Creative Construction Conference 2016

Information and Communications Technology in Construction: A Proposal for Production Control

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Abstract

It is very easy to verify that production information systems in construction works are still based on telephone, written media and intensive use of email; likewise, tracking and monitoring are carried out by taking isolated work samples of certain activities, which often give us a local view instead of a global view of productivity, leading to erroneous diagnosis and decision-making.
This paper presents a proposal of a system and technology for production control in construction that promote the commitment of the workers themselves, who draw up their self-reports using electronic devices and web applications that permit a simple and user-friendly data collection from their worksite. Additionally, the proposal includes processing information in the web that facilitates an easy and unlimited access for all the stakeholders of the project, wherever they are in their own computers, tablets or smart phones.
Having this information available, we can keep a productivity effective control, so we can have access to highly specific levels of production. Therefore, we can find out the root causes of both losses and savings in each construction process, providing the necessary support for a good feedback and the corresponding corrective measures.
In light of the results obtained in this trial stage, we believe that the system proposed will improve the production control level in construction works and make it technological and automated, thus improving the quality and productivity of works, and achieving a holistic conception of construction, with an active participation of all stakeholders throughout its execution.

Keywords: automation; Information Systems in construction; ICT in construction; mobile devices; production control

1. Introduction

If we want to talk about improvement, of either companies or businesses from any field, we necessarily fall under the shadow of *Kaizen* or Continuous Improvement, which proposes putting into practice the Shewhart Cycle, better known in Japan as Deming cycle, since it was Dr. Deming who made it public, or PDCA cycle (Plan–Do–Check–Act) [1-3].
In the civil construction field, applying this cycle consists of improvement-oriented planning, execution, evaluation and corrective measures; however, in practice, the third stage—the one pertaining to assessment—is not successfully complied with. To a great extent, this is due to the fact that information about the use of work resources is not reliable or is not available when necessary [4].

This article proposes an information system and technology to collect data directly from the worksite and process it on the web, thus we will be able to assess and control a construction site continuously, track every activity, and have access to it from wherever we are. This system was already patented by its authors several years ago with excellent results, but now we are incorporating in this new proposal the technology to automatize both data collection and processing. Said system collects data from the three resources of production through electronic devices and process it with an on-line software available in a web application.

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The Workforce resource is reported through touch screens by the workers themselves in the late morning, and in the late afternoon at the end of each shift. Material consumption is recorded on line tracking the materials that left the warehouse and were later consumed. The use of Equipment, as the use of workforce, is controlled by the operators themselves. Finally, the work progress is reported online on a daily basis from their worksite through digital tablets using store-and-forward applications.

2. Managing Production Information in Construction Works

The quality of production information in construction works is not consistent with current times; in practice, often just at the end of the work can accurate information be obtained in a financial statement of income and expenses when it is already late. Apart from being late, the information delivered by traditional control systems is too grouped to be useful for controlling and planning decision making [5, 6].

In the last two decades, construction industry has shown great advances in the use of ICTs worldwide, even in small and medium-sized enterprises, as described by several authors [7-12]. However, as Dave et al [13] conclude based on the work of Tartari et al [14]: the "majority of ICT solutions within construction industry are applied to the peripheral processes" and "site management and other construction related activities have remained virtually unaffected."

This is consistent with Bowden's studies [15, 16], which presents the existence of 85 paper-based tasks carried out on-site in their daily normal work. "These were grouped into different document types revealing the most commonly identified tasks as completing data collection forms (25%), dealing with correspondence (18%), viewing and reviewing drawings (13%) and reading and writing specifications (6%)".

The Information Technology and System proposed in this article reduce to zero the filling out of data collection forms about the use of production resources during the information collection process.

3. Proposed Information Technology and System

Our proposal focuses on production improvement: The first issue is to improve the quality of communication and information among the management, professional staff and work team, and the productive entity by building a bridge that efficiently completes the feedback-based improvement cycle.

The proposed data collection is described below:

3.1. *Defining the Baseline*

Before the commencement of the construction work, it is necessary to define the baseline against which the tracking and control of production is going to be compared. This baseline is made up of construction Time, Cost and Scope; therefore information about work budget, activities schedule and technical specifications must be previously entered in the system.

3.2. *Collecting Information about the Use of Workforce and Equipment*

The main proposal of our system focuses on breaking the deep-seated paradigm, especially in the construction sector, which is managing works according to Theory X. Whereas this theory considers that the workers cannot control themselves, cannot be motivated, and just work for money [17], our system supports on Theory Z, proposed by William Ouchi and intermediate point between Mac Gregor's Theory X and Theory Y [18], which considers that the workers are not motived only by money but also by new challenges and the trust that their company may place in them.

By delegating the responsibility for information to the production source, i.e. the workers, a permanent control is available, not over discretionary samples, but over 100% of activities and 100% of resources. Therefore, when workers are getting off work and at lunch, they go to the registration site, identify themselves using a biometric face reader (Figure 1), and make a self-report about the time destined to each activity (Figure 2) using touch screens.

The web application developed for this operation was designed to be user-friendly, so it does not pose any obstacle for workers to execute this action. The identification of activities shows images to help them easily identify the activities performed, while the display of images on the screen is automatically customized to the worker's profile after his identification. This requires less effort and it is easier for workers to draw up self-reports about the time spent in each activity.

Figure 1. Worker identification and self-report.

Figure 2. Worker self-report on a touch screen.

Before entering the worksite, new workers watch a 30-minute video as training that easily and readily explains the information system, the importance of this system for the company, and how they can participate. Every new worker must watch this video and take a short guided test on self-reporting. Additionally, workers who have operated equipment or machinery must also make a report, in a similar manner, about how long they have been operating them.

3.3. *Collecting Information about the Use of Materials*

All material that enters the worksite must be registered in the warehouse. For this task, the storekeeper has access to the system that allows him to directly register it on the web, recording also the quantity received and unit cost. Then, when these materials are required to be used, he must also record their exit, showing the quantity and destination record.

3.4. *Collecting Information about Work Progress*

Due to the nature of production in construction, work progress is recorded on site, going around the worksite registering information in different places where tasks have been carried out. This information is collected by a person in charge at the end of the workday using a digital tablet (Figure 3). This procedure helps save time normally spent to transfer the collected data—generally on paper—to a control system, that in most cases is done in an electronic spreadsheet. In order to avoid that the lack of Wi-Fi in the worksite where we record the work progress becomes a restriction, an application for mobile phones with the store-and-forward feature is used allowing information to be temporarily stored in the device (figure 4) and then automatically uploaded on the web as soon as Wi-Fi is available.

Figure 3. On-site work progress registration.

Figure 4. Use of digital tablets and store-and-forward

3.5. *Production Reports*

Once the system has all the daily production information uploaded on the web, several reports will be available to track, control and have a quite clear idea of the global workforce productivity at any time given time. The different reports can be accessed at any stage of the works with one-day accuracy and the performance diagnosis can be obtained within the periods matching the dates when the work progress was recorded, thus reaching a 100%

control of the works without bearing excessive control staff expenses, since the system is practically run by the workers themselves.

By reviewing each user profile, the different stakeholders can have access to different reports according to their needs. For instance, crew leaders and the foreman can check their staff performance; contractors can track their staff if they also participate in this system; storekeepers can check all incoming and outgoing materials as well as valued stock; administrative offices can get updated information on staff assistance to calculate payrolls; professionals involved in the works can check the details concerning schedule, costs and performance of each activity; or the management can check the production ratios, the actual results, and the results projected for the end of the works.

Figure 5 shows us the traditional information flow corresponding to the production in construction works, while Figure 6 shows the same flow with the system we propose implemented. The benefit we obtain by simplifying the collection, transfer, storage, processing, distribution and communication of data for the stakeholders can be clearly noticed.

4. Contribution of the system for the Continuous Improvement

Feedback in construction works is managed late with approximate figures, isolated samples, and not very trustworthy information, which prevents us to implement a continuous improvement cycle in an effective manner. Thanks to this system, the information is continuous and permanent. And since monitoring what was executed is carried out with the same accuracy as monitoring what was planned, we have the opportunity to receive a very efficient feedback the next day from the moment each budgeted record is executed. Additionally, this system shows us the root causes behind why the executed activities did not meet the planned goals to take corrective measures, get lessons learned, modify processes, propose innovations, etc.

Having this web-based system makes it possible to share the information with all the stakeholders, thus providing a feedback in different directions, promoting proposals of continuous improvement supported on a collaborative teamwork. An important aspect is the fact that the Management is one of these stakeholders. Normally, due to restrictions of time, distance, access, or poor communication, the Management loses its connection with on-site problems, i.e. it loses its involvement and support to continuous improvement programs for the projects. On the other side, we have the workers who are contributing now with the system in a significant way, making them important agents for project development.

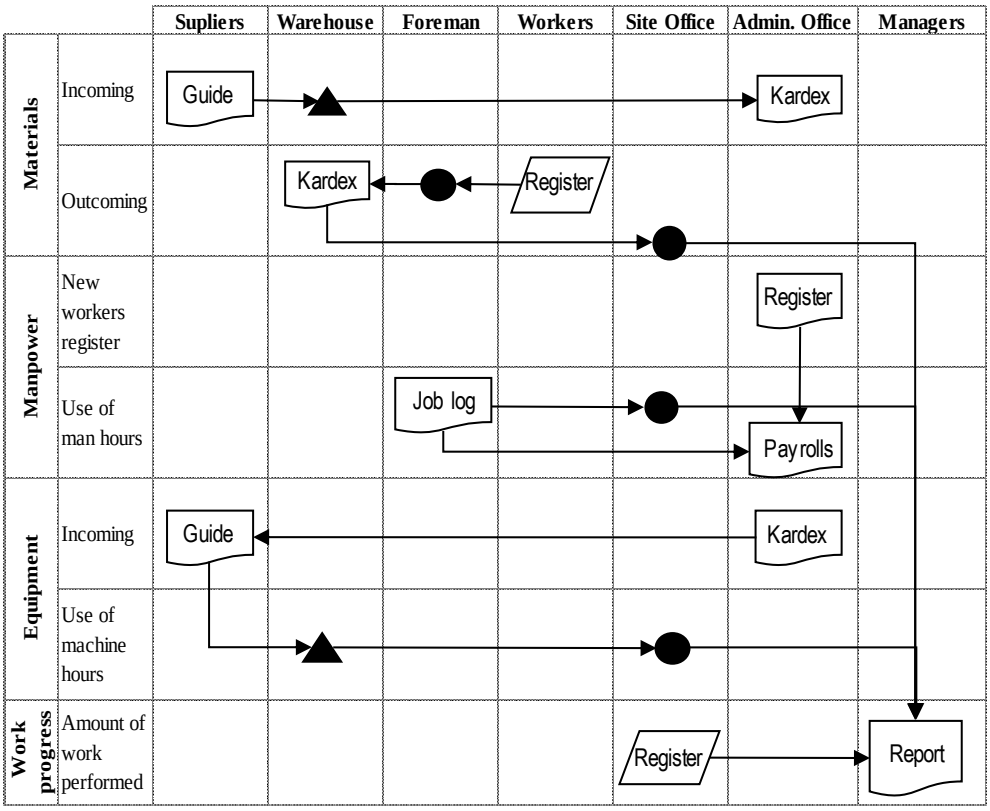

Figure 5. Traditional production information flow.

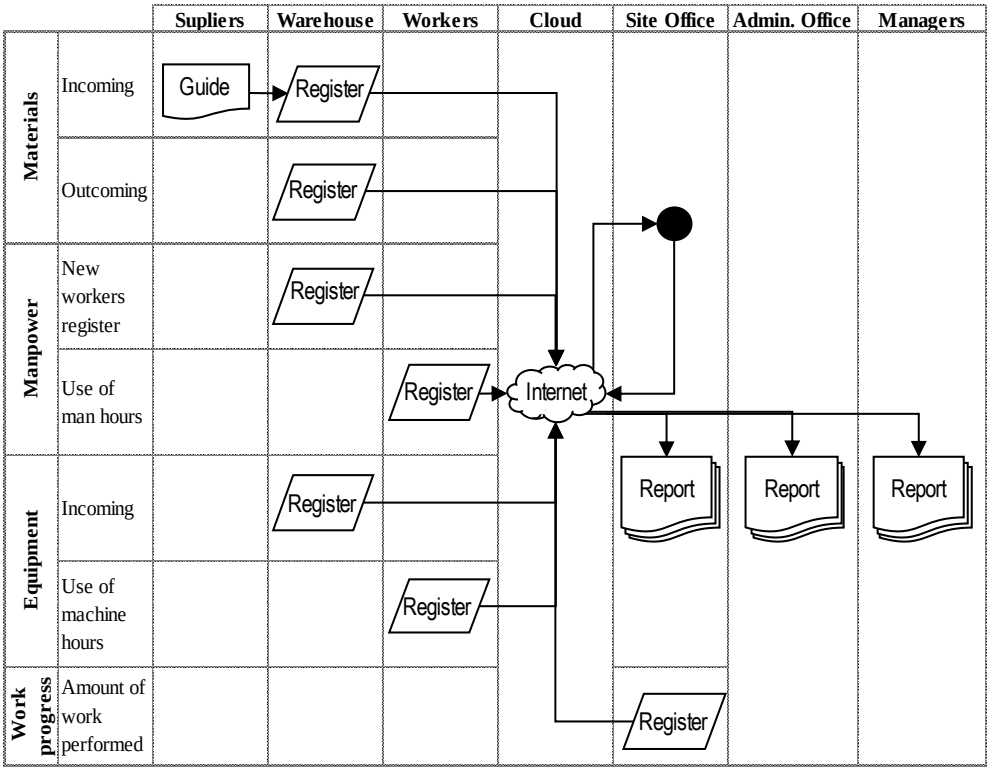

Figure 6. Production information flow with the proposed system.

This constant feedback allow us to evaluate innovations, since we can compare the new results with the ones before the implementation and have a historical data bank for the company, enabling us to plan future projects.

5. Conclusions

The system we propose is based in 3 main points: 1). Transfer the task to obtain most of the production information to the workers. 2). Use web applications to promote collaborative work to enter data and information shared distribution. 3). Use electronic devices to make information collection easier.

The first point - considered crucial and questionable - has been a daily successful practice in all the works our company carries out for many years. The second point also shows the same scenario, since we already have an intranet containing a module with the presented proposal that is extensively approved by all the stakeholders. On the other hand, the third point is an innovation indeed, which is in pilot testing, that we intend to use to complete the missing link to create an efficient Continuous Improvement Cycle application for the construction sector.

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