Performance Evaluation in Civil Construction

Its application to a railway work

Extended Abstract

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1. INTRODUCTION

The measurement of performance is an essential tool for companies from many different sectors. However, its implementation in the building industry has not been made with little difficulty. This is due to certain characteristics of this sector, which appears as an unpredictable business, where the competition is based on price and not on quality, with few obstacles against elements of low efficiency. In short, the construction industry tends to treat the client, regardless of this being the owner of the project or the end user, as a secondary party. The industry focuses essentially on the next element in the contractual chain.

The overall objective of this work is, therefore, to define a group of performance indicators that allow the monitoring of construction procedures and verification of their implementation in accordance with the plan.

The information provided by the indicators should be used in the communication between the builder and the customer/owner of the construction project, so that the latter can monitor the status of construction, and should also serve as a basis for implementing the changes required in each procedure, allowing optimisation efficiency and enhanced performance.

In this study, the selection and implementation of performance indicators in a construction project of removal and conversion of railway level crossings is presented. Moreover, the present study seeks to verify the viability and efficiency of the performance indicators under real construction conditions.

2. MEASUREMENT OF PERFORMANCE

The measurement of performance began in the beginning of the twentieth century as a response to a market demand that exceeded production. Companies needed to develop ways to increase their output by improving the efficiency of production time, while trying to cut costs in order to provide products at competitive prices and ensure profits.

The concept of measuring performance has grown over time to include both financial and non-financial measures, hence providing the organizations with information for preparing forecasts and conceptualizing trends.

The measurement of performance can be defined as a process in which it is decided what to measure and the collection, monitoring and analysis are made. In addition to the process of
measuring, it is necessary to evaluate the performance. This is defined as a procedure in which the standards, the specifications, the requirements and the values or judgements are set to determine the level of performance that meets the needs and expectations of customers and processes.

The purpose of measuring performance entails the anticipation, estimation of significance and solving capacity of arising problems. Furthermore, it aims to control the variation of performance in relation to previously established behaviour patterns, identifying shifts and correcting the causes.

3. PERFORMANCE INDICATORS

An indicator of performance is a mathematical relation that, through pre-set numerical targets, allows identifying the status of a process or its outcome. Performance indicators help assess the progress of an activity, by making comparisons with previous situations and/or through the establishment of relationships with a predetermined reference.

In a broad sense indicators are guides that allow us to measure the effectiveness of our actions. They are rational and objective information to quantify the performance and reduce the subjectivity of the measures.

Performance indicators should meet certain requirements, so that their effectiveness is guaranteed, including:

- **Selectivity**: indicators should be related to essential or critical factors associated with the process under evaluation;

- **Representativeness**: the indicator should be chosen or formulated so that it can adequately represent the process or product to which it pertains to;

- **Simplicity**: they should be easy to understand and apply mainly to those directly involved with the compilation, processing and evaluation of data;

- **Affordability**: they must be generated at low cost. The cost for collecting, processing and evaluating of information must not exceed the obtained benefits. Data already available in the company which was collected through currently implemented systems or procedures can be used for this purpose;

- **Accessibility (transparency)**: The data for calculating the indicator should be easily accessible and made available, preferably, through visual mechanisms;
- **Stability**: must be collected based on routine based procedures which are part of the companies’ activities and on procedures that enable their comparison or analysis of trends over time;
- **Experimental approach**: it is recommended to develop indicators considered as necessary and then test them;
- **External comparison**: some indicators should be developed to allow comparison of the performance of the company with that of other companies in the sector or companies from other sectors, so that they can be used as benchmarks and in the evaluation of the companies’ competitiveness within its field;
- **Continued improvement**: the indicators should be periodically evaluated and, where necessary, should be modified or adjusted to respond to changes in the organizational environment and thus keep its purpose and validity.

In this work, the process of choice selected comprised the monitoring of a series of actions which enabled that the indicators selected were the most consistent with the objectives of the company under evaluation: (analysis and study of existing performance indicators; analysis of all types of maintenance indicators used in several companies; definition of objectives and indicators; establishment of all the objectives that must be considered in the project, including the objectives of the company and all the objectives related to maintenance; identification of indicators that have an effect on the performance of maintenance (quality, deadline, costs) and, finally, the selection of performance indicators.

The literature review carried out has shown that many authors separate the indicators in different types, depending on the type of company that uses them as well as the type of information intended to be measured and communicated. In this work, the selected indicators were divided into two types:

- **Monitoring indicators** - provide information that enable to check the status of processes and seek to control the activities. The information provided by this type of indicator can be used in the correction of activities;
- **Assessment Indicators** - are based on the final results of the procedures and can be used as a benchmark for future similar activities or for comparison with pre-established values. Its value is intended to help undertake the general assessment of the procedures.

The indicators chosen for the case study were divided into several groups and are summarised in the table below:
<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Indicators</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic / Planning</td>
<td>(1)</td>
<td>Index of project changes</td>
<td>Assessment</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>Cost deviation</td>
<td>Assessment</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>Schedule deviation</td>
<td>Assessment</td>
</tr>
<tr>
<td></td>
<td>(4)</td>
<td>Percentage of accomplishment of contract schedule</td>
<td>Monitoring</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>Cost of nonconformance</td>
<td>Assessment</td>
</tr>
<tr>
<td>Equipment</td>
<td>(6)</td>
<td>Rate of equipment-related problems</td>
<td>Monitoring</td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>Equipment reliability</td>
<td>Monitoring</td>
</tr>
<tr>
<td>Supplies and External Services</td>
<td>(8)</td>
<td>Delivery of materials / Evaluation of suppliers</td>
<td>Assessment</td>
</tr>
<tr>
<td></td>
<td>(9)</td>
<td>Index of Subcontracting</td>
<td>Assessment</td>
</tr>
<tr>
<td>Health and Safety</td>
<td>(10)</td>
<td>Index of incidence of accidents</td>
<td>Monitoring</td>
</tr>
<tr>
<td></td>
<td>(11)</td>
<td>Index of frequency of accidents</td>
<td>Monitoring</td>
</tr>
<tr>
<td></td>
<td>(12)</td>
<td>Index of severity of accidents</td>
<td>Monitoring</td>
</tr>
<tr>
<td>Environmental Impact</td>
<td>(13)</td>
<td>Rate of water consumption</td>
<td>Monitoring</td>
</tr>
<tr>
<td></td>
<td>(14)</td>
<td>Rate of electrical energy consumption</td>
<td>Monitoring</td>
</tr>
<tr>
<td></td>
<td>(15)</td>
<td>Rate of fuel consumption</td>
<td>Monitoring</td>
</tr>
<tr>
<td></td>
<td>(16)</td>
<td>Rate of oil consumption</td>
<td>Monitoring</td>
</tr>
<tr>
<td></td>
<td>(17)</td>
<td>Management of solid waste</td>
<td>Monitoring</td>
</tr>
<tr>
<td>Human Resources</td>
<td>(18)</td>
<td>Employee satisfaction</td>
<td>Assessment</td>
</tr>
<tr>
<td></td>
<td>(19)</td>
<td>Rate of absenteeism of employees</td>
<td>Monitoring</td>
</tr>
</tbody>
</table>

Upon careful selection the indicators, the collection of their values was done in the field, more precisely in the construction yard, with the help of the company’s employees, including the engineer responsible for the project and the engineers responsible for the areas of Quality and Safety and Health.

The groups of selected indicators are characterized as follows:

**Economic/Planning Indicators**- This group of indicators are focused on the comparison of costs and predetermined deadlines, with those that actually occur during the construction phase.
Equipment Indicators - This group of indicators are focused on analyzing the quality and reliability of the equipments used in the construction project, taking into account the number of malfunctions that occur during their use.

Supply and External Services Indicators - A company responsible for a construction contract depends not only on their employees, but also, to a large extent, on the hiring of external services and the requisition of material from many suppliers. That said, this group of indicators are meant to enable the analysis of the quantity and quality of the two factors mentioned above.

Safety and Health Indicators - This group of indicators convey the security level of the construction project, based on the number of recorded accidents and their severity.

Environmental Impact Indicators - Given the importance of protecting the environment, it is not of little relevance the use of an effective environmental management policy. The indicators of environmental impact are used not only to examine the environmental impact caused by the construction project in the surrounding environment, but also to assess the degree of commitment with environmental issues demonstrated and the actions taken by the company to reduce the impacts on the environment.

Labour and Human Resource indicators - This group of indicators help evaluate employee satisfaction and reflect the dedication of the company to its employees and also the interest in the quality of their work.

4. APPLICATION OF INDICATORS TO THE CASE-STUDY

The case-study consists of a project of removal and conversion of level crossings on the railway lines of Evora and the Alentejo. Its purpose is to facilitate the crossing of the road with the rail track while improving their safety.

The project consists of six components, which correspond to the construction of two tunnels and four overpasses together with the reestablishment of access roads.

After choosing the performance indicators, it was made de collection of its values on the field. It’s important to refer the lack of official data record. That fact seems to emphasize the idea that the construction industry still has a long way to go in terms of measuring performance.

The application of performance indicators and monitoring at the construction project site enabled to reach the following results and conclusions:

a) There were 32 project changes registered. Changes were not significant and had little influence on the costs and timing (fulfilment of deadlines) of the work.
b) The actual cost of construction was 18.7% (512.800€) higher than expected, due to mistakes and unexpected work.

c) The actual duration of the project was 36.3% (87 days) larger than expected.

d) The schedule established in the contract was only fulfilled starting on the month of March 2008. Until March of 2008, the percentage of accomplishment of contract schedule was negative, which meant that the work was behind schedule.
e) The cost of non-conformance was very small, only 0,088%. This is a very low value, therefore, a positive indicator. Though, this also can mean that the contractor did not respect the Quality Control criteria by registering all the non-conformances.

![Construction cost/ Non-conformance cost](image5.png)

Image 5 – Construction cost and non-conformance cost

f) The average value observed was 0,0019 malfunction/hour. This value corresponds to a large rate of machinery malfunctions, in that the reliability of the equipment decreased significantly over time. These types of results are essentially due to a couple of problematical machines.

![Rate of Machinery malfunctions](image6.png)

Image 6 – Rate of machinery malfunctions

![Machine reliability (per machine) over time](image7.png)

Image 7 – Reliability per machine over time
g) In relation to the reliability of suppliers, there was only information about the steel supplier. Only 5% of the steel supply was irregularly delivered (delayed), which demonstrated high effectiveness in the delivery of the materials.

h) It was found that most of the construction project is performed through outsourcing of external services (84%).

i) The safety at the construction site was found to be high, with only two non-serious accidents over the course of the project.

The company goal, in terms of working safety, correspond to a frequency index of 25 accidents/1.000.000 man-hour worked. This goal was achieved by de subcontracted
companies after January of 2008 and by the contractor employees only in April of 2008.

j) The company demonstrated to have good environmental management policies. All data on water, fuel and electricity consumption were formally registered. The solid waste management is also noteworthy for its high standard, after responding positively to a carefully premeditated inquiry.

With the analysis of these four consumptions rates, we can verify that the biggest consumptions were registered mostly between September of 2007 and January of 2008. These months
coincide with the excavations phase of the construction work, when the large machinery achieved its working peak.

k) Employee satisfaction proved to be high. They were asked a several questions about their global opinion about the working condition and environment.

![Employee Satisfaction Graph]

Image 15 – Results of the inquiry about employee satisfaction

i) The number of absences unrelated to accidents was low, but its formal registration was inexistent, with only an average value available for the calculation of the rate of absenteeism. Only this average value (8h/month) can be analysed with reliability.

5. CONCLUSIONS

One of the conclusions that can be drawn from this work is that, to achieve an effective measurement of performance on construction projects it is important to derive a strategic plan from the outset of the project. When all actions to be taken are established, it becomes easier to conduct their monitoring.

The literature review indicated that construction, despite being a sector that deals with many variables, can evolve to follow the path that companies from other sectors have taken in terms of the measurement of performance. Thus, it is possible to improve the planning of construction projects, thereby reducing the margin of error and variation in costs and delays.

Also, the quality of procedures tends to evolve based on the observation of previously collected information. A good example is the preference of a certain type of equipment over another based on the analysis of the indicator of reliability previously calculated.
This study is a demonstration of the use of a system of monitoring and performance indicators for a construction project.

One of the difficulties of this study had to do exactly with the collection of information for calculating certain indicators. The process of data recording on the majority of cases presents flaws and is not carried out formally.

The entire study and research conducted show that the building industry in Portugal does not yet obtain financial advantages of using this system of collection and presentation of information.

Aside from the reports on the environmental management system, registration of work-related accidents and financial schedule of the contract, no further action is taken to monitor the performance of the construction project. This situation seems to be widespread throughout the industry.

However, the results obtained in this study show that the accurate analysis of information provided by the indicators can be very useful and effective in relation to the performance of procedures carried out in companies within the construction industry.