Simulation of Ready Mixed Concrete Supply Chain in the Building Industry using the Software Flexsim

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Abstract

The research aims to reduce the arrival rate of concrete mixer trucks by enhancing the process of unloading the concrete to concrete slabs, applying the computational simulation. The process is carried out by truck-mixers aided by a pump-lance assembly to discharge the concrete into the slabs. The data were collected in the field, quantifying the time of arrival, the beginning and the end of the concrete discharge by concrete mixer trucks, checking the waiting times. The results of the simulation found a rate of reduction of the time between arrivals of 20%, reducing idleness of the observations by 34% for a mean time of permanence of the truck between arrival and end of discharge of 29.30 minutes below the limit prescribed by NBR7212 / 12 of 30 minutes. The application of this work provides a model to reduce the loss of time (idleness) by assisting in the supply of the concrete machined in the concreting of the vertical constructions using truck-mixer trucks with pump-lance, providing precedents for future studies in this area.

Keywords: Queue Concrete Discret event Flexsim Simulation

1. Introduction

The construction industry has increasingly required practices that contribute to the optimization of procedures, reduction of waste and delivery of higher quality products. In this context, it is essential to carry out internal evaluations of the practices adopted at the building site. The analysis and simulation of the supply chain can contribute to the improvement of the methods used in the construction industry. In Brazil, the construction industry and its supply chain play an essential role in the economy handling 5.6% of Brazil's Gross Domestic Product (GDP) (IBGE, 2017).

Akhavian and Behzadan (2014) recognize that many activities in which queues arise in the construction process are almost inevitable. Delays generated by lines cause disruptions in the work schedule, affecting the flow of financial resources designed.

In dealing with productivity, problems of the concreting process studies have recognized the importance of simulation for an adequate supply of concrete at the construction site. Smith (1998) has developed a concrete supply model using coded Visual Basic for Excel. Wang, Teo & Ofori (2001)
presented a simulation model using the @Risk spreadsheet integration software. Akhavian and Behzadan (2014) have used the @Risk programs to adjust distributions simulating row discipline in STROBOSCOPE. Zayed and Halpin (2001) performed simulations using microCYCLONE and highlighted optimal supply areas around a construction site demonstrating a more efficient resource allocation with minimum delivery time.

Anson and Wang (1998) reported that there is considerable difficulty in supplying concrete promptly due to the limited number of trucks and traffic conditions because it has many variables involved generating a lot of unpredictability. Meanwhile, Smith (1998) in his study on modeling and simulation in the concrete supply process concluded that one of the factors to maximize performance in the concreting method would be to reduce the arrival rate of concrete mixer trucks. Smith found that the difficulty in supply would lie in the interaction between the times between the arrivals of the concrete and the rate of rejection.

In this regard, Azambuja and Chen (2014) conducted a simulation to assess supply chain risks to identify vulnerabilities and measure the impact of ruptures in the machined concrete supply chain. For this, they implemented a tool for fault diagnosis, effects and critical analysis (FMECA). They concluded that in real industrial environments, the sources of uncertainties are numerous and to obtain reliable results, we need to have a reliable estimate of these possibilities. For example, a variation in the time between arrivals of the trucks in work to obtain more favorable scenarios.

Richard and John (2017), in their study on green logistics and the management of the concrete supply chain, used a dynamic model of supply proposing less waste of time in the supply process. They observed 100 concrete delivery events generating an average time of arrival in the queue of twenty minutes and forty-five seconds and the discharge period of fifteen minutes and fifty-four seconds.

Costa et al. (2013) observed 31 deliveries of concrete for three building sites, finding an average waiting time of 2 hours and 30 minutes, which means that the teams were idle or underutilized during this period, generating a loss of time and physical and financial resources. The authors also report the average time for unloading concrete in a slab at twenty-one minutes.

Wang, Teo & Ofori (2001) observed 50 arrivals and departures of concrete mixer trucks, verifying an average arrival time of trucks of eleven minutes. The authors noted that longer arrival times reduced the number of trucks on building site. However, it contributed to the reduction of utilization rates of the concreting process.

Park et al. (2010) developed a dynamic simulation model for the concrete supply process at the building site where they analyzed 100 deliveries of concrete mixer trucks to the construction site obtaining an average arrival time in the queue of twenty minutes and five seconds. In their study, the authors noted that the information generated by the model allows optimum supply of concrete while maintaining a desirable number of trucks waiting in line to meet the concrete process at the building site. This dynamic model developed through simulation could be used as a useful automated tool to assist concrete suppliers in procurement planning.

In concreting operations, the Brazilian Association of Technical Standards (ABNT, 2012) establishes that the unloading of the concrete must take place until thirty minutes after the arrival of the truck mixer in the building site. In situations where it is not possible to obtain this reference time, a technical solution must be evaluated to avoid compromising the quality of the concrete as well as its validity.

The objective of this study was to find an arrival rate of concrete mixer trucks that potentiates the concreting process through simulations using the FLEXSIM computational tool. For this, we collected the truck-mixer arrival periods and their respective times of unloading of concrete. From the identification of the times, we proposed a new configuration of the concrete supply system, to improve the performance of this process in the building site. We present the results comparatively through the analysis of several scenarios to identify the best configuration about the parameters prescribed by ABNT (2012), assisting managers of works in decision-making.
2. Theoretical Foundation

2.1 The Construction Industry Supply Chain

According to Oliveira (2007), the construction process involves a scheduled progression for the execution of activities. Planning must take place correctly to gain productivity and, consequently, speed. This harmonic sequence must begin at the foundation and go through the various stages of the building site. The construction processes represent value creation of a business and can translate to efficient, regular and timely delivery. With the influence of total quality and time-based competition, many companies were encouraged to take steps to reduce their costs and process cycle times.

Machado (2003) conducted a survey of information for the improvement of the production process influencing the construction planning. He found restrictions that hindered the flow of the existing production processes in the building site under study, causing losses of time. Subsequently, he proposed a treatment of information, transforming them into management actions, which called anticipations, which should then be inserted into the production plan.

Moon (2014) observed field operations for a concreting process that generated problems in the activity flow. He found information failures causing interruptions in the process, lack of preparation until the concrete unloaded, lack of identification of the location of the concrete launched, delays in the arrival of the trucks with the concrete, and loss of critical information such as the traceability of the concrete in the structure.

The author proposed a model aimed at improving the quality of the operational process to minimize waste of time generated by inactivity (idle or wait time), which in turn can cause high costs for the project.

The study of the construction supply chain has grown in importance over the years, signaling that the proper management of this chain can have a significant impact on local and national economies, given the high volume of business that moves nationally. However, experiments with supply chains can be complicated, and computational simulation becomes a tool with high potential for their study (WALSH et al., 2004).

2.2. Queue and Simulation Systems

According to Mesquita and Hernandez (2006), two current topics in research on management science are queuing theory and discrete event simulation. The queuing method refers to the development and implementation of analytical models of closed shape and standby lines. A dedicated simulation software usually performs the discrete event simulation. Queuing theory presents a closed form that is not capable of analyzing most of the complex systems that are in practice, and the simulation of discrete events emphasizes simulation software features rather than basic concepts of discrete events.

Bateman et al. (2013) report that the increasing use of modeling and simulation is a good indicator that this idea has been used to generate useful results. Almost all studies that intend to use this method has produced some model to facilitate understanding. Therefore, it is increasing the number of models designed to explain business principles and engineering.

According to Law (2010), most real-world systems are too complex to evaluate realistic models analytically. These models should be studied by observing scenarios proposed by simulations. In a simulation, we use a computer to assess a model numerically, and the data is collected to estimate the characteristics of reality.

For Bateman et al. (2013) many companies are worried about failure in operations. It ends up obstructing the managers to offer suggestions based on their knowledge, ideas, and creativity. Therefore, the simulation is an excellent tool to overcome this fear. The possibility of analyzing a new proposal by a simulation model allows testing the impact of the suggestions. The use of this device, therefore, is essential so that there are changes to the decision makers.

Akhavian and Behzadan (2014) argue that the interest of an operations manager on the queue is to know the waiting time, which resource delays, the length of service and the logistics of the line. Such
knowledge is critical for allocating resources, layout, production forecasts, and determining the duration of individual operations. For this, simulation models have been widely used in queuing systems.

### 2.3. Modeling and Simulation

Simulation Models are logical descriptions of the interactions among the elements of a decision problem or sequence of events occurring in a system. They capture the probabilistic behavior and allow statistically estimate the probability distributions or averages that cannot be derived analytically. The simulation models capture the dynamics and functioning of interacting elements of a system. The variances occurring in the system drive these models (Evans, 2000).

Bateman et al. (2013) discuss the simulation as being the experimentation of a real system through models, generating the possibility of creating and simulating desired phenomena. The process of the conference and analyzing changes contributes to decision making. For these authors, the beginning of the simulation is uncertain, but its importance and application as a tool is evident.

Simulation is the best tool to observe a real operating system, allowing study the situation even when you cannot experience it. It is a significant benefit when the system does not exist or when it is too expensive or difficult to implement it. Thus, we can consider simulation an experimental application that, applied to a methodology, seeks to describe the behavior of a system and use the model to predict its future behavior (Shannon, 1998).

Chwif and Medina (2010) state that we use the simulation model to obtain answers since it can capture more accurately the characteristics of real systems. The simulation model allows analyzing virtually the behavior that a system would present when subjected to the same conditions of reality through repetition in a computer.

According to Law (2007), it is often practically unfeasible to evaluate a production system within its real environment. A simulation model is ideal to minimize this difficulty. Models can involve discrete event simulation, continuous simulation, and Monte Carlo simulation. The discrete and continuous simulations consider the evolution of the system over time.

The discrete event simulation (DES) uses a logical or mathematical model to analyze state changes at precise points that are discrete over the simulated time. In the late 1950s, DES evolved to become one of the most commonly used modeling techniques coupled with the development of computing (ROBINSON, 2004).

According to Montevechi et al. (2007), the DES comprises three stages: design, involving the development of a conceptual model; implementation by generating the computational model; and analysis, obtaining the operating model. In this work will be used a theoretical modeling technique, called IDEF-SIM. Leal et al. (2008) proposed this method, who used and adapted logical elements of the IDEF0 and IDEF3 modeling techniques, allowing the elaboration of conceptual models with useful information to the computational model. A hierarchical series of diagrams support the technique, which show levels of detail for describing functions and interface with the system.

To prepare the computer model a suitable choice of the simulation software is essential. Currently, there are several software options available, which differ in its primary applications, vendor and user criteria, model translation, animation and specific tools. Banks et al. (2010) identify some of options: AnyLogic®, Arena®, AutoModTM, Enterprise Dynamics®, exteNdTM, Flexsim, ProModel®, and SIMUL8®.

### 2.4. FLEXSIM Simulation Software

According to Tijan, Aksentijević, HACA (2014), the Flexsim is a tool used mainly to simulate discrete events. The system behavior is described a non-continuous way, as a sequence of different events and activities. We use discrete simulations primarily to model and analyze systems with waits and compare them with the actual system and its resources.
Flexsim is a software for this type of application, used to model and simulate different systems from different industries. Furthermore, it provides options to adjust the original data, model input data, build graphical models, perform simulation experiments, run the model, optimize the results and generate animation files in 3D. Its structure allows simulation model interface with other computational tools, such as ExperFit and spreadsheet Microsoft Excel, besides the evaluation scenarios focusing on the optimization by the Experimenter (Chen et al., 2013).

We can define and program the FlexSim® objects in four classes. The fixed resource class comprises the principal objects of the simulation, determining the flow of the simulation model (arrival, queues, processors, means of transport and output). The task execution class, which mainly assign tasks to other objects, such as operators and carriers. The node class includes objects used to design the route of work. We use the class of visual object to display the objects and collect incoming and outgoing messages, such as diagrams and texts (Flexsim, 2017).

The use of computer modeling programs and simulation systems in the construction sector is an important initiative to boost the competitiveness of companies in this industry, through the identification and resolution of production bottlenecks as well as possible and with the least time. In this work, we selected the Flexsim software to indicate the interventions to benefit the concreting system.

3. Scientific Methodology
We adopted a modeling and simulation approach aiming at creating and experimenting a physical system of the concreting process through a computer model. Four building sites were adopted to study with constructive characteristics presenting similarities regarding their nature, construction process, technique, number of floors, and the constructed area as showed in Table 1. The launch of concrete was performed using a pump truck striker, who received concrete and pumped through metal pipes to the location of the slabs. After dumping the concrete, the teams began the process of densification, regularization (leveling) and molding of the concrete.

Table 1: Characteristics of the building sites

<table>
<thead>
<tr>
<th>Building site</th>
<th>Nature</th>
<th>Number of floors</th>
<th>Constructed area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Residential / Commercial</td>
<td>28</td>
<td>2,800</td>
</tr>
<tr>
<td>2</td>
<td>Residential</td>
<td>33</td>
<td>2,000</td>
</tr>
<tr>
<td>3</td>
<td>Residential</td>
<td>40</td>
<td>1,800</td>
</tr>
<tr>
<td>4</td>
<td>Residential / Commercial</td>
<td>36</td>
<td>2,500</td>
</tr>
</tbody>
</table>

Source: The authors (2018)

Through field observation, we collected the times involved in the study process, using a stopwatch and a form. We gathered the date of collection, information on weather conditions, the number of internal control mixer truck, instant record that the mixer truck arrived at the queue, beginning and completion of the unloading of the concrete mixer truck, and return to the concrete manufacturing plant.

Initially, we selected a pilot sample of 50 observations as showed in Table 2, based on the studies of Wang, Teo & Ofori (2001) and Costa et al. (2013).
Table 2: Samples extracted from the building sites for arrivals and discharges times

<table>
<thead>
<tr>
<th>Building site 1</th>
<th>Building site 2</th>
<th>Building site 3</th>
<th>Building site 4</th>
<th>Building site 1</th>
<th>Building site 2</th>
<th>Building site 3</th>
<th>Building site 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.133</td>
<td>0.417</td>
<td>0.600</td>
<td>0.233</td>
</tr>
<tr>
<td>1.000</td>
<td>0.933</td>
<td>0.033</td>
<td>0.183</td>
<td>0.250</td>
<td>0.617</td>
<td>0.667</td>
<td>0.317</td>
</tr>
<tr>
<td>0.633</td>
<td>0.483</td>
<td>0.100</td>
<td>1.083</td>
<td>0.217</td>
<td>0.333</td>
<td>0.317</td>
<td>0.500</td>
</tr>
<tr>
<td>0.283</td>
<td>0.750</td>
<td>1.150</td>
<td>1.117</td>
<td>0.267</td>
<td>0.450</td>
<td>0.200</td>
<td>0.533</td>
</tr>
<tr>
<td>0.250</td>
<td>0.517</td>
<td>0.600</td>
<td>1.300</td>
<td>0.283</td>
<td>0.500</td>
<td>0.217</td>
<td>0.550</td>
</tr>
<tr>
<td>0.683</td>
<td>0.317</td>
<td>0.333</td>
<td>1.900</td>
<td>0.233</td>
<td>0.233</td>
<td>0.150</td>
<td>0.333</td>
</tr>
<tr>
<td>0.500</td>
<td>0.833</td>
<td>0.167</td>
<td>1.000</td>
<td>0.217</td>
<td>0.633</td>
<td>0.283</td>
<td>0.300</td>
</tr>
<tr>
<td>0.583</td>
<td>0.333</td>
<td>0.517</td>
<td>0.233</td>
<td>0.250</td>
<td>0.217</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.483</td>
<td>0.783</td>
<td>0.600</td>
<td>0.217</td>
<td>0.250</td>
<td>0.183</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.267</td>
<td>0.467</td>
<td>0.000</td>
<td>0.217</td>
<td>0.417</td>
<td>0.283</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.200</td>
<td>0.833</td>
<td>0.000</td>
<td>0.267</td>
<td>0.250</td>
<td>0.133</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.450</td>
<td>0.167</td>
<td>0.483</td>
<td>0.217</td>
<td>0.250</td>
<td>0.250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.317</td>
<td>0.333</td>
<td></td>
<td>0.200</td>
<td>0.250</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.817</td>
<td>1.583</td>
<td></td>
<td>0.333</td>
<td>0.333</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.900</td>
<td></td>
<td></td>
<td>0.333</td>
<td>0.250</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.467</td>
<td></td>
<td></td>
<td>0.383</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: The authors (2018)

Then, to certify that the sample dimension was appropriated, we considered the Equation 1 to calculate the minimum sample size. We found a standard deviation for the pilot sample of 27.32 minutes. We considered a 95% confidence interval and a sampling error of 7.5 minutes. These parameters revealed from the equations (1) and (2) a sample with a minimum size of 50 observations coinciding with the size of the pilot sample preliminarily suggested.

\[
E = \frac{Z_{\alpha/2} \sigma}{\sqrt{n}} = \frac{1.96 \times 27.3}{\sqrt{50}} = 7.5 \text{ minutes}
\]  
(1)

\[
n = \frac{(Z_{\alpha/2} \sigma)^2}{E^2} = \frac{(1.96 \times 27.3)^2}{7.5^2} = 50 \text{ records}
\]  
(2)

Where:

- \(Z_{\alpha/2}\) = confidence interval for 95%;
- \(\sigma\) = standard deviation;
- \(E\) = sample error;
- \(n\) = sample size.

Each mixer truck could transport a volume of 8 m³ of concrete. The concrete was pumped through metal pipes to the programmed locations of discharge into slabs. After the concrete was discharged, the teams began the process of densification, regularization (leveling) and molding of the concrete.

To perform the modeling of the concreting process, we adopted the proposal presented by Tijan, Aksentijević & Hlaca (2014), as shown in Picture 1. For these authors, it is important to exclude all elements that make the model more complicated and do not contribute significantly to the quality of the responses obtained.
We use the IDEF-SIM methodology to create the conceptual model (Picture 2). The purpose of this resource is to create a theoretical model of the process containing elements necessary to the computational modeling phase, facilitating the elaboration of the model. This model follows the concrete supply flow assessing the time of arrival, waiting in the queue and unloading the concrete in the system according to Picture 2.

**Picture 1: Modeling process, from problem definition to results analysis**

![Diagram](source)

**Picture 2: IDEF-SIM Conceptual Model of Machined Concrete Supply Process**

![Diagram](source)

We used the FlexSim software to develop the current computational model and its simulation (Picture 3). The ExpertFit® software was also associated with Flexsim to perform the function to find the probability distribution models that best fit together in the set of data entered into the system.
Picture 3: Computational model of the machined concrete supply process

Source: The authors (2018)

Picture 3 shows the three processes (Arrival, Line and Discharge) considered in the computational model developed to represent the actual concreting process. The mix concrete supply system starts in the output of the mixer trucks of plants (Arrival) and reaches the places prepared for discharge (Line) in the building sites. The concrete is dumped into lops (Discharge) from which it is pumped through metal pipes to the discharge site. After the end of discharge (Output), the truck returns to the concrete factory.

To evaluate the best arrival rate, with the decrease of the idleness of the process and increase of its use, we created six scenarios about the collected distribution. For this analysis, we considered reductions in the arrival rate of 10%, 15%, 20%, 30%, 35% and 40% for each scenario and maintained the same discharge distribution.

4. Analysis of the Results

According to the described methodology, we chose the building sites considering the similarities in the execution process and the concrete supply. The number of trucks varied in each building site due to the size of the slabs, changing the volume of concrete supplied, as shown in Table 1.

Table 1: Arrival times, unloading beginning and ending

<table>
<thead>
<tr>
<th>Building site</th>
<th>Observations</th>
<th>Arrival time (min)</th>
<th>Discharge time (min)</th>
<th>Total time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Median</td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>590.00</td>
<td>32.50</td>
<td>240.00</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>505.00</td>
<td>29.00</td>
<td>326.00</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>239.00</td>
<td>15.00</td>
<td>210.00</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>335.00</td>
<td>66.00</td>
<td>148.00</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>1669.00</td>
<td>29.00</td>
<td>924.00</td>
</tr>
</tbody>
</table>

Source: The authors (2018)

For the building sites 1, 2, 3 and 4, the samples were, respectively, 16, 15, 12 and 7 observations, totaling 50, taking into account the minimum sample size for this research. The sample produced a median between arrivals of 29 minutes and a median of 15 minutes for the discharges. The total time of the observations, considering the arrival until the end of the discharge was 2593 minutes.

By simulating the discharge times of the sample in Flexsim, we obtained the log-logistic distribution, classified as continuous, as shown in Picture 4.
The distribution shown in Picture 4 is commonly used in reliability analysis in cycles until fatigue failure, material resistance, and probabilistic design with variable loads. The simulation of the distribution of inter-arrival times generated a beta distribution (Picture 5) defined as continuous as well as the log-logistic distribution.

**Picture 4**: Simulation of the distribution of the concrete discharge process

[Image: Simulation of the distribution of the concrete discharge process]

Source: The authors (2018)

The parameters of the sample of the arrival times of the truck mixers in the building sites differ from minimum and maximum, having the function of characterizing times for schedules of activities for planning.

In order to discover a time distribution between arrivals that would enhance the use of the discharge process, without exceeding the queuing and discharge time of 30 minutes, as predicted by NBR 7212 (2012), the distribution times between sample arrivals were reduced to 10%, 15%, 20%, 30%, 35% and 40%. For each proposed reduction, we simulated a new distribution, as presented in Table 2.

**Table 2**: Time distributions between arrivals generated by Flexsim

<table>
<thead>
<tr>
<th>Distribution times of arrivals</th>
<th>Sample</th>
<th>Reduction of 10%</th>
<th>Reduction of 15%</th>
<th>Reduction of 20%</th>
<th>Reduction of 30%</th>
<th>Reduction of 35%</th>
<th>Reduction of 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>beta (0.068798, 219.9000954, 1.710780, 8.006745, 0)</td>
<td>beta (0.068798, 198.500213, 1.720651, 8.084879, 0)</td>
<td>beta (0.068798, 186.827081, 1.727140, 8.008743, 0)</td>
<td>beta (0.068798, 175.153950, 1.742098, 8.101247, 0)</td>
<td>beta (0.013139, 154.697481, 1.688946, 7.926009, 0)</td>
<td>weibull (0.000000, 28.032194, 1.537840, 0)</td>
<td>beta (0.034399, 131.351218, 1.705269, 7.942720, 0)</td>
</tr>
</tbody>
</table>

Source: The authors (2018)
The beta distribution appeared in reductions of 10%, 15%, 20%, 30% and 40%. The Weibull distribution appeared only in the 35% reduction. Both distributions are continuous, which have the characteristic of describing times to complete tasks in the planning and design of systems. These distributions have been applied to model the behavior of random variables limited to finite-size intervals.

The simulation performed showed that the average queue and discharge times increased due to the increase in the arrival rate. Consequently, the total time of the system increased, as shown in Table 3:

**Table 3:** Average time of arrival of the queue and the end of the discharge (minutes)

<table>
<thead>
<tr>
<th>Process</th>
<th>Sample</th>
<th>Arrival time reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>Line</td>
<td>7,60</td>
<td>8,60</td>
</tr>
<tr>
<td>Discharge</td>
<td>18,70</td>
<td>18,8</td>
</tr>
<tr>
<td>Total</td>
<td>26,30</td>
<td>27,40</td>
</tr>
</tbody>
</table>

Source: The authors (2018)

The results obtained from field observations indicated that the total average stay of trucks between arrival and the end of discharge is 26 minutes and 30 seconds. The 20% reduction is closest to the limit established by the standard, recording a residence time of 29 minutes and 30 seconds.

Table 4 shows the performance results of the concrete discharge system, considering the six scenarios constructed.

**Table 4:** System performance and its optimizations according to scenario

<table>
<thead>
<tr>
<th>Process</th>
<th>Sample</th>
<th>Time reductionbetweenarrivals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>Queue</td>
<td>17,2%</td>
<td>20,0%</td>
</tr>
<tr>
<td>Discharge</td>
<td>54,7%</td>
<td>56,4%</td>
</tr>
<tr>
<td>Idleness</td>
<td>45,3%</td>
<td>43,6%</td>
</tr>
</tbody>
</table>

Source: The authors (2018)

We can see in Table 4 that the probability of the system is in service for the analyzed distributions increased, from 54.7% to 88.2%, as the rate of arrival is reduced. However, queue processing rose from 17.2% to 58.7%, increasing the probability of queue generation.

After the start of delivery (or arrival at the building site), the time limit for unloading should be no more than 30 minutes after the truck arrives at the building site to ensure that the concrete does not lose its mechanical properties (NBR 7212, 2012). Chart 1 highlights this limit of time for unloading after the arrival of the truck to building site compared to the results obtained in the simulations of distributions.
In the verification of the time limit for the start of unloading after arrival in the work obtained in the simulations, it was observed that the 30%, 35%, and 40% reductions distributions exceeded 30 minutes, despite obtaining a system idleness of 19.6%, 16.9% and 11.8% (according to Table 4).

In analyzing the parameters of the line generated by the reduction of 20% of the arrival rate we found an idleness of 33.8% and an increase in discharge processing to 66.2%. According to the data in Table 4, this arrival rate reduced the idle rate by 34% about the actual arrival rate of the sample.

5. Conclusion
The results obtained through the simulation using the Flexsim software and its Expertfit tool for the production of statistical distributions proved to be quite useful since through samples collected with real production data distributions were presented comparing the parameters of the queue.

This study can demonstrate that by obtaining a processing rate (supply) with a good predefined efficiency and interfering in the arrival rate, reducing it we can measure a reduction in significant idleness, reducing idle machine and equipment times and generating gains for the project.

The data presented brought us the certainty that the concreting process by truck-mixer vehicles aided by pump-launches for the execution of slabs requires interventions to improve the time of unloading of the concrete in the building sites.

Despite the development of the of civil construction production chain in recent years, there are still detectable restrictions and problems in time losses, causing idleness and capacity decrease and the productive index of the works.

There is still a lot of variability and many restrictions on the workflows in construction. A short-term planning using software for the simulation to re-adjust the realities and minimize the variability of the actions performed in the processes can be one of the initiatives for a better relocation of the operations of improvement in the construction of the building sites.

ON BEHALF OF ALL AUTHORS, THE CORRESPONDING AUTHOR STATES THAT THERE IS NO CONFLICT OF INTEREST.
Bibliographic References


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