CONSTRUCTION PRODUCTIVITY MEASUREMENT: A COMPARISON OF TWO CASE STUDIES

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The construction industry remains one of the few most labour intensive industries in the developed world. It is therefore imperative to understand the measure of construction labour productivity. Furthermore, recent institutional and industrial calls for an increase in productivity suggest a desperate need to get the measurement of productivity levels right. The research reported in this paper forms part of an ongoing Ph.D. study into the issue of construction labour productivity. An earlier study highlighted that less than 50% of the industry actually actively measure and monitor productivity levels, with a majority of those companies that claim to measure go about measuring on the basis of the intuition of key site management personnel. This may seem alarming, however, it was argued that productivity measurement techniques could be perceived as theoretical, arduous and expensive for construction companies to adopt. This paper reviews the methods of productivity measurement available and describes two case studies conducted during this research, with a view of reporting the problems and issues faced when attempting to establish productivity levels at a project level. Lessons learnt are then drawn from the experience.

Keywords: construction, measurement, productivity, project site.

INTRODUCTION

The quest for productivity improvements in the UK construction industry has been an especially important agenda over the last decade (Latham, 1994; Egan, 1998). However, what is found baffling is the fact that the measure of productivity is often conflated with the measure of performance. One only needs to turn to the Construction Productivity Network (CPN) to seek an instance of such misapprehension. Indeed, the very name of the network is misleading since it deals with such far wider issues as risk management and knowledge management. Clearly, the network might be more suited to have adopted the term Construction Performance Network as compared to the use of the term productivity, which traditionally refers to the quantifiable ratio between inputs and outputs in physical terms.

Indeed, the industrial Key Performance Indicators (KPIs) rightly recognise the clear distinction by acknowledging the measure of productivity as a subset of the wider measure of business performance. However, in the pursuit of convincing the industry to take on board improvement programmes and initiatives, recommendations have tended to represent simplistically improvements through headline measures such as reduction in construction time, defects, accidents etc., for instance, in the case of the

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Movement for Innovation (M^4I) demonstration projects. Productivity, interestingly, was measured by the M^4I by taking the median of the company value added in monetary terms per employee. This value added approach mirrors the value-added approach conventionally applied at the industrial (macroeconomic) level (see e.g. Jonsson, 1996). While it is understandable, from a marketing perspective, to report headline indicators *per se*, given the fact that embarking on any initiative undoubtedly needs corporate buy-in by senior managers, it is felt that capturing productivity measurements at the strategic level may be insufficient to guarantee that improvements actually occur at the operational level. Therefore, it is firmly believed that going back to the basics of measuring productivity at the project site level would be necessary in facilitating improvements. This is because the construction industry is largely project-based. Groák, for instance, issued a stern warning that there is an inherent "failure to recognise that the site was the defining locus of production organisation (1994: 288)" for construction.

However, there lies a problem here. Apart from the formal measures propounded by such initiatives as the M^4I stated above, many construction companies just do not have formal measures in place at the project level. For example, Chan and Kaka (2003), in a questionnaire survey to 400 UK contractors, found that of the 77 respondents, more than half of them do not monitor productivity levels at the project level. Furthermore, a third of those who claim to do so base their judgement of productivity on gut feeling and experience of dealing with contract schedules. Similar findings were noted in a large study commissioned by the Investors in People in the UK, which was aimed at examining productivity measurements *inter alia* across sectors including manufacturing, transport, service and construction. The Investors in People (2001) noted that while 22% of the respondents did not measure productivity levels at all, 36% and 22% of the respondents used formal and informal techniques to establish productivity levels respectively. Yet, past research have shown that the very process of formalising on-site productivity measurements itself delivers project improvements. For example, Winch and Carr (2001) notably identified a growing competitive spirit among the workforce as they progressed in their study investigating the benchmarking of on-site productivity, thus reinforcing an earlier comment made about the importance of measuring productivity levels at the project site level.

Nonetheless, Chan's and Kaka's (2003) and the Investors in People (2001) reports beg the question as to why there is reluctance for formal productivity measurements, and which forms the premise of this paper. The chief aim of this paper is to explore the pertinent issues that would explain some of the reasons behind what we would call industrial inertia towards productivity measurement at the project level. In so doing, we would tackle it from both theoretical and practical perspectives. The next section briefly reviews the key textbook approaches to measuring on-site productivity and highlights the limitations in terms of reliability and relevance of these approaches that restrict industrial adoption. Thereafter, we will report on the relevant findings of two live projects observed as part of a wider study into understanding the concept of construction labour productivity, revealing some of the practical issues encountered when measuring on-site productivity. Conclusions are then drawn from both the review and the case studies that lead to the recommendations for future research that would hopefully encourage the industry to measure on-site productivity.

PRODUCTIVITY MEASUREMENT TECHNIQUES

Construction textbooks are awash with details of key productivity measurement techniques and it would be inappropriate to replicate the explanation of these techniques within the constraints of this paper. According to Noor (1998), productivity measurement techniques fall within a spectrum between two broad categories of observational methods, namely continuous observation (e.g. direct observation and work study) and intermittent observation (e.g. audio-visual methods, delay surveys and activity sampling).

Noor recognised that while continuous observations such as direct observation and work study provide high levels of accuracy and detailed data for understanding productivity, these are often time-consuming, arduous and costly. Given the operational imperative of construction projects and the ever increasing time pressures exerted on project schedules, the cost of employing personnel to conduct such observations both in terms of the monetary cost of wages and the time value of observation that does not result in the physical growth of buildings (i.e. non value added) would deter companies from adopting such measurement techniques. Furthermore, the benefits of continuous observations are marred by the inexorable restriction of scope and thus, would make it difficult for large projects to pursue this approach. Where the use of technical equipment for audio-visual methods is concerned, Winch and Carr (2001) were especially cautious that the workers might feel that the surveillance was unnecessarily intrusive. As such, they avoided the use of such methods to observe the workers and opted instead for direct observation where the researchers got to know the individual workers on a personal level. Therefore, while the absence of the workers' uneasiness was achieved, the inability to observe the whole construction process became an evident trade-off.

With respect to intermittent observations, Noor noted that these are prone to errors in determination since the data tends to be aggregated statistically through the observation of a *representative* sample. To add to this, Radosavljevic and Horner (2002) recently revisited formwork and masonry productivity data sets across eleven sites in the USA and the UK, only to confirm their suspicion that productivity is not normally distributed, thereby implying that "some basic statistical diagnostics… may give misleading results and are not applicable (p. 3)". Accordingly, this questions the dubious reliability of conventional productivity measurement techniques. Serendipitously, Radosavljevic and Horner made a brief comparison of the data with volatility studies in econometrics to reveal surprising similarity with Pareto distributions, which are typical of chaotic systems. They concluded therefore that "using test statistics that rely on normality usually have been taken for granted, and consequently not much could have been done to achieve a better understanding of the ubiquitous complexity (p. 11)" as they call for a paradigm shift to understand the complexities of construction labour productivity, possibly through chaos theory. However, it is felt that such complex methods of analysing productivity levels might further discourage companies to measure productivity since this would mean additional investment of statistical expertise.

Another problem with many of the conventional productivity measurement techniques is the reductionistic approach in analysing work time (see e.g. Drewin, 1982). To put simply, much of the analysis of productivity data had been concerned with the binary relationship between productive (or value-adding) time and time loss. However, contenders such as Thomas *et. al.* (1990) challenged this underlying assumption – the inverse relationship between productive and non-productive time, and that reducing time loss leads to productivity improvements – as they claimed “while these assumptions seem sensible and logical, they will be shown to be unsupportable for most construction operations (p. 712)”. In fact, a later study (Thomas, 1991) provided evidence that would cast doubts on the assumption of the binary relationship between productive and non-productive time, and hence on the productivity measurement techniques.

A further limitation relates to the application of productivity measurement techniques in past research. A review of the literature revealed that measurement techniques were mainly concentrated, in past research, on a number of key construction operations: namely concrete works (Proverbs *et. al.*, 1999; Winch and Carr, 2001), masonry projects (Thomas and Yiakoumis, 1987; Olomolaiye, 1990), structural steel (Thomas and Yiakoumis, 1987) and electrical works (Thomas, 2000). Evidently, with the exception of electrical works, much of the studies were concerned with the structural elements, i.e. elements that contribute to the structural frame of the building. This means there is an overwhelming lack of research aimed at studying such other aspects of the building process as architectural elements (e.g. plastering, internal fit-out, painting and decoration) or services installations (e.g. mechanical and sanitary installations). Indeed, the studies surrounding electrical works were related to the effects of schedule acceleration, in part, due to the effects of productivity-related problems of the earlier structural phase of projects (see e.g. Noyce and Hanna, 1998; and Thomas, 2000). One of the possible reasons for this phenomenon is the lack of previous studies (unlike where areas such as bricklaying and concrete operations are concerned) or industrial productivity data for comparison. Notably, the National Electrical Contractors Association (NECA) in the US has been deeply keen in examining productivity issues ever since the late 1960s (Thomas *et. al.*, 1990) and have been actively developing labour consumption curves (NECA, 1983) to inform the industry for possible applications on different project types (Thomas, 2000), offering perhaps an explanation as to why productivity on electrical projects are examined.

Olomolaiye (1990) is one of the few who explains his decision to focus on bricklaying as he attributed his preference to “the predominance of bricks as one of the main construction materials in the UK”. He added “a bulk of construction manpower still goes into bricklaying as it remains highly labour-intensive (p. 302)”. On the decision to focus on concrete operations, Winch and Carr (2001) cited Horner’s and Zakieh’s (1996) claim that “studies of estimating have shown that the largest items in the bill can be used to determine overall outputs very closely”. Furthermore, they expounded that “data on concrete deliveries by ready-mix trucks for any given period are easily obtained from site records, and because concrete is perishable, we can infer that deliveries on a day have been poured that day (p. 581)”. It is argued, however, that concentrating on the predominant or largest activity results in a reductionistic approach, which fails to take into account the entire construction process. Interestingly, Kazaz and Ulubeyli (2004) in a recent study aimed at reconciling governmental statistics and real project data on productivity rates in Turkey elected to examine only 82 work items deemed to be used most in practice, thus affirming the researcher’s observation, although they acknowledged that these only constitute 6.11% of all possible work items. In this respect, conclusions made in past studies are limited in their scope in offering plausible recommendations for implementation for the improvement of construction labour productivity.

The limitations of productivity measurement techniques discussed hitherto, to some extent, help to explain the low industrial uptake within construction. These encompass the issues of reliability and relevance of existing techniques that would inhibit the ability of companies to meaningfully analyse their project productivity so as to bring about improvements to the entire construction process. Furthermore, there are the investment constraints of time and expertise in implementing the existing productivity techniques. These emerging issues from the brief review explains some of the general difficulties claimed by the participants of the Investors in People (2001) study, particularly the difficulties in obtaining accurate information, the varied nature of individual job roles and the complex nature of productivity that is dependent on several intervening factors (p. 6).

CASE STUDIES AND PRELIMINARY FINDINGS

Having briefly discussed the theoretical issues surrounding existing productivity measurement techniques, this section now turns to the two projects, hereinafter known as projects A and B, observed during the course of the study. The purpose of the case studies is to explore the issues faced by practitioners when measuring project productivity. The two projects were selected because project participants had either attempted to measure productivity (project A) or claimed to have a formal method of measuring productivity in place (project B). Each case will begin with a brief synopsis of how the researchers got involved with the projects and an account of the observational process. This will then be followed by a succinct report of the key issues involved in the implementation of the productivity measurement techniques in the two projects.

Project A: Multi-storey Car Park

Background to project A

Project A is the construction of a multi-storey car park for a Scottish airport. This was initially selected as a pilot study at the onset on the basis of convenience, access and geographic proximity as instructed in Yin (1994: 75). It is perhaps worthwhile, at this point, to provide an insight into how and why access was given to this project in the first place. A marketing flyer accompanied by a cover letter was sent to companies to seek collaboration and access to projects, people, data etc. at the start of the research. A positive response from the main contractor executing project A then resulted from this initial call for participation. The contractor was a fast growing company at that time that aimed both to ‘penetrate’ the Scottish construction market and to succeed in gaining repeat business with British Airports Authority (B.A.A.). Because the company had not undertaken any on-site productivity measurement, they were therefore keen for the researchers to assist in the development of on-site productivity measures. And so, access to the project was granted on a two-days-a-week basis and the project quantity surveyor of the company was involved with the researchers in developing the measurement technique.

To overcome the problems discussed in the previous section regarding the isolation of construction activities in measuring productivity, a decision was made to measure productivity levels using the existing company worker timesheets. Timesheets were found to be extremely useful mainly because timesheets were used for the purpose of calculation of hourly wages and linking this to productivity measurement would probably show meaningfully the notion of a fair wage. Furthermore, measuring productivity on a daily basis was considered to be the most appropriate technique as corrective action could be taken as quickly as possible. For data collection purposes, foremen were instructed to complete time inputs and physical outputs for each worker under their charge within a set time sheet on a daily basis. Table 1 below shows a simplified example of a recording on the activity of pouring concrete by a gang of concrete labourers. Based on the data presented in table 1, a total of 66 man-hours were used to produce 232m^3 of concrete, yielding a productivity rate of ≈ 3.5m^3 of concrete per man-hour.

Date	Worker	Activity	Hours	Location/Output
1 Oct 2001	Foreman A	Pouring Concrete	10	Plot 2-6/ 232m^3
1 Oct 2001	B, C, D, E, F, G, H	Pouring Concrete	8 each	Plot 2-6/ 232m^3

Table 1: A simplified example of a completed time sheet

Emerging issues

A number of issues arose whilst attempting to measure on-site productivity levels for project A in this way. The desire for a speedy construction process meant that many proprietary systems, e.g. in the case of formwork, were used as part of the construction techniques. These were undertaken by specialist subcontractors (with whom access was not granted). What was observed was that the core labourers used by the main contractor were general operatives who were often mobile in terms of the task they did. So, for example, an operative could be involved in general housekeeping on day *n*, shifting what is known as ‘tables’ (a proprietary form of the conventional *birdcage scaffolding* that is on wheels to support the formwork) on day *n* + 1, and putting stop ends along the perimeter of a plot prior to concreting to prevent the concrete from spilling over on day *n* +2 and so on. Perhaps the only stable groups of workers were those who were relatively more skilled, e.g. concretors and steelfixers, who tended to stick within the task of their trades. Even so, these workers moved to other projects in the vicinity when their tasks were not scheduled for project A. Therefore, while measuring productivity levels in this way appear to be more holistic and probably closer to reality than the methods highlighted in the previous section, the mammoth task of tracking workers posed an immense challenge. Moreover, although the data was collected at the gang level (through the foremen), the boundaries of the gang were found to be arbitrary because of the volatile movement of the workers. This resulted in high variability of the productivity data obtained, which supports Radosavljevic’s and Horner’s (2002) observations, but which implies that discerning the factors affecting productivity especially those related to the workforce issues was particularly problematic.

Administering the measurement was also not without problems. To start with, foremen were not akin to filling out forms and throughout its implementation, the project quantity surveyor discovered that there was a need to constantly explain to the foremen the mechanisms of recording. Two reasons accounted for this. The first relates to the inevitable problem with determining output quantities given that construction operations are often associated with work-in-progress that can be difficult to ascertain. Rules of credit (see e.g. Thomas and Yiakoumis, 1987) may go some way to facilitate this process, although time and manpower is needed to maintain a database of such information for which the project quantity surveyor did not have. In fact, the project quantity surveyor resigned in the middle of the project and the measurement of productivity halted due to the absence of a willing successor. To exacerbate the problems of measurement, the project quantity surveyor had identified a complex list of more than 170 task descriptions, thus causing further confusion for the foremen in the recording process. This enormous list of task descriptions is believed to be due to the fact that many proprietary systems were used in the construction process. Still, as the predicted trend for the construction industry is towards greater outsourcing and use of innovative technology in the production of buildings (see e.g. CRISP, 2001), it would be sensible to take into account such complexities when measuring productivity. It is here that project B sheds some light.

Project B: Headquarters of a Commercial Bank

Background to project B

Project B involves the construction of the headquarters of a commercial bank on a greenfield site just outside Edinburgh. Access was given to interview senior project managers and to conduct questionnaire surveys with the site operatives. During the interviews, the researchers were struck by the ability of the managers to report what they allege to be the precise number of man-hours expended on the project to date, a phenomenon that was non-existent in other projects observed during the study. Inquisitively, the researchers investigated how project participants captured this data through further probing during the interviews.

According to the project managers, project B utilised what is known as The Last Planner system, a planning system that has gradually gained recognition and refinement since its inception in 1994. Much has been written about the system (see e.g. Ballard, 2000), although this is really related to planning and never intended to be used as a means of measuring on-site productivity. However, one of the KPIs resulting from this system, known as the Percent Plan Complete (PPC), was thought to be extremely valuable by the project participants for them to gain an informed view of the on-site productivity levels. Basically, the PPC refers to how much of the planned work on a weekly basis is actually completed. In a similar vein, this ostensibly is comparable to the earned value analysis used in project management (see Project Management Institute, 2000). Figure 1 above shows an extract from a weekly progress update, which enables project B's participants to keep track of how productively the work packages were performing to plan. To help improve the PPC, the progress meetings were used as a platform to understand what went wrong, i.e. what intervening events or factors resulted in a low PPC (e.g. weather, lack of materials etc.).

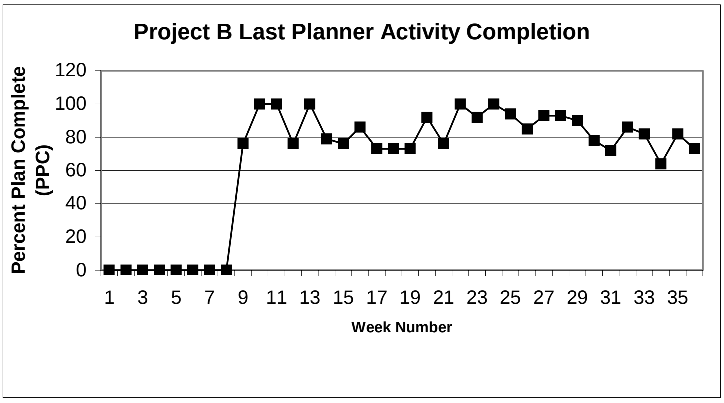

Figure 1: Extract of project B work package 1 planning and progress update up to week 41

Emerging issues

While this paper is not aimed at analysing whether this system constitutes a credible means for measuring on-site productivity, it was felt that this system provided an effective way for managers to establish how progress was being made. Hence, this allowed project participants to get a feel of the productivity of the workers by complementing the measure of PPC with the number of man-hours expended. To show a simplistic example, using figure 1 above, let us assume that work package 1 utilises the same amount of man-hours throughout the project. Therefore, one can safely deduce that achieving 100% PPC in say week 13 and 76% PPC in week 14 would signify a dip in labour productivity. In other words, PPC can be viewed as an output in the productivity ratio and so alleviate the problems of complexities involved in construction operations and sub-contracted work packages experienced in project A above. Furthermore, such information should provide useful feedback to the workforce regarding their performance.

Implementing this system for the project participants was also met with a number of challenges. For instance, the system is largely paper based and therefore archiving such information and managing it within a database would still require the deployment of manpower. Nonetheless, as compared with the attempts in project A, this is perceived to be relatively more straightforward. It would also be tempting to proclaim that running this system commenced from the first day of the project. In fact, the project managers had attempted to implement such a system on a previous project six years ago but faced immense resistance from the project workers as it was then thought to create a blame culture so that fault could be apportioned when things went wrong. Interestingly, another project observed, which involved the construction of an office block in central London and built by the same contractor running project B, had initially tried to adopt the system. However, it was abandoned as soon as it started on the same basis of resistance. Still, project B participants learnt from their previous experience from six years ago and thus, made a conscious effort to allay fears of a blame culture right from the very start of the project through constant reassurances given during early briefing sessions.

CONCLUSIONS

In conclusion, the paper raised the issue of the importance of, and lacklustre attitude of companies towards, measuring on-site productivity. Thereafter, a review of the limitations behind the key textbook approaches to measuring productivity was provided and these represent some of the problems, which contribute to the industry's reluctance to measuring productivity. We have then taken the reader on a journey through two projects observed and summarised here some of the practical issues faced in the implementation of an on-site productivity measurement system. These include the time and expertise needed in handling the complexities of productivity data and resistance from the workforce. In essence, the underlying theme throughout the experience is that a productivity measurement system has to be comprehensive enough to take into account the complexities of today's construction operations and ever increasing emphasis on sub-contract work packages as seen in project A; but simple enough to be effective as portrayed in The Last Planner system in project B. However, the reliability of using The Last Planner system to measure productivity was beyond the remit of this current study. Nonetheless, the experience of project participants in project B shows that it works in reality to help provide that informed view of on-site productivity levels needed to bring about improvements. Therefore, further work is required to establish the feasibility of using such a system in measuring productivity.

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