

RESEARCH BRIEF

2005/003

Productivity of the Construction Industry

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INTRODUCTION

Productivity is a key determinant of a nation's future living standards and the competitiveness of an industry and an economy. In many countries, the level of construction productivity has been found to be lagging behind those of other sectors of the economy. In Singapore, in the past two decades, increases in construction productivity (measured in terms of *value added per person employed*) lagged behind all sectors. A programme has been implemented to improve the industry's productivity performance since the mid-eighties.

The aim of this research study is to formulate a suitable method for estimating the productivity of the construction industry in Singapore. The vision is to help to create a construction industry which is aware of the importance of productivity, and is taking strategic action to enhance its productivity performance. The study applied the following methodology to achieve the stated objectives: a review of the literature on construction productivity, its determinant factors and the methods for its estimation; comparison, of construction productivity for Singapore with those of industrialised countries; analysis of existing methods for measuring industry-level productivity in Singapore; analysis of data on construction projects in Singapore to establish benchmarks; and development, testing and fine-tuning of a suitable model.

The research study is a collaboration between the **Singapore Contractors Association Ltd (SCAL)**, and **Department of Building** and **Department of Civil Engineering, National University of Singapore (NUS)**. It was funded by the SCAL, **Building and Construction Authority (BCA)** and NUS. The project began in August 2003, and was concluded in July 2005.

PRODUCTIVITY AND INFLUENCING FACTORS

The concept of productivity is not well understood in construction owing to the complexity of the process, the products and the participants. This lack of understanding makes the measurement of

construction productivity difficult. In the literature, factors which influence the level of construction productivity range from those internal to the industry to those in its external environment (such as regulations, business cycles and quality of industry's supply chain). The internal factors include aspects of the design, materials and components selected. During construction, the planning process; quality and attitudes of workers, supervisors, and managers; and methods adopted are key factors.

Productivity is the relationship between the output produced in a process, and one or more of the inputs used. There are many methods of productivity measurement. In single factor productivity, one resource, usually labour, is considered. Multi-factor Productivity (MFP) considers more than one resource, often, labour and capital. Total Factor Productivity (TFP) is the most comprehensive measure. It considers all inputs – labour, capital and intermediate inputs. In Singapore, construction industry level productivity is measured as: *value-added per employed person*; *value added per hour worked*; and *floor area completed per manday*. Each of the industry-level productivity measures employed in Singapore construction has some limitations.

Various authors have compared construction productivity in different countries. An analysis of data from 1990 to 2001 (using purchasing power parity for the conversion) found that Singapore compared favourably with selected industrialised countries: Australia, Canada, Denmark, Finland, France, Germany, Hong Kong, Japan, Korea, New Zealand, Norway, UK and US. Singapore was 11th by value added per hour worked; and 5th by value added per employment.

BENCHMARKING PROJECT PERFORMANCE

Data on projects completed between 1997 and 2003 provided by the BCA were organised into six categories: HDB housing, residential landed, residential non-landed, industrial, institutional, and commercial. Input-oriented Data Envelopment Analysis (DEA) models were constructed to obtain

the benchmark projects, and a ranking of the projects in terms of technical efficiency relative to the benchmarks. The inputs for the 'labour-oriented' DEA model were labour productivity (man-days/m²) and unit cost (\$/m²); the output was unit constructed area. A linear regression analysis was also conducted to derive the constant relating (1) total

labour (in man-days) and total constructed area (in m²); and (2) total contract sum (\$) and total constructed area (in m²). The data were also sorted with respect to decreasing technical efficiency, and the labour quotient (man-days/\$million) was obtained for projects in each of the 6 categories. The results are reported in Table 1.

Table 1 Summary of Labour Productivity, Unit Cost and Labour Quotient Figures

	HDB	Comrcl	NonLndR	LndR	Industrl	Instnl
Labour productivity (md/m²)						
Linear regression coeff.	1.55	3.58	0.25	5.6139	2.29	0.21
Benchmarks	0.87 - 1.81	1.60 - 2.68	1.67 - 3.89	2.01 - 6.82	0.632 - 1.464	0.719 - 4.11
<u>Statistics</u>						
Max	4.44	8.42	11.64	15.80	4.69	6.17
Min	0.87	1.60	1.67	2.00	0.60	0.72
Avg	2.03	4.00	4.54	6.40	2.30	2.69
Sd	0.63	1.72	1.90	2.50	0.80	1.36
	HDB	Comrcl	NonLndR	LndR	Industrl	Instnl
Cost (\$/m²)						
Linear regression coeff.	549.7	1799.4	1236.8	1311.8	743.0	1346.9
Benchmarks	218.2 - 523.7	319.8 - 1047.6	446.2 - 1441.7	0.83 - 1396.3	278.3 - 630.4	0.959 - 1288.5
<u>Statistics</u>						
Max	910.2	5583.3	3217.7	3979.4	3591.1	49774.9
Min	218.2	319.9	446.2	0.8	278.3	1.0
Avg	551.3	1833.3	1499.7	1333.9	966.8	1320.5
Sd	138.1	810.2	510.3	584.1	454.9	3616.9
	HDB	Comrcl	NonLndR	LndR	Industrl	Instnl
Manpower quotient (md/\$M)						
<u>Statistics</u>						
Max	9290.7	8378.0	5366.0	15234.0	5845.5	7407.7
Min	1659.1	687.6	1184.7	1260.8	1002.8	338.4
Avg	3832.9	2419.6	2897.0	4879.2	2672.5	2624.7
Sd	1299.8	1260.3	825.5	2496.3	1077.0	1257.5

QUESTIONNAIRE-BASED FIELD STUDY

A questionnaire-based mailed survey was undertaken. The questionnaires were distributed to 528 firms selected from the BCA's list of registered contractors and 60 valid responses were received, giving a response rate of 11%.

All the respondents considered productivity important. The respondents view the productivity of the local construction industry as "average". They consider the industry's productivity to have increased slightly between 1990 and 2003, and to have been the same from 2004 to 2010. More than two-thirds of respondents felt that the industry does not pay adequate attention to productivity. The top three construction participants ranked by respondents in terms of their influence on productivity on projects were: the Architect, Main Contractor and Client. The major causes of low construction productivity are:

delays due to compliance with regulations, errors in design, poor worker skills, rework to rectify defects, inadequate pre-project planning, and changes in design. The top obstacles to productivity measurement are: contractors' perception that there is no direct benefit from measurement; lack of clear definition of "productivity"; level of work subcontracted; uncertainty about what to measure; too much paperwork; and requirement of labour to measure.

Most responding companies have policies on the improvement of productivity on their projects, including: offering incentive payments to workers; developing applying indicators on utilisation of materials; mechanising site operations; setting targets for productivity increases; measuring workers' production; reducing double handling; advising the design team on the impact of the design on

productivity; exercising cost control; reducing the amount of defective works; identifying errors in drawings before construction; ensuring that site personnel work as a team; engaging subcontractors with skilled labour; and making sure that the employees have the desired working attitude.

Only half of the respondents reported that their companies measure productivity of trades and slightly over half of firms assess the overall productivity on their projects. Some 41% of respondents reported that their companies maintain records on productivity on trades or projects. A similar ratio reported that their companies set targets of productivity to achieve on their projects. The trades on which productivity is most important to the respondents' firms, in order of priority are: reinforcement bar fixing, formwork and concreting (equal rank), and plastering. The respondents' companies have taken the following measures to enhance productivity on their sites: training of workers; investment in mechanisation; re-engineering designs; giving workers incentives; and adopting prefabrication.

Over two-thirds of firms consider the current level of man-year entitlements (MYE) too low; a quarter consider their allocation "just right". Over half of the firms have a department which administers the MYE. For one-third of firms, a Director deals with the MYE. About one-third of firms determine the amount of MYE to allocate to subcontractors based on the value of contract. One fifth determine it based on how critical the subcontract is to progress on the project. Another 13% of them determine it based on combinations of value and duration of subcontract. Measures which respondents indicated can help to enhance construction productivity in Singapore are: greater attention to productivity by management; involvement of the contractor in design; training of workers; standardisation of components; more mechanisation of work; increase of MYE; greater extent of design-and-build; review of regulations; and more prefabrication.

SUMMARY OF INTERVIEWS

A series of interviews was held with 17 senior managers of main contractors, 15 subcontractors and officers of the main government agencies concerned with construction policies. The interviewee-contractors were equally split among those who considered the industry's productivity to be higher than, or at least equal to, its value some years ago and those who said it is low. Most interviewees felt the current MYE formula leads to underestimating of manpower requirements.

Almost all the interviewees said their firms had no corporate productivity policies. The reasons are: it is difficult to measure productivity because of the nature of construction work; and most of the work on site is undertaken by subcontractors. The few companies with productivity policies measure trade productivity in terms of the quantity of work done per

man day. The majority of firms do not measure worker productivity on site because: there are many factors affecting productivity; and most of the work is subcontracted. Most firms have no method for measuring trade level productivity. The reasons given include: it is very costly; the results will not be of much use to the firm; and the work is done by subcontractors so it is not necessary to measure it.

The obstacles to productivity measurement mentioned by interviewees are: it takes time, cost, effort and paperwork to measure productivity but there is no clear short-term financial benefit; there is no standard measurement method; subcontractors are suspicious of the main contractor's intentions when the latter tries to measure their productivity, and fear they will be penalised; it is difficult to obtain representative figures and true information on productivity for project-to-project comparison; productivity is linked to other factors such as quality and safety, thus, productivity figures measured independently may be erroneous; and management is not committed to the measurement of productivity. Obstacles to productivity improvement highlighted by the interviewees are: lack of a standard measurement method and guidelines, need for paper work, cost, and resources required; inadequate attention to productivity during design; lack of standardisation of common building elements such as doors and windows; lack of commitment of top management to productivity improvement and lack of investment in mechanisation; too many laws and regulations on construction; and poor worker skills.

Measures proposed by interviewees for improving construction productivity include: components such as windows and doors should be standardised and in tendering, contractors should be able to offer alternative solutions to improve buildability; contractors and subcontractors should be innovative in their work practices, and invest in the right equipment, tools and methods; there should be improved management and better co-ordination throughout the construction process; productivity benchmarks should be developed; designers should choose materials and methods which lead to higher productivity; there should be greater prefabrication but problems relating to it should be recognised; firms should consider productivity as seriously as safety and quality, and management, clients and designers should be productivity conscious; and there should be more education and training on productivity.

A STRATEGY FOR IMPROVING CONSTRUCTION PRODUCTIVITY IN SINGAPORE

A comprehensive, national approach to productivity development in the construction industry is required. The five goals and initiatives under them are now discussed.

Goal 1: Broad, Integrated Action

An integrated strategy for improving the productivity performance of Singapore's construction industry

should be developed. It should consider the entire construction value chain, and be part of a programme for upgrading the industry. The BCA should lead the government-industry productivity network to prepare and champion the implementation of the strategy. The BCA should consider including the value of such fixed assets as a contractor registration criterion. Further impetus should be given, under the BCA's leadership, to the standardisation of component sizes, and prefabrication of elements.

Construction firms should adopt a strategic approach to technology development, and assign managerial responsibility for it. They should procure proper equipment and tools to facilitate effective working. Firms should adopt strategic human resource management as a policy. Post-qualification training and mentoring schemes should be instituted to ensure that the proper techniques and practices are passed on to personnel.

Goal 2: Total Productivity Awareness

A five-year rolling programme should be formulated to generate the awareness of all participants in the construction process of the critical importance of productivity improvement, and their role in it. It should be jointly formulated and implemented by BCA, CIJC, and key public-sector clients such as the HDB, JTC Corporation and Land Transport Authority.

The BCA should collect, process, maintain and disseminate information and data on good productivity-enhancing practices. The BCA and SCAL should provide effective publicity for: best performing Singapore construction companies and projects with regard to productivity; new productivity enhancing construction technologies; new government policies on productivity; and support and incentive programmes.

Goal 3: A Supportive Operating Environment

Clients should set more carefully determined and realistic completion dates for development projects. End purchasers should also be educated to "reward" clients whose projects perform well in terms of productivity well with their patronage.

The BCA should audit the statutes, regulations and codes which have an impact on productivity to provide the basis for rationalisation. A feedback system should be instituted to gather ideas for the continual review of regulations and procedures. A comprehensive assessment of the likely impact of each regulation should be made before it is introduced. There should also be periodic evaluation of the effectiveness and costs of regulations. A series of studies of various types of projects can be undertaken by the BCA, MOM and SCAL to ascertain the usage patterns of foreign workers and aspects of the utilisation and administration of the MYE. The results can be used to revise the MYE formula. The overall effect of the MYE scheme and prevailing levels of 'entitlements' given to contractors should be continuously monitored and continually assessed.

Goal 4: Practical Measurement and Benchmarking

All construction firms should collect systematic information on labour and physical output on each of their projects. They may collect two possible productivity measures on their projects. They are: output attained in each trade per month; and cost expended on each trade per month.

To improve the model and data inputs for the construction industry-level productivity measures, *value added per person employed* and *value added per hour worked*, supplementary data on the structure of the industry in Singapore is critical. The BCA should resume its periodic survey of the construction industry to enable realistic data on the industry's total value added to be determined. The BCA's productivity measure of *mandays per square metre* provides a good guide at the project level. To obtain accurate and consistent data on projects from start to completion, efforts should be made to garner the co-operation of contractors through the productivity network.

A composite model which measures project-level productivity, CONQUAS, wastage level, and safety should be developed, and benchmarks for the industry set. This could be the subject of a research programme initiated by the BCA and supported by SCAL. A TFP for the construction industry and its growth should be estimated. The DEA method for setting benchmarks for construction productivity which has been demonstrated in this study should be adopted in the industry. The estimation of benchmarks should be done once every three years. Projects which emerge as top performers in the calculation of productivity should be further studied to determine lessons for wider application in future. National information on trade-level productivity norms should be published.

Goal 5: Effective Championing and Implementation

The construction industry's productivity improvement effort should draw from, be integrated into, and take advantage of, the national productivity plans and initiatives. There should be a government-industry partnership to formulate, implement and monitor the construction productivity development programme. The section in the BCA in charge of productivity should be strengthened to create a unit which would cover all aspects of productivity.

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