Waste production patterns in hotels and restaurants: An intra-sectoral segmentation approach

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ABSTRACT

Tourism produces >35 m tons of solid waste annually. For waste reduction efforts to be effective, empirical baseline measures of waste production and waste production patterns are needed. This study analyses the waste profiles of hotels and restaurants using national waste data. Results indicate that waste patterns in hotels and restaurants differ significantly from those of other industries and that – within the hotels and restaurants sector – substantial heterogeneity exists in terms of the types of waste generated. These insights highlight the need for targeted improvement approaches to waste management. Data presented in this study also serves as a baseline for benchmarking studies and helps inform the design of segment-specific practical measures to reduce waste generated in hotels and restaurants.

1. Introduction

Tourism produces >35 m tons of solid waste annually (United Nations Environmental Programme and United Nations World Tourism Organization, 2012), contributes to land exploitation and water use, generates greenhouse gas emissions, distracts wildlife and limits biodiversity (Gössling, 2002; Hall, 2010). Existing research on the environmental impacts of tourism and hospitality focuses primarily on the sector's contribution to climate change (Lenzen et al., 2018). Other key aspects relating to environmental sustainability include water use (Gössling, 2015) and food waste (Filimonau & deCouteau, 2019; Juvan, Grün, & Dolnicar, 2018). All these negative environmental impacts are expected to worsen in future because tourism represents one of the driving forces of economic growth (United Nations World Tourism Organization, 2020) and is largely expected to reach the pre-pandemic level by 2024 (United Nations World Tourism Organization, 2023). Finding ways to reduce the negative environmental impact of tourism and hospitality is critically important to ensuring that this sector can continue to contribute to the wellbeing of nations and communities around the world.

Environmental health is one of the four pillars of tourism sustainability (Crotts, Magnini, & Calvert, 2022). Waste production and responsible management is a key indicator of environmental health in tourism's sustainability. Tourism businesses are encouraged to reduce the amount of waste they generate and improve their waste disposal practices where waste cannot be avoided (Global Sustainable Tourism Council, 2012). Critically important to achieving progress in this area is the availability of industry benchmarks on waste volume and waste patterns, which allows the development of effective and efficient waste management measures. If distinct segment-specific waste patterns are found to exist, improvement measures would likely be even more promising when targeted at specific segments. Currently improvement measures *"neglect target group heterogeneity"* (Pedersen, Nielsen, & Daugbjerg, 2020, 608). Improved waste management also has the potential to affect the evaluation of regional sustainability and tourism carrying capacities that are essential to assess growth limits in tourism (Zekan, Weismayer, Gunter, Schuh, & Sedlacek, 2022).

Our study derives empirical waste generation profiles for hotels and restaurants using standardised national data. Understanding waste generation profiles – and the heterogeneity of waste profiles among hotels and restaurants – helps with the formulation of tangible aims for waste reduction action. We examine data from Slovenia because Slovenian businesses are required by law to report the amount and type of waste they generate. Specifically, this study makes the following contributions: (1) it provides baseline waste patterns for hotels and restaurants, along with waste levels; (2) it provides evidence that waste

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patterns of hotels and restaurants are systematically different from waste patterns in other industry sectors; and (3) it highlights systematic heterogeneity of waste patterns within the hotels and restaurants sector. As such, the study is empirical in nature; its purpose is not to contribute to the development of theory, rather its purpose is to assist tourism businesses, policy makers and tourism researchers by providing them with baseline data against which to measure improvement as well as insights as to how improvement measures could best be targeted.

2. Prior work

2.1. The environmental cost of waste

The world produces over two billion tonnes of solid waste annually, with an expected 70% increase by 2050 (World Bank, 2018). Half of municipal solid waste is disposed in landfill (World Bank, 2020), with only a fraction recycled or incinerated (Manfredi, Tonini, & Christensen, 2011). Municipal solid waste consists of food, paper and cardboard, plastic, glass, metal and wood (Saer, Lansing, Davitt, & Graves, 2013; Waste and Resources Action Programme, 2011). When disposed of in landfill, waste continues to burden the ecosystem (Manfredi et al., 2011) when decomposing and by polluting air. Between 30% (World Bank, 2018) and 40% (Thomson, 2014) of waste in landfill is burned in open piles, generating carbon dioxide (CO_2) emissions (World Bank, 2020). Landfilling solid waste within the EU decreased by 18% (on average) from 2008, however, no significant reductions are observed for textile, biowaste and plastic (CE Delft, 2022). In addition landfilling remains a common waste management practice; about 24% of solid waste goes to landfill (European Commission, 2022).

Food waste accounts for about 40% of municipal solid waste (Papargyropoulou, Lozano, Steinberger, Wright, & bin Ujang, Z., 2014; Waste and Resources Action Programme, 2011; World Bank, 2020). Food waste contributes substantially to greenhouse gas emissions, depletion of natural resources and air pollution (Papargyropoulou et al., 2014). In the USA, biodegradable kitchen waste accounts for over 25% of total freshwater consumption and 300 million barrels of oil use (Hall, Guo, & Chow, 2009). Food waste has long been recognised as a serious environmental issue of tourism and hospitality (Youngs, Nobis, & Town, 1983) because it is responsible for 10–42% of energy use in hospitality (Youngs et al., 1983), a substantial share of water consumption (Gössling & Peeters, 2015), 50% of the CO_2 emissions (Dilkes-Hoffman et al., 2018), and about 15% of the total environmental impact of the entire food value chain (Beretta & Hellweg, 2019).

Landfill disposal of glass burdens the environment because glass is not biodegradable, glass waste uses a lot of land, and negatively affects air and water (Jani & Hogland, 2014). Glass waste is particularly problematic in hospitality because the hospitality-generated glass waste often contains liquid leftovers draining into land and hospitality bottles have different colours, further complicating recycling and reuse (Jani & Hogland, 2014).

Stone, concrete, bricks, tiles and other construction materials represent some 20–30% of municipal solid waste (Esin & Cosgun, 2007; Yeheyis, Hewage, Alam, Eskicioglu, & Sadiq, 2013). The negative environmental impacts of construction materials in waste are driven by the extremely high energy- and water intensity in production of these materials. For example, the cement industry accounts for some 7% of the world's CO_2 emissions (Czigler, Reiter, Schulze, & Somer, 2017) and some 3% of the CO_2 emissions in the European Union (Emele, Graichen, & Mendelevitch, 2022).

Plastic waste harms the environment because it is not biodegradable, only about 9% is recycled and nearly 80% ends up in landfill (Geyer, Jambeck, & Lavender Law, 2017). Plastic waste also affects marine and coastal wildlife, and contaminates food and drinks aimed at human consumption (Antão Barboza, Vethaak, Lavorante, Lundebye, & Guilherminio, 2018). Paper and cardboard are the second highest type of municipal solid waste in general (World Bank, 2020), and in the tourism sector specifically (Ezeah, Fazakerley, & Byrne, 2015; Shamshiry et al., 2011; Waste and Resources Action Programme, 2011). Paper and cardboard are highly water-intensive to produce and generate a large amount of biogenic carbon emissions when wasted (Manfredi et al., 2011). The negative environmental impacts of paper and cardboard can be minimised by recycling (den Boer, den Boer, & Jager, 2007).

2.2. Waste in hotels and restaurants

About 1.6 kg of waste is produced per tourist per day (Obersteiner & Gruber, 2017). Richer countries report more waste per tourist and better waste management processes; poorer countries rely on landfilling waste primarily (Ezeah et al., 2015).

A study among 120 hotels in Hoi An (Vietnam) shows that hotels produce about 2.5 kg of solid waste per guest per day, of which 58.5% is biodegradable, 25.8% is recyclable and 15.7% is other waste (Pham Phu, Hoang, & Fujiwara, 2018). Factors affecting variations in waste volume and composition include hotel size, pricing range, restaurant type and presence of garden.

The waste generated by tourism and hospitality globally consists of 37%-72% organic waste, 6%-40% paper and cardboard, 5%-15% plastic, and 3%-14% glass (Pirani & Arafat, 2014). In the UK, 87% of the waste generated by the hospitality industry goes to landfill (Waste and Resources Action Programme, 2011). Within the paper category, only up to 50% is collected separately, with substantial variations between countries (Styles, Schönberger, & Galvez Martos, 2013). About one third of hospitality waste is food waste (Waste and Resources Action Programme, 2011). Of all food waste, about one third is plate waste (edible food left uneaten on guests' plates at the end of a meal), of which 92% can be avoided (Papargyropoulou et al., 2016; Styles et al., 2013).

Food waste is a particularly important social challenge (Aschemann-Witzel, De Hooge, Amani, Bech-Larsen, & Oostindjer, 2015) and remains underexplored, despite growing interest in this topic within the hotels and restaurants sector (Dhir, Talwar, Kaur, & Malibari, 2020). Existing research points to substantial variations in food waste volume across the accommodation sector (Beretta & Hellweg, 2019; Juvan, Grün, Zabukovec Baruca, & Dolnicar, 2021). Most research derives food waste information from a single case study, largely overlooking the sector-wide perspective. Initial evidence (Pirani & Arafat, 2014), however, points to substantial variations in food waste across hotels (25% of total solid waste) and restaurants (56% of total solid waste). Most available data on food waste is self-reported data from management at hotels or restaurants. Such data can be compromised by poor memory, low response rates and ambiguous responses (Radwan, Jones, & Minoli, 2012).

Several approaches have been recommended for tackling tourism-specific waste issues, especially food waste. Menu design, service type, tourist knowledge, infrastructure, guest personality and organisation have been shown to be important food waste drivers (Juvan et al., 2021). Also optimisation of kitchen operations has been suggested as an effective approach to reduce food waste (Filimonau & deCouteau, 2019). Studies on other types of waste are scarce, but acknowledge that recycling, reusing, reducing packaging could reduce paper, glass and wood waste (Bohdanowicz, 2006; Obersteiner, Gollnow, & Eriksson, 2021; Pham Phu et al., 2018; Zorpas, Voukkali, & Loizia, 2015). Department-specific techniques for responsible waste management practice are reported for Cyprus hotels (Zorpas et al., 2015), including selecting suppliers that collect packaging or minimise packaging of food supplies, e-communication rather than printing, renovating used furniture and equipment. Another clear message from existing studies is also that key stakeholders responsible for waste in the hotels and restaurants sector are employees and customers (Hsiao, Chuang, & Huang, 2018; Juvan et al., 2021) as well as suppliers (Filimonau & deCouteau, 2019; Martin-Rios, Demen-Meier, Gössling, & Cornuz, 2018; Radwan et al., 2012; Wang, Filimonau, & Le, 2021).

Despite the lack of data on the amount and composition of waste generated by hotels and restaurants, it is clear that these business types

contribute substantially to this global challenge and offer substantial improvement opportunities that could lead to significant reduction in CO_2 emissions (Obersteiner et al., 2021). Yet, to date, studies that systematically investigate waste patterns of hotels and restaurants at national level do not exist. They are needed to determine the baseline level, and to be able to assess improvement.

2.3. Heterogeneity

The concept of heterogeneity, which acknowledges the existence of diversity between units or people, has been used as a theoretical basis for work across all disciplines of the behavioural and social sciences (Lewin, 2013). Heterogeneity theory informs research across all business disciplines. In economics, the acknowledgement of the existence of differences across study units led to the use of models with heterogeneous agents, such as agent-based computational economics (Tesfatsion & Judd, 2006). In marketing, heterogeneity theory was introduced by Smith (1956) who argued that the "theory of perfect competition assumes homogeneity among the components of both the demand and supply sides of the market, but diversity or heterogeneity had come to be the rule rather than the exception" (p. 3), leading to the conclusion that accounting for heterogeneity leads to better outcomes for a business. Heterogeneity theory is the foundation of market segmentation (Dolnicar, Grün, & Leisch, 2018), a strategy that has been embraced by businesses and, increasingly also by not-for-profit organisations.

Heterogeneity has proven to be an effective theoretical underpinning across a wide range of research fields associated with environmental sustainability, including environmentally friendly behaviour in the home and vacation context (Dolnicar & Grün, 2009), household waste production in European countries (Nicolli, Mazzanti, & Iafolla, 2012), ecological restoration (Larkin, Bruland, & Zedler, 2016), environmental management practices across firms (Hardcopf, Shah, & Mukherjee, 2019) and resource allocation and performance of the hotel industry (Arbelo, Arbelo-Pérez, & Pérez-Gómez, 2020); always aimed at improving the understanding of behavioural patterns and developing effective managerial solutions. In the present study, heterogeneity theory informs the analysis of waste patterns. Accounting for systematic differences in waste patterns is of critical importance in developing the most effective segment-based measures to reduce waste generation in tourism and hospitality. Recognising heterogeneity is a paramount for developing successful interventions for changing undesirable behaviours (Bryan, Tipton, & Yeager, 2021), because otherwise one relies on the improper assumption *"that target groups in environmental policy are homogeneous and thus can be expected to respond to policy instruments in a similar manner"* (Pedersen et al., 2020, 608). This study follows these arguments and aims to identify existing waste patterns among hotels and restaurants to be able to guide segment-specific waste reduction strategies.

3. Method

Slovenian businesses submit their waste reports on the census date of 31st of March for the previous year if they produce at least 10 tons of waste or 5 kg of hazardous waste or have ten or more employees. These businesses report their waste at regional level, along with a standard classification number assigned to the business, which allows identifying the business as a hotel or a restaurant. Waste is categorised in 20 main waste types with a hierarchy of waste subtypes according to the European Waste Catalogue (EWC; European Commission, 2000). For example, the waste type *municipal waste* contains the subtype *separately collected fractions* with further subtypes *paper, cardboard, glass, textiles*, etc. Slovenian waste data is recorded at company-region level. Slovenia is divided into nine regions. Each company has at least one business unit in one region but can have multiple business units across multiple regions. Each unit is one separate entity in terms of waste reporting. The data set covers the reported waste by organisations for year 2018, (the

last pre-pandemic data) in Slovenia and contains 418 waste types on the lowest hierarchy level of the EWC for 11,954 company-region units; 427 of these units are hotels or restaurants.

We profile and compare the distribution of total waste generated by hotels and restaurants and businesses operating in other sectors. We determine waste patterns generated by hotels, restaurants and businesses operating in other sectors of the economy by aggregating the total waste produced and dividing each waste type by this total to obtain a relative proportion for each waste type. We retain for further analysis only waste types contributing at least 1% to total waste.

We identify distinct sub-groups of hotels and restaurants with respect to their waste production patterns through *K*-centroid cluster analysis (Leisch, 2006), which partitions the company-region units into *K* segments such that the sum of dissimilarities between company-region units and their segment centroid are minimal. The cosine similarity serves as dissimilarity measure for waste patterns because it mitigates the effect of different total waste sizes between company-region units (Hornik, Feinerer, Kober, & Buchta, 2012). To avoid the risk of the algorithm getting stuck in local optima, the best result obtained using ten different random initialisations for a specific number of segments *K* is used in the clustering procedure. We use stability of segmentation solutions across numerous repeated calculations to select a suitable number of segments *K*. The adjusted Rand index across 100 pairs of bootstrap samples is the measure of stability used (Dolnicar & Leisch, 2010). We report the resulting segment sizes, waste patterns and differences across segments with respect to total waste and hospitality category (Dolnicar et al., 2018). Total waste is characterised by median and the robust standard deviation (SD) determined based on the interquartile range divided by the interquartile range of a standard normally distributed variable.

4. Results

The average waste generated annually by a business unit on the company-region level across all sectors excluding hotels and restaurants in Slovenia is 535,976 kg; and 41,807 kg among hotels and restaurants. The median value (9,170 kg) reveals that the high average waste outside of hotels and restaurants is likely to be due to a small number of high polluters. The median value for hotels and restaurants is 13,315 kg. Hotels generate substantially more waste (118,141 kg on average per annum, median of 27,840 kg) than restaurants (27,804 kg on average per annum, median of 12,302 kg). This analysis does not account for business size. The following analysis thus focuses on investigating differences in waste type distributions across businesses disregarding the total absolute waste generated by a business.

4.1. Waste pattern of hotels and restaurants versus businesses in other sectors

Fig. 1 shows that the patterns of waste production vary substantially between hotels and restaurants and other sectors of the economy. Other sectors primarily dispose of soil, stones, dredging soil, and coal fly ash – accounting for one third of all waste produced by businesses outside of the tourism and hospitality sector. In stark contrast, most waste generated by hotel and restaurant operations – more than one third – is biodegradable kitchen and canteen waste. Hotels and restaurants also generate substantially more mixed municipal waste (17%) compared to other sectors of the economy.

Other notable differences include mixtures of concrete, bricks, tiles and ceramics (likely the result of necessary building maintenance and modernisations in hotels and restaurants), paper and cardboard, paper and cardboard packaging, and glass and glass packaging (likely a consequence of ongoing deliveries of supplies to hotels and restaurants), plastic (likely a consequence of supplies being wrapped for longevity, as well as the common use of single use plastics for bathroom amenities), and edible oil and fats as well as grease and oil mixtures from oil/water
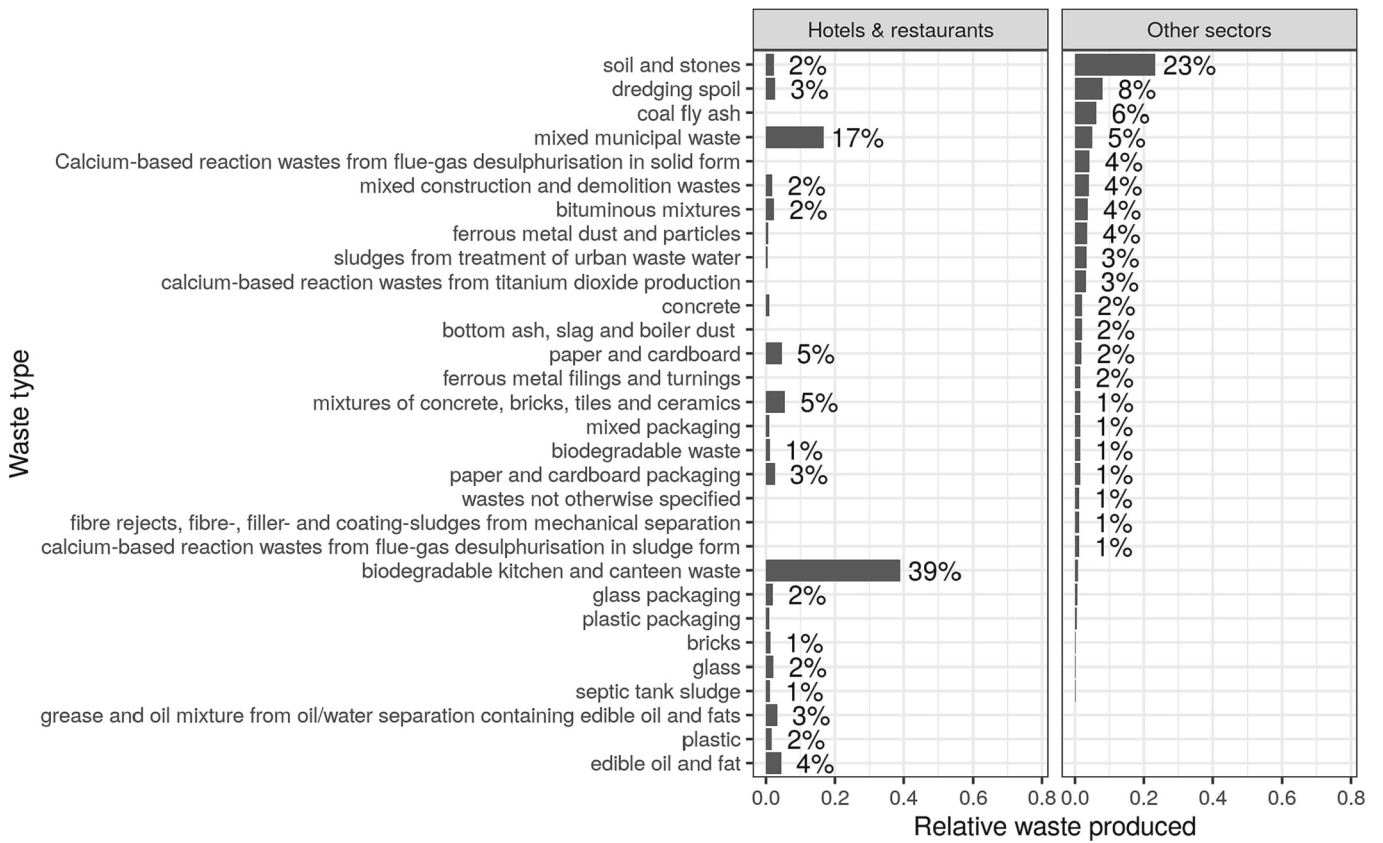
Fig. 1. Waste generation patterns for hotels and restaurants versus businesses in other sectors.
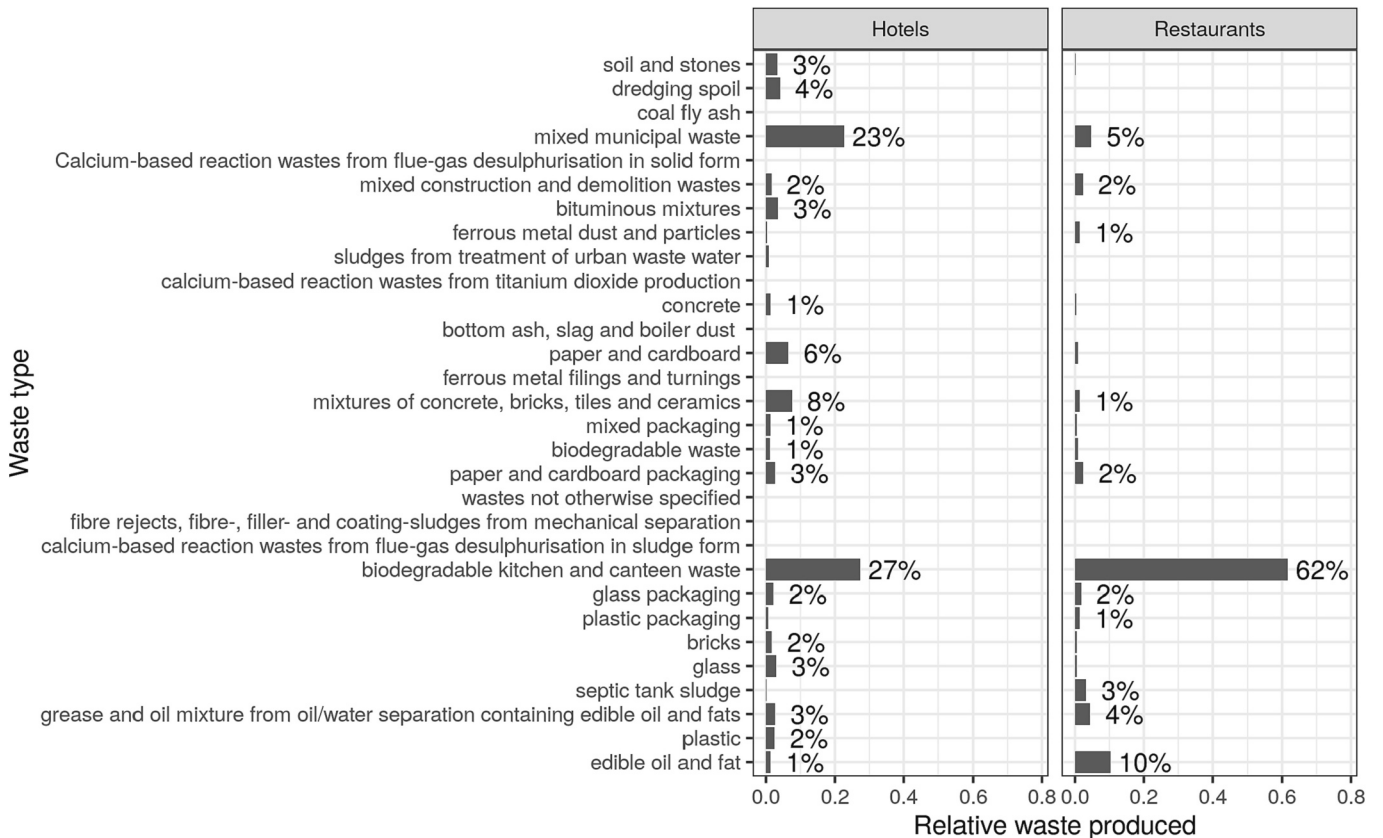

Fig. 2. Waste generation patterns for hotels versus restaurants.

separation containing edible oils and fats (related to food preparation).

4.2. Waste pattern of hotels versus restaurants

Inspecting waste patterns generated specifically by hotels and restaurants reveals additional distinct differences (see Fig. 2). Nearly two thirds of the waste generated by restaurants is biodegradable kitchen and canteen waste; this is more than twice the amount produced by hotels where food preparation is not the primary service sold. For the same reason, restaurants also have ten times as much edible oil and fat as hotels in their waste distribution pattern.

Hotels, on the other hand, produce more than four times as much mixed municipal waste, substantially more paper and cardboard and slightly more paper and cardboard packaging as restaurants. Repairs and regular renovations also lead to substantially more building materials disposal. Restaurants generate <1% plastic waste, hotels 2%.

4.3. Segment-specific waste profiles

This analysis focuses on businesses in the hotels and restaurants sector but otherwise ignores the nature of the businesses, and instead searches for similar waste profiles using segmentation analysis (Dolnicar et al., 2018). The stability assessment (Dolnicar & Leisch, 2010) of different grouping solutions across repeated calculations for different number of segments *K* recommends grouping tourism and hospitality businesses in four or five segments. We analyse the five segment solution in detail (see Fig. 3). The four-segment solution merges the fourth and fifth segment in the five-segment solution and, as such, sacrifices some relevant details.

The waste profiles depicted in Fig. 3 show that hotels and restaurants assigned to waste pattern segment 1 almost exclusively generate biodegradable kitchen and canteen waste, along with some edible oil and fat. Businesses in segment 2 produce the same two types of waste, but in different proportions, with some two thirds being oils and fats and about one third biodegradable kitchen and canteen waste. Businesses in segment 3 display an entirely different waste pattern: they generate some biodegradable kitchen and canteen waste, but predominantly dispose of mixed municipal waste. Segment 4 has the most balanced waste production pattern with no more than one third of waste within each one of the waste types. Finally, businesses in segment 5 are generating substantial fractions of building waste: mixtures of concrete, bricks, tiles and ceramics, metal dust and particles, and soil and stones.

In addition to those differences in patterns, the total waste generated

by businesses in these five segments also varies considerably, as shown in Table 1 (Kruskal-Wallis rank sum test: $X^2 = 61$, df = 4, *p*-value <0.001): the median total waste of businesses in segment 5 is nearly twice as much than the median absolute waste of businesses in the next most wasteful segment 3. Businesses in segment 2 are facing the smallest overall waste disposal challenge according to the median total waste.

Comparing the category distribution between hotels and restaurants across segments (which differs significantly: Pearson's Chi-squared test: $X^2 = 36$, df = 4, *p*-value <0.001) points to restaurants dominating segment 2 which produces the lowest overall amount of waste, but the highest fraction of oils and fats. Segments 1 and 4 also contain predominantly restaurants, segment 3 has an equal split, and segment 5 contains more hotels. These results indicate the importance of analysing waste patterns within sectors in more details: clearly different types of restaurants have distinctly different waste patterns.

5. Discussion and practical implications

Waste is a serious environmental issue. Waste implies the unnecessary use of resources required to produce the items being disposed of. When in landfill, waste further harms the environment by emitting methane and other greenhouse gases and by dissolving poisonous chemicals which can leak into ground water supplies. Reducing the amount of waste produced, therefore, represents a key strategy to improving the environmental sustainability of hotels and restaurants. This is critically important for the achievement of Sustainable Development Goals (United Nations Department for Economic and Social Affairs, 2015).

This study provides the following contributions to knowledge on waste of the hotels and restaurants sector. It 1) determines the amount of waste produced by hotels and restaurants, 2) provides evidence that waste patterns in hotels and restaurants are substantially different from waste patterns in other sectors, and 3) highlights the heterogeneity of waste patterns among hotels and restaurants. An average hotel or restaurant business has a distinctly different waste pattern than any other business: 12 percentage points more mixed municipal waste and 39 percentage points more biodegradable kitchen and canteen waste. Both waste categories have a low level of recycling potential and a high negative environmental impact when disposed of in the landfill. Hotels and restaurants also produce substantially more paper and cardboard and mixtures of concrete, bricks, tiles and ceramics than other sectors. These waste categories have a high recycling potential, thus burdening the environment less. Construction waste is due to regular renovations
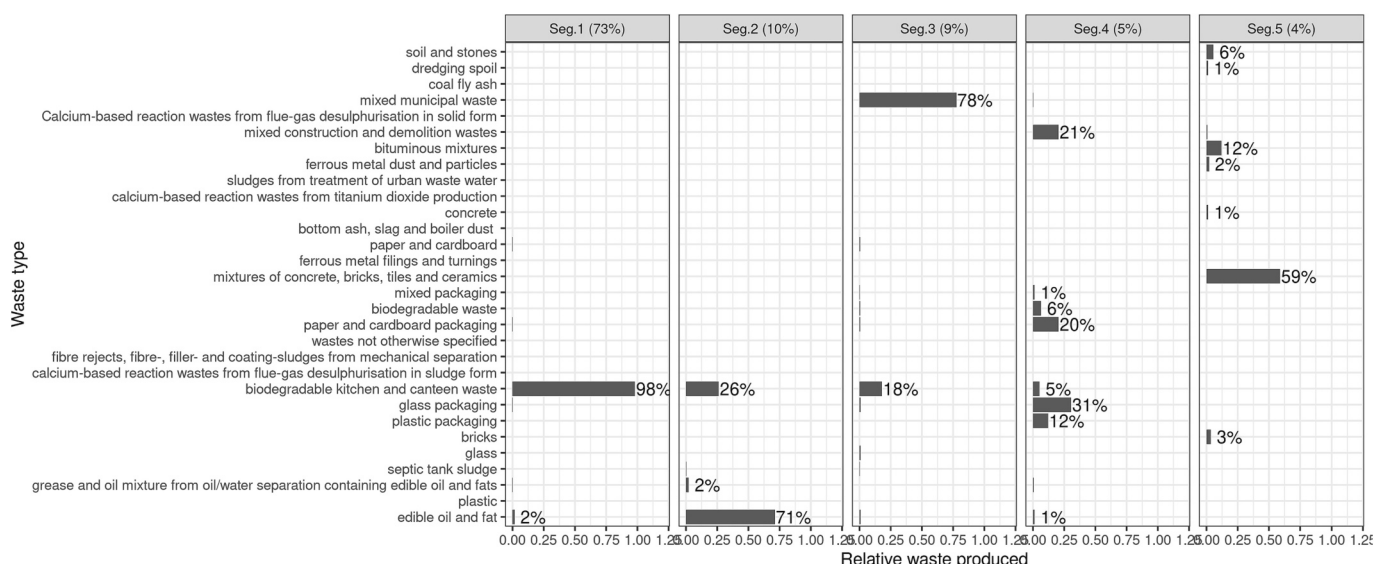

Fig. 3. Segment-specific waste profiles.

Table 1
Total segment-specific waste and category distribution of businesses across the segments.

		Seg. 1	Seg. 2	Seg. 3	Seg. 4	Seg. 5	*p*-value
Total waste	Median	12,931	4396	28,402	21,708	45,763	< 0.001
(in tonnes)	Robust SD	13,797	7181	69,552	11,957	118,697	
Category	Hotel	21%	7%	53%	15%	56%	< 0.001
	Restaurant	79%	93%	47%	85%	44%	

of the infrastructure in hotels. The study also provides evidence for waste generation in hotels and restaurants being highly context-dependent, pointing to the need for context-specific interventions aiming at a reduction in waste generation. Both, managerial and policy implications can be derived from this study.

5.1. Managerial implications

Comparing the waste profiles of hotels with those of restaurants reveals significant differences. Hotels produce substantially more mixed municipal waste, while restaurants and other food outlets produce substantially more biodegradable waste. Two thirds of waste in restaurants and food outlets is biodegradable, but only a third of the same waste characterises the waste profile of hotels. Hotels generate more mixed municipal waste, with nearly a quarter of their waste attributable to mixed municipal waste, while only 5% of the waste of restaurants is attributable to mixed municipal waste. Hotel waste profiles depend on hotel and restaurant operations, services and the behaviour of stakeholders involved. Guests bring food and other items purchased outside of the hotels to their rooms where they dispose of some of them, increasing total waste and mixed municipal waste. In hotels without waste separation infrastructure in rooms guests cannot separate waste. Consequently, all room waste goes into mixed municipal waste. Infrastructural interventions, such as waste separation bins in hotel rooms or hallways would enable waste separation and direct some of the waste towards recycling. Hotels also produce significantly more paper and cardboard waste than restaurants, probably because hotels order more supplies than restaurants. Supplies are delivered in bulk packs which results in higher cardboard and paper waste. Interventions, such as introducing multiple use packaging boxes would reduce single use packaging material and lead to less paper and cardboard waste.

Another key empirical insight from this study is the existence of distinct waste profile segments among hotels and restaurants, in line with the expectation that heterogeneity exists. Of the five segments created in this study, segments 1 and 2 – consisting predominantly of restaurants – generate primarily biodegradable kitchen and canteen waste, edible fat and oils. Yet, some restaurants produce substantially less biodegradable waste and oils than others. Hotels (dominating segment 5 in Fig. 3) produce less biodegradable waste, but substantially more construction waste such as concrete, bricks and ceramics.

The empirical insights gained in this study points to recommendations on how to reduce waste volume and – where this is not possible – reducing the environmental impact of waste via waste management. This study does not provide specific waste behaviour change interventions, but we provide recommendations on stakeholders and working processes within hotels and restaurants that can be targeted at specific waste pattern segments. Recommendations are based on existing studies on drivers of waste and potential measures for better waste management (for example Chavla, Lugosi, & Hawkins, 2020; den Boer et al., 2007; Ezeah et al., 2015; Filimonau & deCouteau, 2019; Jani & Hogland, 2014; Pham Phu et al., 2018; Styles et al., 2013). Table 2 includes key recommendations for targeted behaviour change within each of the identified waste segments for the different stakeholders whose behaviours directly contribute to hotels and restaurants waste.

Biodegradable kitchen and canteen waste is a very specific tourism and hospitality challenge. It is also the type of waste with the highest negative environmental impact because it represents direct waste of

Table 2
Waste pattern segment-specific waste management recommendations.

Waste type	Stakeholder	Working process specific managerial recommendation	
		Reducing waste volume	Reducing environmental impact of unavoidable food waste
Waste pattern segment 1 (mainly restaurants)			
Biodegradable kitchen and canteen waste	Supplier	Delivery scheduling Supply ordering	Incineration *Reuse* for animal feed Composting
	Employee	Menu design Food preparations Portioning Serving	
	Guest	Meal ordering Eating Take-away	
Waste pattern segment 2 (mainly restaurants)			
Edible oils and fat	Supplier	/	Reuse for secondary purposes
	Employee	Menu design	
	Guest	Ordering	
Waste pattern segment 3 (restaurants and hotels)			
Mixed municipal waste	Supplier	Returnable packaging	Incineration
	Employee	Separation Recycling	
	Guest	Production Separation	
Waste pattern segment 4 (mainly restaurants)			
Paper and Cardboard	Supplier	Returnable packaging Delivery scheduling Ordering	Reuse for secondary purposes
	Employee	Separation Recycling	
	Guest	Ordering	
Glass and plastic	Supplier	Returnable packaging Delivery scheduling	Reuse for secondary purposes
	Employee	Separation Recycling	
	Guest	Ordering Sorting	
Waste pattern segment 5 (mainly hotels)			
Construction (tiles, bricks, ceramics and concrete) waste	Supplier	Construction planning	Reuse for secondary purposes
	Employee	Renovations planning Recycling	
	Guest	/	

natural resources used in production. When disposed of in landfill, bio waste produces methane, which is between 28 and 36 times more harmful than CO_2 (Environmental Protection Agency, 2022). Reducing bio waste is best achieved by optimising deliveries. Working with suppliers on just in time deliveries to ensure prompt use of fresh supplies seems reasonable. Approaches targeted at employees leading to less food waste are menu design, food ordering optimisation, improved food processing and preparations as well as optimisation of food portioning. For example, menus containing dishes popular among most guests

reduce food waste (Waste and Resources Action Programme, 2013). Using small transparent food waste bins in kitchens (Chavla et al., 2020) – an infrastructure intervention – also represents a simple, cheap, yet promising approach. Employees reduce food waste because they want to avoid having to empty the bin multiple times. The transparent bin also reminds the employees of the value of food, which, in turn, leads to less biodegradable waste during food preparation.

About one third of food waste comes from customers' plate waste (Papargyropoulou et al., 2016). Interventions leading to responsible portioning and responsible food ordering can substantially contribute to the reduction of food waste. Raising awareness and knowledge about environmental consequences of meal choices in restaurants also offers an attractive approach to increase responsible guest behaviour (for example, ordering, self-serving, eating up); thus, reducing plate waste (Babakhani, Lee, & Dolnicar, 2020; Filimonau, Lemmer, Marshall, & Bejjani, 2017). Restaurants and hotels may also improve guests' behaviour either by better design of meal service areas (for example, reasonably loaded food buffets) and infrastructure changes (for example, smaller plates, tasting samples) or by rewarding less wasteful behaviour during meals (Dolnicar, 2020a, 2020b; Dolnicar, Juvan, & Grün, 2020). Other promising approaches for reducing plate waste are introducing take-away options for edible food leftovers or improving customers' knowledge and skills for eating-up hard to eat or unusual food items. Unfamiliar foods are frequently not eaten up (Dolnicar & Juvan, 2019). Experiences of food service staff indicate that hotels may also pre-plan their guests' days with extra activities to increase guests pleasure with activities and not only through food (Juvan et al., 2021).

When and where biodegradable waste cannot be reduced interventions are needed to prevent such waste going to landfill, where biodegradable waste further harms the environment. Biodegradable kitchen and canteen waste can be used for animal feeding or producing bio-energy through direct incineration or through biogas production. Using biodegradable waste for animal feeding, under strict high hygienic standards is not hazardous and it is the environmentally least damaging method of food waste management (Salemdeeb, Zu Ermgassen, Kim, Balmford, & Al-Tabbaa, 2017). Such food waste management also improves food production (mostly poultry and pig meat) and reduces the need for other foods (for example, soy) for animal feed (Troung, Morash, Liu, & King, 2019). Although considered hazardous in low hygiene standards using bio waste for animal feed is acceptable (Salemdeeb et al., 2017) and practiced (Trung & Kumar, 2005). While constructing a bioenergy plant to re-use biodegradable waste is possibly not within the possibilities of the hospitality industry alone, this may be feasible at destination level to support the hospitality and tourism sector in making bio waste handling more sustainable.

Mixed municipal waste is the second most problematic type of waste generated by the hospitality and tourism sector. Given that over half of mixed municipal waste is recyclable (Waste and Resources Action Programme, 2013), improving recycling is the most effective approach to reducing the volume of mixed municipal waste. Achieving this, however, requires interventions to be developed to change both tourist and staff behaviour. Increasing recycling among guests can be achieved by providing recycling infrastructure in hotel rooms and common areas. Where mixed municipal waste is unavoidable, incineration of mixed waste for electricity or heat production offers a promising alternative (den Boer et al., 2007).

Paper and cardboard can be re-used for print media such as newspapers and promotion leaflets or for furniture and display furniture (Paper Industry World, 2015). This is a great opportunity for hospitality businesses to source construction materials and furniture from their waste. Construction materials (for example, tiles, bricks) resulting from minor construction modifications and renovations can be returned into the construction material lifecycle or used as materials for reconstruction or renovation of the exterior (for example, bricks and tiles can be used for planting pots or constructing and maintaining walking paths; wood can be used for benches or shelves). While this may be too time

and money consuming for individual hospitality businesses, it may work well at the community level.

Segment-specific interventions have the potential to reduce the amount of waste generated by tourism and hospitality businesses. For example, introducing waste separation infrastructure would likely reduce mixed municipal waste for hotels and restaurants (segment 3). Interventions aimed at reducing biodegradable waste and edible oils are needed for restaurants (segments 1 and 2). Such interventions must focus on food preparation and food serving – they represent the food waste production hotspots (Beretta & Hellweg, 2019; Filimonau & deCouteau, 2019). Segment 5 – containing mostly hotels – produces construction waste, most likely as a result of renovations. Interventions for this segment must focus on the implementation of alternative materials or reconstruction methods (Poon, 2007). Alternatively, interventions are needed for returning construction waste materials into production of new materials and to prevent environmental harm by sending such construction materials to the landfill.

At managerial level, this study supports the need to improve monitoring of waste production and management, by monitoring at least minimum characteristics of waste producers, for example, service type, volume of seats or rooms, basic amenities and services, menus offered. Such information would substantially improve the ability of the industry to identify key drivers of waste per specific waste pattern segment and, in so doing, support development of segment specific measures that will effectively and efficiently reduce waste in the hotels and restaurants sector. This study also informs hotels and restaurants managers of the typical waste type patterns generated by their organisation. Understanding to which waste pattern segments an organisation belongs helps to implement tailored solutions aimed to reduce those precise types of waste.

5.2. Policy implications

The present study suggests that waste pattern heterogeneity could be the cause for low progress in reduction of tourism waste. We identify two distinct waste segments of restaurants, one (segment 1) with substantially more biodegradable kitchen and canteen waste and the other (segment 2) with mainly edible oils and fat waste. The existence of these two different waste type segments calls for differentiated policy interventions, suggesting that universal approaches to waste prevention may not be effective for all restaurants. In addition, the two distinct waste segments need policies focused on employees and guests; policies for supply chains appear unnecessary. However, there is a segment of restaurants (segment 4) where supply chain policies are needed to help restaurants reduce paper and cardboard waste as well as glass and plastic waste. Finally, waste segment 5 involves hotels only and reducing waste for this segment requires policy interventions directed to suppliers and employees; guests, have very little or no power to help reducing construction waste.

Existing policy approaches for reducing tourism waste (including hotels and restaurants) assume homogeneity in waste patters. As a result, they propose general and unified waste management or waste prevention strategies, focusing on the tourism sector in general (for example accommodation, food provision) rather than on a specific waste pattern segment within the tourism sector; such as hotels and restaurants. Policy makers must develop waste segment specific interventions and push industry to follow a sustainable path by introducing their waste profile specific interventions. Optimally, governments would also support the development of monitoring systems, which would allow hotels and restaurants to identify their waste types and implement solutions recommended for their waste profile.

6. Conclusions

Tourism contributes about 10% to the global gross domestic product (GDP) but also 8% to climate change (Lenzen et al., 2018). This study

offers a waste generation baseline; a benchmark to compare the tourism and hospitality sector's waste performance with other sectors and to compare businesses within tourism and hospitality to one another. Such comparisons are critically important to highlight to managers the potential for improving environmental performance and, as a likely side-effect, reduce operating cost and overall financial performance (Tan, Habibullah, Tan, & Choon, 2017). This study also offers key insights into heterogeneity in waste profiles, which can be leveraged to develop waste reduction measures targeted at specific tourism and hospitality waste segments.

Given that context plays an important role in waste generation and success of intervention approaches, future research needs to provide empirical evidence about the waste volume per specific stakeholder and the drivers behind the waste production. This knowledge will help understanding the homogeneity of each waste type, volume and drivers within each segment; thus further improving the success of segment-specific waste management practices.

A major limitation of this study is that data on waste producers' characteristics (for example, infrastructure, size, amenities) is not available. Such information would allow to provide detailed business profiles of each waste pattern segment and thus improve the reachability of the segments. Future studies should look at drivers of specific waste segments identified in the study. Such data would support the development of empirically supported practical recommendations on waste management at the level of specific waste segments.

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.

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