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

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Abstract

In order to improve feedback from the Cost Performance Index (CPI), it is necessary to know the reasons why Actual Cost differs from Planned Cost. At present, this information is collected and transferred orally, on paper, by telephone or e-mail. This paper proposes an information and communication technology that uploads information to an Intranet using electronic devices and mobile applications, thus encouraging the participation of workers and other stakeholders. This proposal aims to contribute towards information quality improvement in Production Control.

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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 need to revisit Kaizen or Continuous Improvement, which proposes putting into practice the Shewhart Cycle, better known as Deming Cycle in Japan since it was Dr. Deming who made it public, or the PDCA Cycle (Plan–Do–Check–Act) [1-3].

In the civil construction field, applying this cycle consists of planning, execution, evaluation, and corrective measures for improvement; however, in practice, the third stage—the one pertaining to evaluation—is not successfully complied with. This is significantly due to the fact that information about the use of work resources is not reliable or is not available when necessary [4].

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This article proposes an information and communication system to collect data directly from the worksite and process it on the Web, thus we will be able to evaluate and control all the construction site activities on a continuous basis, having access to it from any place. This system was already patented by its authors several years ago with excellent results, but what we are incorporating in this new proposal is 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 online software available in a Web application.

The Labour resource is reported by workers using touch screens in the late morning, and in the late afternoon at the end of each shift. Material consumption is recorded online by tracking the materials leaving the warehouse and being subsequently used. The use of Equipment, as the use of labour is controlled by the operators themselves. Finally, 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, we can obtain accurate information at the end of the works in a financial statement of income and expenses. 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." Additionally, 90% of ICT expenses are incurred for the technical work office or head office and only 10%, for field use [15].

This is consistent with Bowden's studies [16, 17], which presents the existence of 85 paper-based tasks carried out on-site as part of 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%)".

From the research conducted in the UK by Chen and Kamara [18], it can be concluded that the information necessary for production monitoring (materials, labour, equipment and progress) is collected using paper-based forms (65%); by remembering the information (28%); and through mobile devices (only 7%), as can be seen in Figure 1. In addition, as shown in Figure 2, transfer of the information collected is done mainly in face-to-face meetings (42%), by e-mail (31%) or phone (20%), and only 7% is sent over the Intranet or Extranet [18].

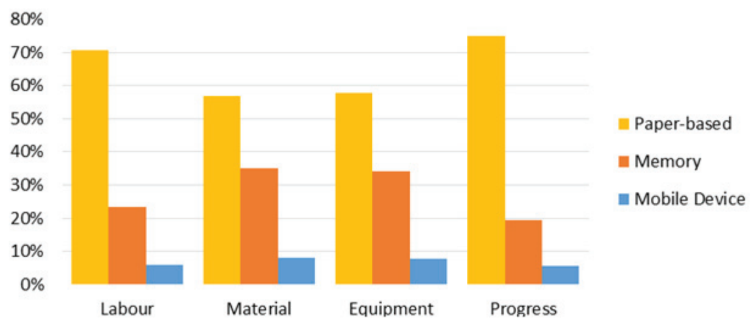

Fig. 1. Production information collection methods.

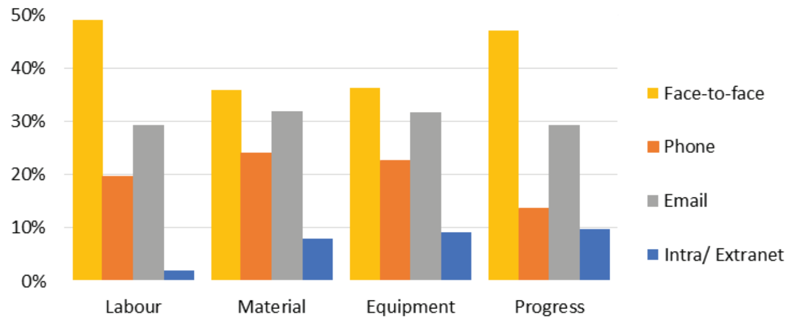

Fig. 2. Production information transfer mediums.

The results presented demonstrate the inefficient manner in which production information is handled on the construction site and the existence of great improvement opportunities. The Information Technology and System proposed in this paper eliminates the need to fill out information collection forms about the use of production resources during the information collection process. In addition, this information is entered directly to a Web application, so it does not require an additional information transfer process.

3. Continuous Improvement in Production Control

Production Control must be planned within the framework of Continuous Improvement. If control activities indicate that we are doing something wrong, it is necessary to identify the problem to solve it. Likewise, if we are getting good results, it is necessary to determine which the effective practices are in order to standardize them. Therefore, the control in the Check stage of the PDCA Cycle must provide enough information to identify why those results were obtained and act accordingly, thus closing the cycle.

In order to implement Continuous Improvement in Production Control, the Lean Construction Institute proposes using the Last Planner System®. For the first stage (Plan), they suggest following this sequence: Master Schedule, Phase Schedule, Look Ahead Plan, and Weekly Work Plan (see Figure 3a). After the Weekly Work Plan has been executed (Do), the Percentage of Plan Complete (PPC) and the Reasons for Non-Compliance (RNC) must be verified (Check) in order to complete the learning process. However, these indicators only shed light on the efficiency of the program, not on the costs.

On the other side, for this Continuous Improvement, the Project Management Institute proposes the Earned Value Technique (see Figure 3b) in its PMBOK Guide. First, Planned Value (Plan) must be estimated, and then Earned Value and Actual Costs (Do) must be calculated at the end of any control period. After obtaining these three values, we have to calculate (Check) the Cost Performance Index (CPI) and the Schedule Performance Index (SPI) and then act accordingly. Nonetheless, these indicators are very broad and we consider that CPI should also include some RNC like PPC does.

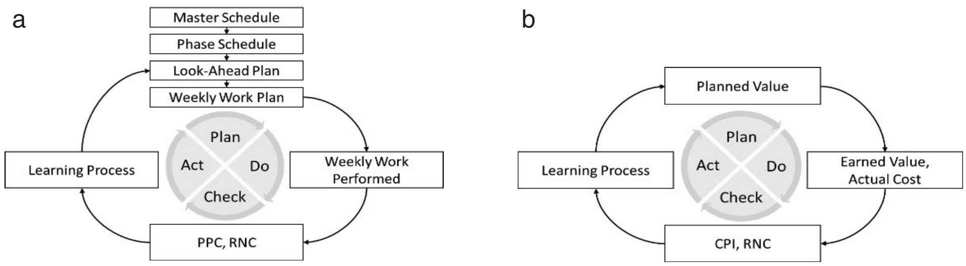

Fig. 3. (a) The Last Planner System® and Continuous Improvement; (b) Earned Value and Continuous Improvement.

Thus, it is necessary to make a Root Cause Analysis of the Actual Cost and apply the 5 Whys Technique, with which we will obtain a Tree Diagram as shown in Figure 4, where the 7 root causes that can make the Actual Cost differ from the Earned Value are displayed.

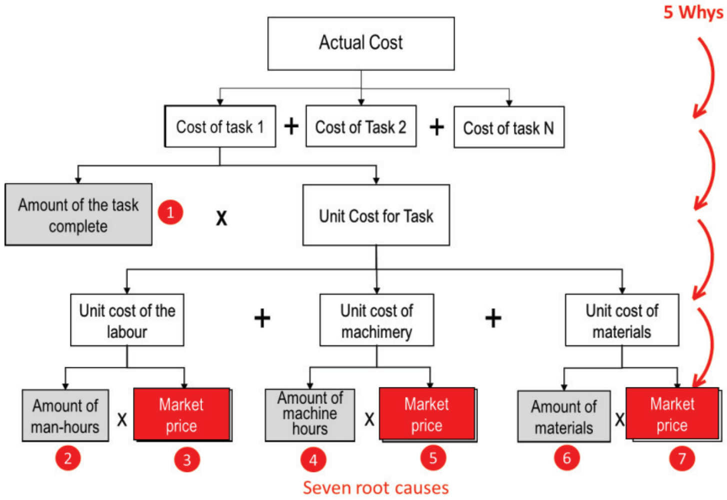

Fig. 4. Root Causes for the difference between Actual Cost and Earned Value.

From these 7 causes, 3 of them are very easy to obtain since they are market prices set for supplies. However, in order to obtain the remaining 4 causes, detailed field information is required. This is where our proposed ICT System contributes to Production Control.

4. Proposed Information Technology and System

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

The proposed information collection is described below:

4.1. Defining the Baseline

Before starting the construction work, it is necessary to define the baseline to which the production control and tracking 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.

4.2. Collecting Information about the Use of Labour 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 [19], our system supports on Theory Z, proposed by William Ouchi and intermediate point between Mac Gregor’s Theory X and Theory Y [20], which considers that workers are not motived only by money but also by new challenges and the trust their company may place in them.

By delegating the responsibility for information to the source of production, i.e. the workers themselves, a permanent control is available, not over discretionary samples, but over 100% of the activities and 100% of the resources. Therefore, at the end of their shifts and at lunch time, workers go to the registration site, identify themselves using a biometric face reader (Figure 5a), and make a self-report about the time destined to each activity (Figure 5b) 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 filtered according 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.

Fig. 5. (a) Worker identification and self-report; (b) Worker self-report on a touch screen.

Before entering the worksite, new workers watch a 30-minute training video that easily and readily explains the information system, the importance of this system for the company, and how they are expected to 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.

4.3. Collecting Information about the Use of Materials

All material that enters the worksite must be registered in the warehouse. For this task, the warehouse keeper can access to the system 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.

4.4. Collecting Information about the Amount Work Progress

Due to the nature of production in construction, the amount of 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 6a). This procedure helps save time normally spent to transfer the collected data—generally on paper—to a control system, which in most cases is done in an electronic spreadsheet. In order to avoid that the lack of Wi-Fi connection in the worksite where we record the work progress becomes an issue, an application for mobile devices with a store-and-forward feature is used allowing information to be temporarily stored in the device (Figure 6b) and then automatically upload it on the Web as soon as a Wi-Fi connection is available.

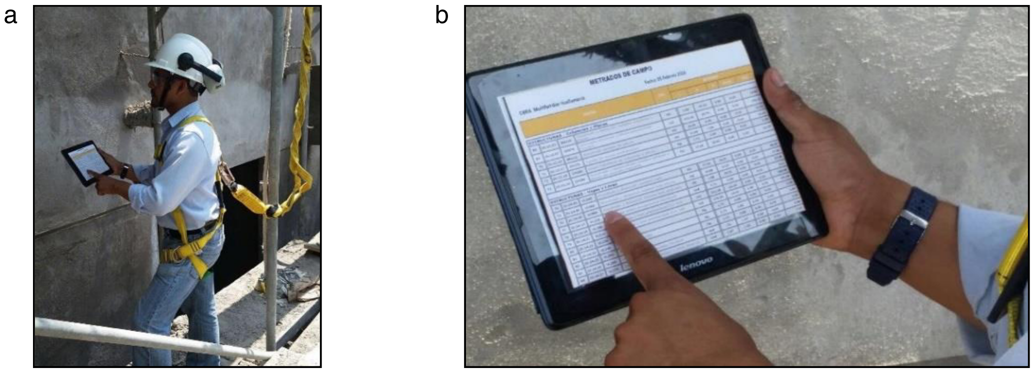

Fig. 6. (a) On-site work progress registration; (b) Use of digital tablets and store-and-forward.

4.5. Production Reports

Once the system has all the daily production information uploaded to the Web, several reports will be available to track, control and have a quite clear idea of the global labor productivity at any 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 incurring excessive control staff expenses since the system is practically run by the workers themselves.

By reviewing each user profile, different stakeholders can access varied 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; warehouse keepers 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 task; or the management can check production ratios, actual results, and results projected for the end of the works.

Figure 7 shows the traditional information flow corresponding to production in construction works, while Figure 8 shows the same flow with the system we propose if implemented. The benefit we obtain can be clearly notice, by simplifying the collection, transfer, storage, processing, distribution and communication of data for the stakeholders.

5. 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 from implementing a continuous improvement cycle in an effective manner. Thanks to this system, information is continuous and permanent, and since the controlling of the activities executed is carried out with the same accuracy as the controlling of the activities planned, we receive a very efficient feedback the day after the execution of the budgeted record. Additionally, this system shows us the root causes behind why the executed activities failed to 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 information with all the stakeholders, thus providing feedback in every direction, promoting proposals of continuous improvement supported on a collaborative teamwork. An important aspect is that the Management should be involved. Normally, due to restrictions of time, distance, access, or poor communication, the Management loses its connection with on-site problems, i.e. it does not get involved or support the 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.

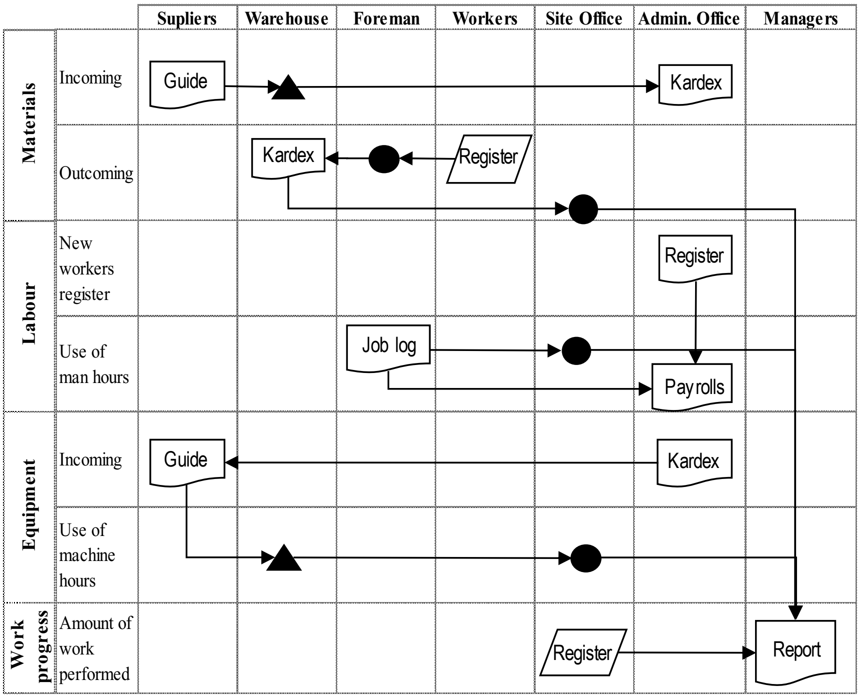

Fig. 7. Traditional production information flow.

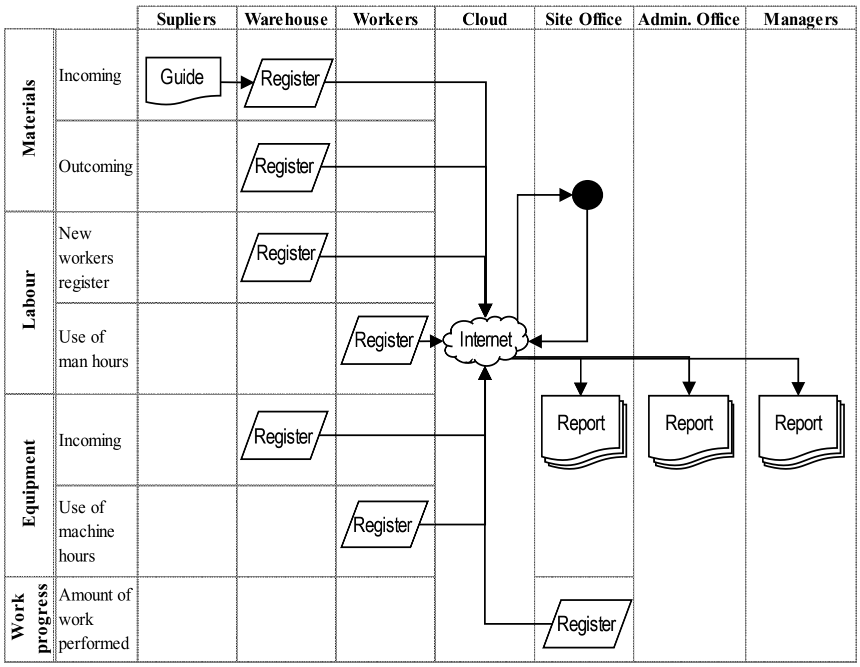

Fig. 8. Production information flow with the proposed system.

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

6. Conclusions

CPI shows how different our Actual Cost is from the Earned Value, but after analyzing the root cause of the Actual Cost and applying the 5 Whys Technique, we will get the 7 causes behind this difference. Getting information on 3 of them is easy because they are market prices; however, for the other 4, an information and communication system as the one we are proposing in this paper is necessary. In this way, we can now have 7 performance indicators for each advanced task and know in detail the reasons for change in our Actual Cost compared to the Planned Cost.

The system we propose is based on 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 distribute shared information. 3). Use electronic devices to make data collection easier.

The first point—considered crucial and questionable—has been a daily successful practice in all the works our company has been carrying 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 thoroughly approved by all the stakeholders. On the other hand, the third point is an innovation in pilot stage, which we intend to use to complete the missing link in order to create an efficient Continuous Improvement Cycle application for the construction sector.

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