Improving the management and allocation of maintenance and cleaning of a university campus infrastructure using a discrete event simulation model

Cesar Corrales[0000-0002-1508-8100], Wilmer Atoche[2][0000-0002-0923-7608] and Jonatan Rojas[3][0000-0001-5498-4090]

[1,2,3] Pontifical Catholic University of Peru, Av. Universitaria 1801, Peru
ccorral@pucp.edu.pe, watoche@pucp.edu.pe, jrojasp@pucp.pe

Abstract. Due to the pandemic caused by COVID-19, university education was adapted to virtual teaching, which has allowed teachers to teach and interact in their classes and carry out their academic activities from their homes, so the university campuses of the universities of Peru were abandoned, with minimal maintenance tasks, especially in gardens. With the gradual return to face-to-face activities, it is necessary to maintain teachers' offices and administrative environments; however, the use of classrooms has a ratio of 60% and the use of offices a ratio of 30%. If the cleaning and maintenance policies are respected on a daily basis and that cover 100% of the infrastructure, with many teachers who do not attend in person, excessive costs and use of cleaning material would be incurred. For this reason, a model for optimal task allocation of support personnel has been developed using linear programming and discrete simulation, with the input of information on the attendance of teaching and administrative staff, which allows establishing a pattern of behavior that allows developing a plan for cleaning and hiring cleaning staff, according to the estimated use of the environments. The results show that the new cleaning and maintenance plan would generate savings in operating costs of around 40%. In addition, the reduced use of cleaning and maintenance materials generates a positive collateral impact on the environment. was taken among students of the Industrial Engineering specialty and the so-called Nordic Kuorinka Questionnaire was applied, an evaluation instrument that allowed to establish these problems. The results will allow measures to be taken to reduce musculoskeletal disorders among students.

Keywords: Optimization Models, Maintenance and Cleaning, University Campus, Maintenance Operating Costs.

1 Introduction

The effective management of the global pandemic caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (also known as COVID-19), resulted in the implementation of severe restrictions on movement and the application of social distancing measures [1]. Due to the spread of COVID-19 on a global scale, most efforts at the national and international levels were directed at mitigating the spread of the disease and its physical damage [2].

Due to the pandemic of COVID-19 then, the modality of work has changed, being so that many workplaces have chosen to allow their employees to continue their responsibilities and functions remotely in order to take care of their health and public health. In fact, according to data from the United Nations (UN), before the pandemic, the number of people teleworking in Latin America was less than 3% [3], and in Peru the Ministry of Labor and Employment Promotion (MTPE) indicates that an average of about 3 thousand teleworkers - February 2020 went to 222 thousand formal workers to work remotely in the private sector, December 2020 [4], and this number has been increasing to 251 thousand by December 2021 [5]. In addition, the International Labor Organization (ILO) in its report "Challenges and opportunities of telework in Latin America and the Caribbean" highlights that this modality of work is here to stay [6].

In that sense, the creation of related laws and the increase of the various modalities of telework in Peru demonstrates how companies and employers have adapted to the new needs and opportunities that arise in the diverse labor environment. Teleworking in the field of online university teaching is posed as a way of working that facilitates autonomy and improves work-life balance due to the time and location flexibility it promotes, although it can generate risk factors such as mental overload, time pressure, lack of a fixed schedule and emotional exhaustion [7].

In the present study, the case of a university -and specifically a section of the same as a sample- in which a large part of the workers, among which are teachers and administrative staff, have opted for partial teleworking, thus seeing that the time spent in the facilities and offices is reduced and minimum necessary. However, teachers and administrative staff who work in person - they attend more frequently - noticed that the cleaning staff continues to do their work in these offices daily, regardless of whether the staff working in the office attends in person or not, so that the number of cleaning staff is oversized. Given the context, this leads us to the scenario, in an objective manner, in which the unnecessary expenses of man-hours of cleaning personnel as well as cleaning materials generated by this oversizing of the cleaning personnel are evident. They can be avoided by making an adequate allocation of these personnel and scheduling cleaning in an accurate manner. In addition to redistributing the workload of the cleaning personnel if necessary.

For the present investigation, attendance data was collected from the teachers who attend the office in order to obtain attendance patterns. These patterns will then be used to assign the cleaning staff to the offices through the application of a simulation model. Finally, a simulation model will be used to determine the man-hours worked and the new cost of cleaning personnel, thus contributing to the improvement of cleaning management and increasing operational efficiency.

2 Literature review

Maintenance and cleaning management in university campus infrastructures is an important aspect of ensuring a proper and safe environment for the staff working in the offices. With a large number of buildings, classrooms, laboratories and common areas, the allocation of resources and the planning of maintenance and cleaning tasks can be a challenge. In this context, the use of an optimal staff allocation algorithm presents itself as a valuable tool to optimize the management and allocation of these services on a university campus.

In that sense, the implementation of a discrete event simulation model would allow to analyze the behavior of resources, thus optimizing man-hours and redistributing the workload of janitors. In addition to a way to evaluate the results of the new allocation without altering the current schedule of janitors, they are based on the following concepts and approaches:

2.1 Linear programming

Linear programming uses a mathematical model to describe a problem. The term linear implies that all functions related to the model must be linear. The word programming in this sense does not refer to the term computation but is more related to planning. It can be defined then as the planning of activities with the objective of obtaining an optimal result, according to the mathematical model, among all possible alternatives that are feasible [8].

The application of linear programming applied to obtain the scheduling of work shifts is the assignment algorithm. This algorithm is a variant of the transportation problem with the particularity that the quantity demanded from each destination is 1 and the capacity of each source is also one. The transportation method as such is not applied because it would have degeneracy problems; the Hungarian method is generally applied, which works on the principle of matrix reduction that reduces the problem to an opportunity cost matrix [9]

2.2 Discrete Event Simulation Models

Simulation comprises a set of technological tools and methods that enable experimentation and validation of the design and configuration of products, processes and systems, especially to achieve a higher degree of product customization and personalization, which may include factory design, material and information flow design, manufacturing network design, manufacturing system planning and control, manufacturing network planning and control, augmented and virtual reality in design, product and process planning and verification (ergonomics, robotics, etc.) [10].

In particular, simulation has played an important role in evaluating the design and operational performance of manufacturing systems. Discrete event simulation (DES) is one of the most widely used techniques to analyze and understand the dynamics of manufacturing systems, being highly flexible, it allows evaluating different alternatives of system configurations and operational strategies to support decision making and has been strengthened by hardware improvements [11].

Simulation modeling and analysis is carried out to obtain information about complex systems, to achieve the development and testing of new operational or resource policies and new concepts or systems, before implementing them and, last but not least, to gather information and knowledge without disturbing the real system [12]. A precursor of the simulation of our days is the Monte Carlo simulation method which, since the 1950s, has been, an essential tool of numerical mathematics, with applications for system optimization in Bayesian inference or maximum likelihood optimization estimation [13] [14]. Generally speaking, Monte Carlo simulation can be in many situations more successful or even the only feasible alternative compared to traditional numerical techniques [15] [15].

Discrete event simulation consists of the development of a mathematical model of a known system, the result of this development is a recreation of the operation of the process over time. The model helps us to understand operational characteristics of the system [16]. Discrete event simulation is so called because the variables related to the system characteristics vary in a given set of time instants [17]. Some advantages of discrete event simulation are the following: It allows comparing many different scenarios, it analyzes large and complex situations, it is not necessary to modify the real system, it can adapt to real-world complications, among others. Some disadvantages are: It is expensive and takes time to develop the model, it does not generate optimal solutions as it is a trial and error technique, a model must be made for each situation, among others [9].

For this modeling, use is made of different computer programs, among which Arena software has been the leading discrete event simulation software in the world, mainly because of its rich object-oriented functional interface and the ease of adapting to different application domains [18]. While it is true that Arena simulation software is mainly employed in industrial applications, it has already been used in work in the transportation field with reliable results, for example, to analyze traffic networks in different transportation modes [19] [20].

The Arena modeling system, from Systems Modeling Corporation, is a flexible and powerful tool that allows analysts to create animated simulation models that accurately represent virtually any system [21]. This tool is a simulation environment consisting of module templates, built around SIMAN language constructs, as well as other facilities and the CINEMA animation package, therefore, when an Arena model is created, it is implemented in SIMAN code that is then compiled and executed without the need to write programming code. SIMAN consists of blocks and elements. Blocks are basic logical constructs that represent operations (e.g., capture block). Elements are objects that represent facilities such as resources, queues, and counts [22]. Today, this software is considered the most popular simulation tool in the world and there are many published papers demonstrating its use [23] [24].

The aim of the present work is to help achieve an effective allocation of human, material and financial resources to ensure an adequate level of maintenance and cleanliness of the work area of a private university, using a simulation model as a means of support. This should be the basis for the planning of manpower, budgeting and procurement of materials, as well as the implementation of strategies to minimize costs and maximize resources, including energy, allowing a reduction in its use.

3 Methodology

The present research took into account one of the sections of the university. A data base of 23 weeks was obtained in which the days on which a given teacher attended the section in person were identified. Only weekdays were considered, so data was obtained for 115 days.

Subsequently, the percentage of days that each teacher attended with respect to the total was obtained, as well as the average percentage of attendance of all teachers. It is assumed that the cleaning service is performed every day and that each teacher has an individual office.

Then, based on the percentage of attendance of each teacher, a new allocation of cleaning personnel was made with the following criteria: if a teacher has an attendance percentage higher than 48%, his office will be cleaned every day; if attendance is lower than 48% but higher than 24%, it will be cleaned three days a week; and if attendance is lower than 24%, the office will only be cleaned once a week.

Finally, the new number of cleaning shifts in the section will be determined and a comparison will be made with respect to the current cleaning shift schedule.

4 Results

The following results are obtained after analyzing the data and applying a scenario simulation model.

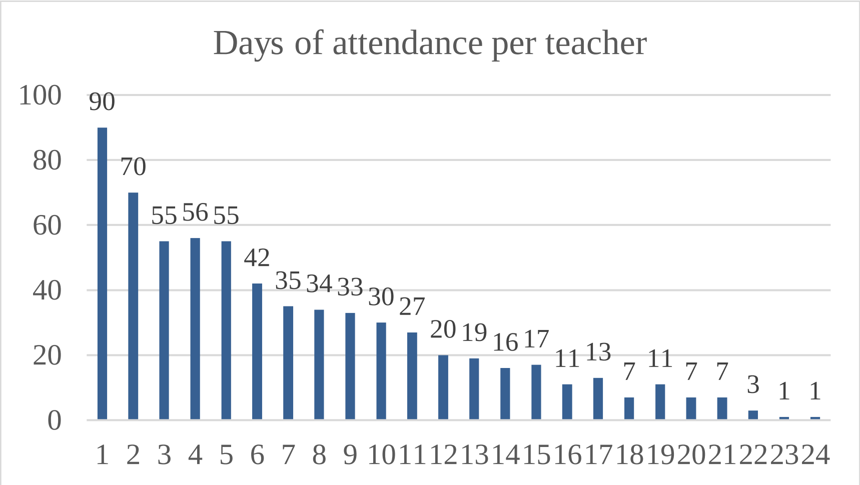

Fig. 1. Days of attendance of the 24 teachers during the study period.

The study covers 115 days, between the months of October 2022 and March 2023, the results give us office occupancy values ranging from 1 day to 90 days, with an average of 27.5 days.

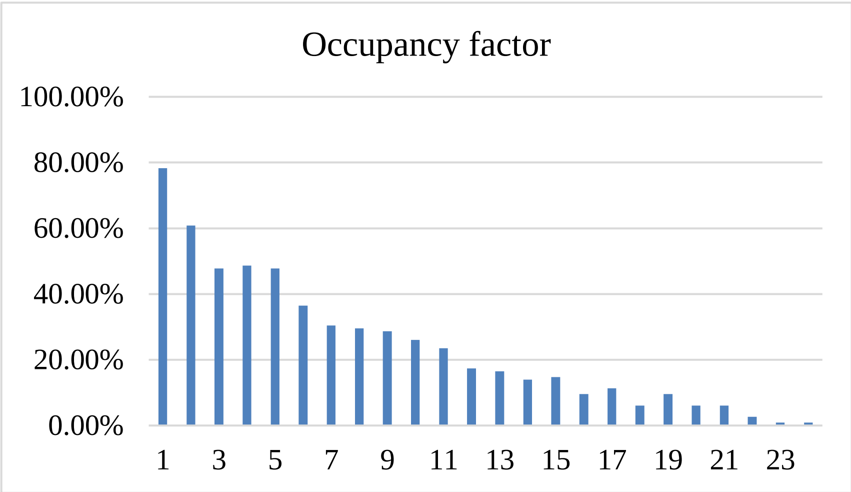

Fig. 2. Occupancy factor of the 24 teachers during the study period.

The occupancy factor of each teacher for the 115 days of study averaged 0.24, which is used to calculate the cleaning frequency.

Table 1 below shows the proposed cleaning days for each office compared to the current one. Note that only 56 cleaning days are needed instead of 120 cleaning days.

5 Conclusions

The current occupancy of the offices is 24%, which leads to a recalculation of the cleaning frequency. The study proposes to change from 100% frequency (cleaning every day) to 47% (cleaning according to the use of the office).

The reduction of cleaning frequency in the offices, not only impacts on the reduction of man hours per week, but also on the reduction of the use of cleaning chemicals, impacting positively on the environment.

The study can be replicated to all university environments, impacting economically and environmentally.

Table 1. Proposed weekly cleaning frequency.

Teacher	Present	Proposed
1	5	5
2	5	5
3	5	5
4	5	5
5	5	5
6	5	3
7	5	3
8	5	3
9	5	3
10	5	3
11	5	3
12	5	1
13	5	1
14	5	1
15	5	1
16	5	1
17	5	1
18	5	1
19	5	1
20	5	1
21	5	1
22	5	1
23	5	1
24	5	1

References

1. Solomou, I., Constantinidou, F.: Prevalence and predictors of anxiety and depression symptoms during the COVID-19 pandemic and compliance with precautionary measures: Age and sex matter. In: International Journal of Environmental Research and Public Health, 17(14), 1–19 (2020).
2. Al-Tammemi, A. B., Akour, A., Alfalah, L.: Is It Just About Physical Health? An Online Cross-Sectional Study Exploring the Psychological Distress Among University Students in Jordan in the Midst of COVID-19 Pandemic. Frontiers in Psychology, Vol. 11 (2020).
3. United Nations (UN). Economic issues: Telework in Latin America: 23 million people worked from home during the COVID-19 pandemic (2021). https://news.un.org/es/story/2021/07/1494012, last accessed 2023/04/13.

4. Guabloche, J., Gutiérrez, A.: The evolution and future of telecommuting in Peru. In: Currency | Labor (2021), https://www.bcrp.gob.pe/docs/Publicaciones/Revista-Moneda/moneda-187/moneda-187-07.pdf, last accessed 2023/04/13.
5. Ministry of Labor and Employment Promotion (MTPE): Peru, and how are we doing? Monthly report of private formal employment December 2021 (2021). https://cdn.www.gob.pe/uploads/document/file/4329828/IMEFP%20N%C2%B0%2054.pdf?v=1679946081, last accessed 2023/04/13.
6. International Labor Organization (ILO): Serie Panorama Laboral en América Latina y el Caribe 2021: Challenges and opportunities of telework in Latin America and the Caribbean. Technical note by Roxana Maurizio. (2021), https://www.ilo.org/wcmsp5/groups/public/---americas/---ro-lima/documents/publication/wcms_811301.pdf, last accessed 2023/04/13.
7. García-González, M., Torrano, F., García-González, G.: Analysis of stress factors for female professors at online universities. In: International Journal of Environmental Research and Public Health vol 17(8), 2958 (2020).
8. Hillier, F., Lieberman, G. Investigación de operaciones. Translated from 10nth edn of Introduction to Operations Researchs. Mac Graw Hill, México (2015).
9. Render, B., Stair, R., Hanna, M.: Métodos cuantitativos para los negocios. 11nth edn. Pearson Educación, México, (2012).
10. Mourtzis, D., Doukas, M., Bernidaki, D.: Simulation in Manufacturing: Review and Challenges. Procedia CIRP, 25, 213–229, (2014).
11. Negahban, A., Smith, J.: Simulation for manufacturing system design and operation: Literature review and analysis. In: Journal of Manufacturing Systems, 33(2), 241–261, (2014).
12. Pedgen C., Shannon R., Sadowski R.: Introducción a simulación usando SIMAN. McGraw Hill, (1995).
13. Robert, C., Casella, G.: Monte Carlo statistical methods. New York: Springer, 319 (2004).
14. Kroese, D., Taimre, T., Botev, Z.: Handbook of Monte Carlo methods. John Wiley 515 & Sons, 706, (2011).
15. Dadashova, B., Arenas-Ramírez, B., Mira-Mcwilliams, J., González-Fernández, C., Aparicio, F.: Simulation-based model comparison methodology with application to road accident models. Communications in Statistics - Simulation and Computation, 46(7), pp. 5340–5366, (2016).
16. Azarang, M., García, E.: Simulación y análisis de Modelos estocásticos. Mc Graw Hill, México, (1998).
17. Pazos, J., Suárez, A., Díaz, R.: Teoría de Colas y Simulación de Eventos Discretos. Pearson Educación, Madrid, (2003).
18. Guseva, E., Varfolomeyeva, T., Efimova, I., Movchan, I.: Discrete event simulation modelling of patient service management with Arena. In: Journal of Physics: Conference Series, 1015, 032095 (2018).
19. Kamrani, M., Hashemi, S., Rahimpour, S.: Traffic simulation of two adjacent unsignalized T-junctions during rush hours using Arena software. In: Simulation Modelling Practice and Theory, 49, 167–179 (2014).
20. Yang, B., Yan, X., Guo, D.: Level of Service Analysis Based on Maximum Number of Passengers in Waiting Room of Railway Passenger Station Using Arena Simulation. Discrete Dynamics in Nature and Society, 2015, 1–14 (2015).
21. Kelton, W., Sadowski, R., Sadowski, D.: Simulation with Arena. 2nd edn. McGraw-Hill, New York (2012).
22. Altiok, T., Melamed, B.: Simulation Modeling and Analysis with ARENA. In: Elsevier Science (2010).

23. Dias, L., Pereira, G., Rodrigues, G.: A Shortlist of the Most Popular Discrete Simulation Tools. Simulation News Europe, 17, 33-36 (2007).
24. Kelton, W., Sadowski, R., Sadowski, D.: Simulation with Arena. McGraw-Hill School Education Group, New York (2002).