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Benchmarking masonry labor productivity

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REFLECTIVE PRACTICE

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Abstract

Purpose – Labor productivity is one of the most important factors that affect the physical progress of any construction project. In order to improve labor productivity, site production should be measured on a regular basis, and then compared to acceptable standard benchmarks. The objective of this paper is to measure masonry labor productivity in Gaza Strip, Palestine, using a consistent benchmarking approach.

Design/methodology/approach – Production data were collected from nine different construction projects located in Gaza. For each project, values for baseline productivity, disruption index, performance index and project management index were calculated.

Findings – Based on the nine targeted projects, the baseline productivity of masonry works in Gaza seems to range from 0.29 to 0.80 work-hours per square meter. Calculated values were utilized to develop a correlation between two project benchmarks (i.e. disruption and project management indices). AS only four out of the targeted nine projects performed reasonably well, the paper strongly recommends developing a benchmarking standard for each local construction firm in Palestine which may lead to an improvement in the national construction productivity.

Originality/value – The outcome of this research will improve the national construction productivity in Palestine and highlights the benefit of improving benchmarking standard.

Keywords Construction industry, Labor efficiency, Labour utilization, Benchmarking, Productivity rate, Palestine

Paper type Research paper

Introduction

In its simplest form, labor productivity could be defined as the hours of work divided by the units of work accomplished (Thomas, 1994). However, in reality, labor productivity is a much more complex phenomenon which largely depends on quite diverse factors such as site conditions, workers' competence, materials availability, weather, motivation, supervision, to name just a few. Management also affects labor productivity. Ganesan (1984), for example, reported that incompetent management of

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the industry and its construction agencies, whether these are public or private, is a prime cause of low productivity. Often, labor productivity is a key factor contributing to the inability of many contracting organisations to achieve their project goals, which include, most importantly, the profit margin. Therefore, it is paramount to understand the main determinants of labor productivity, and to keep and compare accurate records of productivity levels across projects. This approach which is simply referred to as benchmarking has gained popularity in many production and service industries. Put simply, benchmarking is "a systematic and continuous measurement process".

In construction, however, benchmarking is not a straightforward task due to both the very nature of the industry which lacks solid data gathering and the remarkable fluctuation in productivity. Benchmarking attempts in construction are bound to face certain difficulties such as incomplete or non-existent data. Even if data are well recorded and retrievable, it would be highly dependent on the special characteristics of the project, e.g. size, type and budget. Therefore, it is difficult to use it effectively as a basis for comparison. The structure of the industry with its temporary nature in organizing the construction process, where a number of organizations get involved in designing and constructing a single project, adds to the complexity of the benchmarking task (Mohamed, 1996).

Benchmarking construction productivity

Over the years, construction productivity has been the focus of many reported research studies (Abdel-Razek and Hosny, 1990; Thomas and Sanders, 1991; Abdel-Razek, 1992; Hosny and Abdel-Razek, 1992; Abdel-Razek, 2004). Also many attempts have been made to model construction labor productivity (Adrian and Boyer, 1976; Adrian, 1987; Abdel-Razek and McCaffer, 1990; Thomas and Zavrski, 1999a, b; Abdel-Hamid *et al.*, 2004).

Researchers have a long tradition of measuring productivity at the industry or macro-economic level, typically making a longitudinal study of productivity trends, but this high-level analysis does not provide an indication of firm level performance (El-Mashaleh *et al.*, 2001). At the micro-level, however, there is a vast literature addressing productivity at the project or even activity level. Previous literature examined various influences on productivity through both longitudinal and cross-sectional studies among contemporaneous projects and/or activities. Man-hours employed and work produced get measured and compared to past records, or compared with other firms to obtain measurements of how efficient a firm is in undertaking its activities (Thomas and Napolitan, 1995; El-Mashaleh *et al.*, 2001).

The scope of most construction productivity research has been on partial measures, principally labor. While useful at the activity level, partial factor metrics are limited. In particular, they do not address complex interactions between different factors both within and across projects. Thomas and Napolitan (1995) proposed a (total) Factor Model to measure productivity at the activity level. They suggested that several influences on productivity (e.g., skill level, weather, site conditions, management, etc.) are separable and additive in nature. Their model, however, does not address interactions within and across projects and hence, is not applicable at the firm level. This lack of having a productivity measurement methodology for contractors, at the firm level, represents a serious gap in construction research that likely retards industrial adoption of new methods. A productivity measure at the firm level has a host of benefits, as it supports (El-Mashaleh *et al.*, 2001):

- management decisions regarding resource utilization across projects to achieve highest return;
- management decisions about investment in resources and in mix of projects;
- benchmarking efforts, thus allowing contractors to better understand their competitive position and improve their performance; and
- comparative research of various management policies.

In particular, a firm-level productivity measurement methodology allows empirical evaluation of improved management policies. For example, lean production tools such as the Last Planner and Shielding Production (Ballard and Howell, 1998) are productivity improvement techniques at the project and activity levels. While these techniques have proven useful, there is no methodology that could relate the activity and project level performance to the firms' performance (El-Mashaleh *et al.*, 2001).

Benchmarking construction labor productivity has become an important research topic at the global level. Thomas and Zavrski (1999b) developed a conceptual benchmarking model for international benchmarking of labor productivity for selected construction activities. Their model is widely applied in order to compare labor productivity in one construction project to that of another, and to establish the basis of benchmarking labor productivity (Abdel-Hamid *et al.* 2004). This paper adopts the benchmarking model developed by Thomas and Zavrski and builds upon the work of Abdel-Hamid *et al.* (2004), to measure, analyze and compare masonry labor productivity across nine different projects located in Gaza, Palestine.

Research methodology

The model of Thomas and Zavrski (known also as the theoretical model for international benchmarking of labor productivity) comprises two main steps:

(1) Determining project attributes which include collecting data pertaining to total work hours, total quantities, cumulative productivity, baseline productivity and number of abnormal days.

(2) Calculating project performance parameters (benchmarks), these are: disruption index (DI), performance ratio (PR) and project management index (PMI).

Definitions and project attributes

(1) Total work hours: summation of daily work hours in each project.

(2) Total quantities: summation of daily quantities in each project.

(3) Cumulative productivity: a measure of the overall effort required to finish the work.

   Cumulative productivity (hr/m^2) =
   Total work hours (hr)/Total quantities (m^2)

(4) Baseline productivity: the best performance a contractor can achieve for a particular design. It is calculated by applying the following steps to the daily productivity values for each project (Abdel-Hamid *et al.*, 2004; Thomas *et al.*, 2002):

- Determine the number of workdays that comprise 10 percent of the total workdays observed.
- Round this number to the next highest odd number; this number should not be less than five (5). This number, *n*, defines the size of (number of workdays in) the baseline subset.
- The contents of the baseline subset are the *n* workdays that have the highest daily production or output.
- Calculate the sum of the work hours and quantities for these n workdays.
- The baseline productivity is the work hours divided by the quantities contained in the baseline subset.

(5) Number of abnormal workdays: it follows that high variability in daily productivity is associated with poor labor performance. Thus, an important measure of performance is the number of abnormal or disrupted days. The range of random variability in daily productivity values when the project is satisfactorily managed is about twice the average baseline productivity of all projects (Abdel-Hamid *et al.*, 2004; Thomas and Zavrski, 1999a, b).

Project benchmarks DI, PR, PMI

- *Disruption index (DI)*: The first measure of labor performance (benchmarks) is the disruption index (DI). It is a measure of the daily productivity disruption within a single project. The following definition was selected as the simplest form (Abdel-Hamid *et al.*, 2004; Thomas and Zavrski, 1999a, b):

  Disruption Index = Number of Abnormal (Disrupted) Work Days/
  Total Number of Work Days

- *Performance ratio (PR)*: The performance ratio (PR) is the actual cumulative productivity divided by the expected baseline productivity (average values of baselines for all projects). Thus, the following definition was adopted (Abdel-Hamid *et al.*, 2004):

  PR = Cumulative productivity/Expected Baseline productivity

- *Project management index (PMI)*: The PMI is a dimensionless parameter that reflects the contribution of project management to the cumulative labor performance on the project. The lower the PMI, the better was the project management's influence on overall performance (Abdel-Hamid *et al.*, 2004; Thomas and Zavrski, 1999a, b).

  Project Management Index (PMI) =
  Cumulative Productivity − Baseline Productivity/
  Expected Baseline productivity

Data collection

Data were collected from nine construction projects located in Gaza Strip in order to measure the labor productivity for masonry works. The targeted projects include residential buildings, schools governmental buildings, garage extension, and a university building. Table I shows the classification of the nine targeted projects. All projects data including crew size, daily work hours, and daily quantities (output) were

Project no.	Project name	Contractor	Project type	Total actual workdays
1	Noor El Maaref School	Abed Al-Hakeem Ismael Co.	School	18
2	Court House project	Moshtaha & Hassona Co.	Governmental building	114
3	Islamic Univ. building in southern area	Ata sons Co.	University	28
4	Building for General Personnel Council employees	Hettawi Co.	Residential building	83
5	Rehabilitation of packing houses in Goosh Kateef ex-settlement	Saqa & Khodari Co.	Rehabilitation project	16
6	Ministry of Justice	Jehan Co.	Governmental building	22
7	Al Amani building in Tal El hawa area	Abu Shmala Co.	Residential building	17
8	Al Zitoun school	Al Zitoun Co	School	14
9	Extension of Gaza municipality parking	Middle East Co.	Car parking complex	17

Table I.
Classification and characteristics of targeted projects

collected from the daily progress report sheet. Table II shows typical data collected for project number 1, The Noor El Maaref project.

Cumulative productivity = Total work-hours/
Total quantities = 590/1229 = 0.4801 whr/m^2

Data analysis and discussion

Project attributes

To obtain the baseline productivity value for each project, daily labor productivity was calculated using the five steps previously listed. The highest productivity scores (no less than five scores) were considered to define the baseline subset, and the average of these figures represents the baseline productivity in the project. To demonstrate, for Project no. 1, the best scores of daily labor productivity (i.e. the lowest calculated figures) were found as 0.3772, 0.3730, 0.3970, 0.3439 and 0.4055 whr/m^2 and, therefore, the baseline productivity for this project equals to the average of these five figures which is 0.3793 whr/m^2, see Table II and Figure 1. The average baseline productivity of the nine projects, under investigation, is the summation of the baseline productivity, calculated for each project, divided by 9. The average baseline productivity is 0.4755 whr/m^2.

Any daily productivity that exceeds the figure (0.9510), which is twice the average baseline productivity for all nine projects (0.4755 * 2 = 0.9510 whr/m^2), was considered abnormal. As such, all daily productivity values were compared to this figure in order to determine whether they are accepted or abnormal. The cumulative productivity of the nine projects ranged from 0.3453 whr/m^2 to 1.1782 whr/m^2. The cumulative productivity, in each project, is the total working hours in a certain project divided by the total quantities in the same project as shown in Table III.

Table III shows the total work hours, total quantities, cumulative productivity, baseline productivity and the abnormal workdays for each project. It could be seen that projects nos 2, 8 and 9 have the best baseline productivity figures, whereas project no. 3

Day	Crew size	Workhours (hr)	Daily qty (m^2)	Labor daily prod. (whr/m^2)	Baseline days
1	2	16	27.53	0.5812	
2	2	18	31.62	0.5693	
3	4	36	95.44	0.3772	*
4	6	48	128.7	0.3730	*
5	5	45	94.31	0.4771	
6	5	45	96.22	0.4677	
7	6	48	120.92	0.3970	*
8	5	40	116.31	0.3439	*
9	5	44	79.56	0.5530	
10	5	40	71.31	0.5609	
11	4	32	78.92	0.4055	*
12	4	36	51.91	0.6935	
13	5	40	60.2	0.6645	
14	4	32	46.02	0.6953	
15	2	16	34.96	0.4577	
16	3	24	46.4	0.5172	
17	2	16	28.79	0.5557	
18	2	14	19.89	0.7039	
Sum		590	1,229.01	0.4801	

Table II.
Data of Noor El Maaref project

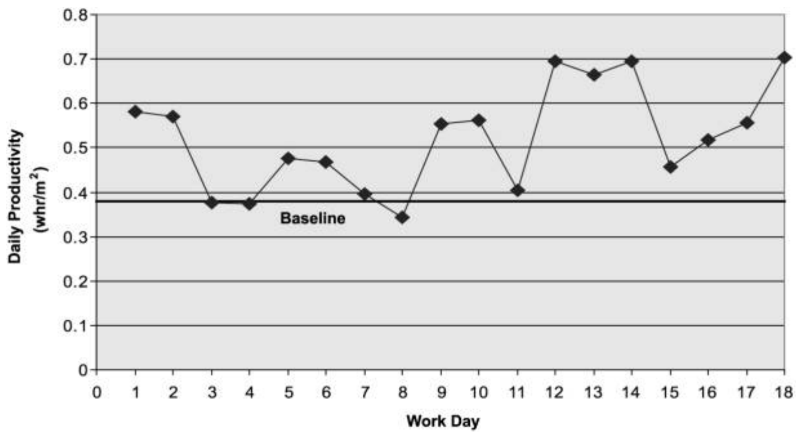

Figure 1.
Daily productivity: project number 1

has the worst baseline productivity which is 0.8012 whr/m^2. This is not surprising as this particular project experienced a remarkably high number of abnormal (disrupted) days (18 out of 28 working days).

Project performance parameters (benchmarks)

Disruption index

As previously mentioned, the disruption index is the number of abnormal days divided by the number of the total working days, this value ranges from 0.0 to 1. The higher the

Project no.	Total workhour (hr)	Total qty. (m^2)	Total work days	Cumulative prod. (whr/m^2)	Baseline prod. (whr/m^2)	No of abnor. days
1	590	1,229	18	0.4801	0.3793	0
2	3,208	9,270	114	0.3461	0.3012	7
3	648	550	28	1.1782	0.8012	18
4	1,997	4,153	83	0.4809	0.4332	14
5	453	452	16	1.0022	0.711	8
6	823	1,296	22	0.6350	0.4431	2
7	690	983	17	0.7019	0.5882	3
8	518	1,500	14	0.3453	0.291	0
9	543	1,370	17	0.3964	0.3312	1

Table III.
Project attributes

DI, the more abnormal days the project experienced (i.e. poor project). The calculated disruption indices for the nine projects are presented in Table IV.

Examining the DI values listed in Table IV reveals that projects nos 1, 2, 8 and 9 have DI values of 0.0, 0.061, 0.00 and 0.059, respectively. These projects with such very small DI values (less than 0.1) were not disrupted projects. On the other hand, projects nos 3 and 5 have DI values of 0.643 and 0.5, respectively. These two projects were highly disrupted and had performed poorly.

Performance ratio (PR)

Table V shows the performance ratios of all nine projects, the lower the PR the better the project performance. It could be noticed that projects nos 2, 8 and 9 have the best performance ratios among the nine projects, with project no. 8 having the lowest ratio (best performance).

A number of projects performed poorly, most notably projects nos 3 and 5 with PR values of 2.48 and 2.11, respectively. These two projects have high PR values (PR > 2.0) and also have high DI values (DI > 0.4). It is worth mentioning that the nature of the rehabilitation work in project no. 5 partially explains the relatively low productivity rates. Resource shortage was also experienced in project no 3. On the contrary, resource availability together with proper planning and follow-up procedures contributed to achieving the best baseline result in project no. 8. Generally speaking, the PR value

Project no.	No of abnormal days	Total work days	Disruption index (DI)
1	0	18	0.0000
2	7	114	0.0614
3	18	28	0.6429
4	14	83	0.1687
5	8	16	0.5000
6	2	22	0.0909
7	3	17	0.1765
8	0	14	0.0000
9	1	17	0.0588

Table IV.
Disruption indices

Project no.	Disruption index (DI)	Cumulative prod. (whr/m^2)	Performance ratio (PR)
1	0.0000	0.4801	1.0096
2	0.0614	0.3461	0.7278
3	0.6429	1.1782	2.4778
4	0.1687	0.4809	1.0113
5	0.5000	1.0022	2.1077
6	0.0909	0.6350	1.3355
7	0.1765	0.7019	1.4762
8	0.0000	0.3453	0.7263
9	0.0588	0.3964	0.8335

Table V. Performance ratios and disruption indices

identifies the poorly performing project. It should be noted, however, that a PR value greater than 1.0 does not necessarily mean a poorly performing project, but rather is a comparison against the best overall performance observed in all projects. For example, projects nos 1, 4 and 6 have PR values greater than 1.0, but they have all performed reasonably well.

Project management index (PMI):
This index reflects the contribution of the project management to the cumulative labor performance on the project. The lower the PMI value, the better is the project management's influence on overall performance. PMI values for the nine projects are presented in Table VI. From Table VI, it could be concluded that projects nos 1, 2, 4, 7, 8 and 9 with PMI values less than 0.4 performed reasonably well. The same could not be said about projects nos 3 and 5 with PMI values 0.79 and 0.61, respectively.

Relationship between PMI and DI

Reviewing the PMI index and disruption index values reveals a strong relationship between the two indices. If the number of abnormal days increases in a certain project, the disruption index becomes larger and most often the reason behind such a case is poor project management. The results obtained for both indices support the correlation between the two indices. The worst PMI value (i.e. the highest value obtained) among all nine projects was obtained for project no 3, and is equal to 0.79. This was attributed

Project no.	Cumulative prod. (whr/m^2)	Baseline prod. (whr/m^2)	Project management index (PMI)	Disruption index (DI)
1	0.4801	0.3793	0.2119	0.0000
2	0.3461	0.3012	0.0943	0.0614
3	1.1782	0.8012	0.7928	0.6429
4	0.4809	0.4332	0.1002	0.1687
5	1.0022	0.7110	0.6124	0.5000
6	0.6350	0.4431	0.4036	0.0909
7	0.7019	0.5882	0.2392	0.1765
8	0.3453	0.2910	0.1143	0.0000
9	0.3964	0.3312	0.1370	0.0588

Table VI. Project management index PMI and disruption index DI to the increased number of abnormal days (18 days were abnormal out of 28 total actual working days and thus producing the lowest value of disruption index which is equal to $18/28 = 0.64$).

The increased number of abnormal days, in a certain project, reflects poor project management and poor labor productivity. Higher values of both DI and PMI are indications of sub-standard labor performance and poor management. As the PMI continues to increase in value, one would expect more abnormal days or disruption, and accordingly the DI also increases. When the DI exceeds the value of 0.5, the PMI increases at a higher rate, as shown in Figure 2, which demonstrates the exponential correlation ($R^2 = 0.6336$) between the two indices.

Conclusion

Daily labor productivity for nine projects in different locations in the Gaza Strip were investigated in order to determine the value of the baseline productivity in each one. Also other project benchmarks such as disruption index (DI), performance ration (PR) and project management index (PMI) have been calculated for all nine projects. The DI and PMI indices were found to have a correlated relationship. The higher values of both indices indicate poor labor productivity.

Checking the DI values in the nine projects reveals that the higher DI the more likely the project experienced abnormal work days (poor productivity). DI values for four projects were found to be very small (i.e. less than 0.1) indicating that four out of nine targeted projects performed reasonably well. Also, the PMI values of in these four projects were found to be less than 0.4, therefore both of DI and PMI could be considered as guiding indicators of project labor performance.

It was also noticed that two out of the nine targeted projects were performing badly as their DI values were higher than 0.4. The PR and PMI values for these two particular projects were greater than 2.0 and 0.5, respectively.

The management of each contracting company should maintain its own record which describing the baseline productivity in different previous projects with similar conditions. Such records help estimating labor productivity in future projects. Also the project managers should be capable to interpret the reasons behind the differences in

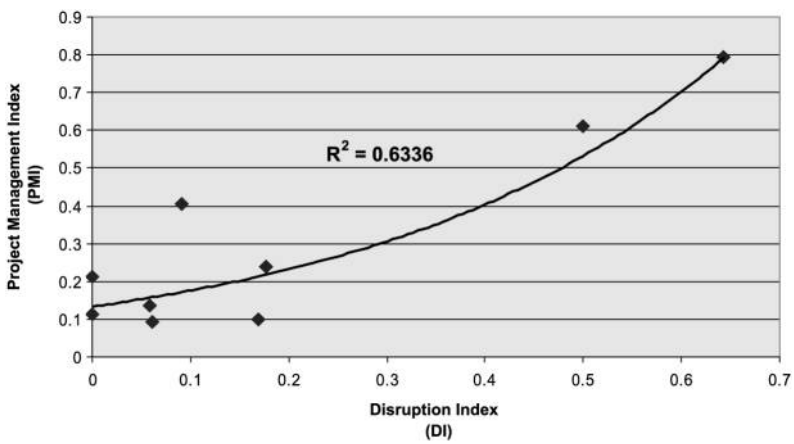

Figure 2.
Disruption index vs project management index

the productivity values in different projects. At the site management level, a daily progress report must include the required information necessary to obtain the baseline productivity. It is strongly recommended to develop a benchmarking standard for each construction firm in Palestine, which may lead to an improvement in the national construction productivity.

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