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DISCRETE SIMULATION MODELLING FOR OPTIMIZING THE CUSTOMER SERVICE PROCESS, CASE STUDY: PRIVATE UNIVERSITY

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Abstract**:** The purpose of the research was to develop and validate a discrete event simulation model to evaluate service processes in university administrative services. The objective was to characterize student demand patterns throughout the academic cycle, design a generic model representative of institutional workflows, and evaluate its effectiveness by measuring it against current operational data to reduce waiting times and improve the distribution of human resources. A pragmatic paradigm with a descriptive-explanatory approach and a propositional component was adopted. Observations were made over 10 days, distributed evenly across periods of high and low demand, using stratified sampling. The simulation model was created with the help of ProModel® software. According to the model, the system's productivity was 29.66%. The above results demonstrate areas of opportunity for improvement in the project process. In summary, the relevance of the study lies in the fact that it responds to the budgetary constraints inherent in the national education system by serving as a predictive tool for improving service quality.

Keywords : University administration, Research, Operational, Student service, computer simulation, process optimization.

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Keywords: University administration, operational research, student services, computer simulation, process optimization.

INTRODUCTION

Over the last decade, process simulation has progressed in educational settings and has become a prerequisite for improving university services. Leskovar (2011) conducted comprehensive research on the adoption of discrete simulation models by European universities. The authors found that after institutions implemented the simulation systems in question, waiting times at service centers decreased by 47%, resulting in a more pleasant and comfortable experience for students. In addition, they highlighted that the cyclical nature of demand in university environments makes human resource planning and the distribution of service spaces particularly valuable. Macal and North (2009) investigated agent-based simulation to model enrollment and final exam processes at Australian universities during peak demand periods. They demonstrated that simulation allowed universities not only to identify operational bottlenecks, but also to predict demand patterns and/or adapt systems accordingly. The authors concluded that predictive simulation was three times more cost-effective than traditional process reengineering methods in a high-demand environment.

In the Mexican context, the simulation of university service processes has gained importance in recent times. For example, Villareal (2007) implemented a simulation model to improve school control services at the Autonomous University of Nuevo León, which allowed them to use the Monte Carlo method to make assumptions about student traffic levels at the university during critical times. As a result, the authors enabled the redistribution of administrative staff to reduce service times by 32% during peak periods, without the need for additional hiring. However, Villareal (2007) described the extent to which the adaptation of international models in the context of the Mexican education system required adjustments related to cultural practices and service expectations. In addition, Quispe et al. (2025), in their study, worked on optimizing the customer service system at the service store reception, for which they used a group of simulation tools, in particular, the specialized ProModel program, as well as statistical analysis, which is performed using the tool integrated into Promodel – StatFit. The findings derived from the experimentation and simulation indicate that, by increasing the number of servers, waiting and service times are significantly reduced.

The overall objective is to develop and validate a simulation model to reduce waiting times, optimize the distribution of human resources and workers, and improve customer service.

The specific objectives of this research are as follows:

- To characterize patterns of demand for university administrative services throughout the academic cycle, identify critical periods and variability in response;
- Develop a model that can "represent the structure of workflows, department induction, service points, and user traffic."

Although simulating service processes in a university setting will not provide a significant number of opportunities to improve the quality of service to students without sacrificing the financial viability of the institution. On the other hand, Mexican universities continue to be subject to greater budgetary restrictions and, at the same time, are asked to maintain higher levels of quality in the provision of government services, creating a simple operational tension that requires innovative and efficient solutions. University service environments can be simulated to predict their performance; therefore, multiple transition outcomes can be predicted without the time and risk costs associated with real-life scenarios. The projective capacity of a simulation, on the other hand, is a welcome tool in the context of Mexican education. Extremely high seasonal utilization dates, including registrations and the closing of the time period, often trigger logistical scheduling problems that are not beneficial to the end customer experience. Also, the technical management approach will be adjusted. This should lead to the optimization of quality influences on indicators measured by national and international authorities, potentially strengthening their position in the market. This, in turn, should translate into reduced waiting times and better distribution of staff work, more efficient use of infrastructure, and greater user satisfaction with university services.

However, there are also several drawbacks to this simulation, which may result in a weak interpretation of the results, despite its many potential benefits. First, the simulation of human behavior is dynamic in nature, with a wide range of problems that are difficult to parameterize. Individual preferences regarding student attention time and gravity-based processing times, as well as subjectivity in student-administrator interaction through the registrar's office, are just a few examples of many.

sources of uncertainty. Second, many Mexican university systems lack good historical data. The waiting times, dropout rates, or arrival patterns described above are rarely measured or not measured at all, limiting the accuracy with which probability distribution parameters can be estimated. They may also be time-dependent: improvements or changes in the university's administrative environment can quickly render simulations obsolete. Together with the general human capital concerns mentioned above, this could make such a system unaffordable in the long term. Finally, models of the type presented here involve some politically or socially contentious proposals. Although we do not provide the necessary estimates here, a "live" simulation—one that would predict, with the collaboration of departments, administration, etc., which administrative office should have which staff and how much they should work based on a model of this type—may face significant administrative resistance.

Fundamentals of process simulation

Process simulation is a systematic technology for representing the behavior of complex systems using computational models, enabling the study of a system's performance under various circumstances. According to Kelton and Zupick (2022), the evolution of modern simulation over the years has been impressive: from the implementation of simple deterministic models, it has evolved to apply more advanced stochastic simulations in which variety is incorporated into the system surreptitiously. Furthermore, for what is fundamentally a service environment such as universities, discrete event simulators are the simulator of choice. The sequential structure of the interactive behavior of users and service providers can be modeled using DES. These methods have been particularly valuable when applied to educational institutions for the management of administrative processes. Al-Therwah et al. (2025) point out that demand for university services is cyclical but irregular. This makes it an ideal candidate for modeling and simulation, enabling universities to plan their resources to respond to peak demand periods without the need for fixed, underutilized capacity. For institutions that must operate on a low budget, its use is crucial.

Types of simulation applied to university services

Simulations applied to university service processes can be classified, among others, according to the following taxonomies. According to Congacha and García (2017), this can be done using tools available in Business Process Management Databases. Modeling aims to design and represent a process flow, which allows for understanding and examining all phases of the process in order to suggest iterative improvements; simulation is used to evaluate the performance of the model without implementing it in multiple configurations and over extended periods of time, as it reduces the probability of insufficient compliance. Touhami et al. (2019) propose a typology of simulation based on the time horizon of the simulation process. In particular, they distinguish between the following levels: operational, tactical, and strategic. As several authors argue, simulations may be most effective in higher education organizations if they are applied by implementing all three levels at the same time. The basic idea is to devise an ecosystem of simulations with levels of decision-making logic at different time horizons.

Methodologies for the development of simulation models in university environments

Structured methodologies that ensure validity and applicability are critical for the development of effective simulations of these university guidelines. Law (2020) defines seven methods in a stage that has been used successfully in the education environment: problem formulation, data collection and conceptual model construction, conceptual model validation, computer programming, code verification, experimental design, data analysis, and finally documentation and implementation. Furthermore, according to Law (2020), "continuous validation throughout the development cycle process, involving subject matter experts and end users, is the most critical determinant of the success of simulation models in practice." In particular, in the context of university services, the methodology has been refined by Howard (2011). They focused on the problem of university services and improved the general approach with specific elements of an educational environment. In particular, they emphasize the need to identify critical points in the academic calendar and their impact on demand processes. They also highlight the importance of contextual factors such as student preferences and regulatory constraints on university programs. In addition, the results of the longitudinal study conducted at several universities showed that general simulation models improved with this methodology can produce predictive power with 85% accuracy or higher, compared to 60 or 70% for general models.

Integration of human factors in service simulation

One of the critical aspects of performance is the issue of accurately incorporating human factors into system behavior. In this regard, Alvarado et al. (2016) propose a conceptual framework for including psychological and behavioral variables in simulation models. Users are only dissatisfied with delays, for example, after interacting with a provider who they feel has not been fair and respectful and whose quality of service delivery was not as good as expected. Complementarily, Rojo et al. (2020) highlight that clinical simulation is a valuable tool for promoting innovation strategies in healthcare organizations, favoring the adaptability of professionals and patients to change.

Practical applications and success stories

To date, several documented success stories of practical implementation of simulation models in universities have been generated. In the discrete event simulation study conducted by Pérez (2018) on the aforementioned model, in the process of customer service in a café, the following information is provided. Alternative 3, according to the indicators, generated more than 60% of revenue compared to the actual system, making it the most effective for service in the cafeteria. Heredia et al. (2020) present a model that allowed them to propose a series of improvements in the processes of the small and medium-sized enterprise analyzed. In this sense, the model also managed to reduce waiting times for the sale of beverages, pizzas, and other items. In their study, Pulido et al. (2021) highlight how the simulation of customer service in a stationery store contributed to improved utility levels, achieving an improvement in a point-of-sale system that minimizes customer service time overload.

DEVELOPMENT

Research paradigm

As can be seen, this research was based on the pragmatic paradigm, which allows quantitative and qualitative methods to be combined to investigate complex problems from a perspective oriented toward expected results. Morgan (2020) states that this paradigm is particularly consistent with simulation studies in organizational environments, as it allows researchers to discover and explain dynamic phenomena by emphasizing the results obtained and contextual interpretations. It is important to understand that the phenomenon of university attention processes cannot be described by a single positivist and interpretive approach, but rather requires a multifaceted approach.

Level of research

The methodological framework used is part of a descriptive-explanatory level of research with propositional components. As defined by Obach et al. (2020), this level not only allows the phenomenon studied to be described in its different dimensions, but also to conjecture causal relationships between variables and propose solutions based on empirical evidence. On the other hand, Torres (2019) argues that any simulation-based research is obliged to exceed the merely descriptive scope, given that the validity of the models depends on their explanatory power over the causal relationships observed in the real system.

Study design

Sequentially, this study was designed using a three-stage mixed research approach: exploratory-qualitative, quantitative-analytical, and experimental. This arrangement allowed all data from multiple sources to be integrated into a simulation model that was refined. In particular, the exploratory-qualitative stage was based on direct observations and unstructured interviews with members of the administration and students about the attendance process. This information was necessary to gain a complete picture of all possible aspects. The quantitative-analytical phase was also based on the collection of historical data on arrival and service times, together with demand patterns. The experimental stage, in turn, was devoted to the development, validation, and simulation of the model. Thus, these three stages complemented each other perfectly so that each phase developed and improved the next. As a result, the complete simulation model simultaneously included all quantitative variables and factors such as time, frequencies, and distribution, as well as qualitative data on the perceptions and preferences of patients and collaborators.

Sampling and participants

Sampling for interviews and questionnaires was stratified, and sampling for direct observations was systematic. The numbers of participants were as follows: 15 administrative staff from various areas of student services; 250 students proportionally distributed across the faculty and academic year; and 8 university executives responsible for managing student services. For direct observations, five critical points of service identified in the exploratory phase were selected; measurements were taken over 20 days evenly distributed across periods of high, medium, and low demand according to the academic calendar.

Simulation procedure

The simulation model was developed following the methodology proposed by Banks et al. (2017), which establishes a structured nine-step process:

1. problem formulation,
2. setting objectives and project plan,
3. data collection,
4. model translation,
5. verification,
6. validation,
7. experimentation,
8. interpretation,
9. documentation,

DISCUSSION AND ANALYSIS OF RESULTS

To evaluate the data, a simulation model was created using the ProModel program. Cerinza (2021) states that this program is one of the most widely used simulators on the market, as it allows systems to be modeled more clearly and easily.

Figure 1 represents the model of the process analyzed.

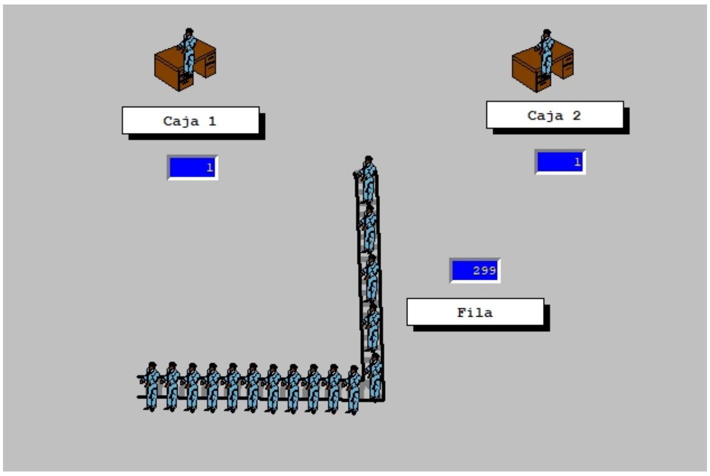

Figure 1. *Model used.*

The preliminary calculations were as follows:

Table 1. *Simulation model results.*

Variable	Total
Failed landings	0
Arrivals in the system	249

Good arrivals	105
Total arrivals	354

The next step was to calculate productivity using the following formula:

$$Productiviad = \frac{\text{Good arrivals}}{\text{Good arrivals + Arrivals in the system + Failed arrivals}} * 100\%$$

Substituting the data, the result was as follows:

$$Productiviad = \frac{105}{105 + 249 + 0} * 100\% = 29.66\%$$

Given the results obtained, this project is justified, since the observations made revealed that the response time was not positive.

CONCLUSIONS

In summary, the results obtained in this research support the viability and effectiveness of process simulation for optimizing university services. Specifically, the model developed with ProModel yielded a productivity increase of 29.66%, indicating multiple instances of potential improvement in the existing system. These conclusions can be organized as follows: methodological validation of discrete event simulation, detection of inefficiencies in the process, feasibility of implementation, and possible improvement. With regard to methodological validation, the study addressed how discrete event simulation could reduce the complexity of the university process and acquire quantitative and qualitative variables. The weakness was that the 249 arrivals we kept in the system exceeded the 105 controlled arrivals. Regarding the feasibility of the application, the pragmatic approach used allowed us to combine quantitative and qualitative applications into a strong and viable model for senior university management decisions. Finally, as noted in the Results section, there is considerable potential for improvement in results, with a feasible reduction in waiting times, concomitant with greater student satisfaction.

The results of this research are consistent with the international background of a significant decrease in waiting times through simulation models; however, the Mexican context in which these results have been obtained has particularities that must be considered. The productivity of 29.66% obtained in the presentation section reflects systemic problems beyond simple operational adjustments, contrasting with the evidence from Leskovar (2011), who reported reductions of 47% in

Europe; the difference is due to contextual factors inherent to the Mexican education system: budgetary constraints, cultural variability in waiting times, and technological infrastructure shortages, to name a few. The model developed confirmed Villareal's (2007) findings on the need for local adaptation; in this case, student behavior patterns, schedule preferences, and administrative dynamics required specific parameters that could not be directly extrapolated from the reference models. The inclusion of human factors was crucial to the model, successfully quantifying the qualitative elements captured through interviews that revealed aspects of student and administrative behavior that could not be justified through "numbers and tables," suggesting that the findings of Alvarado et al. (2016) on the importance of psychological variables reinforced the robustness of the model. Challenges observed during implementation include lack of access to reliable data, management compliance with this process, and the need to update this design over time. While this aligns with the literature, specific strategies are required for the implementation of this design in a university.

FUTURE WORK

An immediate implication of the study results for future research is that the priority line of research is to incorporate artificial intelligence algorithms to improve the predictive power of the simulation model. For a perfectly fitted model, it would be necessary to develop a machine learning system that could dynamically change the model parameters based on emerging patterns in student behavior dynamics and seasonal fluctuations. In other words, a "properly adjusted" model would be "self-adjusting" in the sense that it would retain its predictive accuracy without the need for repeated manual calibrations and would immediately address the most significant deficiency identified during the study.

The second line of research that should be pursued concerns the development of multi-objective simulation tools that would allow multiple performance metrics to be optimized simultaneously. Although this study analyzed student wait times and system productivity, future research should incorporate other objectives, including student satisfaction, operating costs, ecological impact, and equity of access to services. Reducing variability and correlation beyond the aforementioned objectives may not be possible without multi-objective algorithms, such as NSGA-II or MOEA/D, which would allow university administrators to strategically address issues with a holistic approach.

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