PRODUCTIVITY MATTERS

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Concerns have been expressed that construction management research has rarely led to direct improvements in construction industry practice. This may be both a cause and an effect of the relatively low contribution of the construction sector to 'research and development' in comparison with other industry sectors. Current concerns of construction organisations that may benefit from research and therefore should attract the attention of both practitioners and researchers -include the intensified search for enhanced productivities. This paper summarises a series of recent investigations into the productivity of concreting related operations on high rise buildings in Hong Kong. Work Study and related techniques are applied in deriving and comparing concrete placing rates using different methods (such as pumps, and crane + skip combinations). The production rates and activity levels of formwork carpenters and steelworkers are also investigated. Comparisons with somewhat similar investigations in other countries, confirm the usefulness of establishing productivity benchmarks using appropriate indicators, while incorporating allowances for key 'hard' variables such as technologies used (and available). The residual differences productivity levels may be ascribed to 'softer' but perhaps more challenging human and organisational variables, which will therefore be worth investigating further. It is also suggested that addressing such core operational concerns in the context of the key issue of productivity can arouse the interest of both industry and researchers in the light of foreseeable direct benefits. Partnerships forged to focus on such short term improvements may also hopefully continue into researching and developing suitable longer term strategies.

Keywords: construction management research, productivity, Hong Kong, research and development

BACKGROUND AND INTRODUCTION

The duality (rather than apparent ambiguity) in the title is deliberate: This paper deals with 'matters' of construction productivity and concludes that they are an increasingly critical component of construction management, which should therefore 'matter' very much to both practitioners and researchers.

With regard to the latter, Betts and Wood-Harper (1994) stated that there appeared to be 'little two-way flow in construction management thought between theory and practice'. In this context, Ofori (1997) confirmed that the level of R & D (research and development) in construction is relatively low in comparison to other sectors of the economy, in terms of,: monetary investment, while Homer (1996) lamented the lack of direct applications of construction management research in industry. Such observations when taken together confirm the need for enhanced interactions between construction researchers and practitioners.

Such interactions will be easier to initiate and sustain if focused on key concerns of the industry, one of which is identified here as 'productivity'. Apart from being at the root of; or related to, other issues-such as improved procurement, contract management, information management and quality management systems - a renewed interest in productivity itself has been triggered by construction industry downturns in

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many countries, and by the consequential increasing competitiveness, heightened by rapid globalisation, where if 'you are not the best at what you do, you may not be doing it for very long (Magsaysay, 1997).

Apart from such organisational imperatives, a macro perspective of national industries reveals 'remarkable' inefficiencies (Kenley et al., 1997), productivity differentials [(Proverbs et at, 1996) and (Anson et at, 1996)] and suggestions that for example a 10% improvement in construction industry productivity would lead to a 2.5% increase in Gross Domestic Product in Australia as cited by Naoum and Hackman (1996), given the multiplier effects on other sectors of the economy as well.

Such observations confirmed the need to revisit general issues in productivity conceptualisation and evaluation, together with specific examples and comparisons from recent case studies, as presented in this paper, in order to encourage the formulation of a joint (academia -industry) R & D agenda in construction productivity enhancement.

CONCEPTUALISING AND EVALUATING PRODUCTIVITY

Fundamentals of Productivitv

Productivity has been expressed and described in terms of a ratio of 'outputs' to 'inputs' since 1776 (Edomsomwan, 1995). While similar to 'efficiency' in this respect, it transcends one-dimensional efficiency measures to include the overall optimisation of input resources that is at the core of good management. In pursuit of the latter, 'Total Factor Productivity' compares the 'total value-added output' against all 'resource inputs', as distinct from 'Single Factor Productivity' (which compares the total output against each input -such as labour -independently). The usefulness of such conceptualisation was' illustrated, for example, by Chau (1990) who applied this to the building industry in Hong Kong.

Prokopenko (1987) distinguished between three main productivity factor groups: (i) job- related; (ii) resource-related; and (iii) environment-related. He also differentiated (a) external (non-controllable) from (b) internal (controllable) factors; further sub-dividing the latter into 'hard factors' (those relating to product, plant and equipment, technology, materials and energy) and 'soft factors' (people, organisation and systems, work methods and management styles).

Kumaraswamy (1996) suggested that organisational performance (P) can be taken to be dependent on productivity and can be expressed as the synergistic sum of the knowledge (K), skills (S) and attitudes (A) of all its personnel ie $P = f(K,S,A)$. Here 'knowledge' is taken to be learning the necessary techniques; 'skills' as being able to perform these (efficiently); and 'attitudes' as appreciating the importance of learning and applying such knowledge and skills.

Productivity in Construction

It has been reported that productivity rates in general varied by as much as three times between one site and another in the U.K (NEDO, 1987) while planned construction durations for high rise concrete frames in particular, for example, were 'significantly and dramatically' lower in France than in the U.K (Proverbs et al., 1996a). Chan and Kumaraswamy (1995) identified increased productivity as an important factor in further reducing durations in Hong Kong construction products.

A range of special work study and other techniques such as 'multiple activity charts' and 'activity sampling' have been adapted and refined for evaluating and enhancing construction productivity, such as by Prokopenko (1987) and Heap (1987). However, there is little evidence of the use of such techniques by construction organisations, despite the potential benefits such as those suggested in the previous paragraph.

One explanation for the absence of a comprehensive 'in-house library' of work norms that was given to the author by a planner with a leading contractor, was that the need for this was diminished by the predominant practice of sub-contracting, which enabled overall rates to be fixed by negotiation, rather than from 'first' principles' of resource requirements. Whilst a realistic reflection of current practice, a knowledge of standard work norms should assist in negotiating rates on a more scientific (rather than commercial) basis.

Other possible contributors to such reluctance to embark on exercises to evaluate productivity, may be (a) the short-term high-pressure environment on most construction projects, (b) apprehensions, as to the ability to reproduce any 'hard-won' improvements in other projects, given the unique nature of each construction project, (c) the many variables involved and (d) the absence of standardised measures for evaluating productivity that would enable comparisons across projects, organisations, and indeed for 'benchmarking'.

Evaluating Productivity

Standardised and widely accepted indicators are needed to evaluate productivity levels of different production inputs (factors). Considering the different management levels at which such indicators may be useful in comparing actual performance against that estimated, or against industry norms, a framework of productivity indicators is proposed; and an example of how this may be structured is indicated in Table 1. Various productivity indicators have been independently proposed in different scenarios previously, for example: (a) man-hours/ m^3 (Harris et al., 1995); $m^{3/}$ pump-hour (Anson et at, 1996); $m^{2/}$ week (Gale and Fellows, 1990). In another scenario, Lim and Price (1995) have suggested a formula based on monthly progress payment/ total contract sum, gross floor area and monthly manpower to enable evaluations of productivity in $m^{2/}$ man-day on different projects - which measure is also used for comparisons by the Construction Industry Development Board in Singapore.

However, what is proposed herein, as in Table 1 is a general model that links a comprehensive network/ hierarchy of indicators, which provides for an integrated evaluation. While such models may also be developed for typical scenarios, say in building works; the specific selection, modifications, additions and deletions of indictors may be needed to gear the evaluation to a particular project and pre-identified purpose.

Table 1: A proposed framework of 'Indicators' for Productivity Evaluation

SCALE / LEVEL	TARGET GROUP	INDICATORS	EXAMPLES
Macro / Project	Top management	*Primary* (i) Single-factor (ii) Total factor	m^2 / man-day weeks / $ million; m^2 / $ million
Meso / (a) Elemental (b) Multi-operational	Middle management	*Secondary* (i) Single-factor (ii) Total factor	m^2 of roofing / man-day weeks / $ thousand of roofing
Micro / (a) Operational (b) Task	Supervisory management	*Tertiary* (i) Single-factor (ii) Total factor	concrete m^3 / man-hour concrete m^3/ pump-hour concrete m^3 / crane-hour man-hours/ m^3 of concrete man-hours / m^2 of formwork man-hours / ton of steel $ / m^3 of concrete m^3 / concreting cost-centre-hour

Such integrated models can aid management decisions as to the advisability, effects and 1, side-effects of new technologies being introduced to enhance the productivity of one or more resources. Management may verify for example, whether increasing the labour productivity by itself, would adversely affect the overall (total factor) productivity.

As a specific example: Lema et at (1995) described a programme in Tanzania to establish benchmarks for labour productivity among building contractors, in respect of blocklaying and concreting activities; and to consequently stimulate competitive performance.

The applicabilities and usefu1ness of such indicators of productivity are illustrated in the following comparisons of a series of case studies.

COMPARISONS OF CASE STUDIES IN EVALUATING PRODUCTIVITY OF CONCRETING - RELATED OPERATIONS

A Range of Concrete 'placing' output rates

The range of available methods for placing concrete - for example by pump, crane and skip-bucket, or hoist and barrow - are suggestive of the wide variabilities in the placing rates that maybe achieved in terms of m^3/hour, or a 'single-factor' productivity. indicators, such as m^3/man-hour or m^3/crane-hour. Technological, organisational and environmental differentials would also contribute to marked differences between placement rates, utilisation levels of cranes, truck-mixers etc. and single factor productivity rates, for example as compared by Anson et a1 (1996) between Hong Kong and Beijing. Placing speeds by pump in m^3/ pump-hour, as reported in the same study, indicated faster concrete pours in West Germany in general, while concrete pumping in Hong Kong appeared faster than in the U.K for pours less than $120m^3$ and *vice versa*. However, factors such as the type of pumps used, were seen to affect such ultimate values.

Other allowances need to be considered - such as for the type of elements being concreted (eg. faster rates achievable for 'slab' pours, as against 'walls'), the location and floor level, sample sizes and the methods of observation and analysis. For example the apparently lower m^3/man-hour (single factor) concreting rates reported from an European study by Harris et al (1996), as well as those from a UK investigation (Proverbs et al., 1996) and a Tanzanian study by Lema et al (1995) may be compared with the following rates derived from a series of studies on high rise building sites in Hong Kong, by Chan and Kumaraswamy (1995) on site A, and by Ip (1996) on Sites B and C. Table 2 also indicates the averages of the rates derived in the sample of Hong Kong projects studied by Anson et al (1996).

Table 2: Concreting Placement rate in m3/man-hour, from the Hong Kong studies

Element / Concreting Method	Average from sample of Anson et al. (1996)	Site A Floor 4	Site B Floor 10	Site B Floor 18	Site B Floor 33	Site C Floor 4	Site C Floor 6
Walls & Columns / Crane & Skip	1.78	1.60	2.79	2.25	1.85	2.76	2.59
Slabs & Beams / Pumped	3.07	3.30	3.18	2.99	2.20	3.12	2.61

It was also noted that the estimated rates in Site B had been 1.62 m^3/man-hour 'for crane + skip' wall/column concreting and 1.85 m^3/man-hour for pumped slab/beam concreting. While the former appeared reasonably realistic it was realised that the apparent underestimate on the latter may be explained by the pumped pours taking a shorter proportion of the full day, whereas the labour gang would have to be costed for the whole day in any case. This was confirmed by the observations of 'overall average' (as against 'uninterrupted') concreting rates reported on Site A -1.2 m3 /man-hour for crane + skip, and 2.2 m^3 / man-hour for 'pumped' concrete. This aspect is studied further in the next sub-section, in terms of productive/ idling time distributions of various personnel, such as concretors.

On the other hand, analyses of steel-fixing output on Sites B and C indicated a relatively narrow range of variations, as illustrated in Table 3.

Table 3: Steel Fixing rates in ton/ man-hour, from the Hong Kong sample

Element	Site B Floor 10	Site B Floor 18	Site B Floor 33	Site C Floor 4	Site C Floor 6
Walls	0.224	0.183	0.194	0.213	0.219
Slabs	0.202	0.193	0.152	0.232	0.229

Direct comparisons are not possible with for example the European cases studied by Harris et al (1996), because of (a) the total man-hours - ie including for steel-bending - having been incorporated in the latter study, while (b) work on the slabs, beams and columns had also been studied independently, unlike in the former study.

Profiles of 'Working'/ 'Preparatory'/ 'Idling' times of workers

The average profiles of worker activity types (in percentage distribution terms) as derived from 'activity sampling' (Heap, 1987) at the foregoing Site A in 1994 by Chan and Kumaraswamy (1995), are compared with averages from another sample (marked

*) from the same site by Leung (1995), as well as with the summarised results from site B by Ip (1996) another site D by Yip (1997).

Table 4: Activity Profiles in work trades on Site A in 1994 compared with those on Site A in 1995 (*), Site B (#) and site D *(^)* in Hong Kong.

Worker -Trade	Direct Work (%)	Preparatory Work (%)	Ineffective time (%)
Formwork Riggers	30.4 (54.4 *)	35.5 (36.2 *)	34.1 (09.4 *)
Bar-benders	11.1 (58.6 ^)	50.2 (22.0 ^)	38.7 (19.4 ^)
Steel-Fixers	40.6 (46.2 #)	21.8 (24.0 #)	37.6 (29.8 *)
Concretors	16.0 (25.2 #)	40.5 (38.0 #)	43.5 (36.8 #)

Not unexpected variations in the profiles between sites were considered to have been influenced by factors such as the location and type of work (building element), the organisational and information systems (for example that contributed to less 'preparatory' time) and worker morale/ attitude. It is thus difficult to contrast such findings with isolated studies in other countries unless the conditions are comparable. For example, findings by Olomolaiye et al. (1987) from Nigerian projects indicating a profile for steel fixers of 56% (direct work) : 8% (taking instruction or waiting : 36% (idling) - need to be adjusted for technological, environmental and organisational differentials, before any conclusions can be reached on comparative worker productivity.

Comparing Plant and Equipment differentials

(a) Tower Cranes

The utilisation of tower cranes on Hong Kong building sites was studied by Choi and Chan (1990), in terms of (a) frequencies of usage for lifting formwork, reinforcement, concrete and other materials; while (b) the overall utilisation level was found to range from 48% to 87% with an 'average' of 71%; and (c) 32% of the reasons for idling were found to be avoidable (eg due to avoidable breakdowns and/or inconsistent materials flow or labour support).

Table 5 illustrates the breakdown of average tower crane activity times, as obtained from large samples of observations from two of the sites cited m the previous sub-section.

Table 5: Average Utilisation Profiles of Tower Cranes in Hong Kong

SITE (reference)	Lifting / Moving Loaded	Moving Empty	'Idling'
A (Chan & Kumaraswamy, 1995)	62.3	17.1	20.6
A* (Leung, 1995)	62.7	16.2	21.3
D (Yip, 1997)	60.7	15.9	23.4

Interestingly prior to the field observations on site ~ the site personnel interviewed, had estimated the average loaded utilisation of their tower crane at 70%, which was about a 10% overestimate of productive time.

(b) Truck-Mixers

The waiting times of (and for) truck-mixers were also examined in the previous studies in Hong Kong, given the particular need for external batching and transport in the usually crowded sites and large concrete pours encountered. For example, averages of 61.2% (for pumped pours) and 60.4% (for 'crane + skipped' pours) were reported by Chan and Kumaraswamy (1995) in Site A, in terms of the percentage of time spent while discharging concrete in comparison to the total time spent by truck-mixers, including the waiting time to discharge and to wash and manoeuvre. This was similar to the overall average of 63.2% obtained by Anson et al (1996) in Hong Kong as compared to 53.2% obtained in Beijing; and also by Lam (1997) on two other sites in Hong Kong.

Interestingly the latter found no difference in such percentage waiting times of truck-mixers when 'feeding' pumped pours as against 'crane + skipped' pours, but this was largely due to the latter using 2 skip buckets in parallel, to avoid the idling of the crane while the truck-mixer was discharging into one skip bucket. By developing 'multiple activity charts' (based on averages of observed activity times) for the 'one-skip' and 'two- skip' scenarios, Lam (1997) estimated that the potential 'idling' time of the tower crane was reduced from 17% to 0% from the former to the latter scenario.

Concluding Observations on the Case Studies

Whilst ranges of results from different case studies have been compared, it was not possible to integrate all of them comprehensively, because of differentials in technological, organisational and environmental factors for example. However, the foregoing initial (pilot) comparisons confirmed the possibilities and value of such evaluations, in for instance raising questions as to why some organisations appear to be far more 'productive' that others in certain operations.

A further set of studies may be formulated to fit into (as far as possible) standardised ' formats and to be carried out under similar conditions to whatever extent possible, in order to provide 'benchmarks' for evaluating and comparing productivity levels, as a precursor to targeting improvements in appropriate directions.

FACTORS AFFECTING CONSTRUCTION PRODUCTIVITY AND DURATIONS

Construction researchers have previously identified important factors affecting productivity in different countries, for example: (a) Lim and Price (1995) in Singapore; (b) Olomolaiye et al (1987) in Nigeria; Sozen and Girtili (1987) in Turkey; and Naoum and Hackman (1996) in the U.K

In a related context - since low productivity had been found to be a principal source of project delays (Kumaraswamy and Chan, 1995); Kumaraswamy and Chan (awaiting print) identified significant factors (and 'factor categories') adversely affecting' construction durations' (ie causing delays) in Hong Kong; while Walker (1995) identified factors affecting construction time performance in Australia.

Proverbs et al. (1996a) analysed construction planning data collected from French and U.K contractors finding for example that there were relatively fewer workers and supervisors planned for, in equivalent projects in France. Observations from the foregoing study may be compared with those from the recent Hong Kong based investigations of (a) Tsang (1997) who analysed differences in organisational structures and styles among a small sample of Hong Kong contractors on housing projects with particular reference to spans of control, degrees of decentralisation and basic efficiency of information flows; and (b) Poon (1997) who formulated a 'first-order' mathematical model to predict manpower needs for housing construction in

Hong Kong, based on the historical manpower utilisation levels in each trade, as related to project value.

Such comparisons of manpower requirements trigger reminders of the wide variabilities therein and the importance of human and organisational factors, for example as indicated by Maloney (1983) and Khan (1993) in motivating construction personnel.

CONCLUDING OBSERVATIONS

The case studies in Hong Kong, together with the literature, have confirmed the need to formulate a framework of realistic productivity indicators, an example of which is proposed, and to establish productivity benchmarks at macro and micro levels. More reliable and realistic productivity evaluations will also point to areas for improvements at project, organisational and industry levels.

Such improvements may be targeted for example (a) through training programmes to upgrade construction personnel in identified 'knowledge' and 'skills' categories (Kumaraswamy, 1996); (b) by integrating new quality management programmes with specific productivity improvement methodologies (Edomsomwan, 1995); and (c) by identifying and implementing appropriate technological and organisational upgrades.

Research to improve productivity evaluations and forecasts - for example through Artificial Neural Networks (Chao and Skibniewski, 1994), Expert Systems (Boussabaine and Duff, 1996) and Fuzzy Sets (Ersoz and Halpin, 1996) - should thus provide a platform t on which to launch a common agenda for construction researchers and practitioners. The envisaged short-term improvements in productivity, could well encourage continued academia-industry partnerships in R & D (research and development) of construction management theory and practice.

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