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A Social Receptiveness Analysis on Smart Waste Management – A Case Study for Portugal

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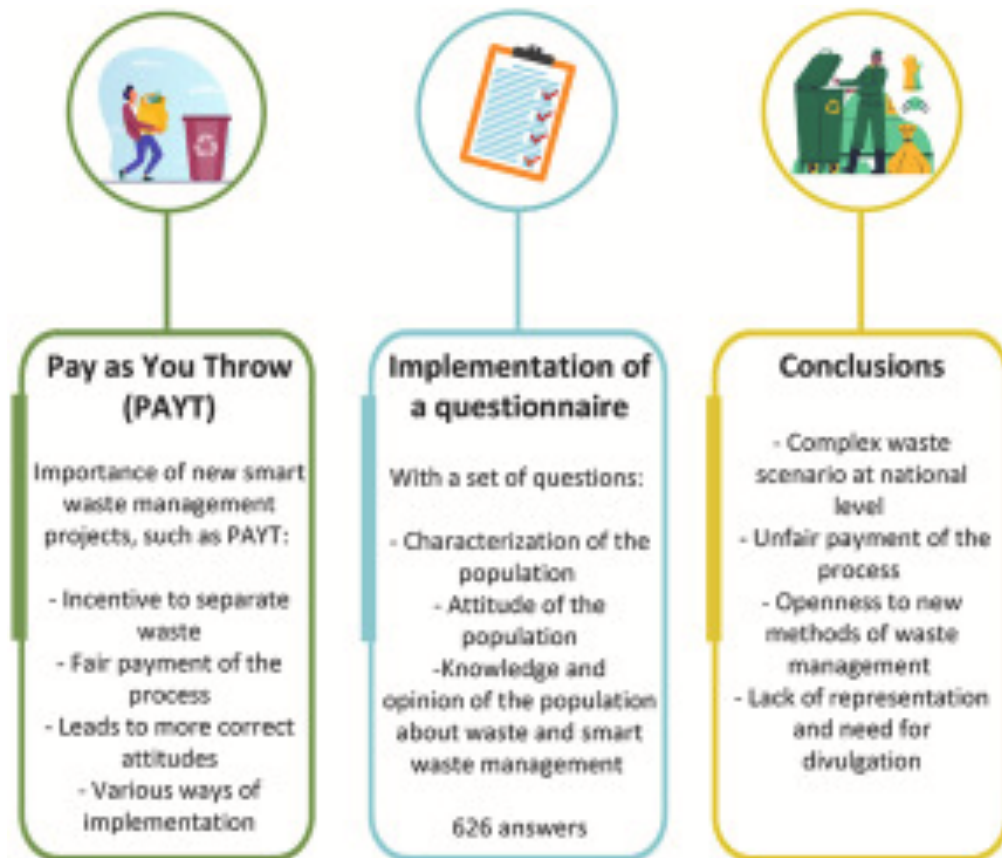
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Abstract – The technical and operational implementation of smart waste management methods is a complex and time-consuming process and therefore there is a strong resistance to its adoption by the public. At the same time, we live in an era marked by the existence of a greater desire for change driven by environmental and social concerns and technological development towards smart city implementation. In this scenario, it is essential, at this point, to draw the portray of the Portuguese awareness concerning intelligent waste management existing projects and evaluate the population's receptivity to these implementations.

To obtain the data from the public, an online questionnaire was implemented, and 626 responses were obtained. From the data collected, the Portuguese population is largely unaware of the existence of new waste management methods (82% are unaware of their existence), existing, however, great openness (80%) to their implementation.

Keywords: Smart Waste Management, Smart City, Recycling, PAYT, Incentives, Social Impact

Graphical abstract:



1 Introduction

In the last century the world population has been moving towards cities, motivated by the expectation of a higher quality of living. This phenomenon resulted in a high concentration of people living in relatively small territorial areas and a surge in demand for housing, basic infra-structures and services, which so far, cities were unable to properly address. In this new scenario, marked by the consequences of population growth, there was a defrauding of the expectations of the population that came to the cities, in parallel with environmental and social consequences. Among the environmental consequences are the increased levels of pollution (Paul and Meyer, 2001), the degradation of ecosystems (Molina and Molina, 2004)

and the reduced capacity to produce resources, accompanied by the lack of space to carry out the waste management process (Grimm et al., 2008).

With the city in need of solutions, the concept of smart city emerges in late XX century, referring to a city that, based on technology, develops its different areas (Caragliu et al., 2011; Zanella et al., 2014), such as education, energy and transport (Nikitas et al., 2020).

One of those areas is waste management, which has also been undergoing changes to make it smarter in its various aspects. Among them, the payment by the consumer stands out, often considered unfair due to its indexation to water consumption in Portugal or to housing size (in other countries), that derives from the fact that the management system ignores who produces “what” and “how much”.

Several initiatives have taken place in the last 5 years in Portugal aiming at the introduction or pilot testing of smart waste systems that measure how much waste is produced by individual citizens and issue a monthly bill accordingly – the Pay As You Throw (PAYT) system, or projects that seek to reward waste separation, as the ones mentioned in section 2.

Therefore, the aim of this article is to understand the knowledge of the Portuguese population that is digitally literate and its openness to new methods by evaluating their knowledge of existing projects and the receptiveness to future implementation at national level.

2 Smart Waste Management

As previously mentioned, projects have been emerging that seek to make the waste management process smarter, such as the PAYT or the reward for recycling.

The idea of paying only for the waste produced has been implemented by using PAYT tariffs. PAYT has been around for more than four decades in the literature. In 1999, Van Houtven and Morris (1999) published an article on the results obtained when implementing this system in Georgia in 1994, a pilot project which resulted in a reduction in waste production, thus demonstrating the potential of this tariff system. In the years that followed, PAYT was implemented in different regions of the world, in the form of pilot projects.

With strong impacts on waste production and separation, PAYT consists of an incentive system for more correct waste management attitudes, which are driven by a fairer payment of the waste tariff, which is paid in proportion to the waste produced (Gradus et al., 2019).

With the implementation of these projects, successful cases have been identified, although their application varies from reality to reality. Gradus et al. (2019) were able to identify several successful cases of PAYT implementation, such as the Netherlands, where the recycling rate increased by 10% with its implementation, and the case of the Czech Republic, where it increased by 8%.

Of the existing projects in Portugal, the Guimarães project stands out. Initiated in 2016, this project was a pioneer in the country, resulting in an increase in waste separation by 126% in the first year (Silva et al., 2019), having been implemented with pre-paid waste bags in the historical centre of Guimarães (Vitrus, 2021). It is also worth mentioning the PAYT Aveiro, integrated in the LIFE PAYT project, in which by using RFID card to open waste containers it was possible to monitor the volume of waste discarded by each user and that demonstrated a positive impact on the separation of recyclable materials from mixed waste, with 50% more paper, 40% more glass and 30% more plastic being recycled (Life PAYT, 2021, 2019).

At a more embryonic stage than the PAYT system, recycling reward systems are beginning to gain greater acceptance. However, these are applied through very different ways.

An example already commonly applied and referred to by Knickmeyer (2020) consists of a deposit return systems, where people return the packaging of the products and, in exchange, they are returned a previously paid amount. Additionally, the author refers to the creation of a system of vouchers, which can then be used in local or online commerce. To explain the system, the author mentions some projects implemented, some of an individual nature and others of a community nature.

In Portugal, there are two outstanding projects that seek to reward waste separation. The Pay in Trash (in the original, "Pago em Lixo") of Campolide Parish Council, where a fictitious currency called "trash" was created and given to residents upon the delivery of recyclable waste. The "trash" currency could then be used in local businesses (Junta de Freguesia de Campolide, 2016). This project ended with more than 4000 kg of recyclable waste collected (Coelho, 2019). The second project, called "The Old Becomes New" (in the original, "Do Velho Se Faz Novo"), was implemented nationally in 23 different places where, through the delivery of plastic packaging, people receive a monetary reward that they can keep for themselves or

donate to institutions. In this case too, the results were extremely positive, with more than 15 million bottles collected (Ministério do Ambiente e da Ação Climática, 2021).

3 Research Method

The study started by defining a set of research questions, presented below, and composed of different hypotheses. With the hypotheses presented below, we seek to understand the attitude and knowledge of the Portuguese population and, by doing so, understand their receptivity to the implementation of intelligent waste management methods.

Research Question 1 (RQ1): What factors influence the population's attitude towards waste?

Research Question 2 (RQ2): What factors influence knowledge on how the waste tariff is calculated?

Research Question 3 (RQ3): What is the relationship between the knowledge of the calculation of the waste tariff and the perception of fairness of the system?

Research Question 4 (RQ4): Do people who have knowledge about waste management and smart waste management methods recycle more?

Research Question 5 (RQ5): What factors influence the population's knowledge regarding the new methods?

The study was based on the application of an online questionnaire. The questionnaire was developed after an extensive literature review on waste management in Portugal and on the implementation of methods considered smart. The questionnaire comprised 14 questions, mostly close-ended, divided into three distinct parts: socio-demographic characterization of respondents; practices of waste separation and knowledge about the waste tariff; and knowledge and receptiveness on smart waste management (Table 1).

PART 1: Characterization of respondents
Questions: 1 – Sex; 2 – Age group; 3 – Place of residence; 4 – Educational Level; 5 – Professional Status
PART 2: Practices of waste separation and knowledge about the waste tariff
Questions: 6 – Do you sort your waste; 7 – Knowledge calculation of the formula; 8 – Do you think the system is fair;
PART 3: Knowledge and perspectives on smart waste management
Questions 9 – Do you know any smart waste project? 10 – Would you be willing to participate in a smart waste project? 14 – Which smart waste management system would you chose: PAYT or recycling incentives

Table 1: Structure of the questionnaire and list of questions

The questionnaire was released via Google Forms, being mostly disseminated through social networks via the research team (Facebook, Instagram, and WhatsApp) using the snowball sampling approach. This study is aware that the target of the responses obtained were from the digital literate population, excluding *a priori* the non-digital literate population and therefore does not intend to be representative of the Portuguese population. Responses were collected between March 2021 and May 2021.

The answers obtained were submitted to statistical analysis using the SPSS program. To try to extract as many relationships as possible between the data, the variables under analysis were crossed using the Chi-Square statistical test. The Chi-Square test compares observed values with expected values, in this work it is used to accept or reject the null hypothesis that the variability of responses observed within categories of a given variable (gender, age groups, location of residence) is due to the natural variability and is not caused by the categories. This means that the expected values are the number of observations divided by the number of categories. For instance, categories were not considered within the variables with less than 5 answers, namely the location of respondents.

4 Survey Results

This section presents the demographics of the survey's respondents and their attitudes and knowledge about waste tariffs and smart waste systems.

4.1 Demographics

The survey obtained a total of 626 responses (table 1), with a greater predominance of female respondents (451) compared to male (172). The gender was not specified by three respondents.

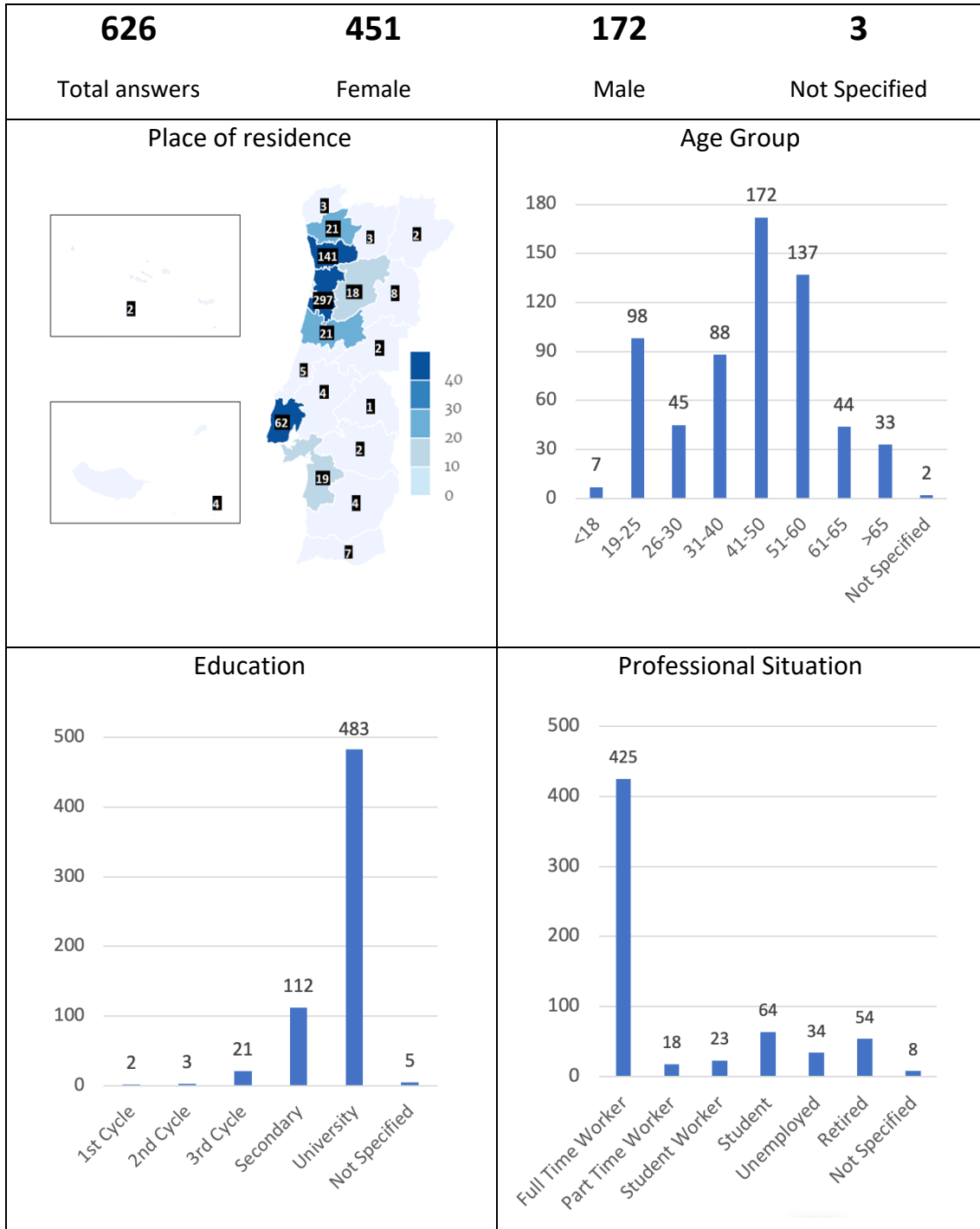


Figure 1 – Socio-demographic characteristics of the respondents

As can be seen in Figure 1, most respondents live in the northern coastal districts, especially Aveiro (297 responses, 48%) and Porto (141 responses, 23%). Additionally, and since some

districts do not have a significant number of responses, these were not considered in the discussion, such as Portalegre and Faro, in the south of Portugal. Regarding the age group, there is a predominance in the 41-50 and 51-60 age groups, representing almost 50% of the respondents.

At the same time, there was a great predominance of responses (77%) from individuals who have completed higher education, whether these are technical specialization courses, degrees, masters, or others. Regarding the professional situation, most respondents (68%) are full time workers, followed by students (10%) and retired individuals (9%).

4.2 Waste separation practices and knowledge about waste tariffs

The vast majority of respondents separates recyclable waste at the household (89% - figure 2, left), with emphasis, as would be expected, on glass, paper and plastic/metal, since these are separately collected in Portugal.

Observing the knowledge of the population regarding the waste tariff (figure 2, middle and right), the scenario is different.

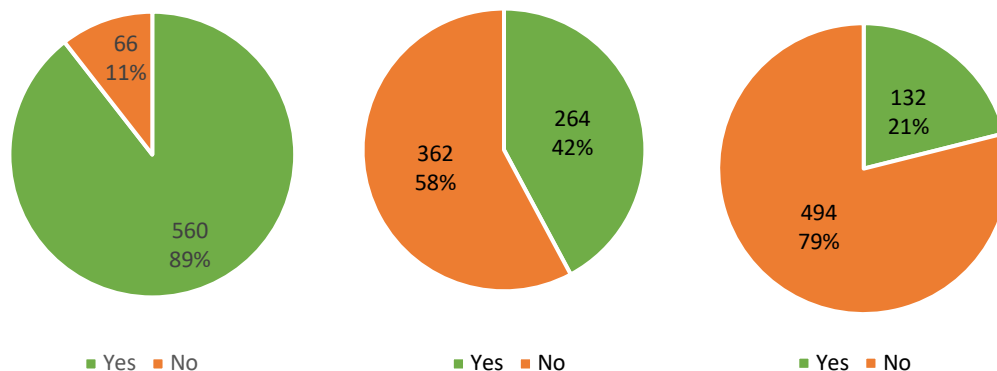


Figure 2 - Answer to the questions "do you source-segregate recyclable waste?" (left), "do you know how much you pay for your trash?" (middle) and "do you know how the waste tariff is calculated?" (right)

The answers show a great lack of knowledge regarding the waste tariff, where most of the population (58%) does not know how much they pay monthly for the waste service (58% of respondents) nor how the tariff is calculated (79% of the respondents).

The relation between the knowledge of the waste tariff (variable 8) and a person's attitude towards waste (variable 6) was not found to be statistically relevant (a chi-square test result of 0,117 obtained when comparing the relation between variables 6 and 8).

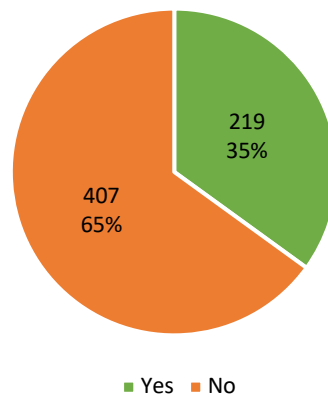


Figure 3 - Answer to the question "do you think the current waste tariff is fair?"

After having been presented with the calculation method for the waste fee (which is based on water usage), approximately two thirds of respondents (65%) consider it not fair (figure 3).

4.3 Knowledge of and receptiveness to smart waste management systems

The inquired population was asked about their knowledge regarding smart waste management methods. Later, it was asked about their openness to participate in this type of projects, as presented in figure 4.

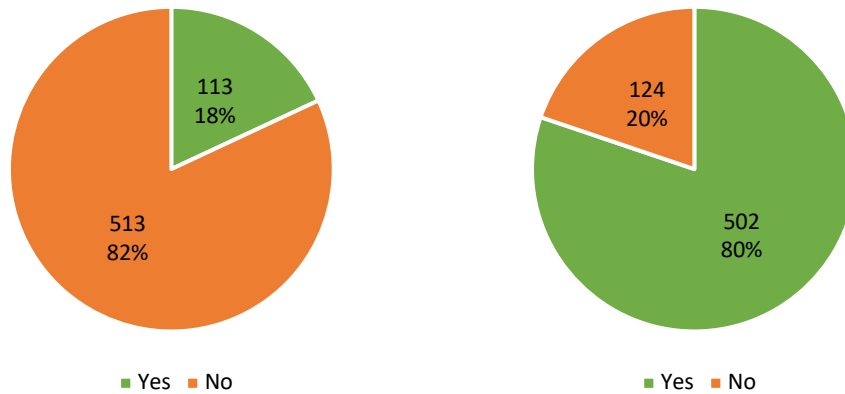


Figure 4 - Answer to the questions "do you know any smart waste management project?" and "would you participate on a pilot project?"

Despite the lack of knowledge regarding this type of system, where the majority of the respondents (82%) do not know any project, there is a great receptivity (80%) to participating in a pilot project (figure 4).

Observing people's knowledge and receptiveness to smart methods, we also verified a great lack of knowledge, accompanied by a considerable receptiveness to experience.

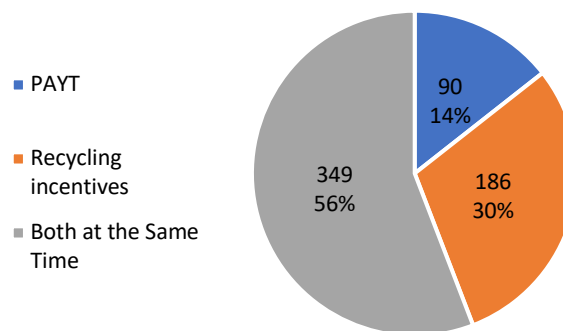


Figure 5 - Answer to the question "which pilot project would you prefer to participate in?"

Regarding the project with more receptiveness by the population, it is worth noting that 56% of the respondents showed willingness to participate simultaneously in both types of systems previously presented (i.e. PAYT or recycling incentives). Among the population that chose to participate in only one of the systems, recycling incentives stands out, that is, direct compensation to recycling.

5 Discussion

Table 3 shows the levels of significance obtained in the Chi-square tests that assesses the dependence or independence between pairs of variables at a confidence level of 95%. When the value obtained was greater than 0.05, the null hypothesis was accepted, meaning that the variables are independent (one does not influence the other). If the value is lower than 0.05 the null hypothesis is rejected and the alternative hypothesis (hypothesis 1) is considered correct, meaning that one variable is influencing the other.

1 – Gender; 2 – Age group; 3 – Place of residence; 4 – Educational Level; 5 – Professional Status; 6 – Do you sort your waste; 7 – Do you know how much you pay monthly regarding waste management; 8 – Knowledge calculation of the formula; 9 – Do you think the system is fair; 10 – Do you know any smart waste project; 11 – Would you be willing to participate in one; 12 – Which smart waste management system would you chose: PAYT or recycling incentives												
	1	2	3	4	5	6	7	8	9	10	11	12
1	-	n.a.	n.a.	n.a.	n.a.	0,048	0,098	0,021	0,197	0,985	0,098	0,049
2	n.a.	-	n.a.	n.a.	n.a.	<0,001	0,010	0,003	0,197	0,489	0,031	0,665
3	n.a.	n.a.	-	n.a.	n.a.	0,585	0,028	0,103	0,969	0,175	0,067	0,739
4	n.a.	n.a.	n.a.	-	n.a.	0,778	0,673	0,092	1,000	0,118	<0,001	0,848
5	n.a.	n.a.	n.a.	n.a.	-	0,024	<0,001	0,555	0,094	0,322	0,062	0,974
6	0,048	<0,001	0,585	0,778	0,024	-	0,124	0,117	0,004	0,517	<0,001	0,034
7	0,098	0,010	0,028	0,0673	<0,001	0,124	-	<0,001	0,043	<0,001	0,793	0,506
8	0,021	0,003	0,103	0,092	0,555	0,117	<0,001	-	0,679	<0,001	0,206	0,507
9	0,197	0,0197	0,969	1,000	0,094	0,004	0,043	0,679	-	0,639	0,128	0,547
10	0,985	0,489	0,175	0,118	0,322	0,517	<0,001	<0,001	0,639	-	0,029	0,138
11	0,098	0,031	0,067	<0,001	0,062	<0,001	0,793	0,206	0,128	0,029	-	0,190
12	0,049	0,665	0,739	0,848	0,974	0,034	0,506	0,507	0,547	0,138	0,190	-

Table 3 - Level of significance of the Chi-Square Tests performed between pairs of variables at a 95% confidence level. Light red shading indicates that the null hypothesis has been accepted, meaning that the variables were found to be independent of each other. Green shades indicate a rejection of the null hypothesis and acceptance of the alternative hypothesis, meaning that it is possible that one variable influences the other (n.a. – not applicable)

5.1 Influences on the Population's Attitude Towards Waste Recycling

When considering research question 1, we must observe the data referring to the characterization of the population (questions 1 to 5 of the survey), crossing it with data referring to the population's attitudes towards recycling, that is, their actions regarding waste sorting (question 6 of the survey).

Research Question 1 (RQ1): What factors influence the population's attitude towards waste recycling?

Hypothesis 0 (Null): Gender, age, place of residence, educational level and professional status do not influence the population's attitude towards waste recycling.

Hypothesis 1: Gender, age, place of residence, educational level and professional status influence the population's attitude towards waste recycling.

Although the location and education of respondents does not appear to have an influence on whether they carry out waste sorting, gender, age and professional status stand out as diverging between people who do and those who do not sort waste.

Women have shown a greater adherence to recycling (90.9%), compared to men (85.5%). Additionally, in terms of age, it is in those under 18 (100%) and people over the age of 31 that we find greater adherence to recycling.

The same situation is verified when we look at the professional status, where full-time workers (89.9%), part-time workers (94.4%), unemployed (97.0%) and retired workers (94,4%) have higher scores, compared to student workers (73.9%) and students (82.8%).

Therefore, research question 1 is true (hypothesis 1) regarding the separation of waste for the variables gender, age group and professional status. In the remaining characteristics, the research question has a negative answer (null hypothesis).

The data allow us to understand that there is a greater adherence to recycling by people over the age of 30. Comparatively, it is in young adults and in students and working students that we observed a lower tendency to recycling.

5.2 Knowledge and Justice in Waste Payment

When we observe the information regarding the knowledge of the calculation formula, we must consider two different situations: the influence of the respondent's characteristics and their knowledge, conducting to two research questions (RQ2 and RQ3).

Research Question 2 (RQ2): What factors influence knowledge on how the waste tariff is calculated?

Hypothesis 0 (Null): There is no relation between gender, age, location, education and professional status and the knowledge about the tariff calculation.

Hypothesis 1 (Null): There is a relation between gender, age, location, education and professional status and the knowledge about the tariff calculation.

Considering the characteristics of the respondents (survey questions 1 to 5) and their answers regarding their knowledge (survey question 8), we verified that the existing relation between gender and knowledge results from the fact that there is a higher knowledge among men (27,33%), contrary to women (18,85%). Regarding age, it is in the age group above 51 that we verified a higher knowledge, including the age group 51-60 (30,7%), 61-65 (29,6%) and older than 65 (24,2%). In the remaining characteristics no relation was found.

Research Question 3 (RQ3): What is the relationship between the knowledge of the calculation of the waste tariff and the perception of fairness of the system?

Hypothesis 0 (Null): The knowledge of the formula and the attitudes do not influence the opinion about the fairness of the system.

Hypothesis 1: The knowledge of the formula and the attitudes influence the opinion about the fairness of the system.

Considering both the knowledge regarding the value paid (survey question 7) and the calculation of that value (survey question 8), compared with the fairness of the system (question 9), we have the following results.

Regarding the amount paid, the relationship between these variables is due to the fact that the vast majority of respondents who are aware of the amount they pay for waste (70.08%) considered the system unfair. Contrary to expectations, there was no relationship between knowledge of the calculation formula and considering the system to be fair or unfair (hypothesis 0).

At the same time, it is possible to understand that people who recycle have a greater tendency to consider the system unfair (91.11% of people who consider the system unfair recycle), being verified the relation between the attitudes and considering the system to be unfair (hypothesis 1).

5.3 Smart Waste Management

Focusing on smart waste management, it is important to conclude what the population's knowledge is and, at the same time, how receptive it is. In this sense, two distinct research questions arise.

Research Question 4 (RQ4): Do people who have knowledge about waste management and smart waste management methods tend to recycle?

Hypothesis 0 (Null): There is no relations between people recycling and their knowledge or openness to new waste management methods

Hypothesis 1: People who recycle demonstrate greater knowledge about the existence of waste management methods, demonstrating greater openness to their implementation

Observing table 3, it is possible to understand that there is no relation between recycling or not and having knowledge about smart waste management projects. On the contrary, there is a strong relationship with the acceptance or not of participating in a pilot project, where there is a strong positive response by respondents who recycle (82.32%), with the same acceptance by the non-recycling population being remarkably lower (62.12%).

Regarding the system to be implemented, there was a preference of individuals who recycle for both systems simultaneously (55.71%) and for recycling incentives (30%), with a higher ratio than expected in both cases. At the same time, individuals who do not recycle showed higher values than expected in the application of both systems (56.06%) and in the implementation of the PAYT system (15.15%).

Research Question 5 (RQ5): What factors influence the population's knowledge regarding the new methods?

Hypothesis 0 (Null): There is no relationship between knowledge regarding smart waste management and other factors

Hypothesis 1: Factors such as knowledge of the amount you pay, the calculation formula or willingness to participate influence knowledge regarding smart waste management

In order to answer this question, we have to look at people's knowledge of these projects (question 10) and the possible influencing factors: knowledge about how much they pay

(question 7), knowledge about the calculation formula (question 8) and willingness to participate (question 11).

It was found that there is a relationship between people's knowledge of the projects and their knowledge about payment (56.64% of people who know smart waste management projects know how much they pay) and its calculation formula (46.02% of the people who know this kind of projects know how the calculation is done).

At the same time, and with regard to openness to participation, it appears that 87.61% of people who were previously aware of this type of project demonstrate greater openness to participation.

6 Conclusion

Inserted in the city and in its various dimensions, waste management appears to be an important area for guaranteeing and improving the population's quality of life. Consequently, it has been undergoing changes to make it smarter.

Regardless of this growth, there is still a lack of dissemination and study of the theme, namely in the Portuguese context where, despite the existence of projects of smart waste management, their implementation is usually regional.

To be able to understand the attempts made to change the process, it is necessary to observe the process today and identify the points where the implementation can be carried out. In the Portuguese case, there has been a strong growth in the infrastructure for the collection, treatment, and destination of waste, demonstrating a political will to achieve the goals defined by the European Union.

Regarding smart waste management methods, and although these are being implemented mainly in the form of pilot projects, a greater acceptance and adherence to these methods is already being verified. Having presented two technologies that seek to make the process more intelligent and sustainable, PAYT and recycling incentive systems, it was possible to understand that these projects are still in an embryonic stage, applied in small territorial areas.

Through the implementation of the questionnaire, it was possible to draw conclusions regarding the characteristics of the population and its relationship with their attitudes, knowledge, and openness to new methods.

In terms of attitudes, the questionnaire allowed us to understand that there is a considerable effort towards the separation of waste, with most of the population (89%) separating waste. In the data collected, females stand out as recycling more, as well as people over 31 years old. Additionally, it was in students and working students that there was a lower adherence to recycling. Simultaneously, the data revealed that younger people also recycle less.

Regarding the payment of the process, there was greater unfamiliarity, with 58% of respondents not knowing the amount paid monthly and with a higher number of respondents (79%) not knowing the formula for calculation. In this scenario, it was male individuals who had greater knowledge of the formula, along with people over 51 years.

At the same time, knowledge regarding smart waste management is very low, with most respondents completely unaware of its existence (82%), despite showing receptiveness to its participation (80%). It was among respondents who already knew at least one project that there was a greater desire to be able to participate.

Having presented the two systems, PAYT and the recycling incentive system, most respondents showed openness to implementing both systems simultaneously.

Considering the information presented above, it is possible to understand the current waste scenario in Portugal, where smart waste management methods do not have a great representation, despite showing openness for their implementation.

In the Portuguese context, pressured by European legislation and targets, it is therefore expected that, in the near future, a fairer tariff payment system will be applied. However, considering the slow evolution of this process, Portugal may have to, in a short period of time, apply a complex system, unknown by a large part of the population, which may lead to resistance to its implementation.

Consequently, efforts should be made to expand the implementation of pilot projects and initiate a movement of national dissemination, seeking to inform people and prepare them for the possible future adoption of a new system and, in this way, ensure greater social, environmental, and economic development.

References

Caragliu, A., del Bo, C., Nijkamp, P., 2011. Smart cities in Europe. *J. Urban Technol.* 18, 65–82. <https://doi.org/10.1080/10630732.2011.601117>

- Coelho, S.L., 2019. Moedas Locais: reflexões sobre três casos em Portugal. *J. Stud. Citizsh. Sustain.* 4.
- Gradus, R., Homsy, G.C., Liao, L., Warner, M.E., 2019. Which US municipalities adopt Pay-As-You-Throw and curbside recycling? *Resour. Conserv. Recycl.* 143, 178–183. <https://doi.org/10.1016/j.resconrec.2018.12.012>
- Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X., Briggs, J.M., 2008. Global change and the ecology of cities. *Science* (80-). 319, 756–760. <https://doi.org/10.1126/science.1150195>
- Junta de Freguesia de Campolide, 2016. Pago em Lixo - O que é? [WWW Document]. URL <https://www.jf-campolide.pt/pago-em-lixo/pago-em-lixo-o-que-e> (accessed 6.9.21).
- Knickmeyer, D., 2020. Social factors influencing household waste separation: A literature review on good practices to improve the recycling performance of urban areas. *J. Clean. Prod.* 245, 1–18. <https://doi.org/10.1016/j.jclepro.2019.118605>
- Life PAYT, 2021. LIFEPAYT project in AVEIRO achieves a significant increase in the separation of recyclable waste [WWW Document]. URL <https://www.life-payt.eu/en/article/lifepayt-project-in-aveiro-achieves-a-significant-increase-in-the-separation-of-recyclable-waste> (accessed 5.30.21).
- Life PAYT, 2019. Improved PAYT container is installed at Forca [WWW Document]. URL <https://www.life-payt.eu/en/article/optimized-version-container-is-installed-for-further-tests-at-forca> (accessed 5.30.21).
- Ministério do Ambiente e da Ação Climática, 2021. Quando do Velho se Faz Novo, Todos Ganham! [WWW Document]. URL <https://dovelhosefaznovo.pt/projeto> (accessed 4.22.21).
- Molina, M.J., Molina, L.T., 2004. Megacities and atmospheric pollution. *J. Air Waste Manag. Assoc.* 54, 644–680. <https://doi.org/10.1080/10473289.2004.10470936>
- Nikitas, A., Michalakopoulou, K., Njoya, E.T., Karampatzakis, D., 2020. Artificial intelligence, transport and the smart city: Definitions and dimensions of a new mobility era. *Sustain.* 12, 1–19. <https://doi.org/10.3390/su12072789>
- Paul, M.J., Meyer, J.L., 2001. Streams in the urban landscape. *Annu. Rev. Ecol. Syst.* 32, 333–365. <https://doi.org/10.1146/annurev.ecolsys.32.081501.114040>
- Silva, V.H., Sepúlveda, D., Pinto, D., Pinheiro, V., Jota, L., Fontão, C., Castro, J.P., Costa, A., Ribeiro, J., Gonçalves, A.M., 2019. Statistical Analysis of Urban Waste Management via Pay-As-You-Throw (PAYT) System in the Portuguese City of Guimarães, in: 34th International Workshop on Statistical Modelling.
- Van Houtven, G.L., Morris, G.E., 1999. Household behavior under alternative pay-as-you-throw systems for solid waste disposal. *Land Econ.* 75, 515–537. <https://doi.org/10.2307/3147063>

Vitrus, 2021. PAYT Pague pelo lixo que produz [WWW Document]. URL <https://vitrusambiente.pt/payt> (accessed 6.8.21).

Zanella, A., Bui, N., Castellani, A., Vangelista, L., Zorzi, M., 2014. Internet of things for smart cities. *IEEE Internet Things J.* 1, 22–32. <https://doi.org/10.1109/JIOT.2014.2306328>