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Adaptation of an automated waste sorting system through image recognition

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Abstract

Bad waste management in Bogotá, Colombia generates health problems in the population, and accumulation and operative problems in sanitary landfills. It is known that creating incentives for people to separate their garbage as well as helping them do it are some useful solutions to this problem. In this project a decision support system solution was created, based on an image classification model, with the aim of helping people separate their waste correctly. The result is a tool that makes people know the requirements needed to adapt the model to a real system.

Keywords

Waste, Garbage, Management, Model, Adaptation, Decision Support System, Logistics

1. Introduction

In Colombia, the resolution 2184 of 2019 implements a new unified color code to classify the solid waste all over the country. This strategy separates garbage into three different colors of bags: white bags for clean and dry usable waste, black bags for non-usable waste and green bags for usable organic waste (Ministerio de Ambiente y desarrollo sostenible, 2019). The initiative was intended to encourage the recycling of some remains and thus be able to make the most of the waste generated in all the country. The resolution came into force on January

1 of 2021 and in most of the deposits of Bogotá, which is one of the most affected cities by the large quantities of rubbish generated, all waste is still being stored in the same place without any classification. In the city, approximately 7,500 tons of solid waste are generated per day, of which only 16% is being recycled (Aguilar, 2019), showing that people are still far from making the most of this waste, because in Colombia more than 40% of the garbage can be used in some way (Blanco, 2019), like the reuse of plastic, the recycle of paper and cardboard, or the reprocess of the glass, etc.

If waste is not correctly separated, it cannot be reincorporated into the recycling chain and therefore ends up in landfills where it takes a long time to decompose, generating more pollution (World Wildlife Fund, 2022) and negative effects on the health of the people around it, such as diseases caused by microbes that are produced by the accumulation of garbage when they come in touch with drinking water or food (Escalona Guerra, 2014). Nowadays the sanitary landfills in Bogotá are almost at their maximum capacity, specially the "Doña Juana" which has caused many problems, not only operational but also environmental (Cortés, 2019). The objective of this project is to acknowledge the operative process of waste generated in a building once it is disposed, and create a solution that delivers the garbage bags already classified. This solution will also take into account the logistic challenges that the waste management operations in Bogotá has.

2. Methodology

The approach was to create the model of a local system that operates in a residential or office building with a waste transport duct system usually known in Colombia as "shut". People usually throw all the garbage bags, no matter the type of waste, through the ducts and these go all the way down to a room where they are stored in a common container waiting to be taken by a garbage truck. The idea of this project is to create a system that is able to identify the color of a disposed bag, through the next flow: first, someone deposits the bag opening the *shut* gates with a personal RFID tag, once it gets down form the duct, it is transported through a conveyor belt where it can be correctly classified by a camera. Finally, when the color is identified, the bag will be placed by a robotic arm in a specific container assigned to that color. The Figure 1 shows a diagram of the operation of the system.

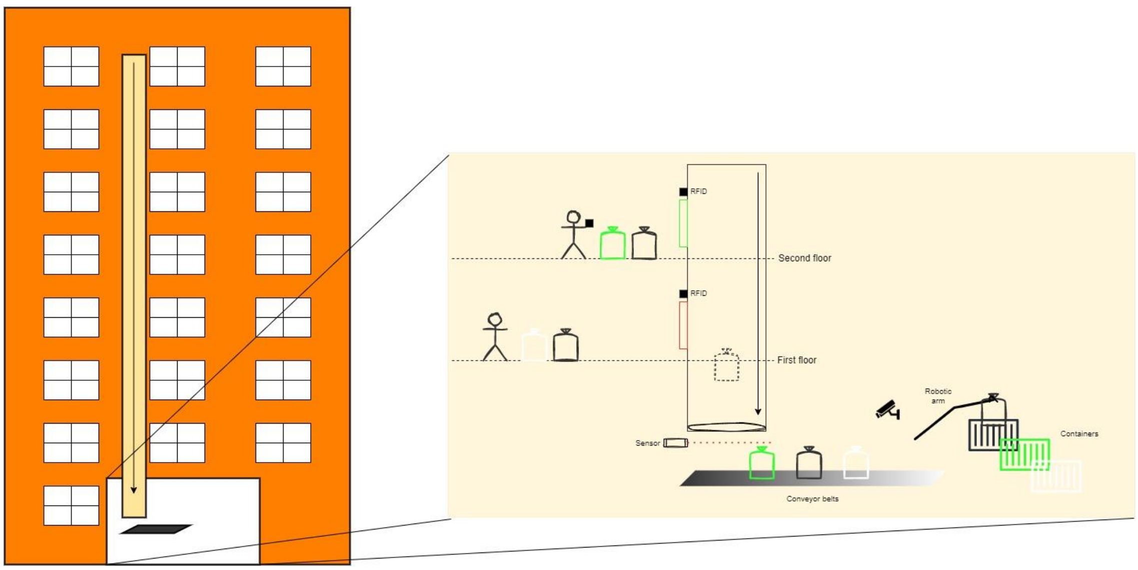


Figure 1. General system operation diagram

In the laboratory we created a scaled model of what it would look like in the storage room and how all the system would work. This is shown in the Figure 2.

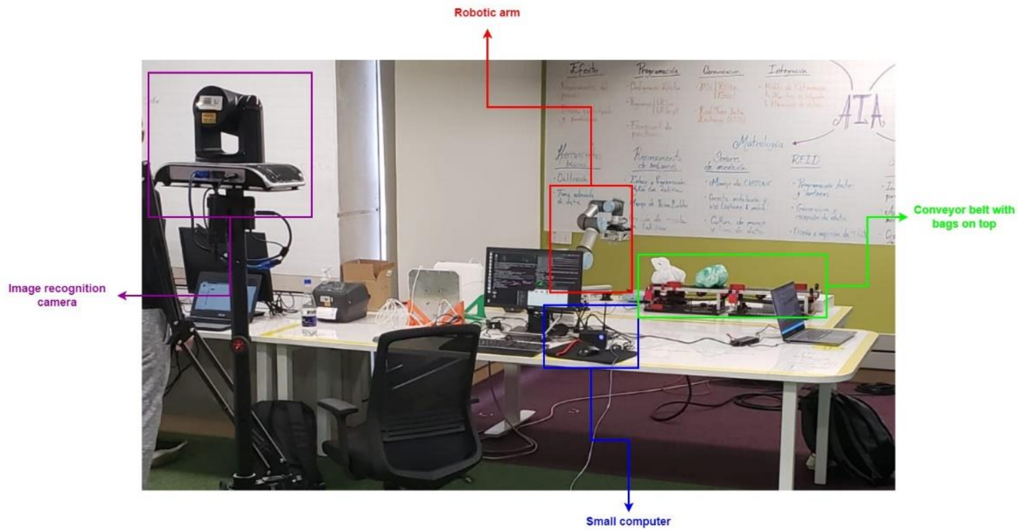


Figure 2. Scale model in lab

It is worth mentioning that the testing of this model and the idea to adapt it to a real system is limited to buildings in the urban area of Bogotá, Colombia. Whether the building concerned is already built or nor, it is necessary that it has the system of *shuts*. The optimal application of the system also will depend on the amount of space that the room has. If it wants to be adapted to a building already built, it might be necessary to make some adjustments to the room.

In order to allow people in the future to adapt the model made to any building in the city of Bogotá, a user-friendly interactive tool was developed. This tool will allow users to know how many containers of each type of waste their building will need in order to make the best use of them, as well as the approximate cost of the system's suitability for the building in question. These data will be calculated on the basis of the location of the building, the number of people living in the building or the size of it.

In order for the tool to do all the calculations and estimations, it was considered the average household in Colombia has 3.1 people (Dirección Nacional de Estadística (DANE), 2018) and each of these people can generate 0.63kg of waste per day (Martinez Arce, Daza, Tello

Espinosa, Soulier Faure, & Terraza, 2010). The percentage separation of each type of this waste would be as follows: usable waste (dry paper, cardboard and plastic) 30.55%, organic usable waste (flowers, grass, food residues, etc) 51.32% and non-usable waste (contaminated paper or plastic, glass and others) 18.13% (Consorcio NCU - UAESP, 2017).

The use of this tool has as its main limit that its purpose is to know the requirements that a building would need in order to adapt the integral model created and mentioned before. All information of the elements used to calculate the final results is taken from governmental organizations. Costs are taken from quotations or commercial prices in Colombia (COP) at May of 2022. The tool was developed in Microsoft Excel using macros (.xlsm), to make it far more accessible for the user.

The process begins with the user opening the file. In the first tab, the application welcomes the user explaining its purpose and functionality. When continuing, a larger window will appear in which the user will select and input the data from one of the following options: the number of floors and apartments per floor, the total number of floors, the total number of people living in the building, and finally the exact amounts of waste generated per day in the building. According to the option selected in the first parameter and the data provided by the user, the other fields will be calculated automatically. Figure 3 shows the example of the selection of the number of apartments in the building.

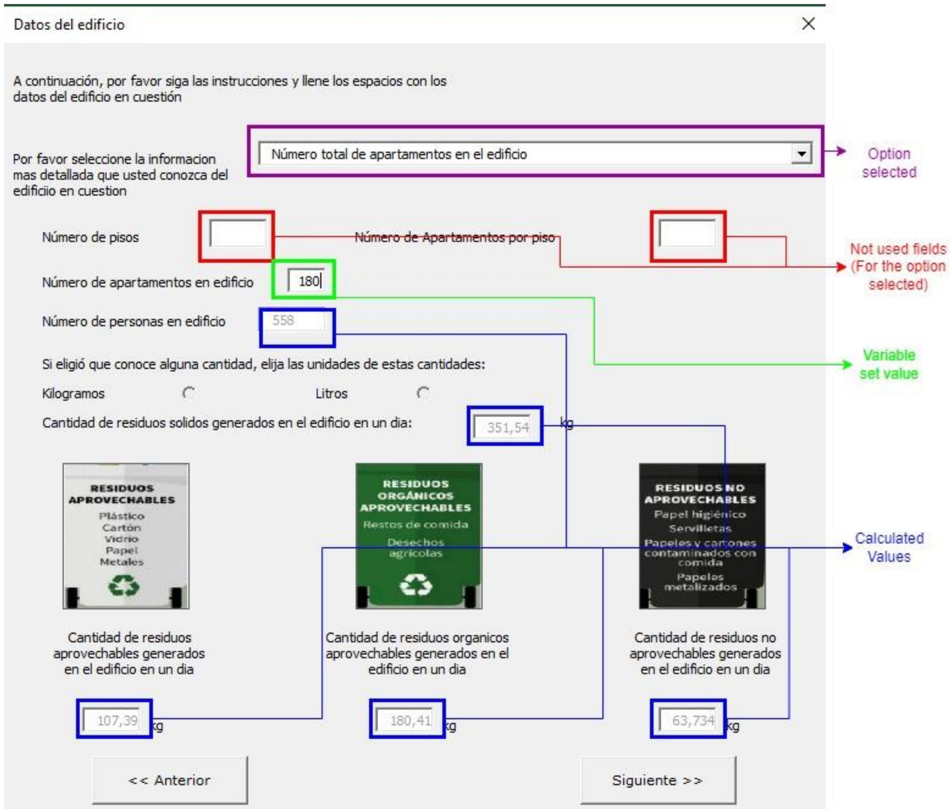


Figure 3. Example of the operation of the first tab of the tool

Once the tool has all of this information, it is necessary to know the local logistics of waste management in the building area in order to get the information of how much time the garbage will accumulate. In Bogotá, the logistics of waste management are not in charge of one government institution, instead they assign the labor to five different companies specialized in this work. Every company has assigned some of the 20 areas in Bogotá and these separately have different schedules for the management depending on the zones and neighborhoods of the area. The information of the logistics of the waste management can be found on each of the companies' websites (See Annex 1).

From these data obtained from the logistics of the building location it is possible to find the maximum number of days that the building's garbage will remain uncollected. For example, if the waste bags are collected on Tuesdays, Thursdays and Saturdays, the maximum number of hours that the garbage is not collected is 72 (3 days).

With all the information, it is now possible to find the approximate amount of garbage at the end of these 3 free days, this is useful to see the amount of containers needed to store the quantity of each type of waste. When the tool has all this information, the result is the total costs requires to adapt the model to a real system. All the costs taken into account will include the cost of containers, conveyor belts, gates and RFID system, camera, small computer, ultrasonic sensors and robotic arm. All of these costs are taken from different commercial references. For exact references and prices obtained from commercial companies, see Annex 2.

3. Results

The main result of this project is the creation of a decision support tool for people who want to adapt the created model of waste management system to any building in the city of Bogotá. This tool takes into account the logistics of waste management in the city while considering the current commercial price index of all the elements needed for the system to function correctly and in the same way as the model was thought.

The prime feedback to the person who uses the tool as a way to guide their self in the adaptation of the model in a real system is the creation of a PDF document with a summary of the parameters and data of the building, the amount of containers of each type of waste, the estimate costs and finally some dimensional recommendations to take into account in the case the user applies the model to a real building. Figure 4 and Figure 5 show the pages of the document that is generated

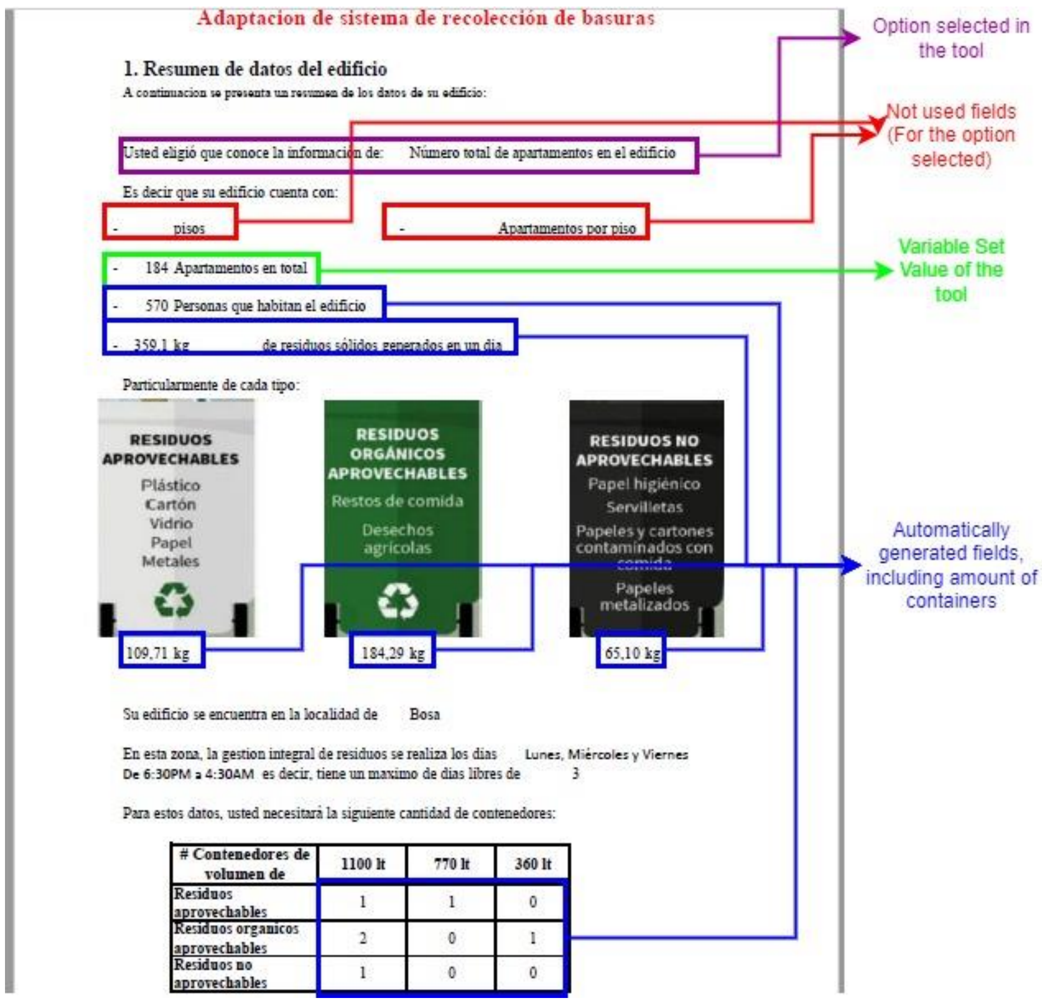
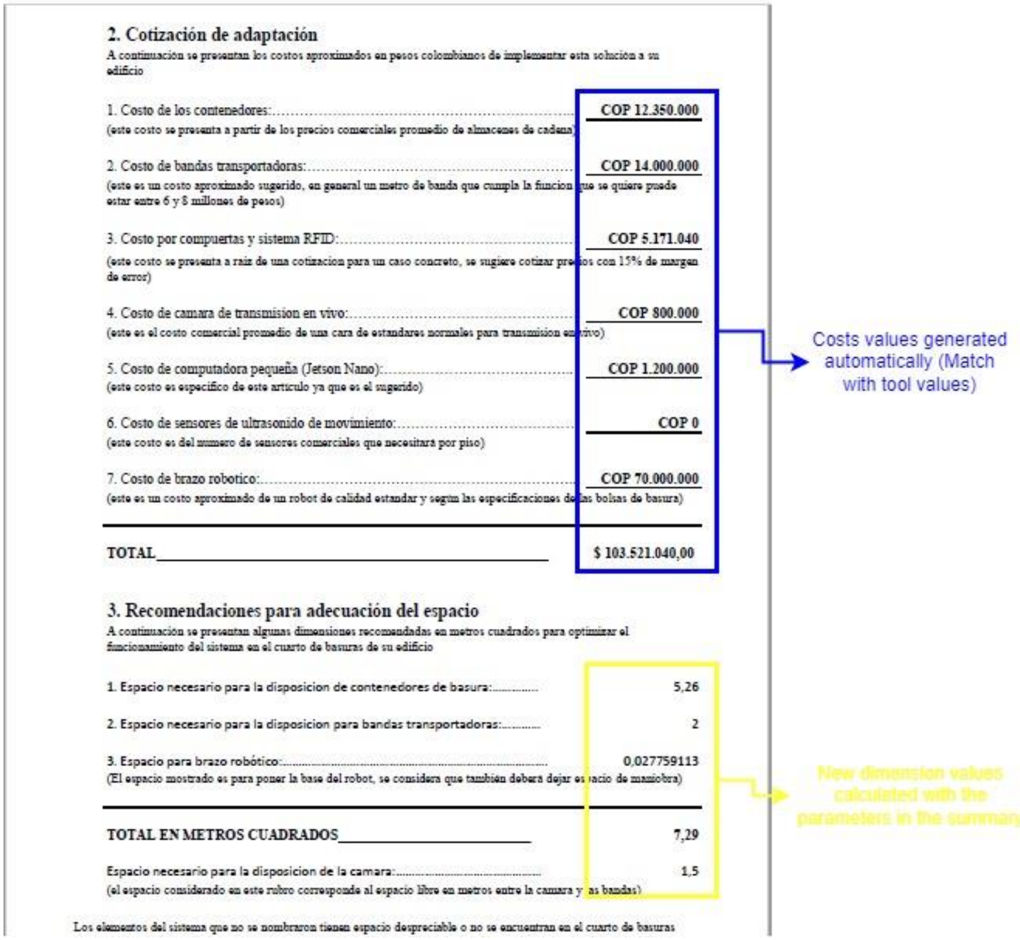


Figure 4. First page of the results document



2. Cotización de adaptación

A continuación se presentan los costos aproximados en pesos colombianos de implementar esta solución a su edificio

1. Costo de los contenedores:........................ COP 12.350.000
(este costo se presenta a partir de los precios comerciales promedio de almacenes de cadena)

2. Costo de bandas transportadoras:........................ COP 14.000.000
(este es un costo aproximado sugerido, en general un metro de banda que cumpla la funcion que se quiere puede estar entre 6 y 8 millones de pesos)

3. Costo por compuertas y sistema RFID:........................ COP 5.171.040
(este costo se presenta a raiz de una cotizacion para un caso concreto, se sugiere cotizar precios con 15% de margen de error)

4. Costo de camara de transmision en vivo:........................ COP 800.000
(este es el costo comercial promedio de una cara de estandares normales para transmision en vivo)

5. Costo de computadora pequeña (Jetson Nano):........................ COP 1.200.000
(este costo es especifico de este articulo ya que es el sugerido)

6. Costo de sensores de ultrasonido de movimiento:........................ COP 0
(este costo es del numero de sensores comerciales que necesitará por piso)

7. Costo de brazo robotico:........................ COP 70.000.000
(este es un costo aproximado de un robot de calidad estandar y segun las especificaciones de las bolsas de basura)

TOTAL $ 103.521.040,00

3. Recomendaciones para adecuación del espacio

A continuación se presentan algunas dimensiones recomendadas en metros cuadrados para optimizar el funcionamiento del sistema en el cuarto de basuras de su edificio

1. Espacio necesario para la disposicion de contenedores de basura:............ 5,26

2. Espacio necesario para la disposicion para bandas transportadoras:.......... 2

3. Espacio para brazo robótico:........................ 0,027759113
(El espacio mostrado es para poner la base del robot, se considera que también deberá dejar espacio de maniobra)

TOTAL EN METROS CUADRADOS 7,29

Espacio necesario para la disposicion de la camara:........................ 1,5
(el espacio considerado en este rubro corresponde al espacio libre en metros entre la camara y las bandas)

Los elementos del sistema que no se nombraron tienen espacio despreciable o no se encuentran en el cuarto de basuras

Figure 5. Second page of the resuts document

It can be concluded that, with these facilities and data a person who wants to adapt the model in question to a real scale can do it.

References

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Annexes

Annex 1: additional specific information.

Annex 2: references and exact prices of the final costs of the tool.