CONSTRUCTION PROCESS SIMULATION USING CYCLONE MODEL

Edward Santa María[1], Igor Rojas Dominguez[2], and Javier Cornejo[1]
[1]Universidad Nacional de Ingeniería, Peru, esantamariad@uni.edu.pe, jcornejot@uni.pe
[2]Universidad Nacional de Ingeniería, Peru, yago1509@hotmail.com

***Abstract*– This article describes some applications for construction process simulation. Firstly, some processes have been conceptually worked using Cyclone Model (Halpin) and then they were simulated on Software Arena and Spreadsheets for testing in some situations with different adjustments in parameters (mainly number of equipment) associated to unit costs and global cost on alternative scenarios that allows decisions about planning and equipment selection to be made. Two types of cyclone models are presented, metal structures works and earthworks optimization. The simulation process helps to get an overview of many options for construction process and to obtain an optimal scenario.**

***Keywords*-- Time compression, job-sequencing, work structuring, Cyclone, Optimization process.**

I. Introduction

In the Construction Industry, the sequence of activities is vital to achieve the planned schedule. The construction processes are basically transformation operations, which progressively generate new materials (like concrete) or assembled elements from the interaction of machines / people, raw material and movement. Today, all engineering processes can be modeled by computational procedures.

II. BACKGROUND

A. Simulation Process

Construction processes involve many activities in where many resources are used along these and many interactions happen in order to complete them. The behavior of the main parameters involved in each of the processes can be studied from the statistical analysis of the measurements, which allows predicting new scenarios that improve or optimize the initial condition.

.

B. CYCLONE

CYCLONE model (CYClic Operations Networks) was proposed by Halpin at 70's (Halpin, 1983). The model focuses in resources utilization; then, these resources can be classified in two states, active task or idle condition. The active status is represented by rectangular forms (normal and combi elements) and the idle status is represented by circular forms (queue and function elements). It exists also the counter for track the number of cycle process (internal o global process, it depends of CYCLONE design)

Normal: It is a non-constraint task. This type of task can represent multiple resources allocated in parallel ways. That is, the transformation or movement process can be started as soon as resources are available to start the process, so that the parallel processing capacity is considered infinite. This task must be reconsidered in cases where the capacity limit is reached and congestion processes are generated. One of the classic examples is the beginning of the transport of material, since once the vehicle has been loaded, it can leave immediately without further restriction. If there are intermediate processes such as inspection in checkpoints or that the road has traffic or capacity limitations, the Normal form cannot be used.

Combi: It is a constraint task, limited by the availability of material resources or the equipment / labor necessary for the transformation or movement in each individual process. When the resource arrive to combi waits the availability of process to execute task.

Queue: It represents the time in which the process resources (transformation or movement) are inactive because there are no materials or other processing resources that are necessary to complete the task. The wait is associated with a Combi task.

Function: Is a flexible parameter than permits reimagine the another way to perform the process, to take into account any process that should be reviewed, an indicator or marker of the process that identifies some aspect that can be improved, or for other purposes.

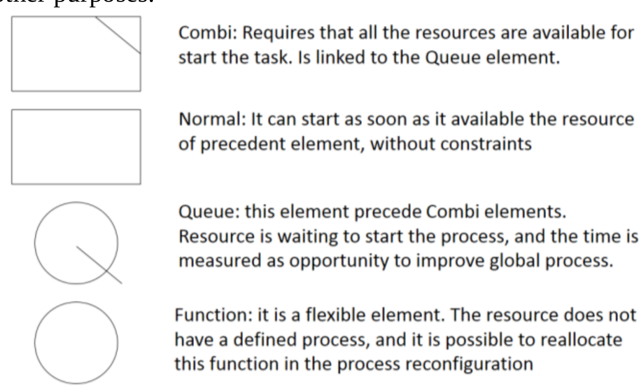

Fig. 1. Description of CYCLONE parameters.

C. ARENA Simulation Software

Arena Simulation Software is an industrial tool for process optimization that allows to create specific models for the process, and, after analysis, can optimize the total of resources.

Some scenarios can be modelled, like detailed processes, supply chain (include external logistic and internal process for storage and distribution), material and equipment uses. The goals are the predicting performance under some conditions and constraints, like costs, time, throughput, cyclic process, bottlenecks. These elements serve to improve global planning.

Digital Object Identifier (DOI):
http://dx.doi.org/10.18687/LACCEI2020.1.1.589
ISBN: 978-958-52071-4-1 ISSN: 2414-6390

III. CONSTRUCTION SIMULATION PROPOSAL

In this paper two cases are presented where simulation is applied. First, the maneuver of steel structures assembly is described, focusing in different equipment combinations to achieve the optimal scenario. The second case is a model to find the optimal fleet size of trucks for a given work cycle, considering loading and scattering.

A. Assembly of Steel Structures

Some buildings projects are standard and has the same cyclic process. In this paper, it is studied the construction of a structure, whose function is an exposition space for scholar buildings (Project: "Expansion and Improvement of Parrish School Pillko Marka", Tomaykichwa District, Huánuco Region, Peru), and that requires a larger span for that purpose. The process analysis is focused on metal structures based on box types, RHS (Rectangular Hollos Steel section) 200 mm x 80 mm, and 18 distributed axis, that is, 18 times for the same process and job-sequencing.

The data for studying this process was taken as follows. Firstly, video cameras were installed in the workspace as well as people were trained to collect data on formats, in which they have to annotate the description and the duration of the different tasks involved in the project. Thanks to videos and formats, all the tasks were fully identified, and the duration of all of them.

After task identification, they were classified into three categories, which are productive, contributory, and non-contributory. Also, resources usage was determined in each task.

Once the data was collected and processed, this is analyzed to determine statistical parameters, so a model can be simulated. The simulation model looks for reproducing the actual process within a confidence interval. This process here presented was analyzed using the CYCLONE model and, after calibration, some parameters can be changed so new scenarios can be evaluated; this way, improvements in the process can be done to increase productivity.

The CYCLONE model identified in the assembly of large span is shown in Fig. 2.

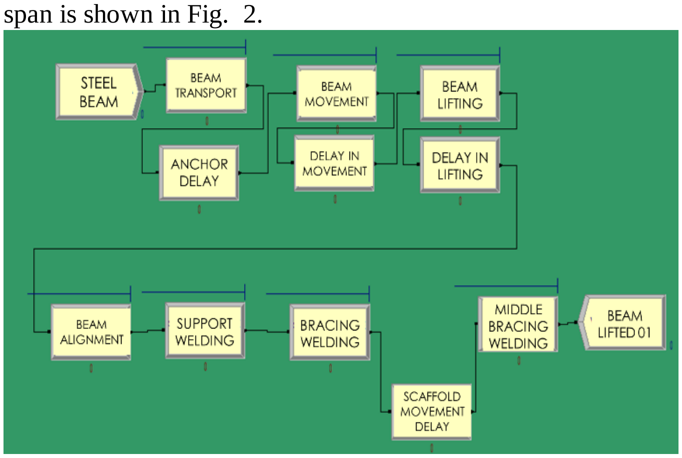

Fig. 2. CYCLONE model for the assembly of large span

With the model identified, it has to be simulated and validated. In order to achieve this, 15 simulations were run and results demonstrated this model was within the 95% confidence interval.

Some aspects to improve were found in the simulation. For instance, the crane was misused during the entire process due to lack of planning. Not only that, but the scaffold was causing delays due to the transfer from sideway to central part.

With the model validated, some parameters were changed for the simulation of seven scenarios, using ARENA software. The scenarios are as follow:

TABLE 1
DESCRIPTION OF SCENARIOS

Scenario	**Description**
Scenario 1	Original model representing real project
Scenario 2	Addition of 01 welding equipment
Scenario 3	Addition of daily planning program to reduce delays
Scenario 4	Addition of bigger capacity crane
Scenario 5	Scenario 2 + Scenario 3
Scenario 6	Scenario 3 + Scenario 4
Scenario 7	Ideal scenario where delays are set to cero

Results for these scenarios are summarized in the next table, indicating time and global costs:

TABLE 2
SUMMARY FOR SCENARIOS RESULTS

	Scenarios						
Parameter	1	2	3	4	5	6	7
# Runs:	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Min. Value (min):	75.09	63.82	64.79	74.55	50.14	68.30	37.71
Max. Value (min):	148.9	138.9	135.2	155.8	119.4	136.8	47.0
Mean (min):	115.42	103.66	103.95	101.17	87.13	92.47	43.00
Std. Dev:	20.22	20.82	19.83	22.92	19.55	20.53	3.05
Cost ($):	27,14	27,05	26,76	27,06	26,45	26,74	24,72

This scenarios demonstrated productivity can be enhanced. In Pillco Marka School, the time for assembling beams could be improved by more than 25% and the cost could been reduced by approximately 2.5% and in the ideal scenario (without delays) the reduction of cost could be 9%.

B. Earthworks Models

Earthworks have a cyclic movement to move material from one side (embankment) to the other (disposal site). The cycles are repeated many times.

The process starts in the area of embankment. It begins with the process of loading with excavators or wheel loaders.

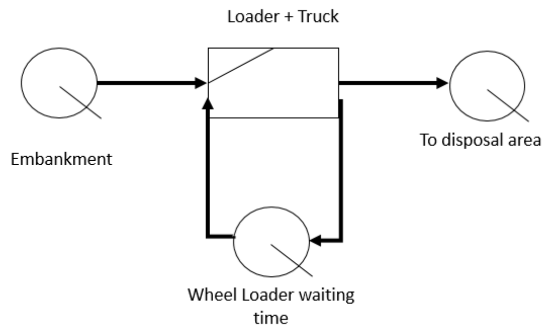

Fig. 3. Schema for CYCLONE loading process

The second process is the transport of removed material. The truck waits for the material to be load. After that, it starts the transport to the disposal site.

In the last stage, the truck unloads the material on disposal site. The bulldozers can level the platform of disposal area.

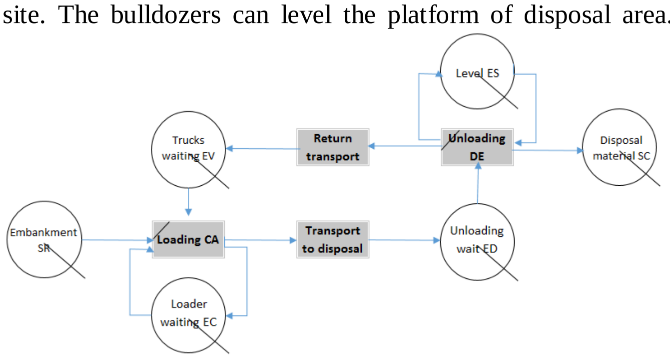

Fig. 4. Schema for Cyclone Earthworks process

The analysis of the earthmoving process allows to evaluate different parameters and scenarios to find the optimal time and cost, or the balance of both (Tao-Ming Cheng, Hsien-Tang Wu, Yi-Wei Tseng, 2007). In this case, the scenario aims to optimize the number of trucks for a certain earthworks circuit in which the dump is 3 km away from the point of removal. It is considered that there are three main equipment in this area: an excavator in the loading area, a group of trucks for transport and a bulldozer for spreading material. The objective is to find the optimal balance between time and cost, varying the number of trucks. Once the CYCLONE model approach is analyzed, it is established that the optimal number of trucks is 7.

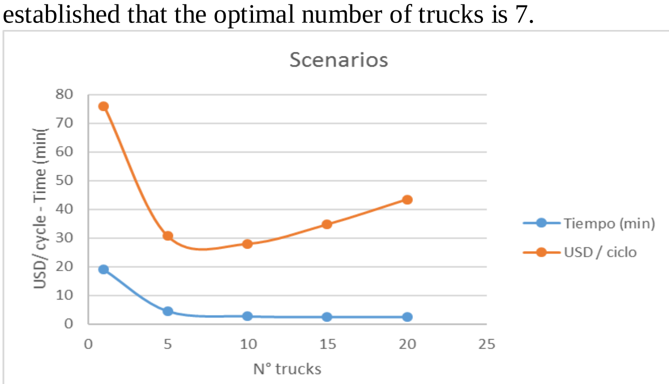

Fig. 5. Analysis of scenario with variable number of trucks

IV. Findings

The models allow to establish the interaction of each of the process variables. The statistical and numerical study of each parameter allows in turn to generate optimization scenarios that can be incorporated into the project planning. In these specific case, the model achieves an optimal combination of welding equipment or heavy earthmoving equipment.

One of the advantages of using simulation models is the identification of idle times that are affecting the entire process, such as, described in this paper, the assembly of steel structures and earthworks.

Not only that, these models allows the generation of scenarios to find the optimal one in order to increase productivity and reduce execution time.

IV. Conclusions

The construction process can be conceptualized and modeled from the observation of the main parameters of transformation and transport.

In the case of the assembly of metal structures (Pillko Marka school), 6 possible work scenarios have been combined to find the optimal scenario that allows to increase productivity. The model determined that Scneario N°5 was the optimal because of the time and cost reduction. The productivity was increase in 25% and the cost was reduced in 2.5%.

The ideal scenario (item 7) was also simulated considering that there are no waiting times, given a cost reduction of 9%.

Besides, a scenario has been simulated to obtain the optimum number of trucks in a cutting material disposal circuit, which tends to be a critical process given the cost of equipment and material.

References

[1] Aguirre, V. A. (2017). "Simulación Estocástica del Proceso Constructivo de Cimentaciones e Indicadores de Desempeño en la Construcción del Edificio Industriales Wanka – Huancayo 2017". Huancayo. Universidad Nacional del Centro del Perú.

[2] Granados, A., Pérez, I. K. (2014). "Simulación para el Mejoramiento de la Logística de Materiales y Equipos en un Proyecto de Edificación". Bogotá D.C. Pontificia Universidad Javeriana.

[3] Halpin, D. W. (1983). "Resource analysis using microcomputers (construction engineering)". Georgia: School of Civil Engineering, Georgia Institute of Technology.

[4] Rojas, I. (2018). "Simulación de Procesos Constructivos en ejecución de obras basada en observación directa de tareas para incremento de la Productividad". Lima: Universidad Nacional de Ingeniería.

[5] Tao-Ming C., Hsien-Tang W., Yi-Wei T. (2007). "Performing Time-Cost Trade-Off Analysis via GA-Simulation Mechanism". Tamkang Journal of Science and Engineering, Vol. 10, No. 4, pp. 307-316.