Solid waste management simulation model in a Peruvian University

Anwar Julio Yarin Achachagua[a], *, Sophia Cristina Uribe[b], Abad Antonio Surichaqui Mateo[c], Miguel Ángel Castillo Corzo[d], Ivan Ángel Encalada Diaz[e], José Coveñas Lalupú[f], Vicenta Irene Tafur Anzualdo[g]
[a] Industrial Engineering Faculty, National University of San Marcos, Lima, 15081, Perú
[b] Engineering and Arquitecture Faculty, University of Lima, Lima, 15023, Perú
[c] Business Administration Faculty, National University of Huancavelica, Huancavelica, 09001, Perú
[d] Physics Faculty, National University of San Marcos, Lima, 15081, Perú
[e] Education Faculty, National University of San Marcos, Lima, 15081, Perú
[f] Industrial Engineering Faculty, Federico Villareal National University, Lima, 15007, Perú
[g] Posgraduate department, Federico Villareal National University, Lima, 15007, Perú
*Corresponding Author: [a]anwar.yarin@unmsm.edu.pe

Article History: Received: 11 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 28 April 2021

Abstract: The purpose of the article is to demonstrate the benefits of implementing the simulation model of a comprehensive solid waste control at a Peruvian University and be recognized in our country as the first university that contributes to environmental benefits and at the same time generate income with the commercialization of solid waste for the benefit of the University, through defined strategies. The model was defined by the diagram of activities and programmed in Arena.

The model integrates different components such as simulation time, location, types and amount of waste. It is concluded that the programming model for solid waste management benefits significantly in the amount of solid waste in a Peruvian university. Finally, we made a comparison of two possible scenarios, one of which contemplates the alternative of use-benefit of waste, while the other scenario maintains the tendency to collect all waste for disposal.

Keywords: Simulation model, Peruvian university, environmental benefits, solid waste control

1. Introduction

Solid waste management represents a problem over time, this is due to two main factors [1]: first, urban solid waste is a problem since the population is only concerned with the disposal of waste without considering the impact it can have on the environment [2, 3]. Secondly, the problem arises from public and private institutions, including municipalities and universities, since they usually do not have efficient solid waste management due to the lack of policies for the subsequent treatment of the generated waste [4, 5].

According to the legislation in force in the municipalities, it is mandatory to regulate and control the process that is in the final disposal of solid waste [5], as well as provide public cleaning service according to the area where waste is accumulated, sanitary landfills; also, taking into account the industrial use [7, 8, 9].

According to the Ministry of Environment, in the last year a total of 7,497,482 tons of municipal waste was generated, with respect to its composition, about 53% of solid waste corresponds to organic matter, 18.64% represent unusable waste, 18.64% corresponds to usable waste and only 6.83% is made up of recyclable waste [4].

Of the total municipal solid waste generated, less than 50% were disposed in the landfills, with the remainder of such waste sent to dumps or other informal facilities, which negatively affects the health of the population

Therefore, Peruvian universities should implement and encourage a culture of recycling, so the purpose of the research was the implementation of a simulation model for solid waste management in a Peruvian university [5].

The amount of solid waste in a Peruvian university is shown (Table 1)

Table 1. Amount of solid waste generated

Year	Amount (kg.)
2015	47064
2016	50945
2017	54827
2018	58708
2019	62590

In table 1, an average 54827 kg of solid waste is produced per year and around 150 kg per day. Therefore, an average number and also the amount of waste generated per year and day was obtained.

2. Materials and Methods

The methodological framework consists of stages: pre-evaluation, research, simulation model and the analysis of results. The purpose of the pre-evaluation is to find the main problem, to start the search for bibliographic review, in this case it focuses on improving the efficiency of solid waste management in universities [9], specifically in the treatment they receive; After that, the results were modeled and finally analyzed [10]. (See table 2)

Table 2. Phases of the methodology

Phases	Steps
Pre-assesment	Problem formulation and Study plan
Research	Data collection and model definition
Simulation model	Define model Do the pilote run Experimental design Validation Make the production run
Analysis of results	Analysis data ouput

2.1. Description of the model structure

Simulation model are built by using various simulation model [6]. In this case we are going to use the Arena software, the model aims to provide a tool [7, 8] that allows to know the behavior of the waste of Peruvian universities, visualizing the economic impact of a management plan in the short, medium and long term. Simulation is the technique of choice of problem solving [7].

The model describes the general dynamics of solid waste in Peruvian universities considering a simulation period of 5 years

2.2. Definition of variables

t= year 2020, …, 2025

j= waste (paper, cardboard, plastic, etc)

k= landfills (Ventanilla, Bellavista)

Variables

Waste not transported$_k$: amount of waste that was not transported to the landfill k, in tons, between 2019 and year t.

Landfill$_k$ (t): solid waste from the university g that goes to the landfill k, in tons, between the year 2019 and year t.

Recycled waste$_i$ (t): solid waste from the Peruvian universities recycled type j, in tons, between the year 2019 and year t.

Waste generation$_k$ (t): amount of waste generated for landfill k, in tons in year t.

Total RS$_j$ (t): total amount of solid waste j collected in year t.

Recycled flow$_j$ (t): amount of solid waste from the university g recycled type j, in tons, in year t.

Parameters

Waste not transported$_k$: amount of waste that was not transported to the landfill k, in tons, between 2019 and year t.

Landfill$_k$ (t): solid waste from the university g that goes to the landfill k, in tons, between the year 2019 and year t.

Recycled waste_i (t): solid waste from the Peruvian universities recycled type j, in tons, between the year 2019 and year t.

Waste generation_k (t): amount of waste generated for landfill k, in tons in year t.

Total RS_j (t): total amount of solid waste j collected in year t.

Recycled flow_j (t): amount of solid waste from the university g recycled type j, in tons, in year t.

The equations that were taken into consideration for the simulation are detailed below:

$$d(\text{waste not transported})_k/dt = \text{waste generation}_k(t) - \text{Total } RS_j(t) \quad (1)$$

$$d(\text{recycled waste})_j/dt = \text{recycled flow}_j(t) \quad (2)$$

$$\text{recycled flow}_j(t) = \text{decomposition rate}_j \times \text{biodegradable waste rate}_k \times \text{generation waste}_k \quad (3)$$

$$\text{recycling recovery}_i(t) = \text{energy saving}_j \times \text{kilowatt price} \times \text{recycled flow}_j(t) \quad (4)$$

The steps that are being considered for solid waste management are as follows [3]:

- Collection and transport
- Waste classification
- Treatment
- Final provision to landfills

The solid waste management model is presented (See fig. 1)

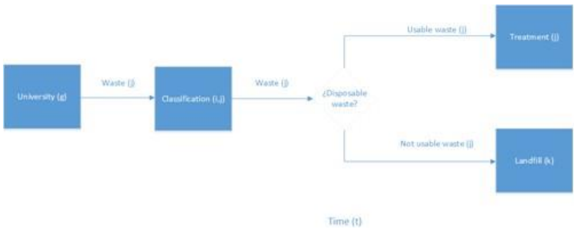

Figure 1. Solid waste management model

The research was carried out at the university, to ensure that the information collected about solid waste management is validated, it also allowed researchers to verify the operations involved from the location, types of waste collected and quantity of waste.

3. Results and discussion

First part of the process consists of the following (See fig. 2)

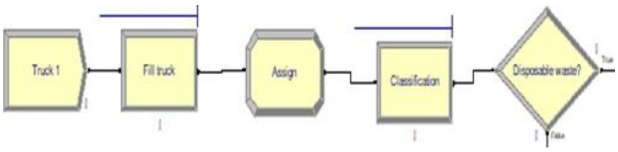

Figure 2. First part of the process

The truck arrives at the university through the creation of a truck entity, for which an arrival time of 10 hours has been considered, the respective attribute was also created to assign the time in which the entity was created and it assigns the capacity through the assign module that was 85 kg.

The Process module was used to represent the waiting of the truck while it is filled with solid waste and the resource associated to the trucks was assigned

With the Assign module the total variable was assigned to simulate the total amount that enters the system.

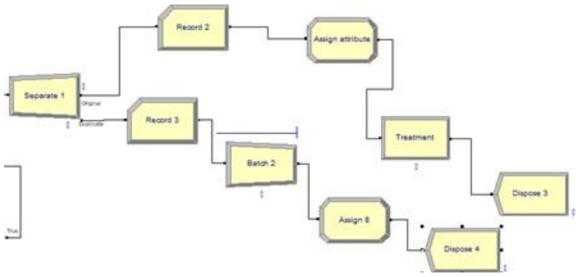

Figure 3. Second part of the process

With the classification module, it is simulated according to the type of waste entering the system

Then, by means of the module Decides the classification of waste to usable and non-usable waste is given.

Second part of the process (See fig. 3):

The Separate module of the original duplicate type was created.

Also, the Assign module was created to associate the attribute with the new entities.

The comparison is made taking into account the waste that goes to the landfill and is not recycled and those that are used for recycling

In the Assign module the cost of energy saving was assigned according to the table 3.

Table 3. Energy saving

Type of waste (1 Ton)	Energy saving in Kilowatt / Ton	Saving in $ representing each Kilowatt (0.098$)
Paper and paperboard	475367.34	465,86
Glass	132102.04	129,46
Plastic	2301795.91	2255,76
Aluminum	1686316.32	1652,59

The batch module was used to join waste that are not usable and that are sent to the landfill.

Finally, in the last stage of the process, the following was simulated (See fig.4):

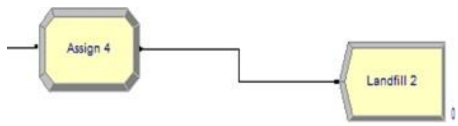

Figure 4. Last part of the process

In the Assign module, the energy saving of zero soles was recorded, since it is in the scenario that no type of treatment after solid waste is carried out and it is going directly into the landfill.

The results of simulation are shown below.

1. The average time from when the truck collects solid waste until it is segmented to usable waste was 3.75 hours

2. The percentage of utilization of total solid waste for recycling increased by 96.47%

3. The percentage of use of trucks that load solid waste is increased by 23.53% thanks to the modeling of solid waste management

4. The average total time since the truck collects solid waste and goes to landfills was 19 hours

4. Conclusion

The Arena software allowed to simulate two possible scenarios to make a comparison of a possible reality in which the implementation of a waste management plan is contemplated against another that does not and that is currently being followed.

The scenario that includes the waste management plan represents an energy saving in Kilowatts for each ton recycled which represents savings in money because it would be reusing materials instead of producing them again.

The conclusion of this article would be that an implementation of solid waste management within a Peruvian University would represent an opportunity to use them through the recycling process in conjunction with strategic alliances, to obtain economic benefits

5.Acknowledgements

We are very grateful to the university that allowed us to obtain the corresponding information

References

1. O. Vásquez, «Management simulation model of solid household waste in the Region Metropolitan of Chile,» Revista de dinámica de sistemas, vol. 1, nº 1, pp. 27-52, 2005.
2. N. Chang y A. Pires, Sustainable solid waste management A Systems Engineering Approach, New Jersey: Wiley, 2015.
3. C. Pharino, Challenges for Sustainable Solid Waste Management, Atizapan: Springer Nature, 2017.
4. F. Alaboid, W. Abed, T. Lanz y M. Haaf, «Dynamic simulation of a municipal solid waste incinerator,» Energy, 2018.
5. M. Céspedes, Implementation of a waste management program, University of Ricaldo Palma, 2010.
6. C. Turpo y R. Mamani, Simulation model for solid waste management using the methodology of soft systems in the puno district january-april 2016, National University of Altiplano, 2017.
7. Z. Ding, G. Yi, V. Tam y T. Huang, «A system dynamics-based environmental performance simulation of construction waste reduction management in China,» Waste Management, pp. 1-12, 2016.
8. M. Rodríguez, Design of a mathematical model of the municipal solid waste generation in Nicolás Romero, Mexico., National Polytechnic Institute.
9. B. Zuzunaga, Thermal Treatment of Solid Waste for Lima and Callao, Lima: University of Ricardo Palma, 2008.
10. O. Tinoco, Gestión y Producción más limpia, Lima, 2019.
11. Torres, Feasibility study for solid waste management, Lima: University of Ricardo Palma, 2008.
12. .S. Yeung, W. Winnie, N. Cheng, T. Cheung y C. Chow, Comparing pedagogies for plastic waste management at university level, Emerald Publishing Limited, 2017.
13. M. Gul y A. F. Guneri, «A comprehensive review of emergency department simulation applications for normal and disaster conditions,» Computers & Industrial Engineering, nº 83, pp. 327-344, 2015.
14. M. Rossetti, Simulation Modeling and Arena, Canadá: Wiley, 2016.
15. S. Puerto, S. Forero, E. Rivera y J. Herrera, «Model and simulation of a road intersection using Arena software,» Revista Digital de la Facultad de Ciencias Naturales e Ingeniería de la UJTL, vol. 5, nº 1, pp. 66-73, 2015.
16. C. Rahman y S. Sabuj, «Process flow improvement proposal of a batch manufacturing system using arena simulation modeling,» Review of General Management , vol. 21, nº 1, pp. 63-77, 2015.
17. R. Chandrappa y D. Bhusan, Solid Waste Management, Berlín: Springer, 2012.
18. H. Gottinger, Economic models and applications of solid waste management, vol. 6, New York: ROUTLEDGE LIBRARY EDITIONS:ECONOMETRICS, 2018.
19. D. Khan y S. Samadder, «Allocation of solid waste collection bins and route optimisation using geographical information system: A case study of Dhanbad City, India,» Waste Management & Research, pp. 1-11, 2016.
20. S. López, Modeling and simulation in arena of modeling and simulation in arena, Spain: University of Valladolid, 2016.