Proposal to Improve the Reusable Urban Waste Management System in Santiago De Surco, Lima, Peru to Increase the Utilization of the District's Treatment Plant

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Abstract

This study proposes an improvement for the reusable waste management system in Santiago de Surco, in a way that it significantly increases the utilization of the treatment plant, which is demonstrated in Arena Simulation Software. Currently, the utilization of Peru's largest treatment plant is estimated at a quarter of it maximum potential. This research proposes the improvement to exploit the installed capacity of the plant and also increase the volume of waste recycled. First, a diagnosis of the current conditions of the system is carried out to identify opportunities for improvement, followed by a comparison between successful models worldwide. From them, the elements that can be replicated are rescued considering the existing limitations both in the district, as well as in the simulation. Finally, a proposal is made from the combination of initiatives taken from countries with high recycling rates. This proposal is transferred to a simulation model to demonstrate that a significant improvement is achieved.

Keywords
Recycling, Simulation, Waste Management, Generation of Reusable Waste, Benchmarking

1. Introduction
The increasing solid waste generation poses a challenge to waste management systems. It is important that solid waste management systems evolve so that they can respond effectively to industry and population growth.

In Peru, 1.9% of total urban solid waste is recycled (Ministry of the Environment [MINAM], 2018), thanks to citizen initiatives and district municipalities. However, the average for Latin America and the Caribbean is 4.5% (Kaza et al., 2018), which leaves Peru well below this point.

In 1997, the Municipality of Santiago de Surco began to contribute to urban waste recycling and in 2016 it implemented a new waste treatment plant with a capacity of 27 tons per day, in which it additionally manufactures the orange recycling bags characteristic of this district. The facility located in the "Voces por el Clima" park has an area of 10,000 m^2 and is the largest recycling facility for a municipality in Peru.

Currently, the utilization of the treatment plant is estimated in 24.53%. This research proposes the improvement of the reusable urban waste management system in the district of Santiago de Surco, Lima, Peru to exploit the installed capacity of the plant and also increase the volume of waste recycled, taking as a reference models that are successful in other locations.

Therefore, first, the current waste collection system in the district of Surco will be analyzed. Secondly, the most successful waste collection systems, their characteristics and which elements of these successful models could be replicated will be identified. Finally, an improvement proposal will be tested and evaluated through a simulation model.

The research hypothesis states that there are elements within successful reusable waste collection models applicable to the district of Surco that can increase the utilization of treatment plant.

1.1 Objectives
Propose an improvement to the reusable waste management system in the district of Surco, to increase the utilization of its treatment plant.

Specific objectives
- Diagnose the current waste collection system in Surco.
- Compare successful waste collection systems worldwide.
- Identify which elements of the successful models can be applied to improve the waste management system in Surco
- Demonstrate the increase in plant utilization through a simulation model.

2. Literature Review
The reusable urban waste considered for this research are those collected by the Municipality of Surco, which are dry (non-organic) recyclable waste: paper, cardboard, metal, glass, and plastics type 1 (PET), 2 (HDPE) and 4 (LDPE).

In this research, information will be collected about the countries with some of the highest recycling rates according to the database of the Organization for Economic Cooperation and Development (OECD), updated until 2019. These are South Korea, Slovenia, Germany, Norway and Switzerland (OECD, 2021).

Likewise, for simulation purposes, only quantitative variables will be considered. Aspects such as culture, mores, social conjuncture, socioeconomic level, and other characteristics of the population in the district of Santiago de Surco will not be taken into consideration. These variables will be discussed to limit the scope of the proposal as cultural and financial differences could significantly impact its effectiveness (Saltzman et al.; Olofsson; Menges et al.; Guerrero et al.).

Previously, qualitative research has been carried out on the recyclable waste management model in the Municipality of Santiago de Surco. This research collected opinions on the campaign "En Surco la basura sirve" that took place between 2011 and 2012 to analyzing the perception of the residents of Surco about the existing recycling program (Carranza Salanitro, 2017). The results revealed that, after the campaign, 78% of the participants did not use the orange bags distributed by the Municipality, which are produced from the collected waste. Also, 66% did not know the location of the Orange Points (collection points) and only 52% knew the waste classification process. The researcher considers that advertising partially contributes to the non-formal education of solid waste collection in the district.

Comparison studies have been carried out between two localities (Ghesla et al.; Lazo and Gasparatos; Marti and Puertas; Lavee and Khatib; Sánchez-Muñoz et al.; Xavier et al.) to determine the differences and similarities between them in terms of participation, model, and legislation. However, the elements are not rescued to seek to implement them in another scenario and the comparisons do not generate proposals that could be replicated.

An investigation on the solid waste collection system in Cantón de Ibarra, Ecuador (León-Jácome et al., 2020), reveals many variables related to the geography of the locality. Through simulation, the researchers optimized solid waste collection, significantly reducing costs by including geographic aspects to the system design.

Information was collected on the system of a German town, where the most efficient measures in this country were identified and sought to implement this model in a developing country (Azevedo et al., 2021). The researcher concludes that it is possible to imitate the German model, but it is necessary to consider the differences between countries in aspects such as citizen participation, financial sustainability, the commitment of local institutions and environmental policies.

A study in Shanghai, China exclusively evaluates the impact of environmental policies on the solid waste management system (Xiao et al., 2020). A scenario was generated for each of the waste segregation policies in the country and their possible combinations, to evidence, in a simulation model, how they would affect the amount of waste generated and where it is destined. After simulating the scenarios, the policies with the greatest positive impact were those that regulate the solid waste management system in general and not those focused on geographical areas. Finally, they conclude that the way to improve the current situation of solid waste management is to consider the factors that increase generation, have a professional treatment of solid waste, and optimize the collection network.

3. Methods

This research is of a quasi-experimental type, with a quantitative approach and correlational scope. A six-stage method is proposed, which are collection and analysis, construction of the model, analysis of proposals, design of the improvement proposal, implementation of improvements, and analysis of results.

Stage 1: Diagnosis
First, data will be collected from the Municipality of Surco, through reports, interviews with experts and the current legislation on solid waste recycling and its utilization. With this information, a diagnosis of the solid waste recycling system in Santiago de Surco will be made. Successful municipal solid waste collection systems in other localities will be reviewed to determine which elements make possible the proper functioning of said systems.

Stage 2: Construction of the model
The variables that will be taken into consideration to simulate the performance of the system and evaluate the improvement proposal are:

Independent: Design of the reusable solid waste collection system (Table 1)

Table 1. Independent variables

Independent variables	Units
Number of collection trucks	trucks
Reusable waste generated	ton/week
Pick up days	days/week
Working days	days/week
Work shifts	shifts/day
Citizen participation (percentage of waste generated that is segregated by the neighbors)	%
Plant capacity	ton/hour
Number of operators	operators

Dependents: Level of recycling in Santiago de Surco (Table 2)

Table 2. Dependent variables

Dependent variables	Units
Reusable waste collected	ton/week
Total cost of treatment	soles/week
Sales income	soles/week
Gross margin	soles/week
Plant utilization	%
Plant capacity	ton/hour
Total processed waste per kind	ton/week

Considering the independent and dependent variables, a simulation model will be built in Arena Simulation Software. The Arena tool, Input Analyzer, will be used to incorporate the data collected by observation to the model. Then, the model will be verified with the support software's animation and it will be validated by running historical data and comparing the results with the records of the Municipality.

Stage 3: Analysis of proposals

In this stage, the possibility of incorporating elements of the successful systems into the model will be evaluated, generating improvement scenarios.

Stage 4: Design of the improvement proposal
The most appropriate combination of elements will be determined, considering the actual limitations of the district.
Stage 5: Implementation of improvements
From the selection in the previous stage, the improvement proposal will be modeled in Arena. Relevant indicators will be obtained that will allow the analysis to be carried out in the next stage.

Stage 6: Analysis of results
Finally, the simulation results after applying the improvements are compared with the results of the current system. The Arena tool, Output Analyzer, will be used to demonstrate if there are significant differences to determine if it is advisable to implement the improvement proposal(s) in the system (Kelton et al., 2008).

4. Data Collection

4.1 Diagnosis

4.1.1 Diagnosis of the recycling system of Santiago de Surco

Recycling in the Santiago de Surco district is managed by the Empresa Municipal de Santiago de Surco SA (EMUSS SA), the same company that manages the treatment plant.

The information collected through the observation of the process is presented below:

The collection process begins with the departure of six trucks from the plant. Each one taking a different route depending on the scheduled sector. When the trucks finish their journey, they are weighed, unloaded, and weighed again to determine the amount of waste collected.

Then, five workers proceed to remove the waste from the bags and separate the glass from the rest of the waste that will enter the process. The suitable waste is transferred to a conveyor belt where a second inspection is carried out to look for metalized plastic and expanded polystyrene. This non-recyclable waste is sent to the landfill. The belt transports the material to a line where it is manually classified according to the type of waste by eleven operators. The next stage is to take the classified waste to a press in which 1m^3 blocks are compacted, which will then be stored. The weight proportion of waste that passes the second filter is 30% glass, 40% cardboard, 18% plastic, 10% metal and 2% other.

In the case of type 4 plastic, low-density polyethylene (LDPE), it moves to a next stage, which is the production of 5-liter orange bags or plastic blocks (eco-plastic) as required. LDPE bags go through a casting process in which the plastic is unified and then passed to a crusher. After being crushed, it follows a pelletizing process with which it is fed to a blower that produces the characteristic orange bags as a product.

The processing cost per ton is 250 soles and the sale prices for each ton of waste are as follows: 300 soles per ton of cardboard or paper, 150 soles per ton of glass, 6,000 soles per ton of metal and 1,200 soles per ton of plastic

The bottleneck is the number of operators and the initial conveyor belt, which has a capacity of 9 tons/shift. Therefore, the plant capacity is 27 ton/day.

4.1.2 Successful systems

After reviewing the solid waste management systems, some of the countries with the highest recycling rates were selected according to the Organization for Economic Cooperation and Development (OECD) database, updated up to 2019. The recycling rate is the proportion of municipal solid waste that is recycled. The success factors of such systems are detailed below.

A. South Korea
According to statistics until 2019, South Korea's recycling rate is the highest in the world reaching 64% of the total municipal waste generated. In this country, the State carries out actions in educational institutions, especially those of initial level, to make future citizens aware of the importance of caring for the environment and recycling.

Policies on environmental issues have been effective in increasing the recycling rate. There are regulations that control the amount of non-recyclable waste that a product's packaging can contain in order to reduce its generation; however, the policy that has obtained the best results is the mandatory commercialization of garbage bags by the State. Citizens can only dispose of their non-recyclable or compostable waste in these bags. Due to their high cost, citizens are encouraged to consume products that generate reusable waste and segregate it properly. This policy has generated a sustained growth of 1.9% per year in the recycling rate (Park, 2018).

B. Slovenia

The European Union has solid waste management policies to reduce the amount of waste sent to landfills or incinerated. When Slovenia joined, it was far behind other European countries when it came to recycling. However, currently, it is one of the countries with the highest recycling rate in the world with 52%.

The best results were obtained in the capital of Slovenia, Ljubljana, where a different strategy was followed. Containers were delivered to each home, in which they had to separate their waste, and the collection days were cut in half. In addition, they have collection centers strategically distributed throughout the city, where segregated waste can be deposited (Dakskobler).

C. Germany

In this country there is the principle "Polluter Pays”, which means that the person who pollutes or does not recycle, assumes responsibility for it by paying a sum or losing some economic benefit. Likewise, the entry of products with new packaging to the market is also regulated, since these must go through a prior review to be certified that they have the required percentage of recyclable material. In addition, there are alliances between public and private entities for mutual benefit. Private companies offer their infrastructure and operation; and the state provides them with benefits both in rights and in tax credits (Schroeder & Jeonghyun, 2019) . Germany's recycling rate is 48% according to the same source.

D. Norway

Norway recycles 30% of the total municipal waste generated. The success of recycling in this country in recent years is attributed to a system of "deposits", which was approved in 1995. As part of this model, the State applies a tax to manufacturers of plastic bottles, and this is reduced as recycling targets for its products are reached. If a company manages to recycle 95% of its products, it is not subject to the payment of this tax. For this, the State works hand in hand with three private companies, which oversee treating this type of waste and transforming it into raw material. In addition, it is called a “deposit” system whereby consumers receive money for each bottle deposited in one of these companies' containers. This measure prompted citizens to even collect waste that they had not generated to benefit economically. This initiative achieved that 95% of plastic bottles get recycled (Meijer & Wolk, 2021) .

E. Switzerland

Switzerland's recycling rate is 30%. In this country, the model of purchasing bags from the State for non-recyclable waste was applied. This policy, which was established in 1993, by 2018, had increased the amount of recycled waste by 32% and reduced incinerated waste by 24% (Ghesla et al., 2018)

4.2 Model Construction

According to what was observed in the recycling plant of the Santiago de Surco district, the following process flow diagram was made (Figure 1):

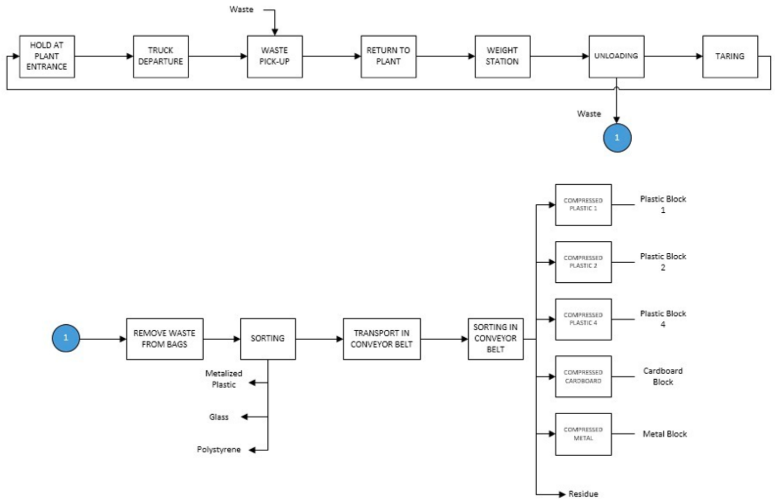

Figure 1. Process flow diagram

Twenty replicas of the weekly process were simulated, considering the work schedule, which begins at 6:00 am and ends at 2:00 pm, from Monday to Saturday.

In Arena Simulator Software, a uniform distribution is abbreviated as UNIF.

The data that feeds the model, based on observation and historical reports, are the following (Table 3,4 and 5)

Table 3. Garbage Collection Data

Residue recollection			
Module	**Number**	**Function**	**Specification**
Create		Spawn all 6 trucks	-
Assign	1	Truck laps	Count the departures of each truck
	2	Assign truck capacity	Amount that each truck can collect UNIF (0.9,1) ton
	3	Assign amount collected	Full capacity is allocated
	4	Allocate remaining amount of waste	The remainder of each day is allocated
	5	Accumulate collected waste	Add up what each truck collects
Process	1	Wait turn to leave the plant	10-minute wait
	2	Pick up road waste	UNIF (90,120) minutes*Quantity(ton)
	3	Weigh the collected waste	10 minutes at the station
	4	Unload the waste from the truck	UNIF (8,12) minutes
	5	Tare unloaded trucks	UNIF (1,2) minutes
Clone		The waste is sent to the process	-
Hold 2		Wait for the signal that the 6 trucks were created	-

Table 4. Control process data

Day Control		
Module	**Function**	**Specification**
Create	Control entity created every 24 hours	One for each working day
Assign	Count the day and generate waste	Waste generation UNIF (7,10); UNIF (10,15) for Thursdays
Hold 5	Wait for the trucks to spawn	-
Signal 2	Release trucks in the process	Prevent trucks from passing without collecting waste

Table 5. Waste generation and management data

Waste generation and management			
Module	**Number**	**Function**	**Specification**
Create		Generate stored waste that was not processed	Waste not processed in previous days
Assign	1	Assign weight of remaining waste to entity	Attribute assigned with amount of unprocessed waste from the previous day
	2	Change entity and assign weight	Reclassify the entity coming from the pick-up
	3	Control the total amount of waste that enters	Control variable
	4	Determine the amount of glass	30% of the residue entered
	5	Determining the amount of processable waste	60% of the residue entered
	6, 7, 8, 9, 10	Assign the type of waste	Metal, cardboard, plastic type 1, type 2, or type 4
	11	Retrieve the corresponding type of attribute	-
	12, 13, 14, 15, 16	Add the weights according to the type of plastic	Control variables for each type
Process	1	Remove waste from bags	UNIF (25.40) minutes * Amount of waste (ton)
	2	Transport waste in the belt	1,125 minutes/ton
	3	Compress the waste	15 minutes
Clone		The waste is sent to the process	-
Hold	1	Ensure there is at least one hour of work available	-
	2	Ensure that 8 working hours are not exceeded	-

The process of collecting and conditioning reusable waste in Arena Simulation Software is shown below (Figure 2):

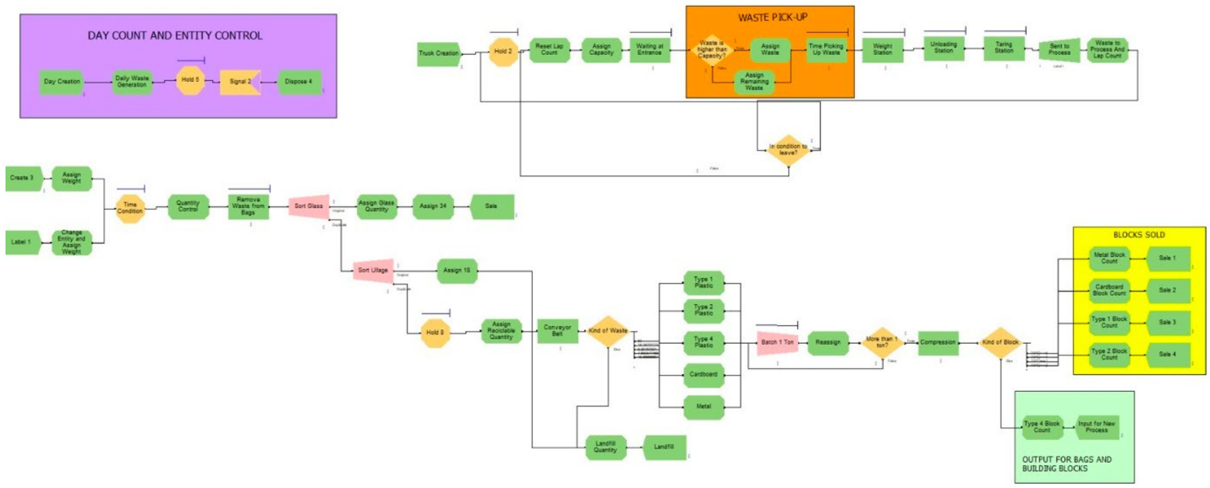

Figure 2. Model in Arena Simulation Software

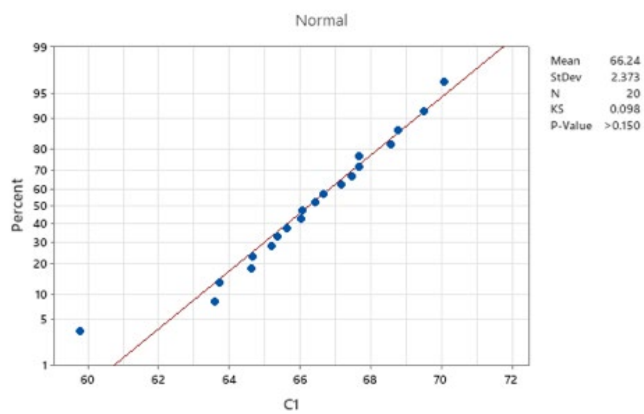

Figure 3. Statistical distribution results

To obtain results with statistical validity, twenty replicas of the simulation model will be executed. To assess whether the number of replicates performed is adequate, a goodness-of-fit test will be performed on the normal distribution:

Ho: the distribution of the sample of values of the indicator amount of waste processed, obtained from 20 replicas, conforms to the normal distribution.
Ha: the distribution of the sample of values of the indicator amount of waste processed, obtained from 20 replicas, does not fit the normal distribution.

The results shown in Figure 3 conclude that there is no evidence to reject Ho, where Kolmogorov-Smirnov's p-value being below 0.150 which means the number of replicates carried out for the model allows statistical inference.

The following results are obtained in the report (Table 6):

Table 6. Simulation report

Indicator	Value	Unit
Total reusable waste generated	[55.30 ; 57.22]	ton/ week

Total reusable waste collected	[55.30 ; 57.22]	ton/ week
Total waste processed	[65.30 ; 67.22]	ton/ week
Total waste processed in the belt	[39.18 ; 40.32]	ton/ week
Total glass	[19.59 ; 20.17]	ton/ week
Total pressboard	[19.47 ; 20.08]	ton/ week
Total PET plastic compressed	[4.68 ; 5.22]	ton/ week
Total compressed HDPE plastic	[2.88 ; 3.02]	ton/ week
Total LDPE plastic collected	[2.64 ; 2.82]	ton/ week
Total compressed metal	[5.48 ; 5.50]	ton/ week
Total sent to landfill	[7.83 ; 8.07]	ton/ week
Plant utilization	24.53	%
Total simulation time	[126.89 ; 127.29]	hours

Note. The utilization of the plant considers a maximum capacity of 162 tons of waste processed per week in the belt, which is obtained by working three shifts.

4.3 Analysis of proposals

The analysis of proposals is summarized in Table 7:

Table 7. Analysis of proposals

Successful system	Items	Impact	Integration to the model
South Korea	Commercialization of bags for non-recyclable waste by the municipality	1.9% annual increase in participation	Increase in segregated waste
Slovenia	Distribution of containers for each type of waste	3.78% increase in tons of reusable waste collected	Increase in segregated waste
	Reduced number of days dedicated to the collection of non-reusable waste		
Germany	Collaboration between the State and private companies	Does not specify	Inclusion of waste from other municipalities
Norway	“Deposit” system	Recycling of 95% of the plastic bottles produced	Not applicable to model
Switzerland	Commercialization of bags for non-recyclable waste by the State	1.33% annual increase	Increase in segregated waste

4.4 Design of the improvement proposal

The improvement proposal consists of three elements from successful systems. The first will be the commercialization of bags for non-reusable waste. This measure encourages the effective segregation of waste and generates additional income for the Municipality. To estimate the effect of this policy, the data observed in South Korea will be taken. In this case, the waste conditioning process will not be modified, only its management, which would be reflected in the increase in participation by 1.9% per year. The rate for Switzerland is ruled out, as growth has slowed markedly in recent years.

The second element is rescued from the German model, in which a private company, commissioned by the State, treats waste. As EMUSS SA is a private company, it can be contracted by neighboring municipalities for the processing of their collected reusable waste. The selected districts were San Juan de Miraflores and Chorrillos, due to their proximity to the Surco recycling plant and the tons of reusable waste correctly segregated by the residents. The trucks of the Municipality of Surco could do the collection since the mileage of the route would be similar to the current routes.

San Juan de Miraflores reusable waste collected is estimated at 61.31 tons per week while Chorrillos is estimated at 38.11 tons per week. This was calculated with 1.9% (the national average) of the municipal solid waste generated in the district according to the database of the National Institute of Statistics and Informatics (INEI) of 2019. Each municipality has a recycling program; however, since it does not have a treatment plant, the collected waste is sold directly, below its market value.

The third element consists in using the machines that produce LDPE bags and eco-plastic blocks for the manufacture of containers for each type of waste. The objective is to imitate the model applied in the capital of Slovenia and consists of delivering the containers to the residents of the Surco district to promote segregation at source.

With this measure, the days of waste collection could gradually be reduced, which would suggest a significant variation to the process. The change in collection days will not be simulated as it would alter the validated model.

Since both, bags commercialization and the delivery of containers, contribute to an increase in participation, to have a conservative approach, an annual increase of only 3.78% will be applied to the amount of waste produced by Santiago de Surco per year. This is the percentage extracted from the Slovenian model, as it is the largest between the two policies.

5. Results and Discussion

5.1 Numeric Results

To observe the impact of the modifications that involve an increase in participation, a simulation after 20 years of the implementation of the proposal is created. This is because in the recycling systems considered successful took an average of two decades to achieve the recycling rate they currently have.

To obtain the indicators, the simulation parameters and the structure of the system were maintained (Table 8). First, the simulation model was executed on the same conditions, only considering an increase in the collection and conditioning of waste from other municipalities where the new distribution of waste generation would be: UNIF (31.27,37.57) and UNIF(37.57,48.07) for Thursdays.

Table 8. Initial report

Indicator	Value	Unit
Total reusable waste generated	[153.93 ; 155.95]	ton/ week
Total reusable waste collected	[101.76 ; 102.56]	ton/ week
Total waste processed	[106.88 ; 107.98]	ton/ week
Total waste processed in the belt	[64.12 ; 64.78]	ton/ week
Total sent to landfill	[12.77 ; 12.89]	ton/ week
Plant utilization	39.78	%

The waste generated exceeds what can be collected in one shift. For the improvement proposal, 2 shifts are considered and also an increase in waste generation due to better engagement with the recycling program after 20 years.

5.2 Validation

The comparison between the current scenario and the improvement proposal is shown below in Table 9:

Table 9. Comparison between the current scenario and the improvement proposal

Indicator	Current	Proposed	Unit
Total reusable waste generated	[55.30 ; 57.22]	[214.18.73 ; 218.14]	ton/ week
Total reusable waste collected	[55.30 ; 57.22]	[181.63 ; 183.07]	ton/ week
Total waste processed	[65.30 ; 67.22]	[191.31 ; 192.81]	ton/ week
Total waste processed in the belt	[39.18 ; 40.32]	[114.78 ; 115.68]	ton/ week

Indicator	Current	Proposed	Unit
Total glass	[19.59 ; 20.17]	[57.61 ; 57.83]	ton/ week
Total cardboard	[19.47 ; 20.08]	[55.70 ; 56.18]	ton/ week
Total PET plastic compressed	[4.68 ; 5.22]	[14.92 ; 15.46]	ton/ week
Total compressed HDPE plastic	[2.88 ; 3.02]	[8.92 ; 8.94]	ton/ week
Total LDPE plastic collected	[2.64 ; 2.82]	[8.31 ; 8.34]	ton/ week
Total compressed metal	[5.48 ; 5.50]	[16.47 ; 16.51]	ton/ week
Total sent to landfill	[7.83 ; 8.07]	[22.85 ; 23.03]	ton/ week
Plant utilization	24.53	71.12	%
Processing cost	[16,325.00 ; 16,805.00]	[47,827.50 ; 48,202.50]	soles/ week
Sales revenue	[53,944.50 ; 55,363.50]	[162,770.66 ; 163,913.66]	soles/ week
Gross margin	[37,619.50 ; 38,558.50]	[114,943.16 ; 115,714.16]	soles/ week

Note. The utilization of the plant considers, both for the current model and the proposed one, a maximum capacity of 162 tons of waste processed per week in the conveyer belt, which is obtained by working three shifts.

After applying the proposed improvements to the current waste management system of the Municipality of Santiago de Surco, it was evidenced how the utilization of the plant increases substantially, going from 24.53% to 71.12%, almost tripling. The aforementioned supports what was stated by Liliana Guerrero (2013) in her research on the challenges faced by cities in developing countries in terms of solid waste management. In it, she affirms that the municipalities of these countries focus on the technological aspect, with modern infrastructure and specialized equipment to reuse the greatest amount of waste possible.

However, to achieve an efficient recycling system, socio-cultural, legal, institutional and economic factors must intervene. This can be seen in the present investigation, since, with the same treatment plant, better results can be obtained by changing the management model.

Likewise, these factors that influence the success of recycling systems are interrelated. In the analysis of proposals, it was possible to determine which were the characteristics that would make a recycling system successful. In the case of Norway, the motivation to obtain an economic benefit led them to reach higher levels of participation and, on the other hand; in Slovenia, providing citizens with disposal containers for their reusable waste had the same effect.

For this reason, to determine the appropriate formula for each environment, one must first know the indicators of social growth, knowledge and predisposition of citizens towards recycling. For simulation purposes, the indicators attributed to the same policies in other countries were used. However, elements typical of the culture are not within the scope of the simulation, so the forecast for the utilization of the plant also depends on the population's response to the authorities' initiatives. For example, in the case of South Korea, the policy of selling bags for non-reusable waste managed to increase the recycling rate from 5% in 1990 to 64% in 2019 (OECD, 2021).

It is important to mention that it has not been considered for the progressive increase in participation, that economic growth influences not only the amount of waste generated, but also the amount segregated. According to the World Bank's What a Waste 2.0 report (2018), low-income regions recycle an average of 3.7%, while high-income regions recycle 29% of the total waste generated. Therefore, since the increase in participation was only considered because of a change in the management model, better results could be expected according to the economic growth of the country.

Another element proposed to increase the utilization of the Santiago de Surco recycling plant was to integrate waste conditioning with the Chorrillos and San Juan de Miraflores programs. Neighboring districts that, although they have a collection program, must sell reusable waste without giving it added value because they lack infrastructure. Therefore, it is recommended to evaluate the possibility of establishing collection networks, which include more than one district, to create synergies and take advantage of the installed capacity of one of them, which would mean both environmental and economic benefits.

Finally, as Peru is a developing country, in which initiatives for environmental care are recently emerging and being promoted, there is the possibility of achieving the expected results in a period of less than 20 years.

6. Conclusions

This research managed to successfully develop an improvement proposal for the reusable waste management system in Santiago de Surco that significantly increases the utilization of the treatment plant, demonstrating it through a simulation model.

The diagnosis of the current management system showed that there was a lot of potential to increase the utilization of the plant since it only worked during an 8-hour shift. To exploit this infrastructure, some of the most successful collection and management models in the world according to the OECD were investigated and elements were extracted from them to replicate them in the Santiago de Surco system.

The comparison between the model of the current situation against the scenario in which the elements of Slovenia, Korea, and the initiative to work together with other districts are incorporated into the current model showed that there really is a substantial improvement in a variety of indicators such as the plant utilization, gross margin and amount of waste processed.

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