WASTE-C para trazabilidad de residuos sólidos y su caracterización

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Abstract

El creciente aumento en la generación de residuos sólidos lleva a realizar estudios de diferentes tipos para un sistema de gestión adecuado para cada uno de ellos. El residuo sólido ha aumentado, y un alto porcentaje de él no se utiliza, y termina en un mejor caso en las basas. Por esta razón, el objetivo de este estudio es mostrar los resultados obtenidos, el desarrollo del software WASTE-C en el valle de Aburrá que contribuye al planeamiento y gestión general del mismo en las diferentes municipalidades. El sistema para determinar el tamaño de la muestra y la trazabilidad con códigos barras contribuyen a la gestión de los residuos para una reducción efectiva de la contaminación producida por este tipo de productos, ya que además de su caracterización, puede mejorar el uso de estos productos y una adecuada disposición final. La usabilidad del software WASTE-C es evaluada con el modelo SQUARE. A través de una revisión de referencias, se identifican los requisitos funcionales para luego presentar un modelo de ingeniería de software a través de UML. Características de usabilidad también se describen en el modelo de medición de la calidad de software. Las evaluaciones realizadas para la aplicación del software son descriptas. Se considera que este producto contribuye a la gestión de los residuos sólidos al permitir el cálculo del tamaño de la muestra para la caracterización en el proceso de cuarteo de residuos sólidos, proporcionando una entrada para la preparación de planes de gestión de residuos sólidos en Colombia. Características que hacen al software usable se identifican, como la facilidad de uso de las funcionalidades, la simplicidad de la información mostrada, el uso de iconos gráficos, soporte alternativo para entender a través de recursos, entre otros.

Keywords: caracterización y tamaños de muestra de residuos sólidos; software de ingeniería; características de usabilidad
Resumen

El creciente aumento en la generación de residuos sólidos conlleva a efectuar estudios de diferente índole para un adecuado sistema de gestión de cada uno de ellos. Los desechos sólidos se han incrementado, y un alto porcentaje de ellos no son aprovechados, y terminan en el mejor de los casos en rellenos sanitarios. Por ello el propósito de este estudio es mostrar los resultados obtenidos, en particular el desarrollo del software WASTE-C en el Valle de Aburrá que contribuya a la planificación y gestión en general de los mismos en los diferentes municipios. El sistema para determinar la muestra y trazabilidad con código de barras contribuye a la gestión de los residuos para una efectiva disminución en la contaminación producida por este tipo de productos, porque además de su caracterización, puede mejorar el aprovechamiento de estos productos y una adecuada disposición final. La usabilidad del programa WASTE-C se evalúa con el modelo SQUARE. A través de una revisión de referencias se identifican los requisitos funcionales para posteriormente presentar un modelo de ingeniería de software a través de UML. Las características de usabilidad también se describen en el modelo de medición de la calidad del software. Se describen las evaluaciones realizadas para la aplicación del software. Se considera que este producto contribuye a la gestión de residuos sólidos al permitir el cálculo de tamaños de muestra para la caracterización en el proceso de cuarteo de residuos sólidos, brindando un insumo para la elaboración de planes de gestión de residuos sólidos en Colombia. Se identifican características que hacen usable el software, como la facilidad de uso de las funcionalidades, la sencillez de la información desplegada, el uso de íconos gráficos, apoyo alternativo para la comprensión a través de recursos como el uso de códigos de barras, entre otros.

Palabras clave: caracterización y tamaños de muestra de residuos sólidos square; ingeniería de software; características de usabilidad

1 Introduction

1.1 Problem Statements

The Tecnologico de Antioquia, through the Faculty of Engineering, has proposed the development of software based on the Solid waste management [1] with the purpose of offering an alternative to the calculation of sample sizes for characterization in the process of quartering in waste, providing an input for the preparation of solid waste management’s plans in Colombia.

The purpose of this article is to show the results obtained through the development of the WASTE-C software (Sample Size Calculator for Solid Waste Characterization and Management), introducing in a first stage, the design for the development and implementation of the calculator, and its application in environmental areas [1].

In the same manner, the most important characteristics of some work in this field are identified, to define the functional and non-functional requirements for the development of the software[2]. Some elements of Unified Modeling Language are examined, those that support Software Engineering design and the usability measuring by means of the SQUARE model[3]. Finally, a conclusion of the fundamental elements is provided in terms of interface design for this type of applications.
1.2 Development software in the field of Solid Waste Management

The development of innovative applications in different productive sectors of the country, requires a human present that is concentrated on the application of methodologies with systemic and interdisciplinary approaches.[2] Therefore, the human manager must have the capabilities to appropriate, generate and use the knowledge required to make organizations more innovative.

From the National Planning Department of Colombia, as noted in the “Plan Vive digital”[4], the national government has identified in the Information and Communications Technology industry, specifically in the aspect of software development, a clear opportunity for the development of the country and has established a policy for supporting the development of this sector; not only by promoting programs for the application of such programs within the context of infrastructure and use of ICT, but also for the promotion of software industry adjusted to high standards of quality in its development.

This particular interest has given rise to the creation, construction and development of interactive software tools that specifically automate and revitalize the processes [4], at an environment level, which identifies a few software applications that are used in processes of intervention and stimulation of characterization and sample sizes of solid waste usage [5].

However, in relation to the specific software to calculate sample sizes and characterization of solid waste [6], used from the profession of environment engineer, It is stated that there is a low production and validation of tests at the national level and in particular technological products that revitalize the evaluation processes so as to respond to the characterization of solid waste; It is therefore necessary to determine the effectiveness of the software WASTE-C implemented through a software application, measuring its quality with a model that validates the usability features of the software. In 2015, the United Nations approved 17 Sustainable Development Goals (SDGs)[7], in which solid waste management is established as a necessity to meet global goals in this regard.

On the other hand, resolution 754 of 2014 obliges all the municipalities of the country of Colombia to formulate and implement the municipal solid waste management plan (PGIRS) [8] by evaluating control and monitoring and establishing its update in each constitutional period of the municipal administration with the purpose of establishing its continuous improvement for the provision of services. Characterizing the waste allows when using these products that generate risks to assume their management with greater responsibility[1]. It also facilitates the design of policies so that people know the correct way to use these products and give them a final disposition.

Likewise, the system to determine the sample contributes to the management of waste for an effective reduction in the contamination produced by this type of product because, in addition to its characterization, there can be a better use of these products and adequate final disposal. Through the characterization it is possible to acquire knowledge about the residues and thus infer the places where they can be deposited, contributing to the improvements in the landscape environment and fewer implications or risks in the population’s health or contamination of ecosystem factors.
2 Theoretical Framework

2.1 Solid waste management
Solid waste management is the biggest challenge for environmental authorities within urban areas. Both the final disposal and the collection of solid waste have been one of the main problems in most countries [9], however, the solutions to this problem must be financially sustainable, technically feasible, socially, legally acceptable and environmentally friendly.

2.2 Characterization
The characterization of solid waste is the first step that must be taken into account to prepare and implement a solid waste management plan that is focused on prevention, minimization, and energy valuation since the characterization results in qualitative and quantitative residues, which will vary according to their source of generation [6]. The objectives of characterization can be based on three aspects: a) determination of the physicochemical waste composition; b) compute the generation rates both by waste class and population and c) carry out a diagnosis of the current comprehensive [10].

2.3 Waste generation per capita, PPC
For the per capita calculation of waste generation, it is established as the sum of each of the fractions of solid waste generated [11] and with the number of people who generate it, by using Equation 1 as follows:

\[ PPC = \frac{Wt}{\text{Person} \times \text{day}} \]  

(1)

2.4 Quartering Method
Due to the large amount of solid waste, the quartering method has been established as a methodology for the characterization of solid waste by the Ministry of the Environment of Peru and the Ministry of the Environment and Sustainable Development of Paraguay [12].

The procedure to carry out the quartering is carried out forming a uniform circumference with all the stored and mixed waste, first two quarters of two opposite parts are extracted (shaded part Fig. 1), then another uniform circumference similar to the previous one is made, of which another two quarters were taken, until a representative and manageable sample was obtained, estimated to be no less than a quarter of the initial sample by weight, as established by the ASTM 5231-92 standard [11]. Then the percentage composition within the sample is determined and the amount of initial residues is extrapolated.

Fig. 1. Exploding method
2.5 The WASTE-C as innovation and a technological product

In the environmental context, we have been implementing some software applications in the processes of intervention, however, many have been developed for use in corporate environment contexts. The interdisciplinary work, product of the teamwork between the environmental engineering and the software engineering programs, constitutes a result of technological development and innovation activities. In this order of ideas, determining the effectiveness of the WASTE-C by means of a software tool will streamline the process of the characterization.

It is therefore considered that this research will enrich the sub lines of research and technological advances of the GITIMA research group at Tecnológico de Antioquia University [13], as well as the automation sub-line with an emphasis on environmental systems interaction of the GITIMA group.

2.6 Referents of applications in the context of Solid Waste Management

In the Aburra Valley, no software like the one intends to be presented was found, for which reason programs found outside the country were taken as background, where characterization issues are not specifically included, but waste collection and storage are encouraged, basically aimed at ecoparks, clean points within organizations and productivity in waste collection fleets.

ACTAIS® Waste[14] This system allows the managing entity of the installation to determine the actual use made of it, better compliance with WEEE regulations, have input and output traceability, and better access control.

At the same time a project SeintoSOFT Waste Software [15], specific module for waste management. Waste software to systematize and simplify the specific processes of the waste treatment sector. It’s flexible to use, SeintoSOFT helps with quality management that involves all the stages of good waste treatment.

GISIR Reverse logistics and waste management platform is a Comprehensive system for management of resources in real-time, accessible from anywhere, and paperless. The solution to accelerate the digital transformation process in the company and increase the productivity of waste collection fleet [16]

2.7 The SQUARE model

Some components set established by the method of development that imply efficient and accurate use of devices in terms of design in the design of devices, include the standardization and interoperability of devices, which refer to the connection between different technologies and software applications for exchanging and the purpose of the data. This requires the use of standards of rules, regulations, guides, or definitions with technical specifications to make integrated systems viable at all levels [17].

The System and Software Quality Requirements and Evaluation model – SQUARE [18][19], covers two main processes in the development of applications: specification requirements of software quality and evaluation of the software quality. The evaluation of use focused on the usability of the product is made under the ISO standard 25010[3]
The model of usability SQUARE proposes that the usability of a software product can be broken down into the following features:

Table 1. Usability features in the model for measuring the quality of the SQUARE software.

<table>
<thead>
<tr>
<th>Usability features</th>
</tr>
</thead>
<tbody>
<tr>
<td>· Recognisability appropriateness</td>
</tr>
<tr>
<td>· Learnability</td>
</tr>
<tr>
<td>· Ease of use</td>
</tr>
<tr>
<td>· Helpfulness</td>
</tr>
<tr>
<td>· Technical accessibility</td>
</tr>
<tr>
<td>· Attractiveness</td>
</tr>
<tr>
<td>· Compliance.</td>
</tr>
<tr>
<td>· Compliance.</td>
</tr>
</tbody>
</table>

3 Methodology

For the development of this software, it was proposed to work through agile methodologies (SCRUM) This methodology consists of working collaboratively, as a team, and obtaining the best possible result from a project. These practices support each other and their selection stems from a study of how highly productive team work.

In Scrum, partial and regular deliveries of the final product are made, prioritized by the benefit they bring to the recipient of the project. For this reason, Scrum is especially suitable for projects in complex environments, where results need to be obtained quickly, where the requirements are changing or poorly defined, where innovation, competitiveness, flexibility, and productivity are essential.

Scrum has its processes which were fulfilled in delivery times.

Also, it was necessary to collect, analyze and relate qualitative and quantitative information. What allowed a further dynamic inquiry, as well as richness and variety of the data collected and a broader perspective at the time of triangulating information.

In terms of population, all were professionals in environmental engineering who serve people with rules and the logical functions of the process in Medellin and a sample was obtained considering all the resources available, the opportunity and time.

A group of five expert professionals attended, trained for the handling of the test both physical and the software tool, of the city of Medellin, who conducted 25 applications of the same aforesaid.
3.1 WASTE-C Software
The application has three modules for the user who requires the calculation. It also allows registering the user and the stratified sample sizes for the quartering of residues; some alerts that facilitate and clarify the use of the software and finally a summary that is the input for calculating the projection of waste generation in the Solid Waste Management.

The following is an example of the elements that make up the system manual which includes some views of the software.

Image 1. WASTE-C Software interfaces.

3.2 Implementation of WASTE-C Software
Inside to the process of software engineering, was possible to obtain documents that illustrate the definition of functional and non-functional requirements; a design document with some design diagrams as proposed by the Unified Modeling Language UML [20] and the source code with the developed application. Although this validation and verification does not evaluate the technical quality in the development process and technology used in terms of software and hardware, it does describe the technology used during application.

The WASTE-C calculator was implemented inside a MySQL database. HTML, CSS Bootstrap, java script and php were used through a Web-oriented Model View Controller (MVC). As a web application server, Apache was used with WAMPP. The test was applied with a Core i5 processor and a computer with Windows 10, and institutional licenses from the University. To view the program, the Google Chrome browser was used, which was stored locally on the computer.
4.3 Model of usability according to the SQUARE standards.

An assessment was performed to check the quality of the software, in which five (5) measurement instruments were implemented in accordance with the SQUARE model of usability.

The evaluation was carried out by five environment professionals were applied and instrument to investigate the discussed aspects of the model of usability focused on the product of ISO 25010 [3]. Another instrument was applied to two technical experts to evaluate the SQUARE characteristics. To them it was commissioned to assess the internal quality of the application developed. It is important to note that the number of patients to whom the WASTE-C instrument were administered, was twenty 20 people in different institutions in the city of Medellin, during the month of October and November 2022.

Table 2. Results of usability measurement according to the SQUARE quality model.

<table>
<thead>
<tr>
<th>Usability features</th>
<th>Indicator</th>
<th>Goal</th>
<th>Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understandability</td>
<td>2.43</td>
<td>3.00</td>
<td>80.83%</td>
</tr>
<tr>
<td>Learnability</td>
<td>0.60</td>
<td>0.80</td>
<td>75.00%</td>
</tr>
<tr>
<td>Ease of use</td>
<td>2.21</td>
<td>3.00</td>
<td>73.61%</td>
</tr>
<tr>
<td>Ease of Help</td>
<td>0.35</td>
<td>0.50</td>
<td>70.00%</td>
</tr>
<tr>
<td>Attractiveness</td>
<td>0.16</td>
<td>0.20</td>
<td>78.00%</td>
</tr>
<tr>
<td>Compliance to Norms or standards</td>
<td>0.49</td>
<td>0.70</td>
<td>70.00%</td>
</tr>
<tr>
<td>Use effectiveness</td>
<td>0.50</td>
<td>0.70</td>
<td>70.83%</td>
</tr>
<tr>
<td>Use efficiency</td>
<td>0.29</td>
<td>0.40</td>
<td>73.33%</td>
</tr>
<tr>
<td>Use satisfaction</td>
<td>0.08</td>
<td>0.10</td>
<td>80.42%</td>
</tr>
<tr>
<td>Compliance to norms usability</td>
<td>0.07</td>
<td>0.10</td>
<td>70.00%</td>
</tr>
</tbody>
</table>

With regard to assessing the use focused on the usability of the product. This is evaluated with the ISO 25010 standard. The aspects that obtained a rating of 70% are: ease of help, use effectiveness in use, and compliance to norms or standards.

Table 3. Summary of results of the SQUARE usability

<table>
<thead>
<tr>
<th>Usability features</th>
<th>Indicator</th>
<th>Goal</th>
<th>Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTEROPERABILITY</td>
<td>1.43</td>
<td>1.50</td>
<td>95.00%</td>
</tr>
<tr>
<td>RELIABILITY</td>
<td>0.57</td>
<td>1.50</td>
<td>38.00%</td>
</tr>
<tr>
<td>USABILITY</td>
<td>0.49</td>
<td>1.00</td>
<td>48.50%</td>
</tr>
<tr>
<td>EFFICIENCY</td>
<td>0.75</td>
<td>1.20</td>
<td>62.50%</td>
</tr>
<tr>
<td>MAINTAINABILITY</td>
<td>1.26</td>
<td>2.00</td>
<td>63.00%</td>
</tr>
<tr>
<td>PORTABILITY</td>
<td>0.78</td>
<td>2.00</td>
<td>39.00%</td>
</tr>
</tbody>
</table>

In this sense, it is possible to observe that there are 3 aspects below the 40% compliance according to the standards, which are reliability, and portability.
The following are the results obtained from the measurement of the aspects with regard to the usability of the application.

4 Conclusions

A software application was generated to implement the stratified sample size calculator, which facilitates the projection of waste generation and allows for expediting its use. It simplifies the registration and analysis, which is reflected in the reduction of the time spent in the process itself. This work contributes to the knowledge about the validation process of computer applications to be used in processes of evaluation of their usability.

As for validity of the test, in the previous study, the physical instrument features the validity and reliability required. Therefore, the analysis of the software usability runs by the requirement of quality as referenced from the standards of quality evaluation of the software product in terms of usability of the product, raised in the ISO standard 25010.

References

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