction using Bartlett's test of sphericity, and sampling adequacy was examined based on Kaiser–Meyer–Olkin (KMO) measure (Field, 2017).

The extraction of factors was done using principal axis factoring. This method was chosen because it is more reliable as it: treats each item/variable as a measurement that may provide information about the same small set of factors or latent variables as other measured items/variables; takes care of measurement errors; identifies weak factors; accounts for co-variation; and removes the unique and error variance (Ngure et al., 2015). The threshold for an item to remain within the factor is a factor loading was 0.40, below which the item is removed (Matsunaga, 2010). Varimax rotation was adopted to maximize the variance shared among items so that they more discretely represent how data correlate with each factor and identify the factor upon which data loaded (Allen, 2017). Cronbach’s alpha, eigenvalues, communalities and rotated factors were calculated using IBM SPSS Statistics 26 software to check for internal consistency and reliability. For the missing values, “exclude cases list-wise” treatment was adopted.

**Characteristics of the sample**

Table 3 shows the characteristics of the 109 respondents. About half of the respondents are working in very large construction firms (graded as A1 contractors by the Building and Construction Authority (BCA)), and may bid for public projects of any value). There is a good mix of companies in terms of turnover. The majority of the respondents (80%) are working in local construction firms. Half (50%) of the respondents hold top level management roles.

Table 3. Profile of respondents

|  |  |  |
| --- | --- | --- |
| Description | Frequency | % (out of the respondents who provided relevant information) |
| Company’s Current BCA Registration (Total 57 responded) |
| A1 | 29 | 50.9% |
| Others | 28 | 49.1% |
| Company’s Turnover in 2014 (T million S$) (Total 52 responded) |
| T ≤ 10 | 13 | 23.2% |
| 10 < T ≤ 50  | 14 | 25% |
| 50 < T ≤ 100 | 7 | 12.5% |
| T > 100 | 22 | 39.3% |
| Origin of the Company (Total 66 responded) |  |  |
| Local | 53 | 80.3% |
| Local/Foreign Joint Venture | 0 | 0% |
| Foreign | 13 | 19.7% |
| Seniority (Total 66 responded) |
| Top Management | 33 | 50% |
| Mid Management | 33 | 50% |
|  |  |  |

**Results**

*Reasons for achieving high productivity*

Based on questionnaire, T-test was conducted to determine motives contractors have in seeking to achieve high construction productivity. Table 4 shows the top 3 reasons are to increase profitability, deliver projects on time and enhance corporate competitiveness. These factors are related: by having high construction productivity, the firms can reduce time and man-hour required, which can help save cost and increase productivity (Ballard *et al.*, 2003) since many of the major cost items on a construction project are time sensitive. Moreover, delays may lead to the imposition of liquidated damages on contractors (Yi and Chan, 2013). High productivity can reduce time and cost required to finish projects, then enables firms to be more attractive when bidding for projects, thereby increasing company’s competitiveness. Meanwhile, winning national construction productivity awards is not a significant reason to achieve high construction productivity.

Table 4. Reasons/motives for achieving high construction productivity

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S/N | Reasons/motives | Mean | T-value | 1-tail Sig |
| 22a | Increase profitability  | 4.45 | 17.124 | 0.000 |
| 22b | Deliver projects on time  | 4.44 | 16.622 | 0.000 |
| 22c | Enhance corporate competitiveness | 4.26 | 13.485 | 0.000 |
| 22d | Reduce number of foreign workers  | 3.61 | 5.346 | 0.000 |
| 22e | Keep within Man-Year Entitlement (MYE) quotas | 3.77 | 7.585 | 0.000 |
| 22f | Enhance corporate image | 3.99 | 9.496 | 0.000 |
| 22g | Win national construction productivity awards | 3.08 | 0.629 | 0.265 |

*Most important strategies to improve productivity*

Based on questionnaire, the most effective strategies that can help construction firms to improve productivity, based on the mean scores of the strategies, are shown in Table 5. The top 3 most important strategies are: training of workers; investment in mechanization; and more complete and firmed-up design (see Table 5).

Table 5. Factor analysis of strategies to improve construction productivity

| Factor  | Initial Total Eigenvalues  | Rank (top 10 only) | Variable | Application | Mean | T-value | 1-tail Sig | Initial Communalities  | Rotated Factor |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| F1: Government’s initiativesCronbach’s alpha: 0.871 | 18.300 |  | guidance from government programmes  | External | 3.63 | 6.154 | 0.000 | 0.979 | 0.738 |
|  | increasing the number of direct workers | Project | 3.57 | 5.649 | 0.000 | 0.882 | 0.708 |
|  | government’s incentive schemes for firms | External | 3.94 | 8.855 | 0.000 | 0.964 | 0.667 |
|  | increase of man-year entitlement | External | 3.63 | 5.358 | 0.000 | 0.913 | 0.632 |
|  | introduction of incentive schemes for workers | Company | 3.78 | 7.617 | 0.000 | 0.923 | 0.574 |
|  | role models in the industry | External | 3.56 | 5.231 | 0.000 | 0.919 | 0.563 |
|  | review of relevant government regulations | External | 3.94 | 8.855 | 0.000 | 0.964 | 0.567 |
| F2: Design factorsCronbach’s alpha: 0.902 | 2.692 | 9 | re-engineering of designs | External | 3.97 | 10.338 | 0.000 | 0.940 | 0.734 |
|  | adoption of prefabrication | Project | 3.71 | 7.978 | 0.000 | 0.977 | 0.726 |
|  | more extensive use of prefabrication | Project | 3.58 | 5.537 | 0.000 | 0.958 | 0.461 |
|  | use of design-and-build | External | 3.72 | 6.738 | 0.000 | 0.925 | 0.707 |
|  | greater extent of design-and-build | External | 3.80 | 7.651 | 0.000 | 0.991 | 0.609 |
|  | input by contractors of accurate data to Electronic Productivity Submission System (ePSS) | Project | 3.25 | 2.182 | 0.016 | 0.922 | 0.577 |
|  | monitoring Buildability and Constructability Scores | Project | 3.23 | 1.974 | 0.026 | 0.974 | 0.551 |
|  | applying information technology (including BIM) | Project | 3.52 | 4.921 | 0.000 | 0.964 | 0.430 |
| 3 | more complete and firmed-up design | External | 4.11 | 10.690 | 0.000 | 0.953 | 0.598 |
| 4 | standardisation of components | Project | 4.07 | 11.659 | 0.000 | 0.942 | 0.575 |
| 8 | involvement of contractor in design | External | 3.98 | 10.398 | 0.000 | 0.971 | 0.524 |
| F3: Site operationsCronbach’s alpha: 0.841 | 2.339 | 1 | training of workers (current) | Company | 4.24 | 16.582 | 0.000 | 0.953 | 0.693 |
| 5 | training of workers (future) | Company | 4.06 | 12.284 | 0.000 | 0.956 | 0.465 |
|  | more effective project planning and monitoring | Project | 3.96 | 12.166 | 0.000 | 0.954 | 0.658 |
| 7 | more attention to productivity by firm’s leaders | Company | 4.00 | 9.723 | 0.000 | 0.959 | 0.590 |
| 2 | investment in mechanisation  | Company | 4.14 | 12.720 | 0.000 | 0.918 | 0.575 |
|  | more mechanisation of construction work | Company | 3.94 | 10.119 | 0.000 | 0.950 | 0.531 |
|  | engagement of more supervisors | Company | 3.21 | 2.279 | 0.013 | 0.838 | 0.509 |
|  | applying techniques to reduce amount of work | Company | 3.94 | 9.791 | 0.000 | 0.890 | 0.457 |
|  | increase in extent of subcontracting | Project | 3.29 | 3.158 | 0.001 | 0.833 | 0.626 |
| F4: Support of stakeholdersCronbach’s alpha: 0.821 | 1.887 | 10 | support of clients | External | 3.97 | 9.063 | 0.000 | 0.966 | 0.749 |
|  | support of consulting teams | External | 3.76 | 6.341 | 0.000 | 0.942 | 0.721 |
|  | support of subcontractors  | External | 3.76 | 7.142 | 0.000 | 0.954 | 0.662 |
|  | better service from subcontractors | External | 3.74 | 7.601 | 0.000 | 0.960 | 0.554 |
|  | clients’ insistence on productivity | External | 3.73 | 6.385 | 0.000 | 0.884 | 0.759 |
| 6 | more prompt payment from clients | External | 4.04 | 10.452 | 0.000 | 0.932 | 0.526 |
|  | better service from suppliers | External | 3.61 | 6.455 | 0.000 | 0.898 | 0.491 |
|  | longer construction period | External | 3.80 | 7.386 | 0.000 | 0.968 | 0.419 |
| F5: Industry pressureCronbach’s alpha: 0.744 | 1.780 |  | pressure from the presence of foreign contractors | External | 3.20 | 1.827 | 0.036 | 0.939 | 0.445 |
|  | mandatory requirement for contractors to pay attention to productivity  | External | 3.54 | 5.110 | 0.000 | 0.949 | 0.538 |
|  | competition within the industry | External | 3.94 | 9.317 | 0.000 | 0.921 | 0.434 |

Notes: Factor Analysis Method: Principal axis factoring. List Value: Exclude cases listwise.

Rotation: Varimax

Re-categorization of variables was done to ensure better logic.

The most important strategy is consistent with Singapore’s effort to improve the quality of its workforce across the board, as discussed above. This agrees with other studies which stressed the importance of workers’ skills (Hasan, 2018) and providing them with a high level of training to improve productivity (Sherekar and Tatikonda, 2016; Javed et al., 2018). Nasir et al. (2014) discovered that one of the main reasons that the rate of growth of construction productivity of Canada has been greater than the US is due to its worker training systems.

The second most important strategy, investing in mechanisation, is directly linked to the Singapore government’s efforts to provide incentives to help construction firms to mechanise their operations (BCA 2019). Instead of merely focusing on what to mechanized, Zhan and Pan (2020) found that technological innovation through new construction technologies, infusion of digital technology and automation may lead to improved productivity.

The third most important strategy about having complete and firmed-up design confirms Hasan’s (2018) finding that one of the most frequently highlighted reasons for poor productivity is incomplete drawings. The continuous requests for design information interrupts work progress (Rivas *et al.*, 2011). The schemes contractors have used are further discussed and evaluated in the discussion section below.

**Discussion**

One sample t-test as described above, was conducted based on questionnaire to identity significantly effective strategies (p < 0.05) to improve construction productivity. Those that were significantly effective were then subject to factor analysis, to group them into several categories. The results in Table 5 show that five categories/factors were extracted.

Cronbach's alpha, which is an internal reliability test, showed that each factor had internal consistency. Some strategies were manually reclassified for better fit. The eigenvalues (which represent the variance that can be explained by the variables included in the category) for every category are more than 1, indicating a good quality score for each factor. Communalities represent how much the variance of the specific variable can be explained by the common factor. Table 5 shows that the communalities for all variables are high (more than the threshold of 0.4), indicating that each variable loads significantly on the factor it is categorized under. Rotated factors represent how the variables are weighted for each factor and also the correlation between the variables and the factor. All the rotated factors are larger than |0.4|, indicating that the variable is important to the factor. The results of the factor analysis as shown in Table 5 are discussed below. The strategies are also differentiated by levels of impact: external, company and project.

*Government’s initiatives to improve productivity*

Factor 1 comprises strategies relating to the government’s initiatives to improve construction productivity, and has eigenvalue of 18.3, which is much larger than other factors (see Table 5), suggesting that this factor represents a principal component of strategies to improve productivity. The effective strategies include: “guidance from government programs”, “government’s incentive schemes” and “increase of man-year entitlement”. Some of the initiatives include the Buildable Design Appraisal System (BCA, 2018) which indicates minimum levels of buildability to be attained in designs, guidance on technology adoption and support for capability development (BCA, 2010), providing incentives for the adoption of productive technologies (BCA, 2015), and the range of support schemes under the Construction Productivity and Capability Fund (CPCF) (BCA, 2019). Incentives for contractors to use technology and reduce the volume of labour they utilise is also one of the factors that help Australia and the US (Huang *et al.*, 2009) improve construction productivity.

The survey showed that two strategies: “increase the number of direct workers” and “increase man-year entitlement” are effective in improving productivity. The latter strategy may give rise to more workers being on construction sites, and this is inconsistent with improving productivity by reducing inputs and increasing outputs, as well as with the Singapore government’s policy priority of reducing the reliance on foreign workers (BCA, 2015). One possible explanation of this result is that the respondents are manifesting the fact that not all construction activities can be mechanized.

The statistical findings were validated by in-depth interviewees. Interviewees C4, C5, C6 and C8 mentioned many initiatives launched by the government have helped them to improve construction productivity. They highlighted these actions: the government’s push for the adoption of precast and prefabricated construction, the prescription of minimum buildability and constructability scores before projects are granted Building Plan Approval, are awarded government tenders, and receive government funding relating to productivity improvement. They considered government’s involvement and leadership as having been key in productivity improvement. According to them, such a process needs to be government-led.

Interviewees C5 and C9 suggested that the government should try to influence developers and incentivize consultants so that they will consider productivity when doing their part of the job. While government initiatives were welcomed, it was also considered necessary to “review relevant government regulations”. Interviewees C6 and C11 suggested the streamlining and reduction of the numerous and complex reporting procedures of the government agencies, especially the BCA. Some suggested that “the government should have flexible in regulating number of foreign workers and extent of prefabrication in each project.” Some proposed that for tender evaluation of public projects, “higher weightage should be given to productivity and safety, as compared to price and quality.” These findings are in agreement with Durdyev and Ismail (2016) who found that bureaucratic processes are bottlenecks in the construction industry.

*Design considerations to improve productivity*

Factor 2 relates to design considerations to improve productivity according to the questionnaire (see Table 5). As suggested by the BCA (2015), when contractors are involved in the design, either through the design-and-build procurement route, or being invited by consultants to provide inputs during the design stage, productivity would improve. The suggested superior efficiency of design-and-build confirms Ling and Kerh’s (2004) finding that design-and-build projects have significantly higher delivery speed than traditional projects.

“Standardisation of components” and “Adoption of prefabrication” need to be considered during the design stage. This confirms the results of previous studies which found that there is significant productivity improvement when prefabrication and value engineering are adopted (Tam *et al.*, 2007; Jeong *et al.*, 2017). Designs that are firmed up early would help to reduce changes and rework during construction, thereby increasing productivity (El-Gohary and Aziz, 2014). The results are in concordance with Javed et al’s (2018) finding that the planning and design aspect is a strategic driver to improve productivity through improved buildability, and increased collaboration between project partners.

Interviewees also commented on design considerations. “Involving contractors in design to improve productivity” is confirmed by interviewee C3 by observing that “design-and-build helps to improve productivity” and suggesting that this procurement mode should be promoted. Interviewees C5 and C9 also confirmed that involving contractors early in the design would improve productivity. Interviewees C3 and C8 shared that simplifying design helps to improve productivity, in line with the findings of Naoum (2016).

On standardisation and prefabrication, interviewees C6 and C8 agreed that prefabrication improves productivity significantly, and this can be monitored through the buildability and constructability scores. When necessary, designs should be re-engineered so that the projects are more buildable or cost effective. Several interviewees (C2, C6, C8 and C9) shared that productivity is improved when BIM is used from the design stage, and the design is more complete and firmed up. Interviewee C8 suggested that “the technical and professional capabilities of design personnel should be improved.”

*Site operations to improve productivity*

Factor 3 comprises strategies relating to site operations based on the questionnaire (see Table 5). Productivity may be improved by the training of workers and employment of more supervisors to oversee their work. The Singapore government also implemented initiatives to develop the workforce of the construction industry (BCA, 2010, 2015, 2016, 2019). The finding is consistent with those in previous studies which found that skill of labour is one of the major factors influencing productivity (Singh, 2010, Durdyev and Mbachu, 2011, El-Gohary and Aziz, 2014, Naoum, 2016), and Oheuri et al.’s (2018) study showed that continuous training and development is one of the factors that motivate labourers to improve their productivity. Effective site supervision is also important to ensure that high levels of productivity are attained on construction projects (Singh, 2010).

Another strategy is to have effective project planning and monitoring. This finding is consistent with those of Naoum (2016) who found that detailed and accurate planning can translate productivity improvement objectives to executable plans in reality. Project planning needs to be done at an early stage, and the time and effort invested in planning would derive many benefits (Mawdesley 2010).

 “More attention to productivity by firm’s leaders” is found to be an effective productivity improvement strategy. When senior management pays attention to improvement of site productivity, team members can credit their leaders for establishing value for productivity and promoting a productive environment (Chen *et al.*, 2006).

At construction sites, other effective strategies to improve productivity are: “Investment in mechanization”; “more mechanization of construction work” and “applying techniques to reduce amount of work”. Technology is one of the keys for productivity improvement because it can reduce the requirement for manpower on the construction site (Yi and Chan, 2013). Productivity may also be improved through the use of automated production (e.g. automated bar bending, precast concrete components and façade, RFID-integrated logistics) (Javed et al., 2018).

“Increase in extent of subcontracting” is found to be effective in improving productivity. This confirms the conclusions of El-Gohary and Aziz (2014) that subcontracting parts of the project to efficient companies and ensuring their effective management may help to increase productivity.

Interviewees also discussed on the effect of site operations. Interviewee C8 acknowledged that “government programs are effective in encouraging and enabling contractors to train their workers.” Interviewee C5 emphasized the importance of “planning and management of resources, assigning experienced personnel to manage scheduling and actual site progress, and having management skills to manage resource utilization and scheduling.” Interviewees C8 and C9 identified a particular software, P6 Primavera, which helped them to improve planning.

Interviewees C5 and C6 mentioned that while mechanization and advanced technologies, which are encouraged by the government, have a large impact on productivity improvement, they use them only when it is cost effective to do so. Interviewee C5 stated that “when the labour cost for a particular job is high, it is better to mechanize.”

*Stakeholders’ support to improve productivity*

Factor 4 is a collection of strategies relating to support from stakeholders based on the questionnaire. Clients are important stakeholders in the efforts to improve productivity. They can influence the way things are done on projects by way of: “insisting on productivity”, “supporting productivity initiatives” and “making prompt payments”. Timely provision of information is important to contractors as it facilitates planning and decision making (Shan *et al.*, 2016).

The strong support of subcontractors for main contractors, and better service from suppliers are also important to improve productivity. Subcontractors should ensure that the part of the work assigned to them is finished on time so that the total productivity will not be affected negatively (El-Gohary and Aziz, 2014). Suppliers can also influence efficiency on the project by adhering to the delivery schedules and ensuring the quality of the inputs provided is in line with the specifications.

Interviewees also discussed the importance of stakeholders’ support. Interviewees C3 and C8 confirmed the importance of clients as one of the driving forces for productivity improvement. Interviewee C3 suggested that “clients need to understand and embrace new or advanced construction methods in order to improve productivity.” Interviewee C8 suggested that “clients should commit themselves to the adoption of prefabricated prefinished volumetric construction (PPVC), BIM and higher buildability scores on their projects.”

Interviewee C9 suggested that “consultants should be given incentives to do their part in the efforts to enhance productivity performance.” Interviewees C9 and C11 suggested that consultants should provide information to contractors on time in order to avoid the wastage of time on projects in waiting for vital information.

*Industry pressure to improve productivity*

Factor 5 relates to external pressures on contractors that may bring about productivity improvement according to the questionnaire. “Mandatory requirement for contractors to pay attention to productivity” may be from clients or the government. The competitive forces from “pressure from the presence of foreign contractors” and “competition within the industry” also drive contractors to seek to undertake and complete their projects in a cost-effective and productive manner.

Interviewees C2, C5 and C6 mentioned that they have experienced the direct linkage between productivity and cost – improvement in productivity helped them to finish their projects on time and there was cost savings.

**Limitations**

The limitation of this study is that the samples were only from Singapore. As most of the workers on site are migrant workers from other countries, Singapore’s construction industry is different from those of many other countries, hence the findings need to be generalized carefully. Notwithstanding this, the findings may be useful to countries that employ overseas migrant workers such as those in the Middle East and certain parts of Europe. Future studies may further examine the effectiveness of different strategies used in small countries that have labour shortage.

**Recommendations and concluding remarks**

The aim of this study is to examine the strategies implemented by construction companies in Singapore to improve the level of construction productivity. These strategies are implemented at both the corporate and project levels. The first objective of this study is to determine reasons or motives for contractors to achieve high construction productivity. The top three reasons are to increase profitability, deliver projects on time and enhance corporate competitiveness (see Table 4). The implication of the findings to contractors is that productivity improvement is likely to be sustainable because the motives to improve productivity are linked to the performance of the firms and internally driven. Construction companies should adopt a strategic approach to productivity as their performance on that parameter can influence their corporate growth and competitiveness. They should adopt corporate productivity policies, as most of the sizeable construction companies in Singapore have done for quality, safety and health, and environmental performance. They should then adopt appropriate organisational structures which incorporate the role for spearheading technology improvement initiatives within the company. The firms should also build their internal capabilities to be able to work effectively in productivity enhancing procurement arrangements such as design and build and early contractor involvement approach.

The primary contribution is the finding that contractors’ motive to improve productivity is underpinned by self-seeking behaviour of profit maximization. Contractors’ profit maximization motive to seek productivity improvement suggests that project owners and consultants need to be watchful of project quality. This is because contractors may go full speed to complete the project but at the expense of quality.

The second objective of this study is to identify strategies to improve productivity for Singapore contractors. The top 10 strategies identified are shown in Table 5 (col. 3). Among the top 10, only three are within contractors’ control - workers’ training, investment in mechanization and leaders’ attention to productivity. As there are numerous ways to improve productivity, the contribution of this finding is in sieving out the top strategies so that contractors can focus on what would really move the needle on productivity, and that it is not predominantly contractors’ fault for low construction productivity. Contractors can encourage their personnel to take ownership of the productivity programme by adopting a campaign similar to what has worked so well with regard to safety. Considering the multi-origin composition of the industry's workforce, language and cultural relevance will be key.

Using factor analysis, the numerous strategies were categorized into five groups: government’s initiatives, design factors, site operations, the support of stakeholders, and industry pressure (see Table 5). With ‘site operations’ being the only category that is within contractors’ purview, the contribution of this finding is that other stakeholders play significant roles in productivity improvement. The category on ‘government’s initiatives’ shows that the Government cannot rely on market forces to improve productivity. The Government has a pivotal role in productivity improvement because it holds the key to supply of migrant labour to carry out construction work, it has the financial strength to offer incentive schemes and it has the power to enact rules and regulations. While the government has launched many schemes to enable the construction industry to improve upon its productivity performance, the contractors’ real initiatives determines the overall attainment. Input should be sought from the industry to ensure that the policies and initiatives are appropriate, considering the needs and aspirations of the companies and practitioners. The schemes should also be reviewed periodically.

Prior to this study, productivity improvement has sometimes been regarded as being within contractors’ ambit. This study adds to knowledge by showing empirically that consultants/ designers have the responsibility for productivity improvement at the upstream. They need to design for higher buildability and constructability so as to improve productivity. This supports the well-established notion in the literature and in practice that productivity improvement is not the effort of any one party, or the result of what is done at any particular stage in the construction process. It is evident that decisions made by the client on many aspects of the project and the desired product, the choices at the design stage, the planning and building control procedures and requirements and so on, all have an impact. The stakeholders in the construction industry, no matter how remote, should be educated about the impact on their own stake of the levels of growth in productivity. Stakeholder awareness building and education should be a thrust of the next construction productivity masterplan in Singapore.

The significance of this study is that it has identified the main motives construction firms have in implementing strategies to improve productivity, as well as the most important strategies they adopt. This provides a steer for government's policies and areas where the government and industry can collaborate. It also indicates areas where further research would yield most benefits. As the top motives are found to be that firms adopt the strategies for their own benefits, and the top two most important strategies for productivity improvement (worker training and mechanisation) are under the control of the contractor, the implication is that contractors should take responsibility for improving productivity and focus on areas which are the most important. From the comparisons, large contractors with high turnover should work closely with stakeholders such as clients, consultants and subcontractors so that they can develop programmes to improve productivity together.

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**Research Data**

Data will be made available on request.

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