Applying a Combined Chronometric-Simulation Method for Optimizing Operation Management in Construction

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This paper describes a Croatian educational experience about the possibility of implementing a combination of the famous method of "work study" and the most modern simulation software to improve construction production. For the first time the students observed the capital technological construction processes "on site" and then measured the necessary time for their execution by the well known "chronometric" method. During the second exercise they analyzed the real observed processes and the sample of collected data. After that, they made a "graphic-simulation" model using the best-known software "Stroboscope" for simulating "just" the construction technological processes. At the end of their training exercise, the students concluded about the possibilities of improving technological construction processes on a "real site". The main goal of this paper was to describe the "real process" of real education for some regular Croatian students. The simulation of construction processes, with real collection of data, may train the students about what to do in real situations. Of course, this paper presents only the general approach without greater detail.

Keywords

Construction Management, Productivity Estimation, Chronometric Measurement System, Discrete-Event Simulation Systems, Croatian Construction Sector

INTRODUCTION

The twenty-first century poses numerous challenges to the national construction industry. On one level we need to develop a coherent classification system if the concept of e-business is to be adopted on an operative level in the construction sector. On another level, companies are still engaging in larger and more complex projects that are increasingly difficult to plan and implement. At the same time, existing codes for construction operations are becoming less and less accurate, as they were created to serve large business systems that formerly existed under different economic, technological, and societal conditions. Most of these large systems ceased to exist during the period of political transition. Although most of their know-how is preserved in the form of smaller, project-based organi-

zations, creating common standards remains a serious challenge. Sector leaders are promoting the competitiveness of the national construction sector, but not enough attention has been paid to the development and implementation of techniques that would enable professionals to continually measure company's productivity in field. This would enable them to improve their processes more easily to contribute to the company's overall competitiveness.

This paper uses two simple methods to determine the productivity of a construction process. These methods can be used by most construction professionals in their daily work to help them to plan the processes within projects better.

Multiple companies usually participate in the execution phase of every larger project. These companies normally use different standards for estimating the site productivity of their operations making the process of planning and control quite difficult for project managers. To reduce this problem, simple methods can be used by either the project manager for estimating the productivity of a project comprising numerous companies, or for the sole purpose of building an internal company database of productivity on different projects.

Methodology

This study began as the product of our students' education process on the post-graduate course entitled "Construction Management" as part of the teaching program of the mandatory course "Work Study". The students learn practically by using well known methods for standardizing construction (for instance the "chronometric method") recording the development of the process on the site and the latest software for simulating the construction process (e.g. Stroboscope) on a PC in the faculty classroom.

As part of the teaching program within the mandatory subject "Teaching on site" the students went on an organized tour of building sites in Zagreb and/or the Republic of Croatia, where quite complex and in a professional sense interesting buildings are being built. Through the helpful cooperation of those responsible for both subjects, the students were enabled at one of the building sites in question first of all to become well acquainted with the technology of construction, the main construction processes, as well as the practical application of well-known methods of modeling and standardization in real construction work. This study also shows one such example during the installation of the main prefabricated flanges of the sports arena for the World Handball Championships, which were held successfully in Zagreb in 2009.

Croatian national construction sector executives have reached a consensus in using the Chronometric Measurement System for conducting internal work studies due to the legacy of this method, its statistical validity and the methodology presently used in the bidding process (which comprises price estimation based on statistical databases of work productivity).

The method establishes a minimal number of values for measuring a specific process. This minimal number is determined by methods of mathematical statistics, according to the obtained dispersion of measured values. For example, if the test measurement series comprises of 10 values, then the total number of values is obtained using the following equation (Žerjav et al. 2008):

$$n = 169 \frac{(t_{max} - t_{min})^2}{(t_o)^2}$$

where t_{max} is the largest value and t_{min} the smallest value obtained by test measurement series, and where the average value of the test series is:

$$t_o = \frac{\sum_{i=1}^{n} t_i}{n}$$

After measuring durations in the final set of values as previously determined, they are integrated into a statistical model to obtain the corresponding final average values that are further elaborated by the following coefficients, as perceived by the person conducting the measurements:

- Estimated level of work efficiency,
- Estimated external influences (such as the weather, overall organization of the processes, etc.)

Thus, a normative value regarding duration and productivity of a specific process is obtained statistically.

These normative values are relevant to companies for creating internal databases to be used in future bidding procedures, as professional codes of practice suggest methods of cost estimation based on such databases. In addition, companies need such a formal database to be able to improve their operative processes and in-field productivity.

Simulating the Test Case

The next step in operations design would be incorporating these field measurements into a simulation system, providing a better overview of the construction process, thus facilitating its optimization.

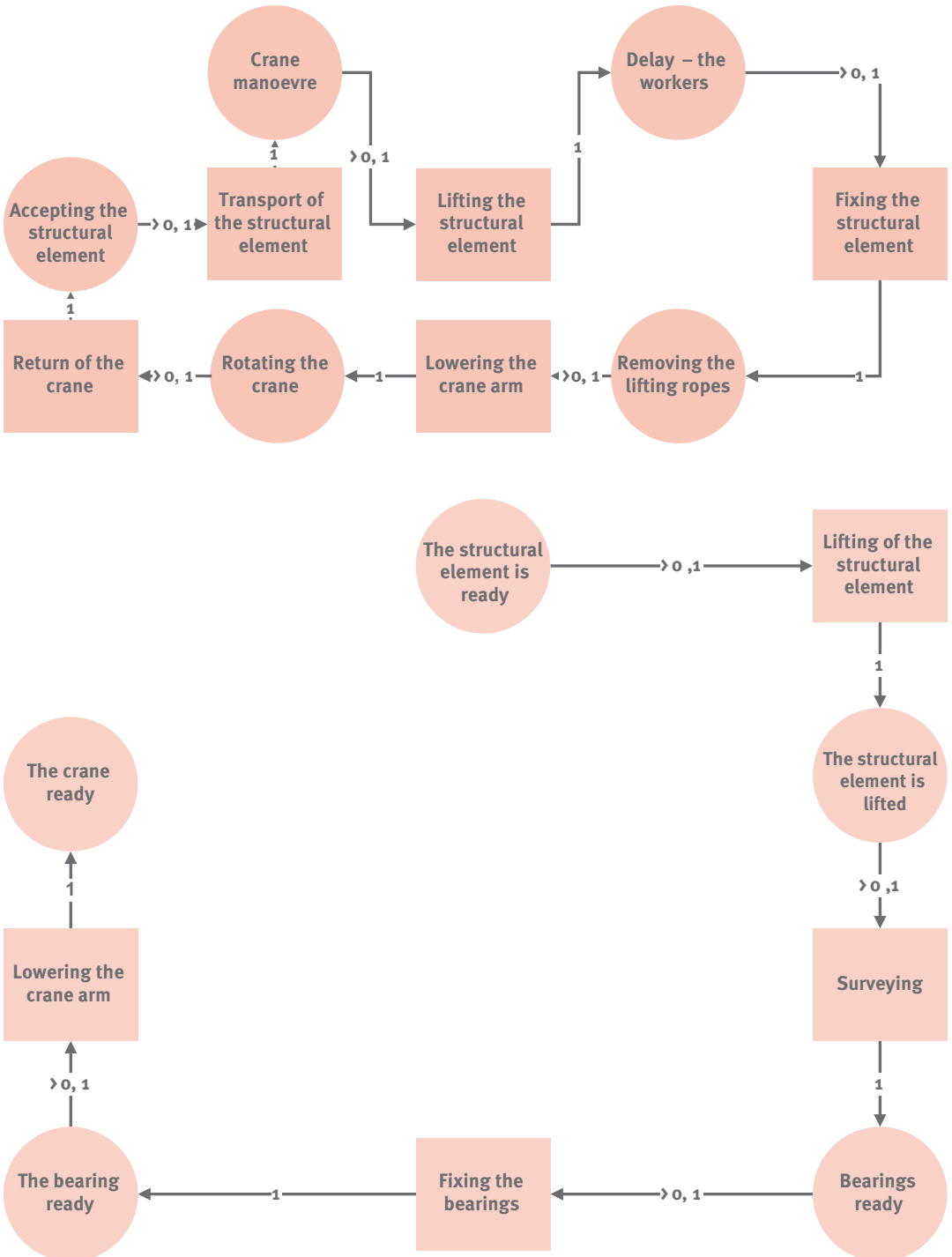

Figure 1. **The Stroboscope model for jobsite transportation and manual installation of a single heavy structural element**

Discrete-event simulation systems are the simplest and most widely used tools for this purpose. A project can be partially simulated to reduce overall programming and still keep most of the benefits that simulation provides. Important parts of the project to be simulated can be chosen based on following criteria:

- Complexity: adopting a discrete-event-simulation based approach makes sense only if the operations comprising the construction process are complex enough.
- Machinery work – driven: Machine-work-driven processes can produce a consistent modeling output as they are modeled more easily than manually–driven processes. Also, these processes can be accurately measured and subsequently put together in the form of a logical model.
- Variety: The idea is to eventually integrate the obtained partial models and create a more complete picture of the interdependencies be-

tween construction operations in a complex construction process.

The authors decided that Stroboscope simulation system is the most easy to use tool for this purpose, because of its convenient graphical user interface, elaborated user manual and availability of a brief tutorial (see Martinez 1996).

The rest of the process is explained through a previously conducted experiment at the Construction Management Graduate Program (Žerjav et al. 2008). The main observed process was jobsite transport and installation of a heavy structural element. The process was mainly driven by construction machinery (two mobile cranes), but it also included a portion of manual work during the installation phase. The building structure consisted of a number of such structural elements, so it was convenient to model this operation, as it is repeated many times during the construction process (Martinez 1996). Simulation output gives information about the duration and productivity of a modeled cycle (Ioannou 1990). Figure 1 demonstrates two simulation models from the final phase of transport and installation of a single element. A complete picture of the process could be reconstructed from the models by measuring the average durations of transport for all structural elements and incorporating them in the initial model. Transport durations differ for each element, and average duration value can be calculated from the data obtained at the construction site. A relatively accurate model for the complete construction process can be obtained by incorporating average duration value in the model, and setting a correct value for a given number of cycles.

The obtained model can further be expanded by integrating the obtained separate models into a single model encompassing a wider range of construction operations on the jobsite. This model would give a more realistic representation of more processes taking place at jobsites, thus playing a decision support role in site managers' practice, when properly used (Halpin and Martinez 1999).
From the following three figures (Figures 2,3 and 4) you can see the real education exercise of our ordinary students who investigated the construction technological processes "on real site":

Integration of approaches

According to the current authors' experience, local companies need to integrate both approaches to better plan and execute their construction operations. Creating comprehensive internal normative databases would help companies set internal standards for their products and services. Although many larger companies have, through time, elaborated their normative databases, small and medium sized companies still need to create them, to further stabilize their

Figure 2. **The real "site" of Zagreb Arena**

Figure 2. **The construction part of Zagreb Arena**

Figure 4. **Students observed processes and "snap-shots" of Zagreb's arena"**

market position and to reduce risk in planning their projects. Simulation techniques are complementary to this process as they enable an preliminary evaluation of multiple design options for construction operations in the bidding phase of a project, and better control of ongoing construction processes during the execution phase.

CONCLUSION

These techniques, if properly used, can lead to the next step of the national construction sector innovation – engaging more heavily in IT enabled integration and interoperability throughout the sector (Izetbegovic et al. 2004). Comprehensive normative databases of construction products and services would lead to better standards, which, in turn, enable the proliferation of e-business practices, such as the creation of a national classification system for products and services in construction, e-tendering, integrated modeling and design of projects, online collaboration on projects (Wilkinson 2005), etc.

REFERENCES

Halpin, D.W. and Martinez, L.H. (1999). Real World Applications of Construction Process Simulation, Proceedings of the 1999 Winter Simulation Conference, Society for Computer Simulation, San Diego, CA, USA, 956-962.

Ioannou, P.G (1990). UM - CYCLONE, Discrete Event Simulation System, Reference Manual, Center for Construction Engineering and Management, University of Michigan, USA.

Izetbegović, J., Orešković, M., and Bandić, M. (2004). "Primjena i razvoj informatičke tehnologije uhrvatskom graditeljstvu." *GRAĐEVINAR*, 8(56), 481-488.

Martinez, J.C. (1996). STROBOSCOPE: State and Resource Based Simulation of Construction Processes, PhD Dissertation, The University of Michigan, Ann Arbor, MI, USA.

Wilkinson, P. (2005). *Construction Collaboration Technologies: An Extranet Evolution*, Taylor & Francis, London.

Žerjav, V., Izetbegović, J., Linarić, Z. (2008) A Discrete-Event Simulation Based Model of a Construction Site: A Teaching Experience, Proceedings of the 8th International Conference in Organization, Technology and Management in Construction, Sept 17-20. 2008., Umag, Croatia.

Žerjav, V., Izetbegović, J., Bezak, S. (2009) Application of Chronometric Measurement and Simulation Systems for Better Planning and More Productive Execution of Construction Projects in Croatia, Proceedings of the Fifth International Conference on Construction in 21st Century (CITC-V): "Collaboration and Integration in Engineering, Management and Technology"; Division of Construction Engineering and Management, Department of Civil Engineering, Middle East Technical University Ankara, Turkey and Department of Construction Management, College of Engineering and Computing, Florida International University Miami, Florida, USA; May 20-22, 2009, Istanbul, Turkey