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Model and Simulation of a Distribution Logistic System for Learning

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Abstract

Computer-based simulation is one of the most extensively used tools of Information and Communication Technologies (ICT). This technique allows to simulate the operation of different kinds of facilities or processes in the real or hypothetical world using computers, making it possible to obtain key data about the system in different scenarios, without affecting the reality. Simulation tools allow develop robust models that are close to the studied reality, which does not happen with other decision-making support tools such as linear programming or some analytical solution methods such as calculus (differential and integral) and algebra, among others. The study develops a virtual platform for the simulation of industrial production systems with the objective of analyzing the operations of a small-scale distribution, especially aimed at students and professionals involved in the planning, design, and operation of logistic systems.

Keywords: *distribution logistic system; simulation; ABP; industrial training.*

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1. Introduction

The business dynamics developed in the globalized world requires the adoption and application of professional competencies that respond in a timely and assertive way to the rapid processes of change in organizations. According to [1], Enterprise, Innovation and Development constitute an approach to the business as a node of interactions, not just from the conception of the production economic unit but also as a node of agent decisions. In this sense, it is necessary to train individuals involved in the decision-making processes to be properly oriented and aligned with the business reality. Although the academic and business offer is growing, it is evident that the teaching-learning processes have not undergone a recognizable transformation according to the needs currently required by the globalized world, which are growing at an accelerated way and are increasingly specialized. In this sense, [2] expresses that elements of importance must be constituted to support not just the learning process but also the development of skills for learning how to learn [3].

It must be considered that, as time goes by, companies are required more in terms of productivity, skills, and quality in professionals with great responsibilities, for example, decision-makers [4]. However, reaching this level in professionals is a complex task due to lack of experience, weak academic background, and/or lack of motivation. For this reason, companies design personnel training programs for specific tasks to allow users experience situations or scenarios for their development, bearing in mind that staff training is considered a means of developing skills in people to be more productive, creative, and innovative, and contribute to reach organizational objectives [5].

The use of simulation is related to the complexity of the studied systems, involving controllable and non-controllable variables with stochastic characteristics and high interdependence between components, while some simplification hypotheses must be proposed with the use of other mathematical tools, which distance the studied system from its reality [6]. Starting from this point, it is possible to reduce risk by making decisions based on experimentation, thus anticipating, to some extent, the effects that they would have on the performance of the real system. There are several applications developed for this purpose and are often oriented to the analysis of specific systems or study fields. Based on these assumptions, a simulation model was developed for discrete events, based on the manufacturing process and distribution of tangible products made by a company for 10 clients located in different cities. The platform allows modifying different decision variables that affect the system operation through a Microsoft Excel interface, considering the time between orders, number of units required by customer, processing time, loading and unloading time, vehicle speed, among others [7].

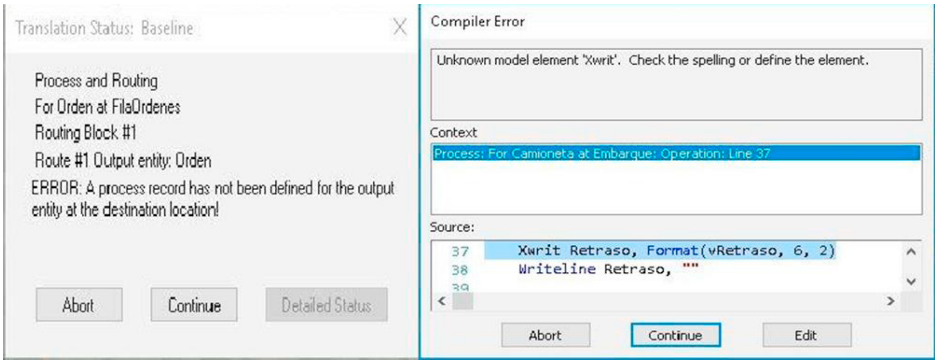
The simulation model permits to obtain various results for different scenarios and determine changes required to improve the performance of the studied system. This tool is expected to help students, professionals, and tutors experience and analyze different problem situations in order to strengthen their knowledge about logistic systems and develop problem solving skills according to the Assumption-Based Planning method (ABP), thus contributing to the improvement of learning-teaching processes in institutions and companies.

2. Method

For the development of the simulation platform of the small-scale distribution logistic system, the method proposed by [8] was selected as a basis, which is an own adaptation from contributions of other authors of great relevance in the field of simulation such as [9], [10] [11] [12] [13] [14] and whose contents describe the stages that make up the procedure of planning and experimentation of a simulation model.

3. Results

Initially, the model was designed to supply just one client and then more complex elements were added, such as the inclusion of other clients (10), the handling of rejected orders as inventory, and the use of vans as resources to deliver the products. The software used as a tool specifically designed for simulation helps the user to constantly perform a visual review for monitoring the behavior of the animation including tracking and debugging windows that provide detailed textual information of what is happening during the simulation in case of finding an error. In parallel, emerging messages were included in each of the programmed phases, showing events that occurred and offering information of the system's behavior in real time, as shown in Figure 1.



Process and Routing
For Orden at FilaOrdenes
Routing Block #1
Route #1 Output entity: Orden
ERROR: A process record has not been defined for the output entity at the destination location!

Unknown model element 'Xwrit'. Check the spelling or define the element.

Process: For Camioneta at Embarque: Operation: Line 37

```
37    Xwrit Retraso, Format(vRetraso, 6, 2)
38    Writeline Retraso, ""
```

Fig. 1. Examples of debug window and pop-up error message scheduled for verification during the model building process

In order to strengthen the validation of the model, a statistical validation was carried out involving the quantitative comparison between the output performance of the current system and the model. For this purpose, Fisher's "F Test" comparison test was selected for comparing the variance of the system data with the variance of the simulation model data. In the specific case, the test concentrates on the programmed travel times versus the actual System data [15].

By means of Fisher's "F Test", it is necessary to formulate two hypotheses: null hypothesis and alternate hypothesis, which will be validated or not according to the results generated by F Test. In this way, the following hypotheses are presented.

Null hypothesis (H0): The variance between the system data and the model data is the same.

Alternate hypothesis (H1): The variance between the system data and the model data is different.

For the validation of the hypotheses raised with the F test, the Microsoft Excel tool was used, which provides the "calculated F" and "critical F" values when entering the data set. This test may valid or not the hypotheses according to the following conditions:

1. If "Critical F < Calculated F", The null hypothesis is rejected.
2. If "Critical F > Calculated F", The alternative hypothesis is rejected.

Based on the above, a data confidence level of 95% and an alpha of 5% were used. With the entry of the system data and the model to Microsoft Excel in the "data analysis" tool, the following results were obtained (Table 1).

According to the results, Table 1 shows that the "critical F" is lower than the "calculated F", fulfilling the first condition and rejecting the null hypothesis. Similarly, test F can be tested using the probability and alpha values, where, if the probability is less than alpha the alternative hypothesis, it is accepted (present case). Accepting the alternative hypothesis demonstrates that the variance between the system data and those of the model are different, but in the same way shows a closeness to reality.

Table 1. Results of F test

Origin of variations	Sum of squared	Freedom grade	Averages of squares	F calculated	Probability	Critical value for F
Between groups	19657.75	1	18458.7	4.51	0.052	4.42
Within the groups	75472.98	18	4015.5			
Total	92365.64	19				

As the model developed is a tool based on the ABP teaching and learning methodology specially designed for experimentation, the alternatives or scenarios to be simulated are unlimited and therefore depend specifically on the problem or case study proposed. It should be noted that modifying the levels of one or more variables results in the generation of a new scenario, each of which responds to a decision model that represents the effect on the performance measures of the system that have such modifications. The expression (1) indicates the logical-mathematical model represented through simulation. The levels of *m* response variables or performance measures (y_j) depend on the logical relationships of the n_j decision variables ($x_{i,j}$) described by the function f_j ($x_{i,j}$) of Eq. (1) 16]

$$y_j = f_j(x_{i,j}) \text{ where:} 1 \leq i \leq n_j ; 1 \leq j \leq m \tag{1}$$

Table 2 presents possible instances of the decision model enunciated in expression (1), which are of practical application in the performance analysis of a distribution logistic system.

Table 2. Possible instances of the decision model.

Xij	*Decision variable description*	*Performance measure*
$X_{1,1}$	Frequency of arrival of orders	Y_1 Processor utilization rate
$X_{2,1}$	Level of demand per customer	
$X_{3,1}$	Processing time per unit	
$X_{4,1}$	Number of processors in the system	
$X_{1,2}$	Promise standard time	Y_2 Number of backorders
$X_{2,2}$	Processing time per unit	
$X_{3,2}$	Number of vehicles available	
$X_{4,2}$	Frequency of arrival of orders	
$X_{5,2}$	Frequency of system failures	
$X_{6,2}$	Required time for corrective maintenance	
$X_{7,2}$	Required time for preventive maintenance	
$X_{1,3}$	Number of vehicles available	Y_3 Average order time in the system per client
$X_{2,3}$	Vehicle speed	
$X_{3,3}$	Processing time per unit	
$X_{4,3}$	Loading time	
$X_{5,3}$	Download time	

Based on the decision model, initial model run parameters were established, which through the estimates made, adjust to the stablished situation (see Table 3). The proposed parameters were subject to evaluation and analysis before being modified through the Microsoft Excel interface that is provided together with the developed model in order to evaluate different scenarios for answering to the objectives of the simulation. The scenarios that satisfy the proposed conditions are varied, however, taking into account the characteristics of the document and the practicality of the development, two alternative scenarios are proposed, altering the levels of the variables that were considered appropriate to meet the proposed objectives.

Table 3. Levels of decision variables for each scenario

Decision variable	*Original scenario*	*Scenario 1*	*Scenario 2*
Number of processors	1	↑ 2	→ 1
Minimum processing time per unit (Seg)	24	24	↓ 21
Maximum processing time per unit (Seg)	27	27	↓ 22
Number of vans available	4	4	↑ 5
Minimum loading time (Seg)	11	11	↓ 5
Maximum loading time (Seg)	12	12	↓ 6,7
Minimum download time (Seg)	4	4	↓ 2
Maximum download time (Seg)	7	7	↓ 4,7

The final phase of the method is framed in the analysis of the results obtained through experimentation when implementing different configurations of the developed model. These results are associated with the performance measures of the system and their ultimate goal is to respond to the objectives set for the simulation. According to the above, the following is a summary with some key performance measures for the analyzed case generated for each of the previously presented scenarios (See Table 4).

Table 4. Summary of the simulation results obtained from the Output Viewer platform provided by ProModel

System performance measure	*Original scenario*	*Scenario 1*	*Scenario 2*
Processed orders	212	↑204	↑ 204
Average order waiting time	9.58	↓ 5.67	↓ 1.6
Average time of an order in the system	455.34	↓ 432.7	↓ 403.6
Processor utilization rate (Px)	75.13	↓P1-63.2 ↓P2-27.18	↓ 73.21
Number of rejected orders	21	↓ 0	↓ 12

4. Conclusions

Considering that the adopted approach is oriented towards the development of an experimental tool that supports teaching-learning strategies in industrial training based on the ABP method and that the character of modeling and simulation does not allow an exact abstraction of the real system, the following conclusions can be drawn. It was possible to develop a valid and functional model that reflects the main attributes of a distribution logistic system and allows stakeholders to understand the dynamics of the different actors in the system, as well as the effects of modifying certain parameters and variables involved in the performance of this system. The main characteristic of the ABP method is to provide the student and the professional a more real and complete approach of the area to work and generate a greater understanding of the system. In addition, thanks to the interface design using Microsoft Excel, the tool was provided with a practical and versatile nature that allows any interested party with a minimum knowledge in simulation software to carry out experimentation and evaluation of completely differentiated scenarios. In this sense, the results that can be obtained through the simulation are wide and allow to evaluate different performance measures of the analyzed system and, as it was evidenced through the use of the platform, it was possible to verify different configurations of the system parameters, as well as to confront the effects of different decisions which are not always the most convenient ones and, if not evaluated, could generate undesired secondary effects in the system or even negatively alter its performance. Finally, the users will be responsible for the experimental design to allow a wide application of the tool in the industrial training context.

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