CAN WE REALLY MEASURE CONSTRUCTION PRODUCTIVITY?

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Recent studies have highlighted that productivity growth for the construction industry have remained stubbornly low or have declined over the last two decades in many developed countries. This observation does not match the advances in materials, project management, procurement, information technology, and increasing specialisation or broad globalised operations that has characterised these modern construction companies. While recent projects are built under more onerous regulatory, health and safety, environmental and quality expectations, these changes are often not considered when productivity measures are calculated. This study critically reviews both the economic and physical measures of productivity from data and methodological perspectives to determine the sources of errors and discrepancies in the computation of productivity measures. Estimates of construction productivity based on identical data sets in the US indicate that these economic productivity measures are very sensitive to the choice of the price deflators. More recent estimates report improvements in productivity using revised deflators. In contrast, physical productivity measures do not suffer from these limitations. Furthermore, market factors and recent changes to the structure of the construction supply chain have led to new challenges in the computation of these estimates. Labour hire and equipment leasing arrangements, offsite prefabrication and increasing use of imported intermediate products shift a large proportion of work away from the construction sector. This leaves the less productive site assembly tasks to be carried out by construction companies. In a highly competitive market, productivity gains in the construction sector are often lost to other sectors of the economy through low profit margins. This review suggests that traditional approaches to construction productivity may no longer be applicable in a modern construction industry. Adopting a value chain approach to construction productivity where all stages of production including the supply and manufacture of intermediate products are analysed may be a better solution to enable the identification of the underlying factors of productivity.

Keywords: market forces, construction productivity, productivity growth, wages

INTRODUCTION

Global consulting firm McKinsey has reported that over the past twenty years the value added per hour worked in the construction sector has risen at a quarter of the rate of manufacturing (Barbosa *et al.,* 2017, Remes *et al.,* 2018). The average annual productivity growth rate of 1% from 1995 to 2015 is the lowest productivity gains of any industry. The trend is particularly concerning in advanced economies such as Germany and Japan where there was nearly no growth. McKinsey attributed the poor performance of the construction industries to increasingly complex projects, extensive

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Chan, T K and Gao, S (2019) Can We Really Measure Construction Productivity? *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 143-152.

regulations, corruption, highly fragmented industry, mismatched risk allocations and rewards, inadequate design processes, poor project management, insufficiently skilled labour and under-investments in technology, equipment and machineries. They estimate that productivity would increase significantly if construction were to transform from a project-based approach to a manufacturing-like system of mass production. Their study relied extensively on research by Sveikauskas *et al.,* (2016) who observed that the productivity of construction in the US remained at the same level as 80 years ago with a consistent decline reported since the late 1960's.

This study seeks to critically review the evidence on productivity in the construction industry. Many studies on construction productivity are premised upon an assumption that the level of productivity in the construction industry had declined, not increasing or increasing at a rate that is low when compared to other sectors of the economy. There is an urgent need to re-examine the evidence objectively and review research that had subsequently re-analysed these productivity data. Therefore, the first objective is to examine the numerous definitions of productivity that are commonly used, and to identify the sources of data associated with these measures. In view of the number of studies reporting conflicting productivity results, the second objective is to review the methodologies adopted in these studies to determine the potential causes for these inconsistencies. While the literature lists numerous drivers that have been found to directly influence construction productivity, challenges such as the heterogeneity of construction outputs and issues in the definition of data continue to obscure the true measure of industry productivity. Comprehensive reviews on the drivers of construction labour productivity globally have been carried out by Crawford and Vogl (2006), Ruddock and Ruddock (2011), Yi and Chan (2013) and Green (2016) and will not be repeated here. In recent years, the construction markets in developed and developing countries have become extremely competitive with companies reducing margins further to win contracts, sub-contracting tasks that are risky or less profitable to other companies and seeking to procure intermediate inputs from a global supply chain. The third objective is to examine how wages, profitability, labour hire practices, greater use of prefabrication and global trade influences the estimate of construction productivity. The results are expected to shed light on the productivity measures that are most suitable for contemporary construction practices.

DEFINING PRODUCTIVITY

Basically, productivity can be described as the output achieved by a stated amount of input. For example, labour productivity can be defined as square metres of building completed (output) per man-days worked (input). Physical measures of labour productivity are often for activities at the task level and may not include the supervisory or management personnel. This definition of physical productivity is straight-forward and easy to compute but requires substantial effort by the builders to collect and report the activity and personnel information. Trade level measures can be aggregated to yield a project-level productivity indicator. Project-level indicators can then be weighted according to different project types and aggregated to produce an industry productivity indicator.

The use of a single factor productivity means that it is not possible to determine if the improvement is achieved though better work processes, greater use of plant and equipment, enhanced technology or better skilled workers.

Labour productivity can also be measured in terms of the gross value of the output (or as value added) and either man-hours or number of workers as the denominator. The use of dollar values for output is convenient as it allows work on different sub-sectors of the construction industry to be aggregated but the differences in labour intensity of these projects may conceal the true measures of productivity. Dollar values require adjustments to eliminate the effects of price changes over time: project price deflators accounts for inflation by converting output measured at current prices into constant-dollar values. International comparisons are further complicated by the choice of appropriate exchange rates although this may be mitigated somewhat by utilising purchasing power parities. Single-factor productivity indexes are not particularly useful to investigate causes of economic growth as the contribution of capital and other factors such as technological change that influence production are not captured.

A production function with two primary inputs labour (L) and capital inputs (K) and the construction output (Y) can be defined as Y = a f(L, K) through a production function (f) and a technology factor (a). This indicates that labour productivity is dependent on a technology function (a) and capital intensity (K/L). Additional investment in capital such as tools, equipment and machinery will in turn enhance the productivity of workers. Capital productivity, another measure of productivity that relates to a single factor - capital, is defined as a ratio of some measure of output to capital input (ABS 2016). Increased capital deepening means that each unit of labour has more capital to work with to produce output. Labour saving practices, such as automation, will result in increased capital deepening, which is often associated with a decline in capital productivity (but possibly offset by an increase in labour productivity). The computation of capital productivity in construction industry studies is problematic (Tan 2000).

The technology factor (a) or Total Factor Productivity (TFP) measures how labour and capital are used in combination to produce construction outputs. A more refined measure for productivity would be to consider labour, capital, material, energy and systems inputs into the production function, and to attribute all other un-measurable factors into a single variable (A). The KLEMS multifactor productivity estimate separates intermediate inputs into capital (K), labour (L), energy (E), materials (M) and services (S) to assist in evaluating how each input affects the production process (O'Mahony and Timmer 2009). Table 1 below list these productivity measures. Using the KLEMS database, Abdel-Wahab and Vogl (2011) found that there was a consistent slowdown in construction labour productivity growth across major OECD countries during the 1971 to 2005 period.

is There Evidence of Declining Productivity?

It is widely accepted that the industry today is building structures of greater complexity and higher quality than in the past and is doing so in shorter periods of time (Bernstein, 2003). On the other hand, major construction projects are often plagued with cost overruns and late delivery which may be indicators for lower productivities. Studies on construction industry productivity have been carried out since the 1950s for various countries using either the index approach, economic measures or a data envelopment analysis (Chancellor et.al 2019). The analyses of different time series and using different methods have resulted in widely varying findings of negative growth, stagnant or low growth in productivity. This review examines a series of successive research publications that rely only on common sets of labour and output data to assess the various methods of estimating productivity.

Table 1: Overview of main productivity measures (Source: OECD 2001)

Type of output measure	Labour	Capital	Capital and labour	Capital, labour and intermediate inputs
Gross output	Labour productivity (GO)	Capital productivity (GO)	Capital-labour MFP (GO)	KLEMS multi-factor productivity
Value added	Labour productivity (VA)	Capital productivity (VA)	Capital-labour MFP (VA)	-
	Single-factor productivity measures		Multi-factor productivity measures	

One of the first indications of a decline in construction productivity in the US was reported by Allen (1985) who reviewed data compiled by the Bureau of Labor Statistics (BLS) from 1950 to 1978. The data suggests that while the labour productivity (reported as value added per hour worked) rose at an annual rate of 2.2% between 1950 and 1968, it subsequently fell at an annual rate of 2.4% between 1968 and 1978. Using a deflator for building construction, Allen determined that half the observed decline in productivity during the second period was attributed to a deflator that was upwardly biased because it was largely based on cost data for labour and materials rather than actual building costs. The other half of the decline was attributed to a reduction in skilled labour intensity resulting from a shift in the mix of output from larger scale projects to single-family houses. Adopting a different labour productivity measure (i.e. value of contracts in real 1992 dollars/workhours), Teicholz *et al.,* (2001) also concluded that productivity declined at a compounded rate of 0.48% per year over the 1964 to 1999 period in the US. They attributed the decline to structural problems in the construction sector that prevented the adoption of labour-saving practices and better management processes that would reduce the use of on-site labour.

Conversely, Allmon *et al.,* (2000) showed that labour productivity had increased for all 20 tasks studied (i.e. labour cost per unit output has decreased) in the US construction industry from 1974 to 1996. All 20 tasks examined reflected a decreasing unit labour cost in real terms over a period of 25-30 years leading to an increase in productivity. This was in part driven by a decline in wages in real terms during the period of study. It appears that many of these productivity increases were due to technological improvements in the processes but in some areas where there were no significant technological changes, these increases must be attributed to labour productivity increases. In a re-analysis of earlier BLS data that indicated declines in construction productivity, Sveikauskas *et al.,* (2016) sought to produce better estimates of project price deflators. Using other official sources of project cost information to produce more reliable deflators in four sectors (office, educational, industrial and warehouse) of the construction industry, they observed clear and substantial productivity growth from Allen's (1985) BLS data. This finding clearly indicates that the correct choice of deflator is a significant determinant of the measure of productivity, and that previous observations of decline may be flawed. The sensitivity of these findings to appropriate estimates of project price deflators puts many of the findings of various industry reports and studies (Richardson 2014, Remes *et al.,* 2018, The Economist 2017) into doubt.

While a Productivity Commission (2014) report started that labour and multifactor productivity growth in the Australian construction industry stagnated in the mid-1980s to the mid-1990s but increased from the mid-2000s, it stressed that the source and credibility of this growth was uncertain. Similarly, in a study of productivity data from the US, Rojas and Aramvareekul (2003) considered data for the 1979-1998

period from the Bureau of Economic Activity (BEA) and the BLS to be too unreliable to be useful in the generation of productivity measures. They attribute the discrepancy to the use of project data rather than establishment data that was less reliable, and to the level of aggregation. They assert that the output mix alone can severely distort labour productivity values by large percentages rendering many observations erroneous.

Data produced by the Singapore Building and Construction Authority (BCA 2019) indicates consistent improvements in project productivity in 6 building categories

This review suggests that many challenges still exist in the estimation of productivity when cost or price data is being considered, and there is considerable debate on the best approach. In comparison, attempts to compute physical productivity such as those by the Singapore Building and Construction Authority (BCA 2019) indicate consistent improvements in project productivity in 6 building categories.

Challenges in the Estimation of Productivity

Construction companies today operate in a highly competitive market with low profit margins and is characterised by increasing specialisation and fragmentation of work and processes. Building materials, intermediate inputs and sub-contract labour are now sourced from a wider geographical region, often from lower-wage regions or lower-cost producers in Central America, Eastern Europe or Asia leading to a globalised supply chain. These changes in market structure and economic factors add to the numerous challenges that already exist in the estimation of construction productivity.

Definition of labour productivity and boundaries of production
While physical measures of labour productivity are easy to compute, it is necessary to consider the boundary of the production process; i.e. if labour input should focus solely on the workers involved in the task or include supervisory and management staff. This is acceptable if the productivity measure is at the task or activity level but may under-estimate the labour input if these measures are aggregated into a firm or industry level estimate. Productivity measures utilising gross output represents the total project value which includes intermediate inputs from the manufacturing, transport and retail sectors that are incorporated into the completed building. Value added, which is defined as the difference between the total revenue of an industry and the total cost of intermediate inputs, is often more representative of the contribution of labour and capital to the production process, and as such is derived by summing factor incomes; i.e. compensation of employees, gross operating surplus and gross mixed incomes. Labour productivity measures derived from national accounts data are based on value added whereas those resulting from industry data are based on gross output leading to further confusion. The use of value added per worker as a measure of labour productivity in construction must consider the high value added when wages and profits are high during a boom period and the converse during a downturn.

Labour hire arrangements
Modern construction companies generally operate as management contractors with minimum direct labour hire, preferring to engage sub-contractors or labour hire companies to carry out most of the construction work. This provides more flexibility (i.e. avoid having permanent staff on payroll, less onerous employee entitlements) in engagement of tradesmen but is often criticised as an arrangement where the workers receive lower wages, few benefits and no training (CFMEU, 2015). The use of labour

hire companies severely misrepresents the number of workers in the construction industry if labour hire companies are classified as part of the services sector.

Capital intensity

The impact of capital in the computation of labour productivity can be traced back to the 1950s when Robinson (2013) questioned the estimate of the value of capital goods in the Cobb-Douglas production function and the associated marginal productivities. The best available estimate of capital is the value of net fixed assets of construction companies. These are depreciated using a straight-line method at appropriate rates of between 10% to 30% per annum for vehicles, machinery and equipment (Tan, 2000). Tan cited difficulties in estimating capital assets such as buildings during the peak of a property cycle where the value of these assets may be extremely high. Other challenges include the separation of the development or investment property assets owned by construction companies. Furthermore, capital assets are valued at historical cost and capacity utilisation of machinery and equipment are often not considered.

Leasing of equipment and machinery

The issue of capital intensity is further compounded by construction companies leasing equipment such as tower cranes, concrete pumps, and excavators from rental or hire companies that will be recorded as expenses in the intermediate inputs. A company that leases rather than purchases capital equipment will understate capital intensity.

Wages

Higher wages will reflect higher value added and therefore leads to a higher labour productivity. This discrepancy was pointed out by Low (2015) when he compared the hourly wages for general labour for Singapore and the US in 2012, suggesting a higher labour productivity in the US based on wage alone notwithstanding any actual differences in physical labour productivity.

Profits

Profit (as gross operating surplus) is another component in the computation of value added that directly contributes to labour productivity. However, the level of profit a company attains is not only dependent on its efficiency in construction activities but largely dictated by market forces. In a highly competitive market, productivity gains are passed on to customers in the form of lower prices rather than higher company profitability. The decline in profitability of Canadian construction firms from 5-6% between 1980-1990 to 1-2% between 1992-2001 resulted in the reduction of value added leading to a consequential decline in the productivity measure (Bernstein 2003).

Off-site prefabrication and embodied labour

With the increasing amount of prefabrication that is taking place, the work that is carried out off-site is captured in the manufacturing sector, potentially reallocating the improvements in productivity to the manufacturers as opposed to the construction sector. The value of off-site prefabrication may be considerable when increasingly larger assemblies such as bathroom pods and curtain wall units are being prefabricated. The transfer of work off-site raises many new issues and their analysis requires a clear demarcation of the boundaries of the construction sector to be studied. Shifting work offsite dramatically reduces the demand for on-site workers and results in significant improvement in physical labour productivity. Off-site construction is generally more productive due to the use of machinery in place of workers and the adoption of manufacturing processes. In time, tasks that remain on-site are those that are labour intensive and cannot be easily automated.

Another important issue in prefabrication is the concept of embodied labour when building components are pre-assembled or manufactured off-site. The primary inputs of labour and capital required to produce these components in the factory are attributed to the manufacturing sector. These assemblies are procured as intermediate products with an embodied labour content but are not accounted for in labour productivity measures. While there is evidence from Singapore (BCA 2019) that indicates improvements in on-site labour productivity in highly repetitive high-rise public housing and institutional buildings, the embodied labour input of off-site production of prefabricated components is not captured.

Expansion of Global Value Chains

In recent years, the increase in global trade as a result of manufacturing moving from G7 countries into Eastern Europe, North America into Central America and the rise of China as a manufacturing powerhouse has also affected the source of intermediate inputs into the construction industries of many developed economies. Labour shares in developed economies continue to fall as more companies participate in these global supply chains and increase trade integration with lower cost producers worldwide (Baldwin 2016). The effects of this phenomenon are not unlike that of off-site prefabrication where value added is lost to manufacturing, leaving the more unproductive site assembly to be carried out by the construction companies.

Recent changes in the structure of the construction industry and the broader fragmentation of its activities have presented new challenges to the measurement of productivity. These factors add further complexity to an already difficult problem.

Suggestions for Better Measures of Productivity

Economic measures of productivity are fraught with difficulties in the definition of productivity measures, data collection and market issues as discussed in the previous section. On the other hand, physical measures of productivity fail to capture the embodied labour of offsite production or productivity measures in the manufacture of intermediate inputs.

In a recent editorial on rethinking construction productivity theory and practice, Pan (2018) concluded that consistency of measure is never going to be achievable. None of the papers in the special issue of Built Environment Project and Asset Management (2018) suggested new or improved methods of producing construction productivity measures, nor how to better collect productivity data. Forsythe (2018) suggested dividing the measurement effort into two distinct parts: A homogeneous component to enable project-to-project comparisons to be made, and a heterogeneous component that caters to the vast variance in the type of projects that are carried out. The difficulties on how to make sense of the heterogenous component remain unresolved.

The fragmentation of labour into labour hire arrangements and sub-contracts, and construction activities to the manufacturing sector or outsourced to suppliers offshore has resulted in a construction sector that is responsible for a declining share of work. The tasks that remain firmly in the hands of the construction company are often the less productive assembly work on-site. Increasing market competition drives profit down to unsustainable levels, allowing productivity gains in the construction industry to be accrued to construction clients instead.

Traditional approaches to construction productivity that are based on final outputs are no longer useful. Given that construction tasks are now increasingly fragmented across companies and geographical borders, a new approach that measures

productivity in each stage of the construction process may be required. The OECD recently proposed a global value chain approach to identify the sources and to quantify the amount of gross flows and value added generated over the entire production chain (Marcolin *et al.,* 2016). Extending this approach to quantify the gross flows, value added, labour and capital inputs for the construction industry may provide a more accurate measure of productivities along this increasingly partitioned value chain. An approach that mirrors Timmer's (2017) global value chain productivity measure where all stages of production are analysed may be a potential solution. In the case of the construction industry, this value chain can be described as all the companies in the supply and manufacture of intermediate products. The contributions from both construction and non-construction sectors will be explicitly accounted for through the modelling of input-output linkages across sectors. Following the same logic, the number of workers that is directly and indirectly involved in the construction value chain, or the amount of capital, can be traced. Numerous practical challenges remain, not least the requirement to obtain data on the various sectors of the economy that is not normally classified as being part of the construction industry.

CONCLUSIONS

A review of existing measures of construction productivity indicates that two classes of measures exists: (i) physical productivity measures that indicate output per unit input such as square metres of building completed per man-hour, or linear meter of pipe laid per man-day, and (ii) productivity in dollar terms such as gross output per labour input or value added per labour input. Inconsistencies in the definition of productivity measures give rise to difficulties in comparing the productivity between tasks, firms and countries, and over time.

Research utilising physical measures indicates that labour productivity is increasing with the productivity growth being attributed to increased use of modern equipment and improvements in technology. These labour productivity measures are sensitive to price deflators that are computed using either wage or material price indices. While improved estimates of price deflators in recent studies has led to observations of increases in labour productivity, there is still considerable debate over the choice of approaches.

The construction production system has evolved from numerous trades working at a single location many decades ago to a multi-stage process involving many different suppliers, sub-contractors and trades in multiple locations and increasingly across geographical borders. This poses new challenges to the estimation of productivity of the construction industry through increasing intermediate inputs, offsite manufacturing, imports, offshoring and widespread use of labour and equipment hire practices. Measuring labour productivity in dollar terms is fraught with difficulties especially when examining the effects of changing production linkages across industries and countries. This review has found that tracking of prices and quantities of intermediate goods and services by sub-contractors and suppliers is especially difficult when combined with the effect of market forces that may limit the capture of the gains from productivity within the construction sector.

Clearly more research and debate are needed about how productivity should be measured. A global value chain approach has been proposed as a potential method of tracing the value added and productivities at every stage of production.

REFERENCES

Abdel-Wahab, M and Vogl, B (2011) Trends of productivity growth in the construction industry across Europe, US and Japan, *Construction Management and Economics*, 29(**6**), 635-644.

Allen, S G (1985) *Why Construction Industry Productivity is Declining*. NBER Working Papers 1555, National Bureau of Economic Research, Inc

Allmon, E, Haas, C T, Borcherding, J D and Goodrum, P M (2000) US construction labor productivity trends, 1970-1998, *Journal of Construction Engineering and Management*, 126(**2**), 97-104.

Australian Bureau of Statistics (ABS) (2016) *Australian System of National Accounts: Concepts, Sources and Methods*. Australian Bureau of Statistics

Baldwin, R (2016) *The Great Convergence: Information Technology and the New Globalization*. Belknap Press: An Imprint of Harvard University Press.

Barbosa, F, Woetzel, J, Mischke, J, Ribeirinho, M J, Sridhar, M, Parsons, M, Betram N and Brown, S (2017) *Reinventing Construction: A Route to Higher Productivity*. McKinsey Global Institute.

Bernstein, H M (2003) Measuring Productivity: An Industry problem, *Civil Engineering*, 46-53.

Building and Construction Authority (BCA) (2019) *Project Productivity*. Available from https://www.bca.gov.sg/Productivity/site_productivity_statistics.html [Accessed 07/01/2019].

Chancellor, W, Abbott M and Carson C (2019) Productivity and levels of output in the construction industry, *In*: R Best and J Meikle (Eds.) *Accounting for Construction: Frameworks, Productivity, Cost and Performance*. Abingdon: Routledge.

Construction, Forestry, Maritime, Mining and Energy Union (CFMEU) (2015) *Labour Hire and Insecure Work*, November 2015.

Crawford, P and Vogl, B (2006) Measuring productivity in the construction industry, *Building Research and Information*, 34(**3**), 208-219.

Forsythe, P (2018) Extending and operationalizing construction productivity measurement on building projects, *Construction Management and Economics*, 36(**12**), 683-699.

Green, B (2016) *Productivity in Construction: Creating a Framework for the Industry to Thrive*. Chartered Institute of Building.

Low, S P (2015) A review of construction productivity indicators in Singapore, *The Singapore Engineer*, August 2015, 24-30.

Marcolin, L, Miroudot, S and Squicciarini, M (2016) *Gvcs, Jobs and Routine Content of Occupations*. Organisation for Economic Co-operation and Development, Paris: OECD Trade Policy Papers.

OECD (2001) *Measuring Productivity - Measurement of Aggregate and Industry-Level Productivity Growth*, Organisation for Economic Co-operation and Development, Paris.

O'Mahony, M and Timmer, M P (2009) Output, input and productivity measures at the industry level: The EU KLEMS database, *The Economic Journal*, 119(**538**), F374-F403.

Productivity Commission (2014) *Public Infrastructure, Inquiry Report No 71*, Canberra, Australia.

Pan, W (2018) Rethinking construction productivity theory and practice, *Built Environment Project and Asset Management*, 8(**3**), 234-238.

Remes, J, Manyika, J, Bughin, J, Woetzel, J, Mischke, J and Krishnan, M (2018) *Solving the Productivity Puzzle: The Role of Demand and the Promise of Digitization*, McKinsey Global Institute.

Richardson, D (2014) *Productivity in the Construction Industry*, Australia Institute.

Robinson, J (2013) *The Accumulation of Capital*. Basingstoke: Palgrave Macmillan.

Rojas, E M and Aramvareekul, P (2003) Is construction labor productivity really declining? *Journal of Construction Engineering and Management*, 129(**1**), 41-46.

Ruddock, L and Ruddock, S (2011) Evaluation of trends in the UK construction industry using growth and productivity accounts, *Construction Management and Economics*, 29(**12**), 1229-1239.

Sveikauskas, L, Rowe, S, Mildenberger, J, Price, J and Young, A (2016) Productivity growth in construction, *Journal of Construction Engineering and Management*, 142(**10**), 04016045.

Tan, W (2000) Total factor productivity in Singapore construction, *Engineering, Construction and Architectural Management*, 7(**2**), 154-158.

Teicholz, P, Goodrum, P M and Haas, C T (2001) US construction labor productivity trends, 1970-1998, *Journal of Construction Engineering and Management*, 127(**5**), 427-429.

The Economist (2017) *The Construction Industry's Productivity Problem - Can We Fix It*? 17 August 2017.

Timmer, M (2017) *Productivity Measurement in Global Value Chains*, International Productivity Monitor, 33, 182-193.

Yi, W and Chan, A P (2013) Critical review of labor productivity research in construction journals, *Journal of Management in Engineering*, 30(**2**), 214-225.