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Analysis of hospitality waste generation: Impacts of services and mitigation strategies

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ABSTRACT

Municipal waste generated by hospitality has become a significant sustainability challenge for tourist destinations. Ambitious sectoral actions to mitigate waste generation will require changes in the hospitality businesses' internal operations combined with costly municipal waste services transformation. We estimate the impact of hospitality services and mitigation strategies on mixed-waste generation. Results reveal that impacts differ according to the meal plans offered and that mixed-waste generation is higher in apartments than in hotels due to the accommodation and structural services nature. Notably, employee training is found to have a greater prevention effect than alternative waste management strategies. We advocate profound changes in municipal waste charge design and provide guidelines to facilitate engagement, underlining opportunities for cooperation between policymakers and hospitality managers.

1. Introduction

The hospitality industry is under increasing pressure to sharpen its focus on environmental and social issues. As a result, hospitality managers are beginning to grasp that sustainability and long-term economic growth are dependent on their environmental practices (Cingoski & Petrevska, 2018; Erdogan & Baris, 2007; Mensah, 2014). Indeed, the adoption of environmental policies in hospitality depends heavily on managers' attitudes towards change and the environment, as well as their knowledge of the benefits derived from improved environmental practices (Fraj, Matute, & Melero, 2015; Horng, Hu, Teng, Hsiao, & Liu, 2013; Kucukusta, 2017; Molina-Azorín, Tarí, Pereira-Moliner, López-Gamero, & Pertusa-Ortega, 2015). In this context, the way in which managers perceive the link between the external environment and their organizational parameters – such as the establishment's size, location and financial situation (Bohdanowicz, 2005; Dewhurst & Thomas, 2003; Font, Garay, & Jones, 2014) – is crucial in determining their course of action. Unsurprisingly, the leading sustainable practices implemented by hotel firms are related to their net operating incomes. As such, these practices normally consist of local environmental interventions and simple voluntary actions and are mainly intended to improve resource efficiency, enhance reputation, increase value or address changes in demand (Graci & Dodds, 2008; Inoue & Lee, 2011; Khatter, White, Pyke, & McGrath, 2021).

The most common environmental practices implemented in the hospitality industry involve water conservation and reuse, integral energy efficiency, reduction of material consumption and solid waste mitigation. They encompass the use of environmentally-friendly products (Pereira-Moliner, Molina-Azorín, Tarí, López-Gamero, & Pertusa-Ortega, 2021) and address challenging issues such as single-use plastics and rising food waste, especially after the COVID-19 pandemic (Filimonau, 2021). Although more effective waste management is vital to mitigating waste generation by the hospitality industry (Pirani & Arafat, 2014), and despite the fact that more efficient use of supplies and raw materials has a direct impact on firms' performance (Duric & Potočnik Topler, 2021), sustainable waste management is not yet as advanced or widespread as other environmental practices.

In order to engage effectively in waste mitigation, hospitality managers should reflect upon their knowledge and experience of waste management choices, improving their understanding of the overall contribution of tourism services to waste generation. This is referred to in the literature as the *reflection-in-action theory*, meaning that managers should apply their practical experience to give sense to realities and provide solutions to them (Boud, Keogh, & Walker, 2013). Building on

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this concept, Filimonau, Dickinson, Robbins, and Reddy (2011) highlight the need for better managerial understanding of the scale and scope of waste problems, which clearly requires both accurate measurement (quantification) and description (characterization) and identification of the underlying causes of waste generation, which are intrinsically linked to any mitigation strategy. In this context, analytical efforts to measure the determinants of waste generation and the impact of waste mitigation strategies provide evidence-based knowledge to improve our understanding of the issue. This is the impact analysis approach adopted in this paper.

Note that simultaneous analysis of the determinants of waste generation and waste mitigation strategies in the hospitality industry can be useful for hospitality managers and policymakers alike. As Martin-Rios, Demen Meier, and Pasamar (2022) observe in the context of food services, developing a sustainable waste management system requires a two-pronged approach that combines waste solutions and widespread stakeholder involvement to create synergies.

On the one hand, quantitative knowledge of waste strategy impacts in the hospitality industry can improve a firm's managerial strategies by identifying specific waste streams and services to target (Ezeah, Fazakerley, & Byrne, 2015). This knowledge may also facilitate the implementation of strategies at the firm level, since waste measurements can identify the impact on waste generation of coordinated industry measures, which can potentially enhance the destination's attractiveness, reputation and competitiveness.

Policymakers, on the other hand – in particular municipal authorities responsible for waste collection services, but also regional and national authorities – play a crucial role in the design of effective waste management systems specifically for the hospitality industry. Indeed, clear and well-defined measurements of the hospitality industry's contribution to waste streams are essential to designing and monitoring public waste strategies, including the promotion and financing of circularity plans. However, the contribution of hospitality services to municipal solid waste generation is impossible to discern from residential or commercial municipal waste indicators; the reason for this must be found in the definition of domestic waste within current regulatory frameworks and the design of local management networks (Diaz-Farina, Díaz-Hernández, & Padrón-Fumero, 2020; Murava & Korobeinykova, 2016).

The main aim of this paper is to analyze the impact of core services in the hospitality industry on mixed-waste generation and the effectiveness of strategies to mitigate waste. Our empirical approach makes several contributions to the literature. First, we analyze simultaneously two flows that act in opposite directions on mixed-waste generation in the hospitality sector: services that generate waste, and mitigation strategies to reduce waste. This prevents bias by ensuring that no significant waste flows are omitted. Second, we model all of the meal plans offered across the sector, identifying relationships between the different plans and determining their impacts on mixed-waste generation. Previously, only the impacts of breakfast-only (Juvan, Grün, & Dolnicar, 2018) and all-inclusive (Okumus, Taheri, Giritlioglu, & Gannon, 2020) services had been analyzed separately. Our analysis incorporates half-board and full-board services to cover the full range of food service options. Third, we compare two models of tourist accommodation that coexist in many coastal destinations, hotels and apartment complexes, revealing the different impacts on mixed-waste generation of distinct accommodation types and structural services.

We run a panel data model with a sample of 41 establishments representing 83% of the total number of beds in the destination of Puerto de la Cruz (Canary Islands, Spain). Data on the mixed waste generated by each establishment were collected daily over a period of nine weeks in 2018 as part of an audit commissioned by the city council. In addition, the local authority commissioned a study on waste management in the hotel sector, allowing us to observe the mitigation strategies implemented at managerial level across firms in the sector. The high representativeness of our sample allows conclusions to be drawn at destination level, helping hoteliers and policymakers to take informed decisions to reduce waste and improve management as part of the wider goal to improve destination sustainability.

The remainder of the paper is structured as follows. Section 2 presents the relevant literature on the determinants of waste generation and mitigation strategies in the hospitality industry. Section 3 describes the study area, the data used, and the model developed for the analysis. Section 4 presents the results and discussion. In Section 5, we discuss the theoretical and practical implications of our study, and conclusions are drawn in Section 6.

2. Related literature

This section presents the relevant literature on the determinants of waste generation in the hospitality industry and strategies to prevent and reduce waste. Special attention is paid to food waste since this has been identified as the main component of mixed waste in the hospitality industry (Williams et al., 2011) and is therefore central to any sustainable waste strategy. However, some clarifications about the different waste streams are needed first.

The waste produced by the hospitality industry can be classified as either hazardous or non-hazardous. Following Pirani and Arafat (2014), hazardous waste produced in hospitality is mainly composed of frying and mineral oils, paint and solvent residues, flammable material, fertilizers and chemicals, cleaning chemicals, batteries, fluorescent lights and other electric and electronic materials. Non-hazardous waste, on the other hand, is composed of food waste, cardboard, paper, plastics, metal, glass, cloths, wood and other organic waste. Non-hazardous waste is commonly managed by municipal authorities, except where the applicable regulations explicitly exclude it from municipal waste flows.

Food waste is "the discarding or alternative (non-food) use of food that was fit for human consumption by choice or after the food has been left to spoil or expire as a result of negligence" (FAO, 2015, p.1). It is categorized as avoidable (food that was edible before it was thrown away), possibly avoidable (food that is eaten by some but not by others, depending on how it was prepared) or unavoidable, for example, during preparation (Pirani & Arafat, 2014). In the hospitality sector, it can be further classified according to the different food service process, such as pre-kitchen, kitchen and post-kitchen (Williams et al., 2011). Note that post-kitchen food waste is directly related to consumer behavior and is, by and large, the biggest food waste stream (Filimonau & Delysia, 2019).

2.1. Determinants of waste generation in hospitality

The main determinants of waste generation in the hospitality industry are establishment size, occupancy rate, hotel type, category, room price, management practices, purchasing power, guest and staff activities, and guest characteristics and behavior (Abdulredha et al., 2018; Ball & Taleb, 2011; Bohdanowicz, 2005; Okumus, 2020; Pham Phu, Hoang, & Fujiwara, 2018; Pirani & Arafat, 2014, 2016; Trung & Kumar, 2005; Williams et al., 2011). Following Pirani and Arafat (2014, 2016), Ball and Taleb (2011) and Abdulredha et al. (2018), we establish the following hypothesis in relation to occupancy rate:

H1. The higher the demand, the higher the level of mixed-waste generation by accommodation service.

Following Pham Phu et al. (2018), Abdulredha et al. (2018) and Kasavan, Siron, Yusoff, and Fakri (2022), we also establish a second hypothesis:

H2. The larger the establishment, the higher its level of mixed-waste generation.

The typology of establishments in the hospitality industry is a relevant factor in some destinations, such as our study area, where two main types of tourist accommodation coexist: hotels and apartment complexes. Apartment complexes are a consolidated branch of tourism business models in Spain (as well as in other southern European regions), accounting for 25% of all beds nationally in 2019 and a higher proportion in regions like Valencia (50%) and the Canary Islands (37%).[1] However, very few studies of waste generation determinants consider both types of tourism establishments. The only combined study of hotels and apartment complexes can be found in González and León (2001), who analyzed the adoption of environmental innovations in the hospitality industry. Their study provides evidence that such innovations, in particular those related to waste management, are less likely to be adopted for apartment complexes. Here, we assume that services which differ between hotels and apartments, such as the availability of in-room kitchens or larger common areas in apartment complexes, will have an unequal impact on waste generation. Formally, we establish the two following hypotheses as extensions of H1 and H2:

H1'. Apartments equipped with kitchens generate more mixed waste than hotel rooms.

H2'. Apartment complexes tend to generate more structural waste than hotels.

More specifically, the determinants of food waste generation can be further identified by examining the entire food service process, classified in six steps, as set out by Kasavan et al. (2022) in their recent systematic literature review. First, the amount of food waste generated during the purchasing of food supplies is related to factors such as buying low-quality food items, buying in excess or bulk buying, not considering expiry dates, and mishandling by suppliers (Okumus, 2020). It is also important to consider the difference between small and large food service establishments, since smaller establishments tend to purchase supplies from food retailers, missing out on the advantages of high inventory turnover (Kasavan et al., 2022). Second, proper inventory and control, sufficient storage space, suitable food preservation machinery and the right storage temperatures help prevent waste in the raw food storage stage (Filimonau & Sulyok, 2021; Kasavan, Mohamed, & Abdul Halim, 2019; Okumus, 2020; Okumus et al., 2020). Third, inaccurate estimation of meal demand (Camilleri-Fenech, Sola, Farreny, & Durany, 2020), notably in the case of buffet-style meals (estimated by Papargyropoulou et al. (2016) to generate as much as 30% more food waste in order to satisfy guests' expectations) results in excess food being prepared, which cannot be stored or reused for other dishes (Kasavan et al., 2019). The experience and training of kitchen staff are also relevant to the degree of waste during food preparation (Okumus et al., 2020).

Fourth, the type of food service (buffet-style, semi-buffet and 'a la carte') and mealtimes (breakfast, lunch and dinner) impact food waste generation in different ways (Kasavan et al., 2022). Buffet-style restaurants generate the highest levels of food waste (Papargyropoulou et al., 2016). More buffet stations also lead to higher food and plate waste (Juvan et al., 2018; Okumus et al., 2020), while 'a la carte' restaurants only generate higher levels of waste during food preparation. In all-inclusive resorts, food waste in the serving process is driven mainly by factors such as all-day food and beverage service to enhance guest satisfaction, offering low-quality food, offering an extensive variety of menus, high guest expectations and the expected speed of service (Okumus et al., 2020; Ozdemir, Çizel, & Bato Cizel, 2012). Interestingly, Juvan et al. (2018) found that children, certain guest nationalities and higher guest concentrations drive plate waste in breakfast buffets. Portion size is another important determinant of plate waste in the serving process (Camilleri-Fenech et al., 2020; Gandhi, Kumar, Paritosh, Pareek, & Vivekanand, 2019), especially in the case of children (Juvan et al., 2018; Kasavan et al., 2019). Other determinants of waste in the serving process are ordering errors, poor communication to guests about cooking methods and portion sizes, and conflicting interests between different hotel departments.

Fifth, plate waste management and processing of leftovers are determined by legal constraints on the reuse of untouched served food (for safety reasons), the reuse of leftovers for other meals (depending on food quality, packaging, and storage at appropriate temperatures), food donations to charities and end-of-day sales (Kasavan et al., 2019; Martin-Rios, Demen-Meier, Gössling, & Cornuz, 2018). Finally, in a sixth step, the disposal of food waste is determined by the separation of food waste practices at the facility, which may allow for food waste to be processed for composting, animal feed, fuel or biogas (Kasavan et al., 2022). The main barriers to food waste sorting reported in the literature are insufficient information, financing, waste storage space, human capital, facilities, time and hotel management support (Kasavan et al., 2019; Sealey & Smith, 2014). Similar determinants condition hotels' capacities for on-site recycling, in addition to the inability to access the necessary technology, insufficient scale of food waste generation for composting (particularly in the case of small establishments), absence of a market for the resulting compost, and scarcity of labor or other resources (Kasavan et al., 2019; Pirani & Arafat, 2016). Note that establishment size also influences waste sorting, as smaller establishments find it harder to cover waste disposal costs (Filimonau & Tochukwu, 2020).

Given the above discussion on foodservices, we establish the following hypotheses:

H3. The meal plans offered (all-inclusive, full-board, half-board and breakfast-only) have different impacts on mixed-waste generation.

H3'. All-inclusive plans have a higher impact on mixed-waste generation.

2.2. *Waste mitigation strategies in the hospitality industry*

The adoption of environmental strategies in the hospitality industry depends on factors such as establishment size, age, ownership (independent or chain) and stakeholder pressure (Álvarez Gil, Burgos Jiménez, & Céspedes Lorente, 2001). Establishment size is a key determinant of the adoption of sustainable solid waste management strategies, with small establishments less likely to do so (Radwan, Jones, & Minoli, 2010). In terms of waste mitigation, Pirani and Arafat (2014) found that sorting and recycling were the most common waste management strategies in the hospitality industry. Other strategies include reducing the volume of waste through pressing, using reusable items, donating old furniture, reducing office paper consumption, buying in bulk, and eliminating single-use plastics (Pirani & Arafat, 2014). Zorpas, Lasaridi, Voukkali, Loizia, and Inglezakis (2012) described a battery of waste minimization strategies for different areas of hotel management, such as offices, housekeeping, food and beverages, and energy equipment.

Martin-Rios et al. (2022) conducted a collaborative European study of waste handling by different stakeholders, working with food service practitioners, institutional representatives, sustainability specialists and leading academics to establish a sustainable set of waste management and minimization solutions for food service managers. They identified 15 solutions classified as organizational, service (offer or delivery) and process innovations according to the objective for managers and employees. The expert panel affirmed that a set of tailor-made practices for resource management and waste minimization together with processing techniques for recycling, reusing and recovering waste are required for a sustainable waste management system.

As part of an in-depth analysis of food services, Vizzoto, Testa, and Iraldo (2021) classified as many as 759 food waste mitigation strategies reported in the literature for the hospitality industry, considering 30 homogeneous groups, seven categories and 180 types of measures. The seven categories (with groups shown in brackets) are: i) managerial (measuring food waste; engaging staff; planning, executing and monitoring; and managerial action); ii) supply chain management (menu planning; purchasing; inventory management; forecasting; and

[1] According to the National Statistics Institute (INE).

appropriate storage and handling of food acquired and leftovers); iii) preparation (cooking proficiency; repurposing leftovers and offcuts/peel/bones; and reducing overcooking); iv) serving (reducing portion size or offering different options; flexible menus, buffet management, waste-preventing table service; and serving style adjustment); v) consumer behavior (awareness campaigns; reducing the amount of dinnerware; and financial incentives and penalties); vi) information exchange (better internal and external communication); and vii) alternative destinations (donations; doggy bags; and last-minute markets).

In this paper, we analyze the causal effect of three waste minimization strategies implemented at the establishment level for the overall mixed-waste stream. We develop in greater detail the managerial strategy category established by Vizzoto et al. (2021) by extending it to encompass waste generation as a whole rather than just food waste. Note that the strategies in this group are performed, led or enforced by the manager, who therefore serves as a catalyst for waste reduction practices, facilitating and accelerating the adoption of other strategies that may also result in waste reductions (Vizzoto et al., 2021). The four strategies considered in the review, which can be activated by waste managers, are: i) measuring waste, which is considered the “first step” to improving waste management as it serves as a baseline and a diagnosis of the problem in the establishment; ii) engaging staff, which refers to increasing the visibility and awareness of the waste problem, training employees in waste prevention and sorting, establishing common goals and offering incentives to achieve them, and exchanging views and experiences; iii) planning, implementing and monitoring a waste reduction plan; iv) taking managerial action, which refers to a miscellaneous group encompassing a range of actions that contribute to the adoption of waste minimization strategies. The latter group includes environmental certification, since the measures carried out after certification are of a transversal nature that pursue specific environmental objectives, commonly including waste mitigation.

We formulate one hypothesis for each of the three managerial strategies defined by Vizzoto et al. (2021), as follows:

H4a. Training employees in waste prevention and sorting reduces mixed-waste generation.

H4b. The presence of a waste manager in the management team reduces mixed-waste generation.

H4c. Establishments with an environmental certification generate less mixed-waste.

Other relevant academic research has empirically analyzed food waste mitigation strategies in the hospitality industry from a variety of perspectives and using different methods. For example, Chalak, Abou-Daher, and Abiad (2018) analyzed how government regulation in 33 developed countries mitigates food waste along the food supply chain in general, and in the HoReCa (Hotel/Restaurant/Café) and retail/wholesale food sectors in particular. They found that well-defined and inclusive legislative frameworks, awareness campaigns (to influence and change individual behavior) and fiscal incentives (such as landfill and incineration taxes) significantly reduce food waste generation. Martin-Rios et al. (2018) analyzed this issue in the context of innovative measures to reduce food waste, finding that restaurant managers adopt mainly incremental rather than radical innovations, mostly related to processes and not to technology, and mainly driven by cost reduction. They also find that increasing stakeholders’ alliances can mitigate food waste, involving hospitality firms, suppliers, non-profit associations, local authorities and waste companies. Vizzoto, Tessitore, Iraldo, and Testa (2020) analyzed the causal relationship between raising awareness of food waste, measuring waste and implementing waste reduction strategies among managers from the HoReCa sector. They provide evidence that increasing awareness among employees of the amount of waste generated translates into action only when this waste is actually measured and only in the kitchen phase. Martin-Rios, Hofmann, and Mackenzie (2021) analyzed advanced technological innovations that provide users with an automated solution to quantify and identify avoidable and unavoidable food waste disposed of in a container equipped with a camera and a scale, called a Kitro device. Users can analyze the food waste components and the quantity, cost and source of waste. Martin-Rios et al. (2021) reported that the use of Kitro devices was associated with an average reduction of avoidable food waste in hotels, restaurants and cafés in Switzerland of up to 60%, 50% and 40%, respectively.

3. Methodology

3.1. Study area

Puerto de la Cruz (Tenerife, the Canary Islands) is a mature tourist destination with major problems in its waste management services due to its tourism intensity. The case study is a close reflection of the problems encountered in other tourist destinations and the factors that hamper the implementation of more sustainable collective actions: high human pressure on the territory, high per-capita waste generation, low recycling rates and the hospitality industry’s low contribution to municipal waste collection costs. Changing to a greener, more sustainable model could provide direct benefits and reverse the destination’s falling competitiveness. However, financial constraints may limit the extent to which the required actions can be implemented.

High human pressure

Puerto de la Cruz is one of the oldest cities in the Canary Islands (Spain) and among the most popular with tourists. It is the smallest municipality in the archipelago (with a surface area of only 8.73 km^2) and also the most densely populated (3454.8 inhabitants/km^2), with an additional daily tourist pressure equal to half the resident population (approximately 30,500 inhabitants and 15,600 daily tourists on average in 2019). Fig. 1 shows the evolution of the average daily human pressure and the equivalent population density in Puerto de la Cruz over the period from 2004 to 2019. The equivalent population (residents + tourists) density is above 5200 people per km^2 for most of the study period, with the exception of 2013–2015.

Poor waste indicators

One of the main environmental consequences of the excessive human pressure on tourist destinations is the large volume of municipal solid waste generated. Table 1 highlights the scale of this environmental problem in Puerto de la Cruz. In 2019, per-capita solid waste generation was 82% higher than the national average and significantly higher than the average for the Canary (42%) and Balearic Islands (22%), the most popular tourist regions in Spain. The two archipelagos are the highest per-capita generators of solid waste in the country, but they differ considerably in recyclable waste collection; the Balearic Islands collect a larger amount of recyclable waste per inhabitant than the national average (68% more), whereas in the Canary Islands the figure is 11% lower than average. The situation is even more alarming in Puerto de la Cruz, where per-capita recyclable waste collection is 23% below the national average. Recycling ratios in the Canary Islands indicate that urgent additional measures must be undertaken in order to meet the EU targets set by the Waste Framework Directive (as amended by 2018/851).[2]

Deficit in the municipal waste collection service

Responsibility for the collection, transport and treatment of waste generated by the hospitality industry in Spain is held by municipal councils. However, these authorities only collect waste streams that are

[2] “By 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50% by weight.” (Directive 2008/98/EC of the European Parliament and of the Council). The target is 55% by 2025, 60% by 2030 and 65% by 2030.

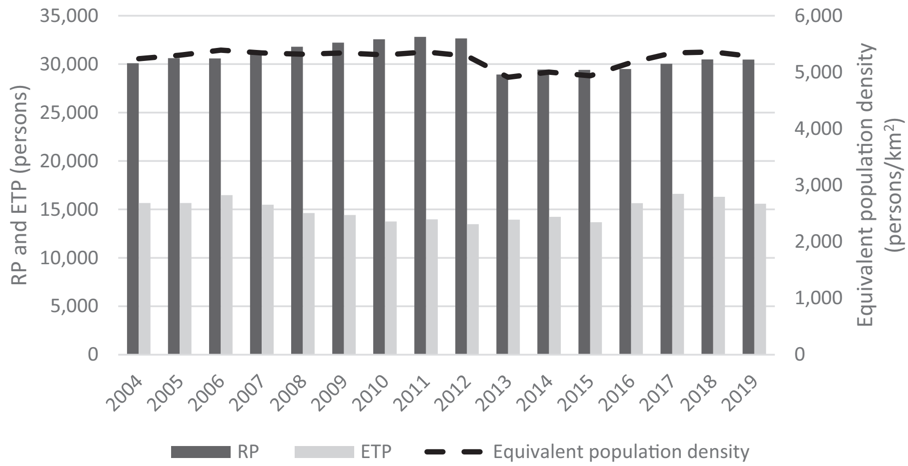

Fig. 1. Resident and tourist poluation (persons) and equivalent polutaion density (persons/km^2) in Puerto de la Cruz from 2004 to 2019. Note: RP, Resident Population; ETP, Equivalent Tourist Population. Source: Prepared by authors from ISTAC (2020) data.

Table 1
Per capita municipal solid waste (kg/inhabitant) generated in 2019 in Puerto de la Cruz compared to the Canary and the Balearic Islands and Spain.

Variable	Spain	Balearic Islands	Canary Islands	Puerto de la Cruz
Mixed-waste	378.48	563.71	485.64	688.10
Recyclable waste	106.95	180.10	95.48	73.32
Total MSW	485.43	743.81	581.13	761.42

Source: Prepared by authors from (INE, 2022) and Cabildo Insular de Tenerife (2020).

similar to the waste generated by households (non-hazardous waste). Consequently, municipal waste management infrastructure, sorting rules and charges are similar to those for the residential sector. The actual volume of solid waste from the hospitality industry is therefore blurred within local waste management costs, practices and indicators.

According to estimates by the company responsible for collecting municipal solid waste (Valoriza), the direct contribution of the hospitality sector to mixed-waste generation in Puerto de la Cruz is around 40%. Moreover, Diaz-Farina et al. (2020) estimate that the sector contributes 0.33 kg/day of mixed-waste per tourist in the average Tenerife municipality, contributing approximately 22% of the overall municipal mixed waste generated in Puerto de la Cruz. By comparing the sector's waste contributions with overall municipal revenues from the waste management charges levied by the Puerto de la Cruz city council, it is possible to estimate the deficit generated by the hospitality industry (see Fig. 2) together with the subsequent cross-subsidy between hospitality and other sectors and households. Although there is a service deficit throughout the observed period, it becomes more pronounced from 2011 onwards, resulting in a difference of 14 percentage points between the hospitality sector's contribution to municipal mixed-waste generation and revenues generated by the flat waste management fee paid by hotels and apartment complexes. In fact, Puerto de la Cruz has the lowest hospitality sector waste tariffs of any tourist municipality in Tenerife, with a range of €11.80–13.10 per bed per year, depending on the category of establishment. This contrasts sharply with the range of €67.50–72.80 (depending on the number of days of services) in Adeje and €29.27–72.98 (depending on the area) in Arona.[3]

Low profitability hospitality industry

Puerto de la Cruz is the least profitable destination in the Canary Islands, according to the average daily rate (ADR) (ISTAC, 2022). Apartment complexes and hotels in Puerto de la Cruz had the lowest ADR in the archipelago between 2009 and 2021, falling further behind other destinations in recent years. Indeed, the ADR in Puerto de la Cruz in 2021 was €55.10 for hotels and €41.30 for apartments, which is significantly lower than other destinations in the same island, such as Adeje (€134.81 for hotels and €73.60 for apartments). For this reason, raising flat waste tariffs would not only exacerbate the low profitability of tourism firms, it would also penalize those establishments that have already implemented more sustainable and costly waste management plans.

3.2. Data

In 2016, the city council of Puerto de la Cruz requested an audit of the amount of mixed-waste generated in a sample of the municipality's hotel establishments. Mixed waste is the waste stream composed of non-hazardous waste that is not sorted for recycling. The audit was carried out by the company responsible for municipal solid waste collection and transport. The audit took place in 2018, and the sample consisted of 34 hotels and eight apartment complexes, which were observed for nine weeks, from 5 March to 6 April. According to official data available from the Canary Islands Statistics Institute (ISTAC, 2022), the final sample (one apartment was omitted as an outlier) represents almost 51% of total accommodation establishments in Puerto de la Cruz in the period in question, but in terms of beds and rooms the representativeness rises to 79.8% and 82.8%, respectively.[4] The total representativeness of the sample and its disaggregation by type of establishment can be seen in Table 2.

The variable of waste registered by each accommodation

[3] These tariffs are regulated at local government level and can be consulted on the websites of the respective municipal authorities. Adeje: http://www.recaudacionadeje.org/n_servicios/VerOrdenanza.php?fichero=./ordenanzas/xml/Basura_2021.xml. Arona: https://www.arona.org/Portals/0/documentos/20210112_85176_43957.pdf. Puerto de la Cruz: https://sedeelectronica.puertodelacruz.es/publico/ordenanza/FI02.

[4] Data on the number of beds, number of rooms and category of each establishment were provided by the Hotel & Apartment Association (ASHOTEL).

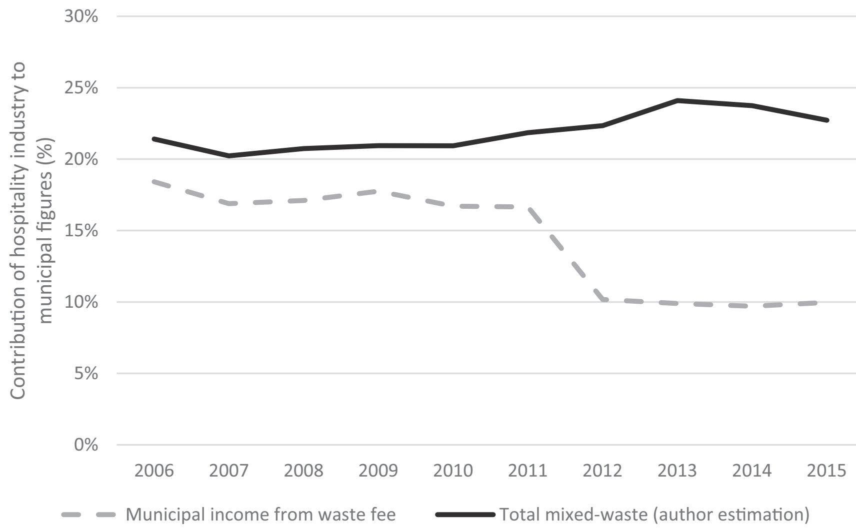

Fig. 2. Contribution of the hospitality industry in Puerto de la Cruz to total mixed-waste generation and municipal income for the waste collection fee from 2006 to 2015 (%). Source: Author prepared from Puerto de la Cruz City Council data and own estimations.

Table 2
Representativeness of the sample used.

Typology	Variable	ISTAC	Sample	Representativeness
Hotel	Establishments	56	34	60.7
	Beds	15,317	13,842	90.4
	Rooms	7788	6921	88.9
Apartment	Establishments	25	7	28.0
	Beds	5496	2764	50.3
	Rooms	2234	1382	61.9
Total	Establishments	81	41	50.6
	Beds	20,813	16,606	79.8
	Rooms	10,022	8303	82.8

Source: Prepared by authors from ISTAC (2022).

establishment was the number of mixed-waste bins collected per day from Monday to Saturday (there is no service on Sunday), indicating the filled volume, that is, assigning values of half-full, three-quarters, full, and overflowing. For the sake of consistency, a full-equivalent bin is defined as having a capacity of 800 l, as stipulated in the municipal waste standards, assigning a weight of 0.5 to half-full bins, 0.75 to three-quarters, 1 to full, and 1.2 to overflowing. To account for daily variability in waste generation, daily data were aggregated by week, resulting in the variable *Full-Equivalent-Bins* (FEB), which is our dependent variable. Additionally, a standard weight of 135 kg (data provided by the company) per FEB was used to normalize our results with previous data in the literature. Our sample shows that hotel mixed-waste generation is higher in absolute values but only slightly higher than that of apartments when FEB is relativized by number of available rooms, as shown in Fig. 3.

For the explanatory variables, structural services are represented by the number of rooms, while the effect of accommodation services is captured through the occupancy rate per room. The latter variable was requested from ISTAC. Weekly occupancy rate was requested both per room and per bed for each establishment. However, so as not to violate the privacy policy, ISTAC provided data with the maximum disaggregation allowed, that is, by type and category of establishment, grouped by micro-destination (tourism areas at a lower scale than municipality).[5] Thus, we implicitly assume that establishments of the same type and category and located in the same micro-destination have the same

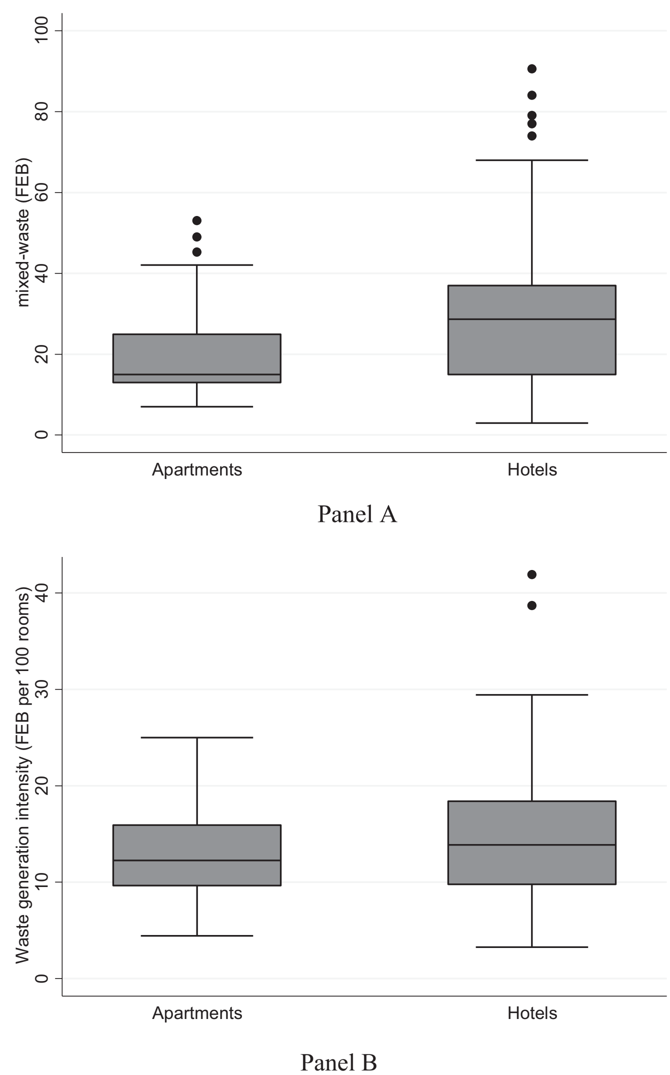

Fig. 3. Box-plot of mixed-waste generated weekly (FEB) in levels (panel A) and per 100-rooms (panel B) within the hospitality sector by type of establishment in the sample used. Source: Prepared by authors.

[5] The hospitality industry in Puerto de la Cruz is split into four micro-destinations.

occupancy rates. Weekly average occupancy of apartment rooms (77.9%) is similar to that of hotels (78.3%), as Table 3 shows.

The impact of food service is captured using the variable of the number of meals served (*MS*) under each meal plan. In the same request to ISTAC, we asked for the occupancy rate per bed for each meal-plan contracted (all-inclusive, full-board, half-board, breakfast-only and no meals). Multiplying the occupancy rate per bed for each meal plan by the number of beds, we obtain the number of overnight stays (guest) under each meal plan (excluding guests with no meal plan). Then, *MS* is created from a weighted sum of the overnight stays for each meal plan, with a weight of 1 for breakfast-only, 2 for half-board, 3 for full-board, and 3.2 for all-inclusive, following Ramazanova, Deyá Tortella, Tirado, and Kakabayev (2021).[6] This process of completing the plans by adding meals helps identify relationships between meal plans.

However, as we aim to test the impact of different food services on mixed-waste generation, we constructed the share of each meal plan following the theoretical model developed in Appendix B. The result is the share for all-inclusive (*SAI*), for full-board (*SFB*), for half-board (*SHB*) and for breakfast-only (*SBr*) meal plans. The most common meal plan contracted across the whole sample is half-board (46.6%), followed by breakfast-only (26.6%), all-inclusive (13.6%) and full-board (13.1%). It is important to note that not all establishments offer all meal plans. The only meal plan that is offered at all establishments is half-board. In total, there are 11 establishments that do not offer an all-inclusive service, five full-board and three breakfast-only (in the latter case, they offer breakfast but only together with dinner under the half-board plan). See Appendix A for the shares disaggregated by establishment type.

Finally, using the audit commissioned by the city council and conducted by Fundación Canarias Recicla (FCR)[7] to analyze waste management in the hospitality sector in Puerto de la Cruz, we included in our analysis some waste management variables considered by Vizzoto et al. (2021) in the four groups of the managerial category. The relationship between Vizzoto et al. (2021) and our variables is as follow:

- *FEB* is the proxy for the "measuring food waste" strategy, which is considered essential to assess the baseline situation, providing an understanding of the magnitude of the problem.
- *Employee Training (EmT)* is the proxy for the "engaging staff" strategy. *EmT* is a dummy variable that takes a value of 1 if the establishment provides employee training on waste reduction and waste management and the value 0 otherwise. Of the total establishments in the sample, 51.2% stated they provided employee training, as Table 4 shows.
- *Waste Manager* (*WMa*) is the proxy for the "planning, implementation and monitoring" strategy. *WMa* is a dummy variable that takes a value of 1 if the establishment has a member of its management team who is in charge of a waste mitigation plan and the value 0 otherwise. In this case, only 24% of establishments declared having a waste manager or similar position in their organizational structure.
- *Environmental certification* (*EC*) is the proxy for the "management actions" strategy group. *EC* is a dummy variable that takes a value of 1 if the establishment holds the ISO 14001, EMAS, Travelife Sustainability System and/or Biosphere Responsible Tourism certification and the value 0 otherwise. Only five out of 41 (12%) of the establishments in the sample have at least one of these environmental certifications. However, this evidence is consistent with the results reported by Rodríguez-Antón, del Mar Alonso-Almeida, Celemín, and Rubio (2012) for the hotel industry in Spain, where the figure was around 10%.

3.3. The model

Waste is considered an undesirable (bad) product generated in a production process. Similarly to a classical production function, the waste generation function determines the factors that affect waste generation in the production processes of the hospitality industry. A set of waste streams or bad goods ($y_1, y_2, \ldots, y_n$) is generated as a function of a given set of services offered ($x_1, x_2, \ldots, x_n$) and a given set of waste mitigation strategies adopted ($z_1, z_2, \ldots, z_n$). In this paper, we analyze only one undesirable product, the mixed-waste stream, simplifying the set of waste streams to $Y(y_1)$.

To estimate mixed-waste generation in the hospitality industry linked to the different elements of the waste generation function (1), we propose a model with four groups of explanatory variables: i) the demand of *food service*; ii) the demand of *accommodation*; iii) the *structural services* for the operation of the activity, such as infrastructure maintenance and human capital; and iv) the *waste mitigation strategies* adopted. Fig. 4 shows a visual representation of the model and the hypotheses associated with each group of variables.

$$Y(y_1) = f(x_1, x_2, \ldots, x_n; z_1, z_2, \ldots, z_n) \tag{1}$$

We assume a multiplicative functional form as it enables us to model a possible relationship between services in explaining their impact on mixed waste generation (especially different meal plans) and provides sufficient flexibility to capture possible decreasing rates in waste generation as services increase. The model specification is as follows:

$$\begin{aligned} ln(FEB)_{it} =& \beta_0 + \beta_1 ln(HOR)_{it} + \beta_2 ln(AOR)_{it} + \beta_3 ln(HRo)_{it} + \beta_4 ln(ARo)_{it} \\ &+ \beta_5 ln(MS)_{it} + \beta_6 ln(SAI)_{it} + \beta_7 ln(SFB)_{it} + \beta_8 ln(SHB)_{it} \\ &+ \beta_9 ln(SBr)_{it} + \beta_{10} EmT_{it} + \beta_{11} WMa_{it} + \beta_{12} EC_{it} + \lambda_t + u_i + \varepsilon_{it} \end{aligned} \tag{2}$$

where subscripts *i* and *t* denote establishments and time, respectively. λ_t is a period fixed effect common to all establishments, u_i is the unobserved time-invariant individual effect and ε_{it} is the idiosyncratic error term, which follows a normal distribution with zero mean and constant variance (σ).

It is important to understand that the introduction of a meals-served *(MS)* variable and the shares of each meal plan in the model (2) follow the theoretical model developed in Appendix B. Therefore, there is no need to expect perfect multicollinearity, as it is the number of meals under the different meal plans that are used. Because the model is double logarithmic and some meal plan shares take a value 0 for some establishments (and *Ln(0)* is undefined), zeros have been replaced by values very close to zero (0.01), as suggested by MaCurdy and Pencavel (1986). It is also noteworthy that the parameter to estimate the meals-served variable must, by definition, be equal to the sum of the parameters of the different shares. For this reason, the model is estimated by imposing a constraint on the parameters ($\widehat{\beta_5} = \widehat{\beta_6} + \widehat{\beta_7} + \widehat{\beta_8} + \widehat{\beta_9}$).[8] Moreover, since the sum of all shares for a given establishment in a given period is equal to 1, we expect some negative estimated coefficients, as an increase in the share of one meal plan entails a decrease in that of one or more other meal plans.

Once the model is specified, the hypotheses can be expressed analytically as follows:

[6] We ran the model (2) assuming different weights for all-inclusive, considering a range of 3.1 to 4, but the results did not vary significantly. It is important to note that the main difference between the all-inclusive and full-board services are the drinks and snacks (food and beverages) consumed in bars, which cannot be considered an extra lunch or half lunch as the quantity of the meals is much lower.

[7] The questionnaire conducted by FCR is available as supplementary material.

[8] Equivalent to equation B.5 of Appendix B.

Table 3
Variable description and descriptive statistics.

Variable	Label	Units	Obs.	Mean	S.D.	Min	Max
FEB	Full-Equivalent-Bins of mixed-waste	Bins	369	26.9	15.2	3.0	90.6
CaH	Hotel-category	Stars	306	3.8	0.6	2.0	5.0
CaA	Apartment-category	Stars	63	2.9	0.4	2.0	3.0
HBe	Hotel-beds	Unit	306	419.8	201.6	58.0	1152.0
Abe	Apartment-beds	Unit	63	397.7	115.0	244.0	574.0
HRo	Hotel-rooms	Unit	306	202.6	88.3	31.0	390.0
ARo	Apartment-rooms	Unit	63	178.7	57.4	120.0	287.0
HOR	Hotel occupancy rate	Percent	306	78.3	7.4	44.2	95.3
AOR	Apt. occupancy rate	Percent	63	77.9	8.5	60.2	91.4
MS	Meals served	Unit	369	3255.4	2148.6	164.2	10,769.6
SAI	Share all-inclusive	Percent	369	13.4	10.5	0	30.6
SFB	Share full-board	Percent	369	12.9	13.6	0	51.7
SHB	Share half-board	Percent	369	46.6	15.7	12.5	81.9
SBr	Share breakfast-only	Percent	369	26.6	15.8	0	60.0

Source: Prepared by authors.

Table 4
Distribution of managerial variables by typology of the accommodation establishment of the sample used.

Variable	Typology	No (value = 0)	Yes (value = 1)	Total
Employee training (*EmT*)	Apartment	3	4	7
	Hotel	17	17	34
	Total	20	21	41
Waste manager (*WMa*)	Apartment	5	2	7
	Hotel	26	8	34
	Total	31	10	41
Environmental certification (*EC*)	Apartment	5	2	7
	Hotel	31	3	34
	Total	36	5	41

Source: Prepared by authors.

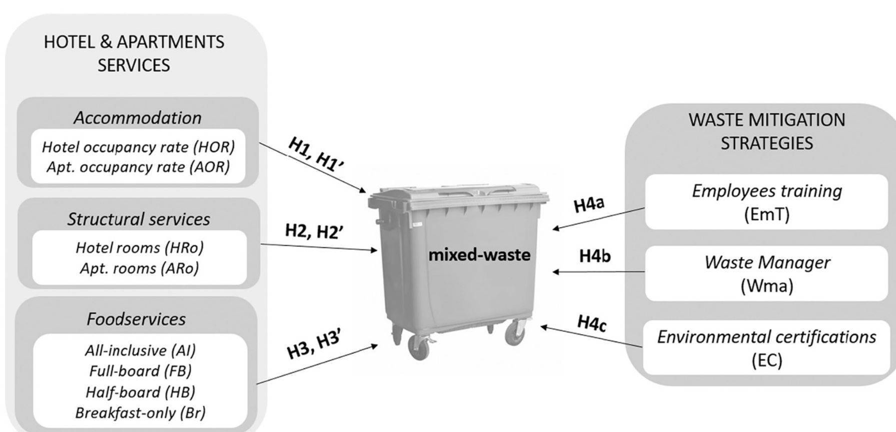

Fig. 4. Scheme of model (2) and hypotheses associated to each group of variable. Source: Prepared by authors.

- $H1 : \widehat{\beta_1}, \widehat{\beta_2} > 0$, the higher the demand, the more mixed waste generated by accommodation service, with a particularly high impact due to in-room kitchens in apartments, $H1' : \widehat{\beta_1} < \widehat{\beta_2}$.
- $H2 : \widehat{\beta_3}, \widehat{\beta_4} > 0$, the larger the establishment, the greater its mixed-waste generation, where apartments tend to generate more structural waste than hotels, $H2' : \widehat{\beta_3} < \widehat{\beta_4}$.
- $H3 : \widehat{\beta_6} \neq \widehat{\beta_7} \neq \widehat{\beta_8} \neq \widehat{\beta_9}$, each meal plan has a different impact on mixed-waste generation, for example the all-inclusive plan has a higher waste impact, $H3' : \widehat{\beta_6} > \widehat{\beta_7}, \widehat{\beta_8}, \widehat{\beta_9}$.
- $H4a, H4b, H4c : \widehat{\beta_{10}}, \widehat{\beta_{11}}, \widehat{\beta_{12}} < 0$, the implementation of waste mitigation strategies effectively reduces mixed-waste generation.

Lastly, as the model is double logarithmic, the coefficients must be interpreted directly as elasticities. However, the interpretation of a meal served under a specific meal plan should be interpreted as the sum of the common effect of the meal served (the estimated coefficient of the meal served, $\widehat{\beta_5}$) and the specific effect of the meal plan under consideration, as shown in eq. B.8 of Appendix B. For example, the overall elasticity of all-inclusive meal plans is given by the sum of $\widehat{\beta_5}$ and $\widehat{\beta_6}$.

4. Results and discussion

The model explains 66.5% of the variation of the dependent variable: that is, the weekly number of full-equivalent mixed-waste bins (*FEB*) collected in tourist accommodation establishments in Puerto de la Cruz,

Table 5
Results of the model (2).

Production element	Regressor	Coefficient	Robust St. error	[95% Conf. interval]
Accommodation services	*Ln(HOR)*	0.5938**	(0.2929)	[0.02–1.168]
	Ln(AOR)	0.8854***	(0.2641)	[0.368–1.403]
Structural services	*Ln(HRo)*	0.5329***	(0.1551)	[0.229–0.837]
	Ln(ARo)	0.5678***	(0.1498)	[0.274–0.861]
Food services	*Ln(MS)*	0.1351***	(0.0413)	[0.054–0.216]
	Ln(SAI)	0.0599*	(0.0358)	[−0.01–0.13]
	Ln(SFB)	−0.0597***	(0.0197)	[−0.098 - -0.021]
	Ln(SHB)	0.1487***	(0.0314)	[0.087–0.21]
	Ln(SBr)	−0.0139	(0.0259)	[−0.065–0.037]
Waste mitigation strategies	*EmT*	−0.3446***	(0.1041)	[−0.549 - -0.141]
	WMa	−0.0318	(0.0563)	[−0.142–0.079]
	EC	−0.2569***	(0.0987)	[−0.45 - -0.063]
Constant		−0.3831	(0.6969)	[−1.749–0.983]
Period FE		Yes		
Obs.		369		
R-Squared		0.65		

Note: The dependent variable is the log of the weekly 800 l full-equivalent bins *(FEB)* collected. Standard errors clustered at the category level in parenthesis. Three stars indicate statistical significance at the 1% level, two stars at the 5% level and one star at the 10%. Source: Prepared by authors.

higher the level of mixed waste generated by the accommodation service, in line with the findings of other authors such as Pirani and Arafat (2014, 2016) and Ball and Taleb (2011). Additionally, higher occupancy has a greater impact on mixed waste generation in apartment complexes than in hotels, which can be substantiated by the presence of individual kitchens in apartment rooms. An increase of 1% in the occupancy rate increases mixed waste generation by 0.89% in apartments and by only 0.6% in hotels.

Estimated coefficients for *structural services* also confirm H2, as the positive sign of coefficients indicates that the larger the hotel or the apartment complex, the greater the number of weekly *FEBs* collected. This result is in line with the findings of Pham Phu et al. (2018) and Abdulredha et al. (2018). Note, too, that coefficients are below the unit, which points to decreasing returns of scale in mixed-waste generation, with a greater impact for hotels than for apartments.

Results for the differential impact of *structural services* by type also validate H2', indicating that a 1% increase in the number of rooms in an apartment complex increases mixed-waste generation by 0.57%, which is slightly more than the equivalent impact in hotels (an increase of 0.53%). This may be related to larger common areas, offices, gardens, etc. in apartment complexes, but more detailed analysis is required to obtain a complete understanding.

Table 6
Elasticity and marginal effect of variables included in model (2) evaluated at the mean values of the sample.

Production element	Regressor	Elasticity	Marginal effect (bins/week)	Marginal effect (kg/week)	Marginal effect (kg/day)
Accommodation services	*Ln(HOR)*	0.5938	0.002	0.28	0.039
	Ln(AOR)	0.8854	0.0031	0.41	0.059
Structural services	*Ln(HRo)*	0.5329	0.0708	9.55	1.365
	Ln(ARo)	0.5678	0.0855	11.54	1.648
Foodservices	*Ln(MS*SAI)*	0.1951	0.021	2.83	0.404
	*Ln(MS*SFB)*	0.0754	0.0105	1.42	0.203
	*Ln(MS*SHB)*	0.2838	0.0102	1.38	0.197
	*Ln(MS*SBr)*	0.1351	0.0095	1.28	0.183
Waste mitigation strategies	*EmT*	−0.3446	−9.2697	−1251.41	−178.77
	WMa	−0.0318	−0.8554	−115.48	−16.5
	EC	−0.2569	−6.9106	−932.93	−133.28

Note: The dependent variable is the log of weekly full-equivalent bins collected. Marginal effects are shown in 800-l full equivalent bins and in kg with a conversion rate of 135 kg/bin of mixed-waste. The elasticity of the only breakfast meal plan is the same than the effect of any meal served (MS) as its estimated coeffient is not statistically significant. Source: Prepared by authors.

which has been estimated using *random effects*,[9] adjusted for robust standard errors clustered at establishment category. This procedure was developed following Wooldridge (2003), as it initially violated the homoscedasticity condition.

Table 5 shows the estimated coefficients for each explanatory variable in the model (2). All variables have the expected sign (the negative sign of some meal plans was expected, as discussed in the methodology) and all variables, except the shares of breakfast-only (*SBr*) and waste manager (*WMa*), are statistically significant. Table 6 provides the homogenized elasticities together with the marginal effect for each variable in order to draw further conclusions from our sample. It is important to note that all results are interpreted under the condition of ceteris paribus, everything else remaining constant. Finally, columns expressed in kilograms were estimated using a common standard in the region.

The results for *accommodation service* validate both H1 and H1'. The positive sign of both variables indicates that the higher the demand, the

The results for *food services* validate H3. Therefore, in view of the elasticity values, all meal plans have a differential and positive impact on mixed-waste generation. However, H3' is rejected, since the meal plan with the greatest impact is half-board and not all-inclusive. Indeed, a 1% rise in half-board meal plans increases mixed-waste generation at the establishment by 0.28%, which is a greater impact than exerted by an identical rise in the number of all-inclusive (0.20%), breakfast-only (0.14%) and full-board (0.08%) plans. Since adding meals to the food plans does not increase waste generation to the same degree, some insights have been provided to highlight the relationships among plans. Note, for example, that the difference between half-board and full-board is that the latter includes lunch in addition to the breakfast and dinner included in half-board. According to the practitioners consulted, half-board can be expected to have a greater impact on mixed-waste generation because food prepared for lunch can also be served for dinner. In other words, adding one guest with lunch (in addition to breakfast and dinner) to the weekly meal plans reduces the overall contribution to mixed-waste generation with respect to a half-board plan. This effect can also be explained by economies of scale in the meal preparation process. Note that both explanations can also be applied to the comparison between breakfast-only and full-board, where breakfast-only has a greater impact on mixed-waste generation.

Comparison of full-board and all-inclusive plans provides another interesting insight. While both plans include breakfast, lunch and

[9] All pre- and post-estimation tests can be seen in Appendix C. The Hausman test suggests the *random effects* model as the *p*-value is 0.911 and where the null hypothesis is that the preferred model is random effects. The estimator assumes that the individual-specific effect is a random variable uncorrelated with the explanatory variables.

dinner, all-inclusive also offers the possibility of consuming food and beverages at any time. Therefore, the greater impact of all-inclusive can be explained by the additional mixed waste generated by snacks and beverages between meals. Moreover, because some guests do not attend all meals, or due to the excess food supply commonly associated with all-inclusive (Okumus et al., 2020), an all-inclusive guest make a greater contribution to mixed-waste generation than a full-board one.

All-inclusive plans are subject to uncertain demand (Okumus et al., 2020) and entail constant food preparation and service (Ozdemir et al., 2012). However, tourist behavior is also a factor in the high level of mixed-waste generation, since all-inclusive promises abundance or the possibility of acquiring food at almost any time, which has a direct impact on tourist satisfaction (Ozdemir et al., 2012). Indeed, tourist habits greatly affect waste generation, especially because their behavior with respect to meals varies considerably from their everyday lives. As reported by Okumus et al. (2020), tourists are generally unaware of the magnitude and impact of food waste.

The marginal effects in Table 6 indicate the contribution of each meal plan to mixed-waste generation, with implications for our case study. Note that mixed-waste generation per guest increases non-linearly with the addition of a meal to the food plan, reducing the marginal contribution per meal, except in the case of all-inclusive, as shown in Fig. 5. The first meal (breakfast) shows the highest marginal effect on mixed-waste generation, of 180 g per guest; adding a meal to the food plan results in waste of 197 g per guest (99 g per meal) in half-board, 203 g (68 g per meal) in full-board and 404 g (126 g per meal) in all-inclusive. These results are consistent with the 120 g of food waste per meal in Scandinavian hotels reported by Marthinsen, Sundt, Kaysen, and Kirkevaag (2012).

Lastly, the results for *waste mitigation strategies* validate H4a and H4c, as their associated estimated coefficients have a negative sign and are statistically significant. Our results provide evidence of the significant impact of implementing managerial actions to reduce mixed-waste generation in the hospitality industry. Establishments that provide *employee training* to prevent and manage waste generate 34.5% less mixed waste, on average, than those that do not provide training, validating H4a. This underlines the importance of adequate training and information for hospitality staff, as suggested by Gandhi et al. (2019), Luu (2020) and Mabaso and Hewson (2018) for the specific case of food waste. In addition, establishments that have been audited and awarded an environmental certification (*EC*) generate 25.7% less mixed waste, which supports Geerts' (2014) findings that environmental certification encourages the implementation of sustainability practices, validating H4c. Finally, the presence of a waste manager (*WMa*) does not have a statistically significant impact on mixed-waste generation, rejecting H4b. Note that the low correlation between the presence of an waste

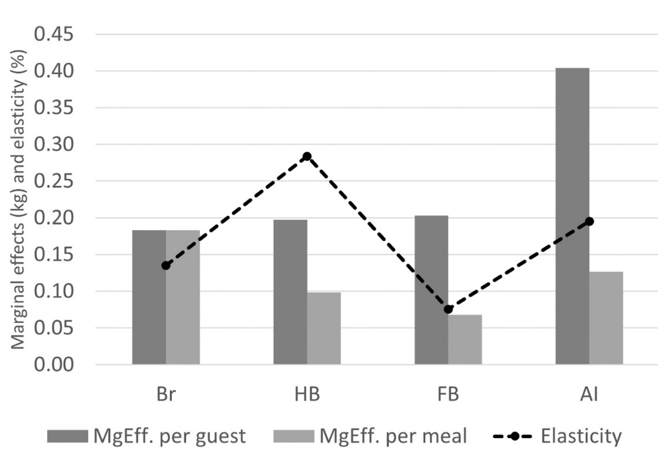

Fig. 5. Marginal effects in mixed-waste generation per guest and meal (kg) and elasticity (%) for each meal plan. Source: prepared by authors.

manager in the organization and environmental certification, on the one hand, and employee training, on the other, rejects the supposition that either certification or training may capture the impact of the presence of an waste manager on waste reduction.

5. Implications

Our model and empirical strategy make several contributions to the literature. First, we analyze the impact on waste mitigation of three waste management strategies, adding a group of variables that control for cyclical and structural information in our sample, thus avoiding (to a certain extent) biases in policy analysis. Second, we independently model the contribution of each type of meal plan, using a flexible functional form that captures some interesting relationships. This is a novel approach, since previous research has only captured the individual contribution of a single plan, such as breakfast-only (Juvan et al., 2018) or all-inclusive (Okumus et al., 2020), and not how different plans might interrelate. Finally, this is the first time that the waste generation contributions of hotels and apartment complexes have been estimated differentially. Therefore, our results provide further insights into the waste management problems of two accommodation models that coexist in many coastal destinations.

In terms of practical implications, our results provide strong evidence of the positive impact of waste mitigation strategies, particularly employee training and certifications. In addition to these managerial actions, the structure of meal plans offered by the establishments was found to be central to their overall contribution to mixed-waste generation. Indeed, our results indicate that adding lunch to a half-board plan may save resources and reduce waste, which can contribute to total revenue management strategy and enhance competitiveness. Moreover, according to the marginal effects, all-inclusive and breakfast-only have the greatest potential to reduce mixed-waste generation in our case study of Puerto de la Cruz.

In addition to improving hotel operations and management, we believe our results can be harnessed to guide waste mitigation through public-private partnerships and collective actions of destination management organizations or, more generally, by public waste services. These collective actions can significantly enhance a destination's image and sustainability, overcoming the limitations of the voluntary corporate approach, which is not suitable for all firms. Indeed, from a social perspective, it makes sense to concentrate financial resources on waste-intensive generators, such as the hospitality industry and, in particular, accommodation.

In this context, demand-side waste mitigation policies include both monetary and non-monetary instruments. Monetary policies, more in line with the *polluters pay principle*, include both unit pricing and subsidizing, but also price differentiation according to some of the agent's features or the time (e.g., peak periods). Our results suggest that economic incentives of unit pricing such as Pay-As-You-Throw (PAYT) tariffs, directly targeted at mixed-waste in hospitality, are likely to achieve better results than price differentiation penalizing larger hotels.

According to our empirical results, apartment complexes should be charged a higher waste tariff than hotels, as they have a higher impact on mixed-waste generation due to the nature of the accommodation service they provide (in-room kitchens) and from their structural services. Additionally, returns of scale on mixed-waste generation are lower for apartments than for hotels.

Subsidizing or facilitating widespread actions for employee training and/or audits and certifications may help achieve significant waste reductions at a lower cost. As an alternative to subsidies, price differentiation, if used, should be based on the effectiveness of observable waste management actions undertaken by hospitality firms. Note that environmental audits and certification procedures generate systematic costs for a firm, as well as requiring possible investments to upgrade infrastructure, which in the case of smaller hotels may be unaffordable (Font & Buckley, 2001). Policymakers could extend their waste strategies to more firms with initial support in the form of credit lines, soft credits or direct subsidies.

Some monetary measures give hospitality firms greater flexibility to decide how and where to mitigate waste as they face higher costs. However, there are some drawbacks for waste management services, as directly targeting waste requires costly monitoring and tax collection actions, such as digitalization of the waste network. Furthermore, measures to prevent illegal dumping and reduce improper waste in sorted streams are needed (Dahlén & Lagerkvist, 2010).

Regarding non-monetary measures, the following policy implications can be highlighted. First, providing information and specialized training for employees in the hospitality industry increases awareness of the wasteful nature of hospitality operations, facilitating change and rethinking operations, especially in food service logistics (Gandhi et al., 2019; Luu, 2020; Mabaso & Hewson, 2018). Providing training materials and guidance, including best practices for waste management, can also be an effective approach. Consequently, we provide an example of waste management for hotel establishments from the island government of Gran Canaria (FCR, 2018). In their manual, policymakers advise the hospitality sector how to best prevent and minimize all waste streams commonly generated within hotel establishments and provide options to mitigate waste that extend to all areas of the business, such as kitchens and restaurants, gardens, laundry, cleaning services, technical services, administration and reception.

Other non-monetary policies at the destination scale include nudging behavioral change. Developing sustainability indicators for tourism destinations can be useful in changing hospitality managers' attitudes towards the local environment and the repercussions of their decisions for waste generation. Furthermore, sustainability indicators at the local destination scale – focusing specifically on the environment – may act as social references and change social norms, promoting the engagement of all actors in the tourism industry, especially when indicators are segmented by activity, agent or even by zone or specific firm features (Crotts, Magnini, & Calvert, 2022).

6. Conclusions

In this paper, we provide strong evidence of the impact on mixed-waste generation of managerial actions such as employee training and environmental certifications at the establishment level. Our model controls for accommodation type, structural services and occupancy rates, as well as for a common structure of meal plans in a sand-and-beach destination. The results capture relevant interrelationships among food plans, probably caused by both food preparation scales and meal reuse, which may have important implications for waste management and revenue management strategies in hospitality firms.

Estimates of waste generation by the hospitality industry and analysis of its main determinants are needed to improve waste mitigation strategies in local destinations. Widespread actions such as specialized employee training and support for environmental audits can help to extend effective waste management practices to all agents in the industry. In addition, waste pricing reforms may be required to prevent the penalization of firms that are implementing costly measures to reduce mixed waste generation.

This research has some limitations. While our sample includes observations of total daily mixed waste for each establishment over nine weeks, we do not have an independent measurement of food waste or of additional sorted fractions for the same period. Therefore, our estimates of the impact on waste of the different meal plans reveal changes in the overall mixed waste generated by hotels and not just changes in food waste. On the other hand, investigating whether the reported waste management actions reduced waste generation or improved sorting strategies could indicate what type of training is most effective for these purposes. Future research should focus on the design of a randomized control trial to evaluate the impact of alternative training and social reference nudges on kitchen staff and guests.

CRediT authorship contribution statement

Eugenio Diaz-Farina: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft. **Juan J. Díaz-Hernández:** Methodology, Formal analysis, Writing – review & editing, Supervision. **Noemi Padrón-Fumero:** Conceptualization, Methodology, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.annale.2022.100083.

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