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# Construction Site Productivity Measurements

*Selection, Application and Evaluation of Methods and Measures*

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## ABSTRACT

A construction company consists of a number of different sites where the physical production is taking place. This production is not always performed in the best possible way. There are numerous things such as organisation, logistics, co-ordination, technique, quality and others that can be improved. To have a process of continuous improvement at sites it is necessary to be able to evaluate their performance. Doing this only in terms of profits, which is the most common way, is not sufficient. Other ways of evaluating site performance such as productivity measurements are therefore needed.

The purpose of this study was to find measures of productivity which could be used to evaluate site performance. Such measures should be cheap, understandable, univocal and be possible to relate to company objectives.

With the results from productivity measurements a process of internal benchmarking could be initiated at construction companies. This could make it possible to find sites with excellent performance, investigate the factors of importance for such performance and try to use these results in a process of continuous improvement. Finding such determinants of site productivity is of vital importance for the improvement of the performance of a company.

The overriding method in this work has been to "steal" ideas from others. By investigating how others had been measuring productivity and by evaluating these measures, the expectation was that measures would be found that could be applied on construction sites. However, a number of other and more "well defined" methods such as Data Envelopment Analysis, inquiries, multiple regression analysis, case studies and practical tests have been used.

Data Envelopment Analysis (DEA) had not previously been used to measure construction site productivity in Sweden. DEA was used to analyse 104 projects constructed during the period 1989 to 1992. The output factor used was value added, and the inputs were the costs of staff, workers and machines. The projects analysed included 33 office buildings, 40 blocks of flats and 31 roads and bridges, and the total invoicing amounted to SEK 2 232 million. Substantial differences in input saving efficiency could be noted regarding the projects included in the analyses.

A second step in this benchmarking process was that of trying to relate the differences in efficiency to variables affecting the result. A questionnaire was therefore sent out to all the site managers. This information, together with the results from the DEA, was then analysed using multiple regression. The result was that variables such as additional work ordered by the client, formal education and employment time of the site manager and participation of workers in planning did not seem to have any significant effect for any of the types of products studied. For the blocks of flats the variables which showed a negative correlation with the result from the DEA were extended construction time, design and build contract, major parts prefabricated and serious disturbances. The only positive variable was in-house design.

For the offices, variables such as a large share of the work being performed by subcontractors and a high proportion of the people employed being staff, were positive, while many different persons being involved in planning before the actual start of construction were negative.

For the roads and bridges studied the positive variables were in-house design, a high proportion of staff, and many different persons being involved in planning before the start of construction work. The negative variable found was in this case high wages to the workers.

Manufacturing industry exposed to foreign competition was assumed to have used measurements of productivity for a long time. Case studies were therefore performed at a number of production units throughout Sweden to find out how such measurements were made and how the results were used. As a reference case studies were also made at three sites within the construction industry. The findings were that there were large differences between the plants studied in the manufacturing industry and the construction industry.

One of the major differences was the extent of the measurements. The units studied in manufacturing used many more different measures than did the construction sites studied. Another important and clear difference was the purpose of the measurements. The measurements performed in the manufacturing industries studied had several purposes. The main aim was to use the results for a comparison with those of competitors or with other units within the same company. The results from the measurements were also used to inform and motivate the employees, follow-up investments in new technology or changed organisations, control operations and as a basis for bonus wages. At the construction sites studied, on the other hand, the results were used mainly for cost forecasts and for estimates in connection with tendering.

The most frequently used measure was labour productivity, and the reason for this was that labour productivity was considered to be both important and easy to understand. Other measures were, however, used to evaluate performance such as delivery time, stoppage times, actual hours or costs versus budgeted, energy used and many others. All these measures were considered by the company management in the manufacturing companies to be important for controlling their operations. At the construction companies the results were mainly used by the site managers to estimate the final costs.

A general conclusion was that making performance measurements is never an easy task. There are always shortcomings with the measures chosen. In spite of this the advantages of measuring instead of not measuring are great when it comes to having a process of continuous improvement in a company.

Various key ratios were measured at eight construction sites in northern Sweden and the results were evaluated. The different projects were followed for periods of between three months to one year with the help of personnel at the sites. The key ratios chosen

were selected after performing the DEA and the case studies and after discussion with the persons at the sites. The key ratios were used to measure labour productivity, machine productivity, machine utilisation, material stock, material consumption, quality, actual hours versus budgeted hours, actual time compared to scheduled time and attendance. All these measurements showed that almost all the measures used could be obtained with limited effort with regard to both time and money. The results also contained valuable information which could be used to control site operations in a better way than that of today.

Labour productivity was measured regularly using both value added and physical units as outputs. The use of value added was as a result difficult, mainly due to the great variations in site turnover. The results were easier to evaluate when physical units were used. These measurements, however, in some cases required more time. The measurements of material consumption, which were made using both physical quantities and monetary value, were also in most cases easy to perform. Due to changes in both quality and size the results were sometimes difficult to interpret when physical quantities were used. Measuring actual costs, or hours, versus budgeted showed that this method of measuring is relatively easy but it also has many disadvantages. If such measurements are compared with the results from other sites it is necessary to use a reference against which these comparisons can be made. Informing and discussing the results with the workers revealed that there was a great interest from the workers in having feedback regarding their performance.

A number of general conclusions regarding the execusion of measurements of site performance were drawn based on the results from the data envelopment analysis, the case studies and the tests with key ratios. One was that measurements of site performance could serve two purposes. The first was as a strategy tool for company management. By using the results from the site measurements in an internal benchmarking process it could be possible to identify sites with excellent performance within the company. By finding the characteristics of the good and the bad projects company management can improve competitiveness and long term profitability of the company. The second purpose was as a help for the site management in their daily work. The results could thus be used in a process of continuous improvement on site.

In the selection of measures the purpose of the measurements should not soley be considered. The type of product also determines what measures should be used. For simple products with short manufacturing times and low complexity physical outputs should be used. For complex products with long manufacturing times the product has to be broken down into smaller, more measurable parts.

Most of the data required to perform measurements are already available, or can be obtained with a moderate amount of effort. By using the workers for collecting and reporting some of the data, the work for the site management in this regard would be facilitated. This would, however, require that there would be a different flow of information than that of today. The workers should have more information regarding development at the site than they have today. There should also be a different flow of information from the site to the main office. The sites should report productivity data

which could be used in an internal benchmarking process where the prerequisites for good performance could be known to all sites and where excellent performance could be used as a reference.

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