Mejoramiento de procesos constructivos a partir de un módulo programable para captura de imágenes y simulación digital

Improvement of constructive processes based on a programmable unit for images capture and digital simulation

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Resumen

Los constructores de proyectos civiles se enfrentan permanentemente al reto de aumentar la productividad a través de la optimización de recursos y la interacción de los mismos, situación que ha sido abordada desde diferentes perspectivas utilizando estrategias computacionales y manuales. Este reto también exige al sector de la construcción, la implementación de nuevas tecnologías de información y herramientas digitales como estrategia efectiva para la captura de datos confiables que contribuyan en mejorar indicadores de productividad, seguridad y calidad. Particularmente en este trabajo se presenta una propuesta para la generación de valor en proyectos de construcción, a través del uso de tecnologías para captura de información digital que permiten hacer una reingeniería de procesos constructivos a través de la implementación de la filosofía Lean Construction y la simulación digital. Inicialmente se presenta el diseño y desarrollo de un módulo programable y autónomo para captura de imágenes digitales de procesos constructivos, con alimentación a través de energía fotovoltaica. Se incluyen equipos de hardware y componentes electrónicos como cámaras fotográficas, cámaras de video, tarjetas electrónicas, computadores, paneles solares, plataforma web y sistemas de comunicación; controlados a través de un software diseñado específicamente para este fin, que facilita el control de equipos y componentes. Este sistema facilita la toma de decisiones respecto a métodos constructivos y recursos involucrados, con el fin de minimizar el costo y aumentar los rendimientos. En la segunda parte del documento se presentan los resultados obtenidos de la implementación del módulo en la construcción de un proyecto de edificación en la ciudad de Bogotá, Colombia. El documento incluye el análisis de la información obtenida, la caracterización de procesos constructivos utilizando videos Time-Lapse y la realización de un modelo de simulación digital del proceso constructivo. Los resultados obtenidos, permiten reducir tiempos de ciclo y dar un mejor uso a los recursos, representando ahorro de recursos para el proyecto.

Palabras Clave: Simulación digital, Lean Construction, mejoramiento de procesos constructivo, módulo programable, time lapse

Abstract

Civil projects executors are constantly dealing with the challenge of increasing productivity through resources optimization and their interaction; this has been addressed from different points of view using computational tools and manual tools. This challenge demands also, the implementation of new information technologies and digital tools as an effective strategy to capture reliable data that could contribute to improve the productivity, quality and security indicators. This work presents a value generation in construction projects, through the use of new technologies to capture digital information that allows a construction process re-engineering using Lean Construction philosophy and digital simulation. At first, the design and development of an autonomous and programmable module is presented, powered with solar energy, used to capture digital images of construction processes. This system includes hardware and electronic components such as cameras, video cameras, electronic cards, computers, solar panels, web platform and communication systems; all controlled by a specially designed software which simplifies the control of the equipment and its components. This system simplifies the decision-making process regarding the construction methods and the resources involved, in order to minimize the costs and to increase the performance. The results obtained in the implementation of the module in a construction project in Bogota, Colombia, are presented in the second part of this paper. The analysis of the results, the constructive process characterization using Time-Lapse videos and a digital simulation model of the construction process are presented. These results allow reducing cycle times and using better the resources, which is translated into resources savings for the project.

Keywords: Digital simulation, Lean Construction, construction process improvement, programmable module, time lapse

1. Introduction

So as to improve construction productivity, Lean Construction philosophy (Koskela, 1992) was proposed, which is based on prioritizing activities that provide aggregate value on products over the ones which do not, thus eliminating losses by means of inventory reductions, diminishing cycles times, developing processes automation, cooperation to providers, change of production scope, among its main objectives. In order to implement such philosophy, different tools and techniques have been used. Some of them are described below.

Chang and Lu (2008) proposed a tool for material handling during a viaduct construction.

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Such method consists of an algorithm that selects the best choice among several options; however, it does not guarantee the chosen option is the best one. Mao, Zhang (2008), proposed to carry out constructive process re-engineering by including Lean Construction and digital simulation principles. By observing constructive processes, improvement actions are proposed by following "lean" principles, which are later modeled by means of a software simulation specialized in construction, the so called "Symphony".

In Latin America Pabón (2005) researches a methodology for processes productivity control in construction area by using the time lapse technique, which follows up activities considered as productive or waste of time by employing a photo-montage with an analog camera and the other with a digital camera.

Núñez (2006) searches the causes and proposes solutions so as to diminish non-contributory time in construction projects in Colombia. After finding the project-loss causes, he proposed improvement strategies to reduce or to eliminate non-contributory time, such as planning in advance; providing workers with necessary safety elements to avoid accidents and operational risks; stock-pile materials considering final destination and avoiding long distance transportation; scheduling working day and resting time for the staff and; counting with selected workers to develop contributory activities.

Alarcón et al., (2009) present a computer methodology that facilitates data collection, processing and analysis for production improvement and safety in the job site, by means of video tapes and digital images. In order to approach opportunities, a software was developed (the so called CAPCAM2), which includes tools designed to retrieve data from video tapes and digital images for conducting analysis intended to improve productivity and to decrease accident rates during construction activities. Diverse methodologies are explained which allow identifying development opportunities, improving productivity and decreasing accident rates during construction activities by obtaining advanced parameters and effective use of resources.

Regarding the implementation of time-lapse, there are productivity improvement researches employing such technique (Escobar, 2005) (Arango, 2006) (Rodríguez, 2009). Such technique has also been employed in the construction processes work-flow (Vargas et al., 2009). The time-lapse technique consists in capturing fixed images that are later reproduced at a higher speed than the one existing at the capture moment, so as to observe slow processes easily.

By using Arena software researches related to the construction of concrete walls and slabs have been made (Páez, 2007), (Mesa, 2008) and (Echeverry et al., 2008) providing project executors with a tool for assessing different situations with a probabilistic approach, thus allowing a better decision making process under uncertain conditions.

Such researches have intended to design models allowing the constructive processes imitation, so as to optimize their involved resources by increasing productivity by means of time and cost reductions.

On the other hand, Gómez (2009) takes measurements from the job site using a chronometer and constructive processes pictures, also considering experts opinions to determine the work flow, estimated time of execution for each activity and the required resources in each case. A constructive process simulation model and some theoretical situations are developed to reduce execution time of the project. Considerable reductions are obtained when combining resources optimization, constant materials availability and the beginning of some specific activities at early stages.

By incorporating time-lapse and simulation technologies, a research was developed where video images are captured by means of an electrically powered camera and, images are analyzed and employed in the simulation of the constructive process. As a result (Céspedes, 2010) proposes a staff re-organization in order to decrease execution times and also expresses the need of placing construction material close to the transportation area. It is also important to guarantee that activities are properly assigned thus avoiding re-processes due to poor practices and staff redeployment to increase their performance. Using conventional energy as power source for cameras might hinder video tape continuity and lead to data losses. Other disadvantage is the images storage capacity of the digital camera memory.

The present study introduces a mix of technologies, beginning with the instrumentation for digital data capture, the analysis of data obtained for establishing the constructive processes characterization as an input to develop a digital simulation model, which requires information on time, resources and priority of executed activities.

The simulation model establishes some improvement proposals to implement Lean Construction philosophy and the simulation of processes in a construction project, by using digital cameras to record Time Lapse videos intending to identify cycle times and the work flow of involved parties. Times shown on videos were analyzed and a data compilation was achieved, which is used to carry out a constructive process simulation by means of the Arena software. Finally, new theoretical situations were established in order to improve productivity, such as modifications on the project logistics, increase or reduction of equipment and staff, which were simulated and delivered time and costs savings.

The research was carried out in a construction project in Bogota city, composed of two 17 floor- apartment blocks, having three apartments by floor, common areas and three parking basements.

2. Methodology

The research was scheduled in 3 stages: instrumentation for images capture, characterization of constructive processes, simulations of construction processes and improvement proposals. A diagram is presented below.

Figura 1. Diagrama de las etapas de desarrollo de la investigación

Figure 1. Diagram of the research development stages

2.1 Stage for information capture

This project included the hardware and software development to control photo cameras, by means of the scheme presented below.

Figura 2. Esquema del sistema para captura de imágenes

Figure 2. Scheme of images capture system

The whole system has three sub-systems managing the control of power, sequences of images shots, images storage and retrieve. Such sub-systems are:

2.1.1 Central control unit, internet and Wi-Fi network connections

It consists of a wireless router for GPRS connection, which has Wi-Fi and Ethernet ports for connecting other devices. On an Ethernet port there is a rabbit-core card plugged-in, which works as a central control unit. This unit accesses internet and provides support to an HTML web page, which controls the configuration of images shots. This modulus has a wireless link that works as a Modbus-master sending and receiving control data and, modules conditions of images shots. This unit is powered by the public energy network. HTML web page can be remotely accessed on the Internet by using a password. This page is able to indicate beginning and ending time for images shots on a daily basis and, also their capture intervals.

Configuración cámaras/Camera configuration

Hora de inicio de toma de imágenes (formato 24 horas)/Beginning time for images shots (24 hours format): :

Hora de finalización de toma de imágenes (formato 24 horas)/Ending time for images shots (24 hours format): :

Intervalo de captura de imágenes (minutos)/Images capture intervals (minutes):

Nota: Un 0 corresponde a no tomar imágenes/Note: 0 corresponds to no images captured

Configuración nodos/Configuration nodes

Tiempo que dura apagado el xbee (minutos)/Time the xbee is switched-off (minutes)

Nota: Un 0 corresponde a no apagar la xbee/Note: 0 corresponds to never switching of the xbee (minutes)

Tiempo de espera de datos antes de apagar el xbee (segundos)/Holding time for data before switching-off the xbee (seconds)

Umbral Vbateria para apagar las cámaras (mV)/Threshold battery to switch-off cameras (mV)

Umbral Vbateria para encender las cámaras (mV)/Threshold battery to switch-on cameras (mV)

Umbral Vpanel para toma de fotos (mV)/Threshold panel for shooting images (mV)

Figura 3. Página web de configuración coloca en la unidad central de control

Figure 3. Configuration of web page in the control central unit

The software developed for control central unit has three routines which are recurrently called up in the software primary loop, in accordance with the following general diagram presented below.

Figura 4. Estructura del software unidad central

Figure 4. software central unit layout

The process begins with the initialization of ports and variables in the system. The router is dynamically connected, the HTML web page is initialized and, the system clock is synchronized with the universal clock. Afterwards the software primary loop is accessed. "DHCP update" routine is in charge of maintaining the internet connection even though there is a change of IP allocation in the network. The HTTP handling routine is in charge of controlling HTML web page, in such a way that configuration changes done remotely by the user are validated, registered and sent to the nodes. The Communication and nodes update routine is in charge of sending new configuration updates - done by the user - to images shots modules.

2.1.2 Images Shots

The autonomous-energy unit charges the battery with photo-voltaic panels. The unit is in charge of capturing pictures and stores them locally. This unit is installed within the reach of Wi-Fi and Modbus wireless data network. Two images capture points were installed, one with a camera connected to a local node by means of a remote shooting cord, which has an optical isolator for elements protection. The node is in charge of shooting according to configuration parameters settled by the user. So as to obtain such parameters, the node communicates with the central control unit using Modbus protocol by means of an Xbee card. This card provides connectivity at a small range, low consumption and cost. At the same time, it guarantees a reliable data delivery among devices. The assembly installation of cameras can be seen on the following pictures.

Figura 5. Punto de captura de imágenes N° 1

Figure 5. Pictures Capture Point Nr. 1

Figura 6. Punto de captura de imágenes N° 2

Figure 6. Pictures Capture Point Nr. 2

Data processing for images capture is done by a digital signal processor. The general diagram of software developed for this processor is shown below.

Figura 7. Estructura del software procesador de señales

Figure 7. Software layout of digital signal processor

Communication routine in the control central unit is in charge of establishing wireless communication using Modbus protocol by means of an Xbee card. From these routine, the user configuration parameters are received and measured voltage and current values are sent. Such values allow the diagnosis of solar panel and batteries conditions. The “Camera Shooting” routine is in charge of shooting the camera in accordance with received configuration parameters. Finally, the “Control of Voltages and Currents” routine is in charge of providing data on voltage and current values from solar panel and batteries.

Solar panels and batteries allow an autonomous feed for the module and camera by means of photo-voltaic energy. The advantages of this kind of feeding are that the risk of losing information due to a conventional electric system failure is avoided. Besides, there are no wires limiting the camera assembly according to the project requirement and executed constructive process. Panels were assembled on the upper side of security box containing other devices, in such a way they are exposed to solar energy. The camera has a SDHC memory card with Wi-Fi technology. Such memory card, besides storing the picture locally captured, automatically sends it to the industrial computer throughout the Wi-Fi network. The computer is an industrial computer connected to the Wi-Fi network, which works as images local storage unit and has the required software to store images on an external server. Therefore, pictures can be remotely accessed. Besides, this computer can be accessed remotely enabling the control of the system general performance.

In Assembly Nr. 2 a picture camera, a webcam and an industrial computer were installed for data storage. A picture of the webcam can be observed below.

Figura 8. Instalación cámara web

Figure 8. Webcam assembly

Cameras were strategically installed to achieve wide-range coverage of activities in progress. They were installed on the two tower cranes as shown below.

Figura 9. Montaje de unidad de toma de fotografías y paneles solares

Figure 9. Assembly of pictures camera units and solar panels

2.1.3 Storage computer

The industrial computer is connected to the Wi-Fi network working as an images local storage unit; it also has the required software to place pictures on an external server, therefore, pictures can be remotely accessed to check the general performance of the system. Cameras shall be installed on strategic points to capture the concrete structure constructive processes under study.

The computer installed next to the cameras was remotely accessed and by means of the webcam software, the recording of real-time videos of constructive processes was achieved in order to include information initially obtained in the search of identification for new additional aspects, as shown below.

Figura 10. Visualización de pantalla para captura de videos

Figure 10. Video capture screen

These points can be re-installed at any job site location and data recording continues in progress in the same way. Some pictures obtained by the camera are shown below.

Figura 11. Serie de fotografías obtenidas por el sistema

Figure 11. Picture sequences obtained by the system

2.2 Processes characterization

Pictures and video captured in the structure construction stage allowed the identification of work flow, by means of the observation of activities sequences and execution times. In addition to pictures and videos obtained from the job site instrumentation and from the camera installed on the tower crane, inspections on the job site were also carried out in order to check such information. The work flow included the following activities:

Figura 12. Actividades estudiadas

Figure 12. Studied activities

For each activity workers crews were identified and a work flow analysis was developed for the field resources. Resources were allocated per crews established as follows.

- Blacksmith crew
- Columns crew
- Beams crew
- Supports and trusses crew

These crews were allocated in three areas, so as to optimize the utilization of resources in such a way crews are continuously developing an activity that aggregates value to the project.

Figure 1 shows the partition of proposed areas on floor 1 in the first apartment block.

Figura 13. División de zonas de trabajo

Figure 13. Partition of working areas

2.3 Identification of productive, contributory and non-contributory activities

Among constructive processes comprised in a project development, productive activities can be identified which aggregate value to a given activity, contributory activities that provide support to productive activities, and non-contributory activities which are considered as losses in the project (Botero, 2006).

During the monitoring of constructive process by means of digital images and complementary field supervisions, these three kinds of activities were identified as well as their execution time. This stage was carried out by means of the analysis of obtained pictures and additional measurements were developed by using a 5 minute test to classify Productive, Contributory and Non-contributory execution times. Data analysis enabled the determination for each activity, considering columns constructive process as example.

Tabla 1. Clasificación de actividades por proceso constructivo
Table 1. Classification of activities per constructive process

ACTIVIDAD/ ACTIVITY:	COLUMNAS/ COLUMNS	
ACTIVIDADES PRODUCTIVAS/ PRODUCTIVE ACTIVITIES	ACTIVIDADES CONTRIBUTIVAS/ CONTRIBUTORY ACTIVITIES	ACTIVIDADES NO CONTRIBUTIVAS/ NON- CONTRIBUTORY ACTIVITIES
Cimbrado de columnas. Columns formwork	Transporte de acero (Grúa). Steel transportation (crane)	Reubicación del material. Material re-allocation
Amarre de acero. Supporting steel beams	Clasificación y organización de acero. Steel classification and organization	Espera por falta de material (formaleta, acero y herramienta). Holding time due to material shortage (camber piece, steel and tool)
Instalación de formaleta. Installation of camber piece	Corte de alambre. Cutting steel wires	Espera de concreto. Holding time for concrete supply
Vaciado de concreto. Concrete cast-in	Transporte de herramienta. Tools transportation	Reproceso por ejecución incorrecta Re-work due to wrong performance
Retiro de formaleta. Stripping camber piece	Transporte de alambre de acero a lugar de ejecución. Transportation of steel wires to the execution location.	Suspensión de actividad por mal clima. Activity recess due to bad weather conditions.

Additionally crews balance analyses were developed to establish human resources productivity. An example for the columns steel reinforcement process is shown below.

Figura 14. Clasificación de tiempos productivos, contributivos y no contributivos
Figure 14. Classification of productive, contributory and non-contributory execution times

Results obtained for the whole Project are presented by the following graphs.

Figura 15. Clasificación de tiempos productivos, contributivos y no contributivos

Figure 15. Classification of Productive, Contributory and Non-contributory execution times

3. Simulation of processes and improvement proposals

As digital images are analyzed, the information for constructing a model for digital simulation and probabilistic activities behavior is obtained. Initially, the model conceptualization is developed by Arena software based on the activities in the construction process, which are considered as representative and, considering the work flow. The following parameters are defined: activities execution time, amount of executed works, physical resources involved (machinery and equipment), staff involved (officers and assistants) and recesses.

For the elaboration of Arena software, its layout is first defined, taking into consideration activities sequences, defined probabilities distributions and registered resources. Afterwards the model is cross-checked and a statistical validation is developed by following confidence intervals method. In the last stage, based on an elaborated simulation model, significant losses and improvement opportunities are identified in accordance with Lean Construction philosophy. The activities that represent performance and productivity reductions are also identified, thus establishing improvement opportunities, which are simulated by theoretical scenarios based on the initial model. Each developed stage is described below.

3.1 Timming of execution activities

For each activity identified in the work flow minimum, maximum and average values of measurements performed were established, thus finding the probabilistic distribution which adjusts each data series the most.

Afterwards, execution times per constructive process are organized in order to define a distribution curve for each particular activity. This task was performed by Arena Input Analyzer – Rockwell Software, which also develops goodness of fit tests. After organizing data, this tool calculates parameters of each probabilistic distribution and allows the comparison of adjustment values obtained for each function.

Probabilistic distributions included by this software are Beta, Erland, Exponential, Gamma, Lognormal, Normal, Triangular, Uniform and Weibull (Kelton et al., 2008).

Once data are organized per activity and item, probabilistic distribution curves are elaborated from a sufficient amount of data (minimum 10). From such information, data behavior histograms were depicted, which served to define a distribution curve for each particular activity.

Arena Input Analyzer – Rockwell Software provides distributions that adjust data the most and develops goodness of fit test such as Chi-square and Kolmogorov-Smirnov. Chi-square test is applied for sample large enough size finding out that when n is equal to 5 times the number of types, the results are acceptable. Kolmogorov-Smirnov test is applied when the requirement of n equal to 5 times the number of types is not met, since data do not need to be grouped and the test is applicable to a sample small size (Canavos, 1988). During the development of these tests, p -value (p) is particularly relevant, corresponding to the probability of achieving an inconsistent data set from adjusted distribution. Higher p values represent a better adjustment. If p value is equal to 0.10 or higher, a good confidence level is achieved ensuring a good data representation (Kelton et al., 2008).

A distribution was selected meeting test parameters (p -value > 0.15). An example of this analysis corresponding to the “Steel Columns” activity is shown below.

Tabla 2. “Análisis de datos realizado en la herramienta Input Analyzer”

Table 2. “Data analysis developed by the Input Analyzer Software”

DATOS (horas) DATA (hours)
2.33
1.5
1.88
1
2
2
1.5
2
2

Datos obtenidos en Input analyzer Data obtained by the input analyzer	
Number of Data Points	9
Min Data Value	1
Max Data Value	2.33
Sample Mean	1.8
Sample Std Dev	0.398

Function	Sq Error
Triangular	0.0449
Beta	0.0708
Normal	0.0737
Uniform	0.084
Weibull	0.133
Erlang	0.159
Exponential	0.159
Gamma	0.173
Lognormal	0.268

In this case triangular distribution is selected (TRIA 0.999, 2.03, 2.47), which represents a better adjustment. Histogram and obtained data are presented on the following image.

Figura 16. “Ejemplo función de distribución”
Figure 16. “Example of distribution function”

3.2 Simulation

In order to construct the simulation model, the work flow, each activity probabilistic distributions, project beginning date and required/available resources were employed as input data, among other particular characteristics of the job site. The model general layout and each comprised parts can be seen below.

Figura 17. Estructura general del modelo de simulación
Figure 17. Simulation model general layout

The parts in the model are:

- [1] Allocation of variables required for an adequate model operation. Variables are defined as the amount of camber pieces or the amounts of floors to be simulated.
- [2] Entities are created, which shall cover constructive processes. Required attributes are also assigned to execute the model properly.
- [3] Vertical elements are constructed including columns, elevator walls and staircase.
- [4] Afterwards supports, trusses and batter boards are installed.
- [5] Beams construction is executed.
- [6] Then, Metaldeck sheets are placed and covering concrete is casted-in.
- [7] Finally, before the total construction of floors to be simulated has not finished yet, the process is initiated again.

3.3 Simulation Results

In order to achieve model results, a model cross-check and validation was performed. Cross-checking considered a review of the model logic performance, inventories, entities holding times, and supervision was conducted by the constructor manager. So as to validate the model, the number of required replications was calculated to guarantee a 95% of data reliability. The total duration of simulation model was 203.15 days, which matches with actual duration. The percentages of human resources employment is observed on the following graph.

Gráfico 1. Resultados modelo de simulación

Graph 1. Simulation model results

From these results it is concluded that the use of resources is quite low; therefore, staff redeployment is required.

3.4 Improvement scenarios

Based on Lean Construction philosophy and trying to reduce losses identified in the project, the following simulation theoretical scenarios were proposed for the created model.

Scenario 0: Original model

Scenario 1: Staff reduction of support, trusses and batter board crew

Scenario 2: Staff redeployment of columns construction crew.

Scenario 3: Staff reduction of blacksmith crew.

Scenario 4: Staff reduction of beams construction crew.

Scenario 5: Staff redeployment of all crews' availability.

Scenario 6: Modification of camber pieces amount in available vertical elements.

Scenario 7: Change of execution strategy by dividing a floor of 3 areas into a 6 areas floor. The figure shows partition layout of the proposed area.

Figura 18. Propuesta de división de áreas de trabajo

Figure 18. Proposal of working areas partition

Scenario 8: Redeployment of resources availability by means of OptQuest (Rockwell Software) for optimization purposes.

Scenario 9: Redeployment of resources requirement and availability in accordance with inspection at the job site.

Scenario 10: Mix of scenarios 7 and 5.

Scenario 11: Mix of scenarios 7 and 8.

Scenario 12: Mix of scenarios 7 and 9.

Such scenarios proposed by images analysis processes, inspections at the job site and observation of 5 minutes video tapes are based on the Lean Construction philosophy, because they intend to establish a more effective use of resources by identifying losses or low level performance of staff employment. Processes shall be made simpler by splitting activities and focusing the whole process to the continuous improvement, together with the identification of enhancing opportunities.

3.5 Results of theoretical scenarios

By conducting the modifications required to represent each detailed scenario, achieved results in terms of execution time savings for a complete apartment block are presented below.

Figura 19. Resultados escenarios propuestos

Figure 19. Results from proposed scenarios

4. Recommendations

- When material arrives in the job site, it shall be properly piled and placed near the execution site to avoid re-work due to transportation.
- A worker is able to perform more than one task during an activity, in order to reduce holding times while other workers finish their jobs.
- It might be useful to install an elevator to reduce holding times and workers would be able to begin another activity earlier.
- In the case of concrete cast-in, the material arrival schedule shall be considered.
- Staff must be motivated so that working time does not become non-contributory time due to conversations or idle times.
- The constructor company is suggested to implement the partition of areas in the second apartment block. Resources schedule shall be guaranteed in order to obtain a significant reduction of execution times.
- It is also relevant that when performing the kind of job depending on digital pictures or video tapes, the tasks or inspections at the job site are not disregarded.
- By following this research strategy, a further analysis on another constructive system using the implemented method is proposed.
- The constructor company is able to carry out tests with the implementation of staff head-counts proposed in this research job.

5. Conclusions

- The implementation of the programmable module enabled the continuous control on the Project, which was quite useful to analyze constructive processes based on reliable information that contributed to make decisions on productivity improvements.

- *The application of communication technologies in the project facilitated the control by project directors and managers, who were permanently in contact with processes executions by remotely accessing on the internet, thus counting with information to be repeatedly used for more detailed analyses than the ones executable from data on specific site inspections.*
- *The results of this Project provide pictures and digital videos that support the staff training process in the company, thus becoming a knowledge management strategy.*
- *The analysis of constructive processes based on real data achieved at the job site, represents an advantage over other projects planning methods since results considered are intended for a particular company. Besides specific actions are defined and they might be repeated in the same project or in future projects, thus increasing the capability of fulfilling quality, times and costs goals. In the same way, a record is kept on the knowledge generated by the project and on the lessons learnt at each job site.*
- *This system implementation involves an initial investment in equipment, technology and software development that can be used in future projects, which will only require a new internet service contract since the other devices are reusable and easily installed. This balance makes the benefit/cost balance quite attractive.*
- *Feeding by means of photo-voltaic energy facilitates the allocation of capture points at any place in the job site, thus minimizing electrical plugs limitations and the lack of flow at any time. Wind energy can also be an alternative source.*
- *This research will serve as reference to plan works of similar characteristics when establishing execution strategy of constructive projects and the allocation of available resources for a job.*
- *Instrumentation enabled the identification of improvement opportunities in the job site, such as material storage and equipments not unloaded near the area where activities are executed. In some processes as concrete cast-in for different structural elements, the number of staff involved is higher than required. In beams construction process, time is mostly contributive because only well trained workers are required for specific jobs, such as beams formwork and measuring verticality of a camber piece. In column construction process activities are mostly productive.*

- According to results from reducing execution time in Apartment Block 1, it was concluded that the best modification is to implement a partition from 3 areas into 6 areas achieving a time reduction of 20 days. When this theoretical scenario is mixed with reduction of available staff on the top floor, execution time and resources obtained individually are kept for proposals.
- From the simulation considering a project scenario where the floor is not divided in 3 areas but in 6 areas, it can be observed that the greater division of large activities, the more productive a system is, therefore, reductions of time and costs are achieved.
- These kinds of simulations of constructive processes provide as result a better resources planning, a better organization of activities to be assigned to the staff and better execution times to be achieved.

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