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Discrete Event Simulation Analysis of the Effect of Labor Absenteeism on the Duration of Construction Activities in Housing Projects

Carlos A. Osorio-Sandoval*, Jesús N. Zaragoza-Grifé**, Gilberto A. Corona-Suárez***, José A. González-Fajardo****

**(Department of Civil Engineering, The University of Nottingham, United Kingdom)*
*** (Faculty of Engineering, Universidad Autonoma de Yucatan, Mexico)*
**** (Faculty of Engineering, Universidad Autonoma de Yucatan, Mexico)*
***** (Faculty of Engineering, Universidad Autonoma de Yucatan, Mexico)*

ABSTRACT
Labor absenteeism has been identified as one of the main factors delaying construction projects. This paper reports an approach to quantitatively estimate the effect of labor absenteeism on the duration of construction activities in housing projects, using discrete event simulation. Absenteeism and productivity data from fourteen housing projects were used to estimate the effect of absenteeism on four construction activities from three different projects. Moreover, four different absenteeism scenarios were analyzed with this methodology: no absences of skilled or unskilled workers; with absences of unskilled workers only; with absences of skilled workers only; and with absences of both skilled and unskilled workers at the same time. As expected, the results exposed that the absences of skilled workers have a greater impact on the runtime of construction activities than the absences of unskilled ones; while the scenario with simultaneous absences of skilled and unskilled workers caused the greatest delays and productivity losses in the activities. The methodology was proved effective to determine the effect of labor absenteeism on the duration and productivity of construction activities. Contractors could apply this approach in order to improve their scheduling procedures, as well as to increase certainty in the attainment of project goals.
Keywords-Labor absenteeism, Discrete-event Simulation, Duration of construction activities, Productivity, Housing projects

I. INTRODUCTION

The factors and causes affecting labor absenteeism in construction projects have been extensively studied (Hinze et al. 1985; Hanna et al. 2005; Salehi Sichani et al. 2011; Omar and Fayek 2012; Ahn et al. 2013; Ahn et al. 2014; Bhosale and Biswas 2015; Loganathan and Kalidindi 2016). Moreover, a number of studies have concluded that absenteeism is one of the major factors affecting labor productivity in construction projects (The Business Roundtable 1982; Lim and Alum 1995; Zakeri et al. 1996; Kaming et al. 1997; Makulsa-watudom and Emsley 2002; Enshassi et al. 2007; SalehiSichani et al. 2011; Omar and Fayek 2012; Gundecha 2012; Mahamid 2013; Shree Raja Gopal and Murali 2016). As expected, absenteeism has also been found as one of the causes of construction delays (Toor and Ogunlana 2008; Soekiman et al. 2011; González et al. 2014). However, research work on estimating the impact of labor absenteeism on the productivity and schedule performance of construction projects has been mostly neglected or limited. For example, Hanna et al. (2005) collected quantitative data on the absenteeism of construction workers and the productivity of construction activities from a number of projects, which was used to develop a regression model to evaluate the relationship between productivity and percent of absenteeism. However, they acknowledged that due to the limited availability of data the model could not be used for estimation purposes. Another attempt by Soekiman et al. (2011) evaluated the factors related to labor productivity that affect schedule performance of projects in Indonesia, in which they found absenteeism was one of the top ten factors having a “High” effect on schedule performance of projects. Yet, the evaluation of such effect was based on the perception of the project managers that participated in the survey.

The reason for neglecting the estimating of the effect of labor absenteeism on the productivity and the schedule of construction projects may be related to the significant number of factors affecting construction performance, being absenteeism only one of those factors. For instance, amid several other studies, Soekiman et al. (2011) used infor-mation from previous research to identify 113 factors affecting construction labor that may have an impact on schedule performance of projects in Indonesia; Makulsawatudom et al. (2004) studied the effect of twenty three factors on the productivity of construction projects in Thailand and concluded the ten top critical factors include: lack of material, incomplete drawings, incompetent supervisors, lack of tools and equipment, labor absenteeism, poor communication, instruction time, poor site layout, inspection delay, and rework; Horner et al. (1989) identified thirteen significant factors affecting labor productivity in the UK construction industry, namely: skill of labor, buildability, quality of supervision, method of working, incentive scheme, site layout, complexity of construction information, crew size and composition, length of working day, availability of power tools, absenteeism, total number of operations on site, and proportion of work sub contracted. It may then be difficult discerning the sole effect of one of those factors (e.g. absenteeism) on the performance of construction projects.

II. RESEARCH METHODOLOGY

This paper reports the experience obtained in a case study that used simulation analysis to estimate the extent to which labor absenteeism affects the duration of construction activities. In this case, discrete event simulation (DES) was used to experiment with different scenarios in which absenteeism could be there or not. As reported in this case study, this estimating approach could reduce the uncertainty project managers usually have to deal with when considering the impact of factors affecting construction activities, such as absenteeism, while preparing the project schedule.

2.1 Case study

Housing construction is a labor intensive production process in which productivity greatly depends upon the teamwork of the crews performing construction activities. This means the absence of one of the crew members could affect the productivity of the on process activities. Unfortunately, in the context where this study was conducted, i.e. Southeast Mexico, absence behavior of construction workers is a major issue in housing projects. For instance, in this context, Arcudia et al. (2003) estimated an average index of absenteeism of 12.40% in housing projects, which according to their observations this result is especially due to the habit of local construction workers of missing work on Mondays. Those authors further found that this behavior may be in part explained by the piece-rate compensation system that local contractors regularly use to remunerate constructions workers, especially in housing construction projects. This compensation system implies workers are paid based on the number of units, or pieces, they complete rather than on the number of hours they actually work. In this particular context, the problem arises when employers (i.e. contractors) assume this compensation scheme suffices to motivate laborers to work more efficiently, while they neglect the control that is required to take care of the production rate.

Under this premise the concern of a local contractor was to estimate the effect of the existing labor absenteeism on the schedule performance of the housing projects in charge of this organization. Thanks to the availability of sufficient data on labor productivity and absenteeism, gathered from fourteen housing projects that the organization had previously completed, it was possible to estimate such effect using DES. This organization was especially interested on estimating the effect on construction activities with great absenteeism rates. Table 1 shows a list of four constructions activities that were identified with significant labor absenteeism rates, obtained with absenteeism data from previous projects. These activities were then analyzed in this case study.

Table 1. Construction activities with significant labor absenteeism rates

Construction Activities	Average Absenteeism Rates
Masonry Walls with concrete blocks	19.4%
Inverse T joists and block flooring system	24.6%
Rooftop finishing	16.4%
Concrete floors and tile installation	14.2%

2.2 Modeling duration of tasks

In order to model the duration of the construction activities the first step was to break down their corresponding construction process into simple tasks. For example, the activity of Masonry Walls was broken down into sixteen different tasks: Carrying concrete blocks, Mixing mortar, Carrying mortar, Squaring the outline of walls with mason lines, Laying concrete blocks, Installing scaffolding, Moving scaffolding to the next wall section, Carrying wood for framework, Assembling framework for concrete tie-columns, Verifying measures of openings for doors and windows, Assembling framework for concrete lintels, Mixing concrete for pouring columns and/or lintels, Carrying concrete for pouring columns and/or lintels, Pouring concrete columns, Pouring concrete lintels, and Disassembling wood framework.

Productivity data was then collected for each of these tasks by measuring only the time that the worker effectively used to perform the assigned task. This would clearance the effect of absenteeism from the duration estimates obtained from simulation models. The data collection included the time effectively used to complete the task, the amount of work executed during the observed time, and the amount and type of workers involved in the execution of the task. Labor productivity values of the different tasks were computed using data obtained from fourteen small and medium size housing projects carried out by the contractor during the last two years. The labor productivity values were obtained using equation 1 (Project Management Institute, 2013).

$$P_{ij}^{k} = \frac{Q_{ij}}{D_{ij} * N_{ij}} \quad (1)$$

Where P_{ij}^{k} is the labor productivity of the task; Q_{ij} is the total amount of work executed during the observed time; D_{ij} is the time required to complete the task; and N_{ij} is the amount of workers involved in the execution of the task.

The productivity values were then used to determine the durations that the tasks would take, considering the amount of work required to complete the corresponding activities in the case studies that will be analyzed. Each productivity value previously obtained for a given task, was then converted to a duration value using equation 2, which was derived from equation 1.

$$D_{ij} = \frac{Q_{ij}}{P_{ij}^{k} * N_{ij}} \quad (2)$$

Where D_{ij} is the absenteeism-free duration of the task considering the amount of work that includes the case that will be analyzed, Q_{ij} is the amount of work that includes the case that will be analyzed, P_{ij}^{k} is the labor productivity of the task obtained earlier, and N_{ij} is the amount of workers involved in the execution of the task in the case that will be analyzed. The best fitting distribution for the set of durations was identified for each task with the use of EasyFit. Fig. 1 illustrates the output obtained from EasyFit: the probability density function that best fits the distribution of duration values of one of the tasks involved in this study. This software depicts an efficient approach to carry out goodness of fit tests such as Kolmogorov-Smirnov, Anderson-Darling, and Chi-Squared, and determine the probability distribution that best fits a set of data. It is important to remark these tests will provide the distribution parameters required as inputs to the simulation elements that depict construction tasks in the simulation models. Based on these parameters random values of durations of the tasks will be generated during the execution of the simulation models and, then, duration estimates of the corresponding activity will be obtained.

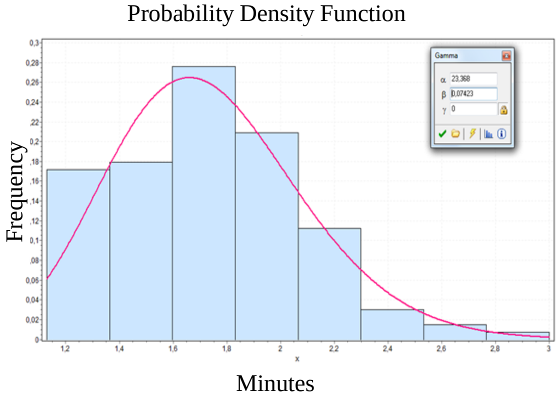


Figure 1. Example of output from EasyFit: Probability density function best fitting the distribution of duration values of a task

2.2 Modeling labor absenteeism

As mentioned before labor absenteeism data were collected from fourteen different housing projects in charge of the contractor involved in this study. Construction activities are usually executed by labor crews that involve skilled and unskilled workers. Skilled workers may have different behavior and performance from unskilled ones, given that they usually perform different tasks. For instance, as part of the “Masonry Walls” activity skilled workers would be in charge of laying concrete blocks, while the unskilled workers would be dedicated to carrying concrete blocks. For that reason labor absenteeism of skilled workers was collected separately from that of unskilled workers. It is also important to clarify that since construction activities greatly differ from each other in terms of characteristics and execution conditions, labor absenteeism data were collected for each different activity.

In this case, the approach to model labor absenteeism included the appraisal of two different variables: the duration of absences of workers and the recurrence of absences (i.e. the duration between one absence and the next one). For each activity, the behavior of a number of skilled workers (between fifty-eight and eighty-two) and unskilled workers (between forty-seven and sixty-nine) was appraised directly in the construction site in order to collect data on both variables. This required taking a detailed registration of the absences of each worker during a full workday. The best fitting distributions of both variables (i.e. the duration of absences of workers and the duration between one absence and the next one) were then determined using EasyFit. The determination of best fitting distributions was based on the

Kolmogorov-Smirnov, Anderson-Darling, and Chi-Squared methods performed by EasyFit. For instance, Fig. 2 and 3 respectively show that in the "Masonry Walls" activity the Burr distribution was the one that best fitted the frequency of the durations of absences of both skilled and unskilled workers. These tests provided the input parameters to the elements that depict the duration and recurrence of labor absences in the simulation model constructed for each of the four activities analyzed in this study.

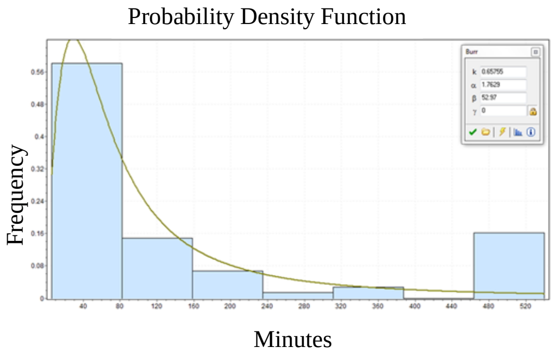


Figure 2. Distribution of absenteeism durations of skilled workers in "Masonry Walls" activity

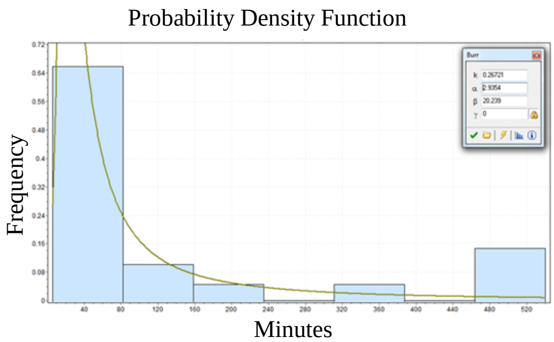


Figure 3. Distribution of absenteeism durations of unskilled workers in "Masonry Walls" activity

2.3 Simulation models of construction activities

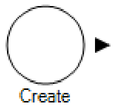
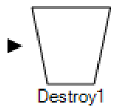
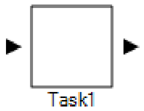
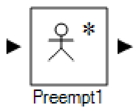
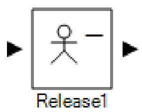
Simphony.NET 4.0 was used to build the simulation models of the four construction activities. Simphony.NET 4.0 features a friendly interface to build construction simulation models using modelling elements that are intended to model the dynamic interaction between activities and resources (Simphony.NET Development Team, 2011a). The modelling elements included in the General Template, a general purpose modelling approach developed in Simphony.NET, were used in this case. The reader may refer to the User's Guide for General Template in Simphony.NET (Simphony.NET Development Team, 2011b) in order to learn about the details on the use of these modelling elements.

The construction of the simulation models involved the following steps:

1. Identifying the tasks and the resources involved in each of the construction activities, as well as the interaction between tasks and resources.
2. Selecting the appropriate modelling elements to depict the real system from those available in the General Template.
3. Building the simulation model for each of the four activities analyzed in this case, according to the previous two steps.
4. Introducing the effect of absenteeism into the simulation models using the simulation elements available in Simphony.NET (Simphony.NET Development Team, 2011b), described in Table 2. Two different variables were appraised to model labor absenteeism: the duration of absences of workers and the recurrence of absences (i.e. duration between one absence and the next one). As seen in Table 2, the first variable was modeled with the Task element, while the second one involved the Create element. Moreover, Fig. 4 shows the logic relation among the modeling elements used to represent labor absenteeism of skilled and unskilled workers in the simulation models.
5. Validating each simulation model with a sample house selected from a housing project that was carried out by the contractor that participated in this study. Based on the drawings and specifications of this sample house, the volume of work necessary to perform each task was obtained; this information was required as input data to the corresponding simulation models. As previously explained, these volumes were also used to determine the distribution parameters of the durations of the tasks, which were required as inputs as well. The simulation model of each activity was executed for one hundred runs in order to obtain the average estimate of the activity total duration. This average estimate was then compared to the actual duration of the activity completed in the sample house. Any of the simulation models was assumed valid if it was able to predict the actual duration of the activity with an accuracy greater than 80%, which is a precision degree used in previous studies (Song and AbouRizk 2008; Zayed and Halpin 2004). Table 3 shows the results of the validation process for each of the four activities analyzed in this case study. As seen in this table, all of the four models were considered valid since they provide fairly accurate estimates. The number of skilled and unskilled workers used to validate each model was consistent with that actually employed to perform the different tasks in this sample house.

Once the simulation models of the activities were completed, they were used to experiment different absenteeism scenarios, as described next.

Table 2. Modelling elements used to incorporate absenteeism to the simulation models

Modelling Element	Symbol	Description	Input parameters
Create		Generates labor absences according to the given distribution of the lapse of time between the absences.	Interval: parameters depicting the distribution of the lapse of time between the absences.
Destroy		Destroys the entities (i.e. the created absences) that arrive to this element.	N/A
Task		Consumes the time of the random value generated according to the distribution of the durations of absences.	Duration: parameters depicting the distribution of the durations of absences.
Preempt		Holds a resource from the task in which it was being used and diverts it to perform another one.	Resource: type of *Resource* element to be hold by the *Preempt*element.
Release		Releases the resource that was hold and diverted by the *Preempt* element.	Resource: type of *Resource* element to be released. Servers: number of resources to be released.

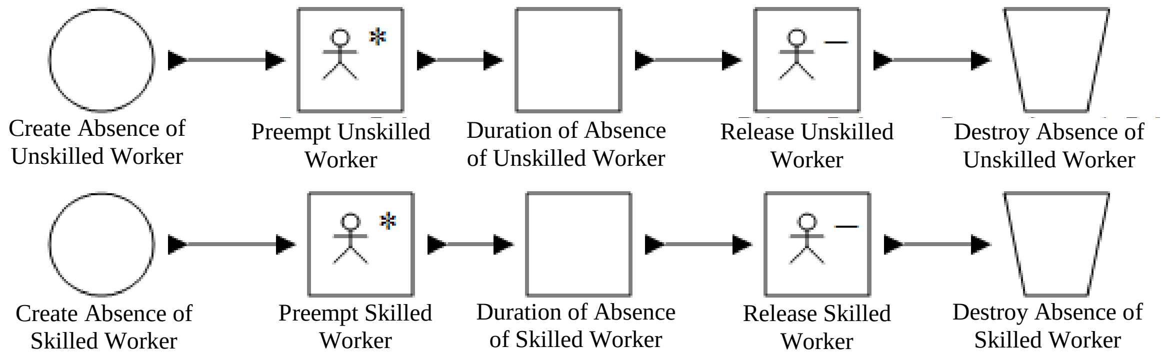


Figure 4. Use of modeling elements to introduce labor absenteeism in the simulation models

Table 3. Results of the validation of the simulation models

Construction Activities	Actual duration (minutes)	Simulation estimate (minutes)	Variation (minutes)	Accuracy (%)
Masonry Walls with concrete blocks	3853.29	4493.16	639.87	83.39
Inverse T joists and Block flooring system	576.83	617.01	40.18	93.03
Rooftop finishing	3042.58	2982.99	59.59	98.04
Concrete Floors and Tile installation	3448.96	3296.43	152.53	95.58

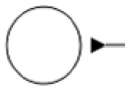
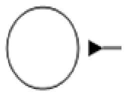
2.4 Simulation analysis of effect of absenteeism

Three prototypes of dwellings from different projects and featuring different designs were used to perform the simulation analysis of the effect of absenteeism on the duration of the construction activities. The construction of these projects was in charge of the contractor that participated in this case study. The drawings and specifications were reviewed to compute the volumes of work that would be completed in each of the tasks in the simulation models. The numbers of skilled and unskilled workers used in this analysis were based on those usually employed in previous housing projects with designs alike to those of these three dwellings. This information was used as inputs to the simulation models.

Four different absenteeism scenarios were simulated to analyze the effect of absenteeism in each of the three dwelling prototypes that were analyzed. The first scenario included no absences of skilled or unskilled workers; the second scenario included absences of unskilled workers only; the third scenario included absences of skilled workers only; and the fourth scenario included absences of both skilled and unskilled workers at the same time. Table 4 shows the values used as inputs to the Create elements (see Table 2) in each of the four scenarios, which depict the number of absences to be created during the simulation runtime. In this case, fifty absences was the estimated value that would suffice to supply the absences that would be required during all simulation time of the models.

The simulation models of the four activities were run two thousand times for each scenario and the results were compared to determine the effect of labor absenteeism on the duration of these activities. Two simulation outcomes were observed in order to conclude about such effect: the average execution time and the average productivity attained during the execution of the activities.

Table 4. Input parameters used to depict the number of absences in the simulation models

Simulation Element	Input parameters			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
 Create Absence of Unskilled Workers	Quantity: 0	Quantity: 50	Quantity: 0	Quantity: 50
 Create Absence of Skilled Workers	Quantity: 0	Quantity: 0	Quantity: 50	Quantity: 50

III. RESULTS

Fig. 5 and 6 illustrate the outcomes obtained from the execution of the simulation model of the "Inverse T joists and Block flooring system" activity, using inputs taken from dwelling prototype No. 1. These figures represent the frequencies of execution time values obtained with scenarios 1 and 4, respectively, throughout the two thousand simulation runs.

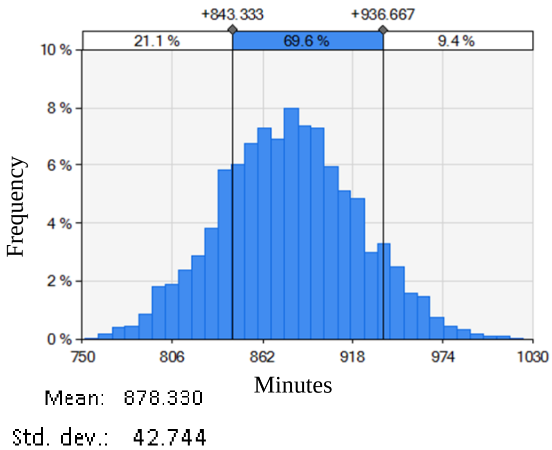


Figure 5. Example of outcomes obtained for the "Inverse T joists and Block flooring system" activity with Prototype 1, Scenario 1

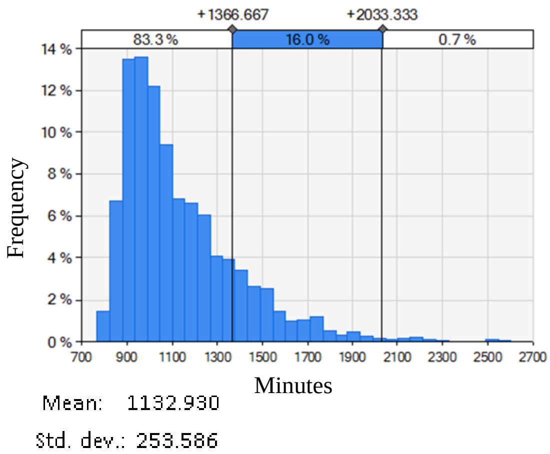


Figure 6.Example of outcomes obtained for the "Inverse T joists and Block flooring system" activity with Prototype 1, Scenario 4

As observed in these figures, the outcomes were significantly different between these two scenarios.

Moreover, Table 5 reports on the execution time estimates obtained with the four simulation scenarios in each of the three housing prototypes analyzed in this case. On the other hand, Table 6 shows the increase rates in the execution time estimates of the construction activities due to the effect of absenteeism. These rates depict the extent to which the execution time estimated with the simulation of the scenarios that do include absenteeism (i.e. scenarios 2, 3, and 4) increased in comparison to the execution time estimated with the scenario that include no absenteeism (i.e. scenario 1). For instance, in Project 1 (P1) the execution time estimated with Scenario 1 in the Masonry Walls activity (i.e. 4851.9 min, as seen in Table 5) increased by 15.14% (as seen in Table 6) when the estimate includes the absenteeism assumed for Scenario 4 (i.e. 5586.4 min). Furthermore, as seen in Table 7, the average increase rates were obtained for each of the three simulation scenarios based on the rates corresponding to the three projects shown in Table 6.

Table 5. Execution time estimates obtained in the three projects with the simulation scenarios

Activity	Scenario 1			Scenario 2			Scenario 3			Scenario 4		
	P1 (min)	P2 (min)	P3 (min)	P1 (min)	P2 (min)	P3 (min)	P1 (min)	P2 (min)	P3 (min)	P1 (min)	P2 (min)	P3 (min)
Masonry Walls …	4851.9	10161.5	4552.6	5168.1	10967.2	4889.8	5274.5	11181.0	4895.4	5586.4	12000.6	5217.2
Inverse T joists …	878.3	1703.6	588.2	996.2	1916.6	660.6	990.2	1911.5	662.9	1132.9	2159.4	748.2
Rooftop finishing	3924.6	6688.9	3053.2	4189.2	7259.5	3240.5	4444.3	7860.5	3399.6	4790.7	8494.0	3594.6
Concrete Floors …	3489.7	4095.9	3340.9	3588.3	4263.6	3427.0	3645.2	4374.1	3463.8	3749.0	4516.3	3557.0

P1 = Project 1, P2 = Project 2, P3 = Project 3

Table 6. Increase rates in the execution time estimates due to the effect of absenteeism

Activity	Scenario 2			Scenario 3			Scenario 4		
	P1 (min)	P2 (min)	P3 (min)	P1 (min)	P2 (min)	P3 (min)	P1 (min)	P2 (min)	P3 (min)
Masonry Walls …	6.52%	7.93%	7.41%	8.71%	10.03%	7.53%	15.14%	18.10%	14.60%
Inverse T joists …	13.42%	12.50%	12.31%	12.74%	12.20%	12.71%	28.99%	26.76%	27.21%
Rooftop finishing	6.74%	8.53%	6.14%	17.52%	17.52%	11.35%	22.07%	26.99%	17.73%
Concrete Floors …	2.83%	4.09%	2.58%	6.79%	6.79%	3.68%	7.43%	10.26%	6.47%

Table 7. Average increase rates in the execution time estimates of activities in the three projects

Activity	Scenario 2	Scenario 3	Scenario 4	Average
Masonry walls with concrete blocks	7.28%	8.76%	15.94%	10.66%
Inverse T joists and Block flooring…	12.74%	12.55%	27.65%	17.65%
Rooftop finishing	7.14%	14.03%	22.26%	14.48%
Concrete Floors and Tile installation	3.17%	4.98%	8.05%	5.40%
Average	7.58%	10.04%	18.48%	12.03%

The effect on the productivity of the activities was also estimated following a similar approach used to estimate the effect on the execution time. Table 8 shows the productivity estimates obtained with the four simulation scenarios in each of the three housing prototypes analyzed in this case. Table 8 reports on the average percentage of the productivity loss due to the absenteeism assumed in scenarios 2, 3, and 4. For instance, given that in the

Masonry Walls activity the productivity estimated for Project 1 with Scenario 4 was 1.21 m^2/hour (as seen in Table 8) the productivity loss was 15.70% if compared to the productivity estimated for the same project but with Scenario 1 (1.40 m2/hr, as seen in Table 8). Then, as seen in

Table 9, the average productivity loss in simulation scenarios 2, 3, and 4, was based on the productivity loss computed in the three projects (see Table 8).

IV. DISCUSSION OF RESULTS

As might be expected, scenarios with absences of skilled workers depicted greater delays (average = 10.04%) and productivity losses (average = 9.04%) than scenarios with absences of unskilled workers only (7.58% and 6.95%, respectively). Naturally, scenarios with absences of both skilled and unskilled workers resulted with the greatest average of estimated delays (18.48%) and producti-vity losses (15.24%). As seen in Table 7, the activity with the greatest affectation in its execution time was the "Inverse T Joists and Block Flooring System" (average = 17.65%); while the one with the least affectation was "Concrete Floors and Tile Installation" (average = 5.40%). Though determi-ning the causes of these outcomes was out of the scope of this research work, the contractor perceived these results related to the exhaustive-ness workers experience during the execution of these activities.

Table 8. Productivity estimates (m^2/hour) obtained in the three projects with the simulation scenarios

Activity	Scenario 1			Scenario 2			Scenario 3			Scenario 4		
	P1 (min)	P2 (min)	P3 (min)	P1 (min)	P2 (min)	P3 (min)	P1 (min)	P2 (min)	P3 (min)	P1 (min)	P2 (min)	P3 (min)
Masonry Walls ...	1.40	1.54	1.16	1.31	1.42	1.08	1.29	1.40	1.08	1.21	1.30	1.00
Inverse T joists...	5.20	5.47	5.58	4.58	4.86	4.97	4.61	4.87	4.95	4.03	4.31	4.38
Rooftop finishing	0.94	1.21	0.79	0.88	1.11	0.74	0.83	1.03	0.71	0.77	0.95	0.67
Concrete Floors and Tile…	1.21	2.19	0.93	1.17	2.10	0.91	1.15	2.05	0.90	1.12	1.98	0.87

P1 = Project 1, P2 = Project 2, P3 = Project 3

Table 9. Average productivity loss based on the productivity loss of the three projects

Activity	Scenario 2	Scenario 3	Scenario 4	Average
Masonry Walls with concrete blocks	6.79%	8.04%	13.74%	9.52%
Inverse T joists and Block flooring…	11.30%	11.15%	21.66%	14.70%
Rooftop finishing	6.65%	12.26%	18.13%	12.35%
Concrete Floors and Tile installation	3.06%	4.72%	7.43%	5.07%
Average	6.95%	9.04%	15.24%	10.41%

On the other hand, the estimate of the effect of absenteeism on the productivity of the activities, which resulted with an average productivity loss of 15.24% as seen in Table 9, concurs with the values of productivity loss in between 13% and 24.4% reported by Hanna (2005) for electric construction projects.

However, the main contribution of this research work was the methodology itself, based on DES, since proved pertinent to determine the effect of labor absenteeism on the duration and productivity of construction activities. Moreover, it should be mentioned that no similar approach was found in the literature to estimate such effect quantitatively. Contractors could apply this approach in order to improve their scheduling procedures, as well as to increase certainty in the attainment of project goals. Actually, the contractor that participated in this study was able to estimate the effect of absenteeism on the duration of the activities featuring high absenteeism rates and use the outputs for scheduling purposes. In this case, the contractor thought appropriate to affect the performance of the analyzed activities by increasing their duration according to the corresponding average delay estimated with this approach. For example, the duration of the "Masonry Walls" activity would be increased by 10.66%, as seen in Table 7.

V. CONCLUSIONS

The DES-based approach proposed in this research work proved effective to quantitatively estimate the effect of labor absenteeism on the duration and/or productivity of construction activities. Four different scenarios of absenteeism were analyzed with this methodology: no absences of skilled or unskilled workers; with absences of unskilled workers only; with absences of skilled workers only; and with absences of both skilled and unskilled workers at the same time. These scenarios were simulated in four construction activities from three projects and the results exposed that the absences of skilled workers have a greater impact on the runtime of construction activities than the absences of unskilled ones. Moreover, the scenario with simultaneous absences of skilled and unskilled workers caused the greatest delays and productivity losses in the activities. The average increase rate in the estimated execution time, due to absenteeism, was 7.58% with absences of unskilled workers only; 10.04% with absences of skilled workers only; and 18.48% with absences of both skilled and unskilled simultaneously. The average percentage of productivity loss due to absenteeism was 6.95% with absences of unskilled workers only; 9.04% with absences of skilled workers only; and 15.24% with absences of skilled workers only; and 18.48% with absences of both skilled and unskilled simultaneously.

Construction project managers will find the proposed approach useful to reduce uncertainty in project scheduling, as well as to assess alternatives to reduce absenteeism and deliver projects on time.

Finally, the proposed methodology can be used to study other factors that produce construction delays, such as rework, materials supply, design issues, weather conditions, and poor supervision.

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