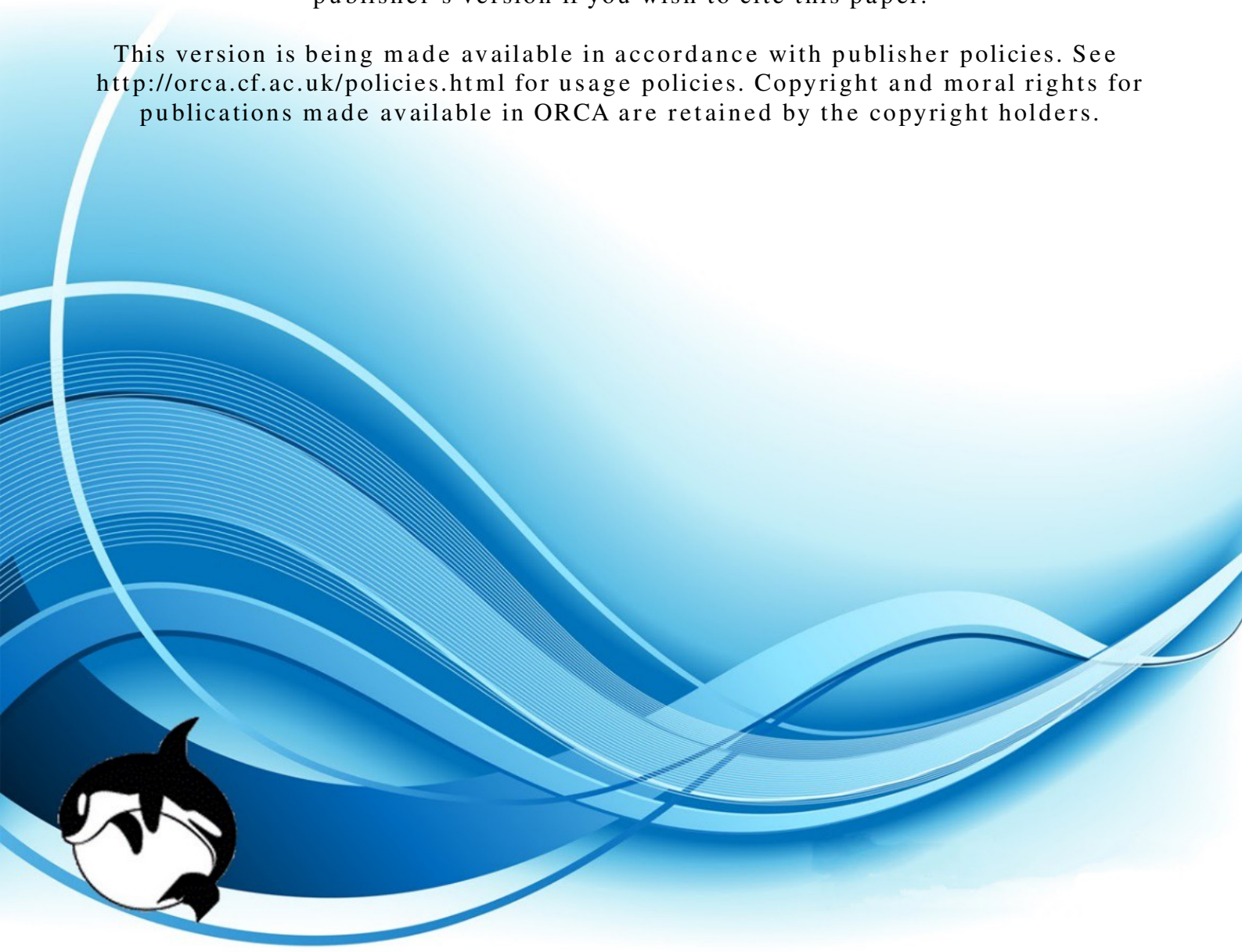

Food waste management in the catering industry: enablers and interrelationships

Abstract

Food waste has a wide range of negative implications on the environment, economy and society and it is a concern for the catering industry and a growing percentage of the population. This work investigates the main root causes of food waste, in the catering industry, based on data collected from 32 businesses located in Wales, UK. The research uses multi-criteria decision making methods (Analytic Hierarchy Process and Decision Making Trial and Evaluation Laboratory), to analyse the degrees of importance and interrelationships of food waste enablers using holistic cause and effect diagrams and priority ranking. The analysis identifies critical food waste enablers in different dimensions (procurement and storage, processing, operation strategy, people and consumer) for various business outlets. Those causes can be addressed with limited resources and create the maximum value for the business and environment. The methodology could be used as a strategic tool by businesses in daily operations by managing and controlling identified root causes.

1. Introduction

The restaurants and related services in the UK accounted for over half of the hospitality industry's employment with over 1.4 million jobs in 2014 (Oxford Economics, 2015). These services generated to the UK economy over £24bn of Gross Value Added (GVA) and contributed over 40% of the hospitality industry GVA with a turnover of £57bn (ibid., page 17). The industry has experienced significant growth over the last ten years, and food waste is one of key priorities that requires urgent attention. FAO and International Food Waste Coalition (2018) reported that the total amount of wasted food is approximately 1.3 billion tons and it is expected to increase to 3.4 billion tons annually due to the increase in population as reported by the World Bank in 2018. According to WRAP (2017), 75% of all food waste could have been avoided, where on average 66% of waste is attributed to food spoilage and preparation, and 34% is linked to customer leftovers. The cost of UK food waste in the hospitality sector in 2011 was estimated at £2.5 billion and restaurants, pubs and hotels account for 54% of this financial cost (WRAP, 2017). This study focuses on food waste in the catering industry that includes restaurants, bars, takeaway service, cafe and other business models and it involves any waste generated in facilities in pre-consumer and post-consumer phases (Baldwin, 2012). Although some catering businesses introduced clear policies to prevent food waste (Bharucha, 2018), several researchers suggested that those challenges have not been resolved and need more focused attention (Pirani & Arafat, 2016; Sakaguchi et al., 2018). Furthermore, during the COVID-19 pandemic the industry had to deal with unprecedented challenges (Gursoy and Chi, 2020) and food waste appeared

high in the agenda (Smithers, 2020). Due to last minute announcement of lockdowns in different parts of UK, businesses struggled to plan their stock levels to accommodate ever-changing rules that contributed further to food waste issues. This is in addition to a decline in dining, the introduction of strict hygiene and curfew times (e.g. 10 pm is some areas).

Food waste refers to the food that does not include animal feed, inedible parts of products; and originally produced for human consumption and is wasted somewhere in the food supply chain (FAO, 2013; Gustavsson et al., 2011). Figure 1 illustrates the different stages of a supply chain where food waste could happen. For perishable products, the cooling equipment is very important (Bilska et al., 2016) and strict regulations on food quality and safety force suppliers to dispose of food that is not suitable for consumption (Mena et al., 2014). At distributors, wholesalers and/or retailers, food waste results from operational enablers that include inappropriate packaging, mishandling, transportation and poor ordering policies (Mena et al., 2011; Lukic et al., 2014; Cicatiello et al., 2016) and the expiration date is another common reason (Lewis et al., 2017). At the household stage, consumer-human enablers are the most critical due to a lack of understanding of food waste issues (Buzby et al., 2011; Gustavsson et al., 2011), over-stocking or confusion over "use by" and "best before" dates (Parfitt et al., 2010; Gustavsson et al., 2011). In catering, food waste occurs when food is prepared in the kitchen and consumed by customers (Baldwin, 2012). In the commercial kitchen, the core contributor could be preparation residue from unskilled trimming process or over production of food that exceeds the customer demand (Baldwin, 2012; Papargyropoulou et al., 2016). The food waste from customers mainly occurs as a result of leftovers due to several reasons, such as bad flavour, avoiding certain food categories and/or large portion sizes (BCFN, 2012; Santos, 2017).

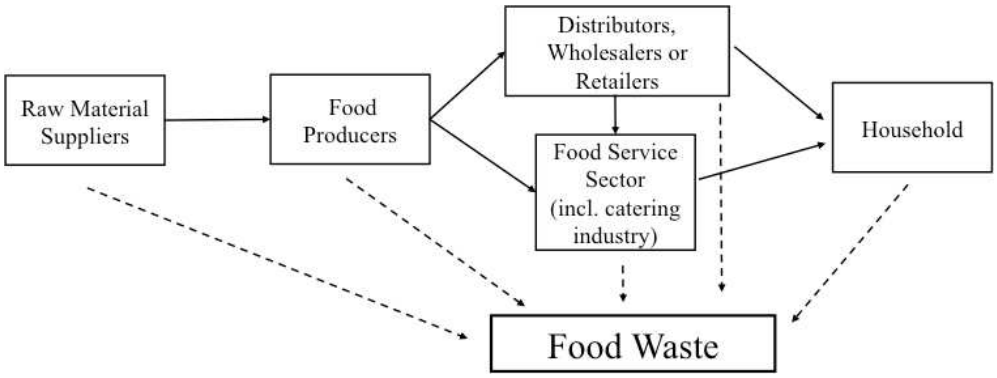

Figure 1. Food waste and different stages of the food supply chain (adapted from Gustavsson et al., 2011; Mena et al., 2011; BCFN, 2012; Priefer et al., 2016).

Sustainable food waste management leads to a reduction of greenhouse gas emissions, which in turn gives possible economic gains. Sustainability is a topic that is high on the agenda in all disciplines including industrial marketing (Oruezabala & Rico, 2012). Wind (2006) reflected on the evolution of the industrial marketing field over 40 years and emphasized the rise of small businesses, importance of breaking functional silos and that developments on the Internet led to the convergence of B2B and B2C markets. The research presented in this paper links all parts of the value chain where there is an on-going interaction between functions and different stakeholders. Through the integration of marketing with sustainable supply chain functions, and the use of effective communication, customers and other stakeholders (e.g. businesses) will become informed of the sustainable practices initiated by companies (Chan et al., 2012; Oruezabala & Rico, 2012). The strategic tool presented in this paper would help businesses to assess the food waste enablers that should be targeted as a priority to support the on-going development of their positive corporate image and sustainable agenda including their marketing strategy presented to other businesses. This research would lead to the development of food waste reduction approaches with advantages to marketing strategies in B2B and B2C environments.

The causes of food waste have many reasons, thus identifying and reducing the main causes requires substantial attention (Papargyropoulou et al. 2016). Researchers and practitioners are increasingly interested in mitigating avoidable food waste where possible. However, progress in this area has been slow to target the root causes of food waste and uncertain identification of root causes could lead to confusion regarding the order in which they should be targeted resulting in low efficiency. To design effective food waste prevention and reduction strategies it is critical to understand food waste causes and their interrelationships where the majority of published studies focus on a single type of the business model (e.g. Falasconi et al. 2015; Betz et al, 2015; Duursma et al., 2016, Bharucha et al., 2018; Filimonau et al. 2019a; Coşkun & Özbük, 2020). Filimonau & de Coteau (2019) and Filimonau et al. (2020a) emphasize that there is a lack of research that uses quantitative assessments of food waste enablers in the industry where published case studies, for example, of specific restaurants are not necessarily sector representative. They confirmed our findings that only very few papers used quantitative techniques to analyse the importance of food waste enablers. More recently, Parashar et al. (2020) used structural modelling and matrix of cross-impact multiplications to formulate food waste enablers across an entire supply chain towards the diminishment of carbon footprint level. Raut et al. (2018) performed an analysis study using AHP method on food waste causal factors at the post-harvest stage of fruits and vegetables supply chain.

Decision makers need to identify the main root causes of food waste to direct their efforts in mitigating and avoiding them rather than factors that include both causes and effects. Although some research conducted on

causes of food waste (Mena et al., 2014; Parizeau et al., 2015; Bonadonna et al., 2019; and Aschemann-Witzel et al., 2020), their findings do not categorize them as root causes and effects to support better decision making (Filimonau, V. and Delysia, 2019; de Moraes et al., 2020), especially, in the catering sector. Furthermore, to the best of our knowledge, no research undertook cross-comparison analysis among business types and applied the multi-criteria decision making (MCDM) methods (i.e. Analytic Hierarchy Process (AHP) and Decision Making Trial and Evaluation Laboratory (DEMATEL) to explore the significance and interaction effect of these causes in the food waste context that this research considers. We also believe that this may be the first study to present a comprehensive literature review on food waste management in the catering industry and it develops holistic cause-effect diagrams using MCDM. Within these boundaries, this research seeks to contribute to the fields of food waste management and sustainable supply chain management via the multi-criteria decision making and it has links to other disciplines such as industrial marketing. The study would help decision makers to address the following research questions:

RQ1: What are the factors (enablers) of food waste in the catering industry?

RQ2: What are the root causes and effects of food waste out of those factors (enablers)?

RO3: Where should managers direct their efforts as a priority to mitigate and avoid them?

A hybrid AHP-DEMATEL method is proposed to identify the most important food waste enablers and the relationship among those enablers. The application of MCDM methods will help managers to (i) quantify the relative importance of food waste enablers (i.e. by using the AHP method); (ii) to clarify the interrelationships and correlation among these enablers and to categorize them as causes and effects (i.e., by using the DEMATEL method); (iii) to guide managers in prioritizing their efforts to address the causes rather than effects; and (iv) to target causes based on their revealed importance via AHP. This research develops a holistic cause-effect diagram and priority rank table of enablers in the general catering sector and specific food businesses (i.e. coffee shops, takeaways, restaurants and pubs). These points would not be achieved, in detail, without the application of MCDM methods considering (i) the amount of experts' opinion collected that might conflict where aggregation required, and (ii) a large number of food waste enablers to be evaluated. The advantage of MCDM is in an aggregation of decision-makers opinions when considering the multiple evaluation criteria (Shih, 2008). This cause-effect and relative importance analysis would allow decision makers to identify potential interventions among enablers and to help them to address these root food waste causes via tailored mitigation strategies that would boost sustainable food management in the future.

This paper continues as follows. In section 2, food waste literature is presented to summarise the major enablers of food waste in a unified framework. Section 3 presents the methodology, including AHP, DEMATEL and the questionnaire design. Section 4 presents the findings and Section 5 includes the discussion. Section 6 concludes with theoretical and managerial implications and future research directions.

2. Literature Review

2.1 Causes of food waste and waste minimisation strategies

This section discusses the causes of food waste (Table 1) and waste minimisation strategies (Table 2) that can be applied by businesses in the catering industry at different levels: procurement and storage, processing, operation strategy, people and consumer. We included the review of food waste reduction strategies because both topics (causes and strategies) are interlinked and this discussion informs the reader (especially business managers) of possible strategies and alternatives that could be available to them as a result of identifying the most significant food waste causes, and how possibly to target root causes that were identified as a priority in different levels. To identify these levels and factors, a review of the literature concerned with food waste was conducted using business information databases (Scopus, Google Scholar) and keywords such as "food waste", "food waste causes", "food waste strategies", "food waste multi-criteria decision making". Then a categorisation based on the literature review was undertaken where a spreadsheet was developed to classify all factors. A coding system was designed and agreed to facilitate identification of the common features using an iterative approach to highlight those factors that were coded into themes (e.g. levels) according to their features. As a result of the categorisation, the following levels were identified: procurement and storage, processing, operation strategy, people and consumer.

The procurement and storage level concerned with uncertainty related to customer demand and other enablers that are not under management control. Procurement and the storage of the raw materials is the most basic function of the business to maintain their supply to meet the demand. The waste occurs at this level as a result of that uncertainty and is well documented in the literature, which could lead to purchasing an excessive inventory of raw ingredients (Derqui et al., 2016). Demand management is critical here when balancing the needs of several stakeholder and customer groups (Brindley & Oxborrow, 2014). With regards to strategies, one option would be to make a prediction plan based on the historical data taking into account weather, season, holiday and other external enablers (Betz et al., 2015; Priefer et al., 2016). The forecasting of consumer demand as a prime strategy is discussed by Filimonau et al. (2020b) in their UK and Netherlands study, where restaurateurs in both countries

use this approach but forecasting does not always work and in-house training on forecasting and procurement for managers and chefs is highlighted (Filimonau & de Coteau, 2019).

The food processing level has a number of activities that transform the raw materials into food that is served to customers. At this level, the strict quality and safety regulations are the main drivers for the disposal of unqualified food (Charlebois & Hielm, 2014). Noticeably, preparation residue includes the waste that is generated from over-production, peeling, cutting, expiration, and trimming which could be regarded as a common reason for food waste in the commercial kitchen (Papargyropoulou et al., 2016). Businesses must reduce the preparation losses during processing, different strategies can avoid over trimming (Sakaguchi et al., 2018) through improvement in food preparation techniques (Papargyropoulou et al., 2016) and employee training (Betz et al., 2015). McAdams et al (2019) discuss that quality assurance standards are the most consistent key contributor towards food waste across the participating restaurants in their study.

Table 1. Food waste causes in the food service sector.

Levels	Causes	References
A. Procurement and Storage	Difficulty in forecasting (A_1)	BCFN (2012), Brindley & Oxborrow (2014), Charlebois et al. (2015), Derqui et al. (2016), Filimonau et al. (2020b), Gao et al. (2021), Priefer et al. (2016), Santos (2017)
	Lack of purchase plan (A_2)	Baldwin (2012), Santos (2017)
	Forgotten and spoiled food (A_3)	BCFN (2012), Charlebois et al. (2015), Derqui et al. (2016), Gao et al. (2021)
	Over-stocking (A_4)	Baldwin (2012), Charlebois et al. (2015), Derqui et al. (2016),
B. Processing	Strict regulation on safety and quality (B_1)	Baldwin (2012), Gao et al. (2021), Gustavsson et al. (2011), Papargyropoulou et al. (2016), McAdams et al (2019), Priefer et al. (2016), Santos (2017)
	Preparation residue (B_2)	Baldwin (2012), BCFN (2012), Derqui et al. (2016), Filimonau & de Coteau (2019), Papargyropoulou et al. (2016), Santos (2017)
	Unaware of cooking amount (B_3)	BCFN (2012), Halloran et al. (2014)
	Lack of equipment and tools (B_4)	Rodgers (2005)
C. Operation strategy	Inappropriate portion size (C_1)	BCFN (2012), Baldwin (2012), Betz et al. (2015), Charlebois et al. (2015), Derqui et al. (2016), Falasconi et al. (2015), Priefer et al. (2016), Lipinski et al. (2013), McAdams et al (2019), Santos (2017)
	Buffet style leading to over-taking (C_2)	Baldwin (2012), Gustavsson et al. (2011), Priefer et al. (2016)
	Large menus (C_3)	Charlebois et al. (2015)
	Poor waste management (C_4)	Derqui et al. (2016)
	Poor layout of facility (C_5)	Panisello & Quantick (2001)
D. People	Staff mishandling (D_1)	Baldwin (2012), Charlebois et al. (2015)
	Miscommunication between management and staff (D_2)	Baldwin (2012), Charlebois et al. (2015), Papargyropoulou et al. (2016)
	Unskilled staff (D_3)	Baldwin (2012), Charlebois et al. (2015); Filimonau et al. (2019a)
	Attitude towards food waste (D_4)	Gustavsson et al. (2011), WIE (2014)
E. Consumer	Customer attitude, values and behaviours towards food (E_1)	Coşkun & Özbük (2020), Filimonau et al. (2019a), Gustavsson et al. (2011), Lipinski et al. (2013), Lorenz et al. (2017), Santos (2017), WIE (2014)
	Random customer purchase (E_2)	Baldwin (2012), Charlebois et al. (2015); Filimonau et al. (2019a)
	Different dietary preference of customers (E_3)	Baldwin (2012), Betz et al. (2015)
	Considering food unattractive (E_4)	Betz et al. (2015), Falasconi et al. (2015)
	Over-ordering (E_5)	Santos (2017); Gao et al. (2021)

The food waste produced at the operation strategy level is concerned with specific plans deployed by different food outlets related to their menu offerings, waste management and layout. Inappropriate portion size is discussed

by several academics as the most critical driver in the operation strategy level (Betz et al., 2015). Many studies proposed different methods for a better adaptation of portion size to customer needs, which includes offering different portions sizes (Sakaguchi et al., 2018), smaller portions (Coşkun & Özbük, 2020) and allowing customers to choose the size of serving (Bharucha, 2018), and buffet composition where a customer can decide on how much to take and what to eat (Priefer et al., 2016; Filimonau & de Coteau, 2019). Harvey et al (2019) also discuss that reduction in food waste can be achieved through the use of popular food sharing mobile applications that reconfigure traditional supply chain roles of consumers.

Table 2. Possible strategies for food waste reduction in the food service sector.

Levels	Possible strategies	References
A. Procurement and Storage	Measuring the occurring food waste	Clowes et al. (2018), Derqui et al. (2016), Duursma et al. (2016), Sakaguchi et al. (2018)
	Analysis of historical data, forecasting	Betz et al. (2015); Brindley & Oxborrow (2014), Derqui et al. (2016), Duursma et al. (2016), Filimonau & de Coteau (2019), Priefer et al. (2016)
	Optimisation of storage management	Betz et al. (2015), Pirani & Arafat (2016), Sakaguchi et al. (2018)
	Using the food near expiration date first	Betz et al. (2015), Bharucha (2018), Derqui et al. (2016), Filimonau et al. (2019a), Gao et al. (2021)
	Enhancement of order interval and reduction in stock pilling	Betz et al. (2015)
B. Processing	Preparation losses control (e.g. avoid over trimming)	Betz et al. (2015), Sakaguchi et al. (2018), Papargyropoulou et al. (2016)
	Development of strategies against overproduction	Betz et al. (2015), Clowes et al. (2018), Filimonau & de Coteau (2019)
	Reusing the leftovers (under permission of law)	Betz et al. (2015), Clowes et al. (2018), Filimonau & de Coteau (2019)
	Fast cooling down of food to avoid microorganism growth	Betz et al. (2015)
C. Operation strategy	Adaption of portion size to customer needs	Betz et al. (2015), Clowes et al. (2018), Coşkun & Özbük (2020), Derqui et al. (2016), Duursma et al. (2016), Papargyropoulou et al. (2016), Priefer et al. (2016), Sakaguchi et al. (2018)
	Rethinking the buffet (e.g. using small serving bowls at buffet)	Betz et al. (2015), Bharucha (2018), Clowes et al. (2018), Derqui et al. (2016), Papargyropoulou et al. (2016)
	Possible donation of food to local charities	Betz et al. (2015), Bharucha (2018), Harvey et al (2019), Sakaguchi et al. (2018)
	Redesign of supply chain to use existing food as possible	Sakaguchi et al. (2018)
	Waste management and effective waste disposal practice	Bharucha (2018)
	Removing dishes that generate too much waste from the menu	Derqui et al. (2016)
	Replacing the buffet by “pay by weight” system	Priefer et al. (2016)
	Make food more attractive	Betz et al. (2015), Gao et al. (2021)
D. People	Staff training	Betz et al. (2015), Bharucha (2018), Clowes et al. (2018), Derqui et al. (2016), Filimonau & de Coteau (2019), Gao et al. (2021), Priefer et al. (2016), Sakaguchi et al. (2018)
	Better communication between staff and management to increase awareness about food waste	Betz et al. (2015), Clowes et al. (2018), Duursma et al. (2016), Pirani & Arafat (2016), Priefer et al. (2016), Sakaguchi et al. (2018)
	Enhancing coordination between the departments	Papargyropoulou et al. (2016)
E. Consumer	Communicating with customers to enhance awareness of food waste issues	Betz et al. (2015), Coşkun & Özbük (2020), Derqui et al. (2016), Duursma et al. (2016), Ellison et al. (2019), Filimonau et al. (2020a), Gao et al. (2021), Harvey et al (2019), Lipinski et al. (2013), Pirani & Arafat (2016), Sakaguchi et al. (2018)
	Collecting feedback to survey plate waste reasons	Betz et al. (2015)
	Rewarding sustainable behaviour	Duursma et al. (2016)

The people level concentrated on staff training and their attitude towards work and food waste with higher levels of management control. Poor communication between the management and staff can trigger staff mishandling, placing of wrong orders, spoiled and spilt food (Charlebois et al., 2015). To tackle this, for example, staff training as an effective way to control food waste has been discussed by several researchers. Through the training, staff can improve their skills (e.g. purchasing, storing and freezing) which is critical to food waste reduction (Priefer et al., 2016). Better communication is also a helpful way to engage staff in food waste prevention (Clowes et al., 2018) and increase staff awareness of waste (Sakaguchi et al., 2018).

At the consumer level, the food waste generated as a result of consumer behaviour and their attitudes (Filimonau et al. 2019b), needs, dietary requirements, and food appearance. The consumer here can be an individual (B2C) or business (B2B) and when dealing with, for example, public sector organisations (as a consumer), the business would also need to comply with their sustainable regulations (Oruezabala & Rico, 2012). The random customer purchase pattern and different customer dietary preferences and attitudes increase the challenge in forecasting the food quantity to produce (Baldwin, 2012). Some prevention strategies include raising awareness about food waste among customers where posters can be used to highlight ordering what you need (Priefer et al., 2016). Businesses can launch an awareness campaign to make customers realize the severity of food waste (Lipinski et al., 2013; Filimonau & de Coteau, 2019; Coşkun & Özbük, 2020).

2.2 Multi-criteria decision making (MCDM) in food waste management

Multi-criteria decision making methods primarily used for choosing probable options using multiple criteria in a complex system (Mardani et al., 2015) and there are many techniques available, such as AHP, TOPSIS, ISM, MICMAC. AHP can be used to evaluate the most important food waste enablers; where some of them may have an impact on other major causes thereby influencing the strategies of food waste reduction. DEMATEL method can be used to identify the interrelationship among the enablers in the system (Tzeng et al., 2007) and divide those enablers into cause and effect groups (Wu & Tsai 2012). Table 3 presents the literature of MCDM methods that have been applied in a food waste context. For example, Parashar et al. (2020) present a study into supply chain enablers for carbon footprint reduction where they use the matrix of cross-impact multiplications applied to classification (MICMAC) analysis to categorize fourteen enablers (eg logistics, information sharing, traceability, technology, collaboration, regulation) as driving power and dependence power. Their research engaged three academic experts and two industrial practitioners (raw materials/ingredients suppliers to the hospitality sector).

As can be seen from the table 3, there is limited research into food waste analysis in the catering sector using MCDM, mainly the AHP/DEMATEL - base method. In this research, the DEMATEL method aims at revealing two groups of enablers: cause-enablers and effect-enablers. Efforts of decision makers should focus on cause-enablers that might eliminate, accordingly, enablers in the effect group. However, several enablers might be grouped as causes and decision makers hereby need to prioritize their efforts. The AHP method can tackle this prioritizing decision-making problem by quantifying the relative importance of cause-enablers in which cause-enablers with a high weight should be targeted before cause-enablers with low weight. Further features of the AHP and DEMATEL methods are presented in section 3.1 and 3.2, respectively.

Table 3. MCDM methods used in food waste management.

Reference	MCDM	Description
Hung et al. (2006)	AHP	Find the optimal food waste management scheme.
Chen et al. (2014)	Entropy method and AHP	Assess the safety of animal feed food waste.
Babalola (2015)	AHP	Evaluate different waste management options and their applicability in Japan and select the most suitable waste treatment option.
Oprea & Gaceu (2016)	MCDM method	Identify the most appropriate waste and by-products suitable to be used in the bakery industry.
San Martin et al. (2017)	AHP and GIS	Evaluate the main parameters involved in the decision process and helps decision-makers to implement food waste valorisation strategies.
Chauhan et al. (2018)	ISM method	Identify and model the drivers of agri-food waste management in India.
Liu et al. (2018)	DEMATEL, ANP and VIKOR	Improve and select the location for the best food waste composting facilities.
Raut et al. (2018)	AHP	Identify the crucial causal factors of post-harvest losses in the fruits and vegetables supply chain in India
Parashar et al. (2020)	MICMAC technique	Identify the critical enablers for food supply chain management which impact the carbon footprint creation and develops a contextual relationship amongst the identified enablers

3. Research methodology

Figure 2 presents an overview of the methodology used in the research. The questionnaire to collect data for AHP and DEMATEL methods was designed to allow businesses to undertake a pairwise comparison concerned with the importance and causal relationship among the causes. The questionnaire was divided into three part: 1) general information about the business; 2) the company was asked to undertake a comparison between different food waste causes; 3) evaluation of the influence level for food waste causes.

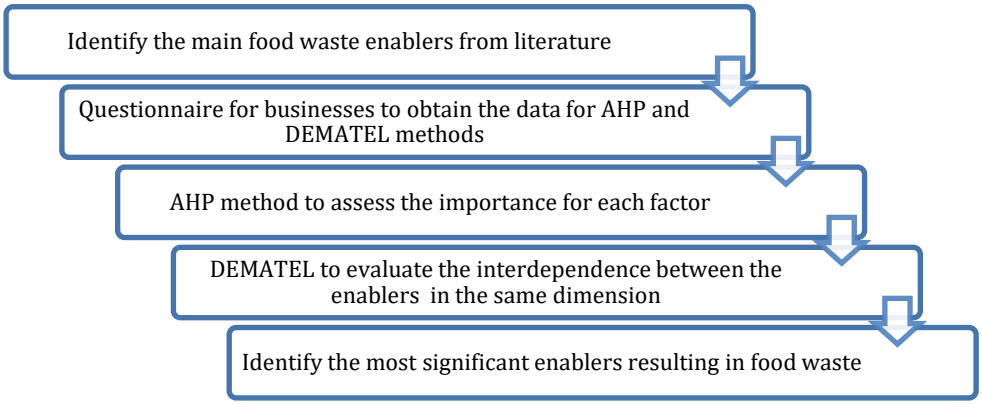

Figure 2. Methodology overview.

We investigated the food waste enablers in this sector at five different levels (Figure 3) and they covered the major food management steps. Figure 3 presents the framework of food waste enablers based on the literature discussed in Section 2 and they are clustered into five levels: procurement and storage (A), processing (B), operation strategy (C), people (D) and consumer (E). As part of the methodology, the enablers are classified as a cause or an effect enabler and this grouping will help managers to identify of food waste and target them rather than randomly focus efforts on addressing all enablers.

The relative importance of each enabler in each level was quantified using AHP. Then, DEMATEL was applied to investigate the interrelationships among enablers and present them as causes and effects in a holistic diagram. Compared to the AHP method (Saaty, 1980), this approach considers the independencies among dimensions and enablers in addition to obtaining the importance degree of enablers. Using this approach, cause enablers have a strong impact on effect enablers and this interrelationship should be taken into account. According to the interdependence, the enablers could be divided into two groups: cause and effect, where enablers in the cause group should be targeted and solved before enablers in the effect group. The integrated priority ranks are generated as the cause enablers with high AHP weight before causes with low AHP weight; preceding to effect group with high AHP weight prior to effects with low AHP weight, to allow managers to identify the most conclusive determinants.

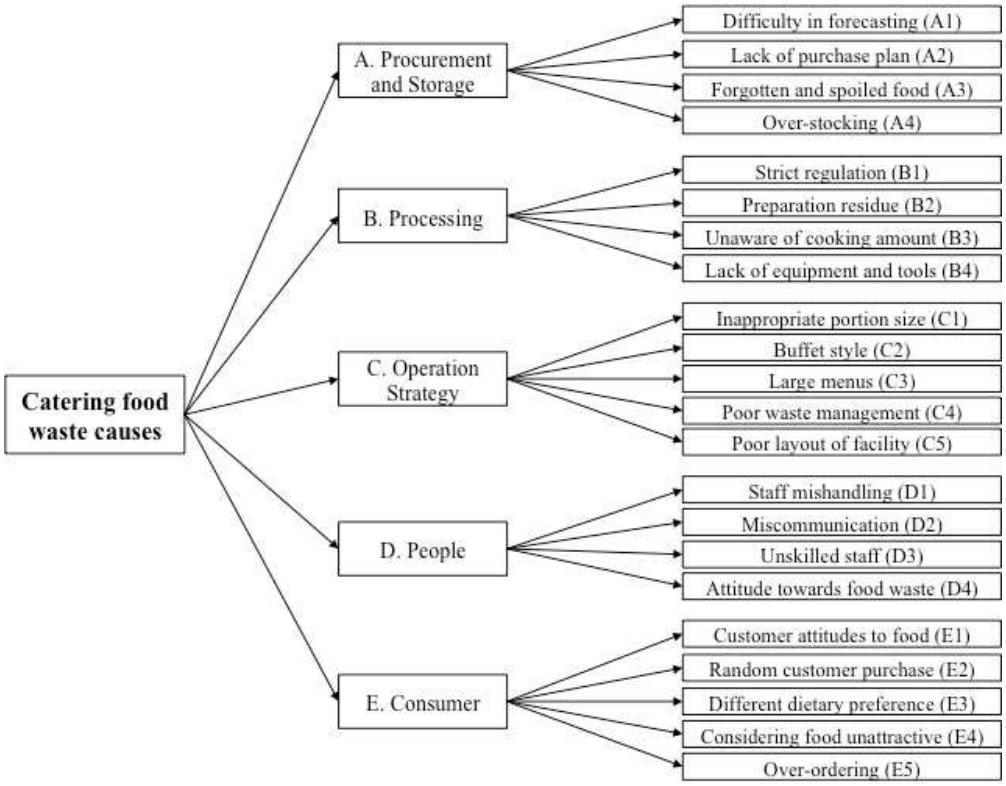

Figure 3. A framework of food waste enablers in catering industry.

The data for the AHP-DEMATEL method was collected using questionnaires that were distributed to forty companies with a response rate of 80%. Thirty-two responses consisted of 7 coffee shops, 5 takeaways, 13 restaurants and 7 pubs. The companies were randomly selected in one city and employees with management responsibilities filled in questionnaires. The number and diversity of participants allowed for distinctions among food waste enablers in addition to cause-effect analysis at different levels. Bloom et al. (2003) discuss that the most important factor in the amount of data collected for analysis to be sufficient is when there is enough data to identify distinctions. The authors also argue that the "more may not be better" as Rodgers et al. (1992) state that after identifying distinctions, each extra response increases the validity coefficient by almost 0.04. Therefore, considering the complexity of getting responses from, mainly a managerial level we have used the responses to proceed with this research.

3.1 AHP

Analytic Hierarchy Process (AHP) method was originally proposed and developed by Satty (1980) to support MCDM (De Felice and Petrillo 2014). This method quantifies the qualitative preferences of decision-makers and transfers them into measurable aspects (Ortiz et al. 2016). The AHP method analyses the sophisticated decision-making problem by conducting a number of pairwise comparisons among involved criteria and accordingly derive

the criterion's weight. Since it was developed, AHP has proved its applicability for solving real-life decision-making problems. Govindan et al. (2015) and Chai et al. (2013) review research that identified AHP as one of the most successfully employed MCDM method due to its simplicity and ability to handle qualitative and quantitative criteria. Fallahpour & Moghassem (2012) discuss that AHP is one of the most popular MCDM methods in weighting problems. Due to simplicity, the method satisfies the requirement of current research in weighting food waste causes, AHP was also used to support managers in determining the priority order of these causes.

In this work, AHP was applied to determine the importance of weight for each ABCDE criteria and sub-criteria and Table 4 shows the evaluation scale of linguistic variables that were used to perform pairwise comparisons. Decision-makers need to give their opinion regarding the importance of each criteria / sub-criteria with respect to the others. AHP steps toward the solution also can be found in Satty (1980), Handfield et al. (2002), Mathiyazhagan et al. (2015), Gandhi et al. (2016).

The general AHP procedure consists of following steps (Satty, 1980; Gandhi et al., 2016):

Step 1: Defining the causes: The main food waste causes were identified based on knowledge and previous studies.

Step 2: Development of judgement matrix. The participants were asked to evaluate relative importance using the scale developed by Satty (1980) (Table 4). For instance, if the decision-makers think that A1 is 'very strongly important' compared to A2 then we put 7 based on the evaluation scale.

Table 4. AHP scores.

Scores	**Linguistic meaning**
1	Equally Important (EQI)
3	Weakly Important (WI)
5	Strongly Important (SI)
7	Very Strongly Important (SI)
9	Extremely Important (EXI)
Please note: 2, 4, 6, 8 are the intermediate values	

The judgement matrix A (eq.1) was calculated using the geometric average of all the comparison matrixes $\mathrm{A}_1, \mathrm{A}_2, \ldots \mathrm{A}_\mathrm{m}$., where *m* and *n* denote the number of participants and criterion, respectively.

$$A = \sqrt[\mathrm{m}]{\mathrm{A}_1 \cdot \mathrm{A}_2 \ldots \mathrm{A}_\mathrm{m}} = \begin{bmatrix} 1 & a_{12} & \ldots & a_{1i} & \ldots & a_{1n} \\ a_{21} & 1 & \ldots & a_{2i} & \ldots & a_{2n} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ a_{i1} & \ldots & \ldots & \ldots & \ldots & a_{in} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ a_{n1} & a_{n2} & \ldots & a_{ni} & \ldots & 1 \end{bmatrix} \left(i, j = 1,2, \ldots n;\ a_{ij} = \frac{1}{a_{ji}} > 0 \right) \quad (1)$$

Step 3: Developing a normalised decision matrix. The matrix can be constructed by summing the column number in judgement matrix *A* and then dividing each value in the matrix by its column sum. Thus, column sum (S_j) and normalised decision matrix (B) (eq. 2, eq. 3):

$$S_i = a_{1i} + a_{2i} + \cdots + a_{ni}\ (i = 1,2,\dots,n) \qquad (2)$$

$$B = \begin{bmatrix} \frac{1}{S_1} & \frac{a_{12}}{S_2} & \cdots & \frac{a_{1i}}{S_i} & \cdots & \frac{a_{1n}}{S_n} \\ \frac{a_{21}}{S_1} & \frac{1}{S_2} & \cdots & \frac{a_{2i}}{S_i} & \cdots & \frac{a_{2n}}{S_n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \frac{a_{i1}}{S_1} & \cdots & \cdots & \cdots & \cdots & \frac{a_{in}}{S_n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \frac{a_{n1}}{S_1} & \frac{a_{n2}}{S_2} & \cdots & \frac{a_{ni}}{S_i} & \cdots & \frac{1}{S_n} \end{bmatrix} \qquad (3)$$

Step 4: Determining the weight of each enabler: Calculate the average value of each row in the normalised matrix, the results for each row should be the weight (w_i) of the corresponding criteria (eq. 4).

$$w_i = \frac{1}{n}\left(\frac{a_{i1}}{S_1} + \frac{a_{i2}}{S_2} + \cdots + \frac{a_{in}}{S_n}\right)\ (i = 1,2,\dots,n) \qquad (4)$$

Noticeably, the weight value for each criterion can constitute the eigenvector (W), which is

$$W = (\mathrm{w}_1, w_2, \dots, w_i)^T\ (i = 1,2,\dots,n) \qquad (5)$$

Step 5: Checking the consistency. The consistency of the judgement matrix calculated using the Consistency Ratio (CR) that is equal to Consistency Index (CI) divided by Random Consistency Index (RCI) (eq. 6).

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RCI}} \qquad (6)$$

The CI value is related to the eigenvector (*W*), maximum eigen value (λ_{m}) and order(n) of the judgement matrix (A), eq. 7.

$$\mathrm{CI} = \frac{\lambda_m - n}{n - 1} \qquad (7)$$

The maximum eigen value (λ_{m}) can be generated from the judgement matrix (*A*) and eigenvector (*W*) (eq. 8).

$$\lambda_m = \frac{1}{n} \cdot \sum_{i=1}^{n} \frac{(AW)_i}{w_i} \qquad (8)$$

RCI value depends on the number of the judgements for a particular matrix of order *n* and presented in Table 5 (Satty, 1980).

Table 5. RCI value.

n	1	2	3	4	5	6	7	8	9	10
RCI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

If the value of CR < 0.1, the judgement matrix could be considered at a rational consistency level. Otherwise, the judgement matrix might be inconsistent among some comparison values and needs further adjustment.

3.2 Identifying causes and effects: DEMATEL

Decision Making Trial and Evaluation Laboratory (DEMATEL), which was first proposed by the United States Bastille laboratory in 1971, is extensively applied to analyse and evaluate the influence among all the criteria (Ortíz et al. 2016). This technique synthesizes the opinions or experience of experts by quantifying the influence level between each criterion. This method helps in identifying the relationship among involved criteria by categorizing them as either cause or effect. In other words, it reveals the correlation among criteria and can direct efforts of decision-makers in targeting causes rather than effects, which will be addressed accordingly (Büyüközkan & Çifçi, 2012; Mohammed, 2020). DEMATEL is described as a method for identifying causes-effects outcome in decision-making (Doraid et al., 2011; Nujoom et al., 2019; and Si et al., 2018). DEMATEL allows verification of interdependence among all selected criteria and development of a holistic cause-effect diagram. The implementation of the method has the following five steps (Tzeng et al. 2007, Wu and Tsai 2012; Yazdani et al. 2017):

Step 1: Generating the direct-relation matrix from the questionnaire response. Using the questionnaires, the participants were asked to score the influence level between each pair of criteria using scores presented in the Table 6. For instance, if a participant thinks that A1 has 'low influence' on A2, we would put score of '1'.

Table 6. Influence level scores in DEMATEL.

Scores	Linguistic meaning
0	No influence
1	Low influence
2	Medium influence
3	High influence
4	Extreme influence

For each questionnaire, the response is converted into an influence matrix and the direct-relation matrix (C):

$$\mathrm{C} = \frac{\mathrm{C_1} + \mathrm{C_2} + \cdots + \mathrm{C_m}}{\mathrm{m}} = \begin{bmatrix} 0 & c_{12} & \dots & c_{1i} & \dots & c_{1n} \\ c_{21} & 0 & \dots & c_{2i} & \dots & c_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ c_{i1} & \dots & \dots & \dots & \dots & c_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ c_{n1} & c_{n2} & \dots & c_{ni} & \dots & 0 \end{bmatrix} \quad (9)$$

Step 2: Computing the normalized direct-relation matrix (eq. 10, eq. 11.)

$$\mathrm{N} = x \cdot \mathrm{C} \quad (10)$$

where

$$x = min\left[\frac{1}{max\sum_{i=1}^{n} c_{ij}}, \frac{1}{max\sum_{j=1}^{n} c_{ij}}\right](i, j = 1,2, \dots, n) \qquad (11)$$

Step 3: Generating the total-relation matrix. The total-relation matrix (T) (eq.12) reveals the total relationship including direct influence and indirect influence between each pair of criteria.

$$\mathrm{T} = \mathrm{N}(\mathrm{I} - \mathrm{N})^{-1} \qquad (12)$$

where I refers to the identical matrix.

Step 4: Dividing the criteria into cause and effect groups. Values $\mathrm{D_i} + \mathrm{R_j}$ ("prominence") and $\mathrm{D_i} - \mathrm{R_j}$ ("relation") were computed for each criterion. $\mathrm{D_i}$ and $\mathrm{R_j}$ are the sum of rows and columns of (T) (eq. 13 and 14).

$$\mathrm{D}_i = \sum_{j=1}^{n} t_{ij}\,(i = 1,2, \dots, n) \qquad (13)$$

$$\mathrm{R}_j = \sum_{i=1}^{n} t_{ij}\,(j = 1,2, \dots, n) \qquad (14)$$

Where the "relation" value (i.e. $\mathrm{D_i} - \mathrm{R_j}$) of one criterion is positive, this criterion would be regarded as a cause group. Where the "relation" value is negative, this criterion would be classified as an effect group.

Step 5: Developing a cause and effect diagram according to the threshold value. The setting of the threshold value (α) is helpful for a decision-maker to develop the cause and effect diagram (eq. 15). For example, when the value of total relationship between criterion *i* and criterion *j* in the matrix (T) is greater than the threshold value (i.e. $t_{ij} > \alpha$), it means that criterion j is caused by criterion i, where the arrow begins from criterion *i* to criterion *j* and vice versa.

$$\alpha = \frac{1}{num}\sum_{i=1}^{n}\sum_{j=1}^{n}[t_{ij}] \qquad (15)$$

where *num* is the number of elements in T

4. Results

Different types of catering outlets have diverse customer profiles (demographics and behaviour) with different offerings where food contribution to total sales depends on many factors: location, menu, standards, management and service (Negus, 2004). By taking into account different types of business, the analysis is undertaken for all outlets in the catering industry under investigation and for each type to support the cross-comparison discussion in Section 5.

4.1 Catering industry: all outlets

The AHP and DEMATEL analysis using 32 responses from all businesses presented in Table 7. The CR values are below 0.1 showing the high consistency across all responses. As shown in Table 7, the procurement and storage, and operation strategy have the highest AHP weights, indicating relatively higher importance towards food waste. Difficulty in forecasting (A_1), strict regulations (B_1) large menus (C_3), miscommunication (D_2) and over-ordering (E_5) are the most important enablers in each level when considering only AHP weights, with the weight of 0.316, 0.369, 0.224, 0.278 and 0.335 respectively.

After obtaining enablers weights, DEMATEL method was used to categorize the food waste enablers into cause and effect and to develop a holistic cause-effect diagram. The category for each factor is derived using prominence value (D+R) and relation value (D-R) (see Table 7). At procurement and storage and processing levels, two enablers might lead to the three enablers leading to food waste. At the sub-level, difficulty in forecasting (A_1) and customer attitude towards food (E_1) are among enablers that have a high prominence and relation values among the sub- enablers.

Table 7. AHP weights, priority ranking, cause and effect for each enabler across all outlets.

Level enablers	AHP weight	D+R	D-R	Group	Priority Rank	Sub-level enablers	AHP weight	D+R	D-R	Group	Priority Rank
A. Procurement and Storage	0.256	36.804	0.68	Cause	1	A_1	0.316	44.233	0.372	Cause	1
						A_2	0.196	42.352	0.263	Cause	2
						A_3	0.242	43.312	-0.052	Effect	4
						A_4	0.246	42.539	-0.584	Effect	3
B. Processing	0.17	37.388	0.877	Cause	2	B_1	0.369	19.454	-0.105	Effect	3
						B_2	0.24	19.820	-0.779	Effect	4
						B_3	0.268	19.610	0.444	Cause	1
						B_4	0.123	17.111	0.440	Cause	2
C. Operation strategy	0.237	38.181	-0.711	Effect	3	C_1	0.222	18.959	0.044	Cause	1
						C_2	0.21	18.540	-0.043	Effect	4
						C_3	0.224	18.078	-0.456	Effect	3
						C_4	0.206	19.618	-0.275	Effect	5
						C_5	0.138	16.227	0.731	Cause	2
D. People	0.183	38.241	-0.146	Effect	4	D_1	0.192	61.166	-0.639	Effect	4
						D_2	0.278	60.129	-0.082	Effect	3
						D_3	0.263	61.395	0.229	Cause	2
						D_4	0.268	58.385	0.491	Cause	1
E. Consumer	0.154	35.815	-0.7	Effect	5	E_1	0.174	25.938	0.914	Cause	2
						E_2	0.153	24.544	-0.320	Effect	5
						E_3	0.175	25.532	0.538	Cause	1
						E_4	0.163	25.214	-0.509	Effect	4
						E_5	0.335	25.040	-0.623	Effect	3

According to Yazdani et al. (2017), the elements in the cause group should be regarded as the main drivers to the elements in the effect group and can be considered as a priority. Using AHP results, the food waste enablers can be ranked following the principles that cause group (high AHP weight to low AHP weight) ranked before the effect group (high AHP weight to low AHP weight). The ranking guides the decision-makers to identify the most

significant food waste enablers to be targeted as a priority, for example in the procurement and storage. Difficulty in forecasting (A_1), cooking amount unawareness (B_3), inappropriate portion size (C_1), attitude towards food waste (D_4) and different dietary preference (E_3) are the priority sub-enablers in each dimension.

Figure 4 depicts the holistic cause-effect diagram that reveals the contextual relationship and provides a visualisation of interrelationships among the food waste enablers. The value in brackets following the factor is the AHP weights and the number on the arrows specifies by how much one factor influences another. Processing is the only dimension that would affect the other four dimensions, especially the operation strategy and people, with a high influence level of 4.003 and 3.971. When the number of flow-out arrows is larger than the number of flow-in arrows, this enabler tends to affect others more than being influenced by others and deserve the attention. However, for some enablers, the numbers of flow-in and flow-out arrows are equal, therefore the influence level on the arrow could determine this enabler as cause or effect. Noticeably, lack of equipment and tools (B_4), poor facility layout (C_5) and attitude towards food waste (D_4) are the enablers that affect preparation residue (B_2), poor waste management (C_4) and staff mishandling (D_1) respectively without being influenced. Regarding the influence level, some of them are higher than the threshold value as well as the other influence levels in the same dimension which might imply the strong influence relationship of two enablers. For example, unskilled staff (D_3) would significantly affect the D_1 at the level of 7.961, while the threshold value and ordinary influence level are around 7.6 to 7.7. This might suggest that D_3 will lead to D_1.

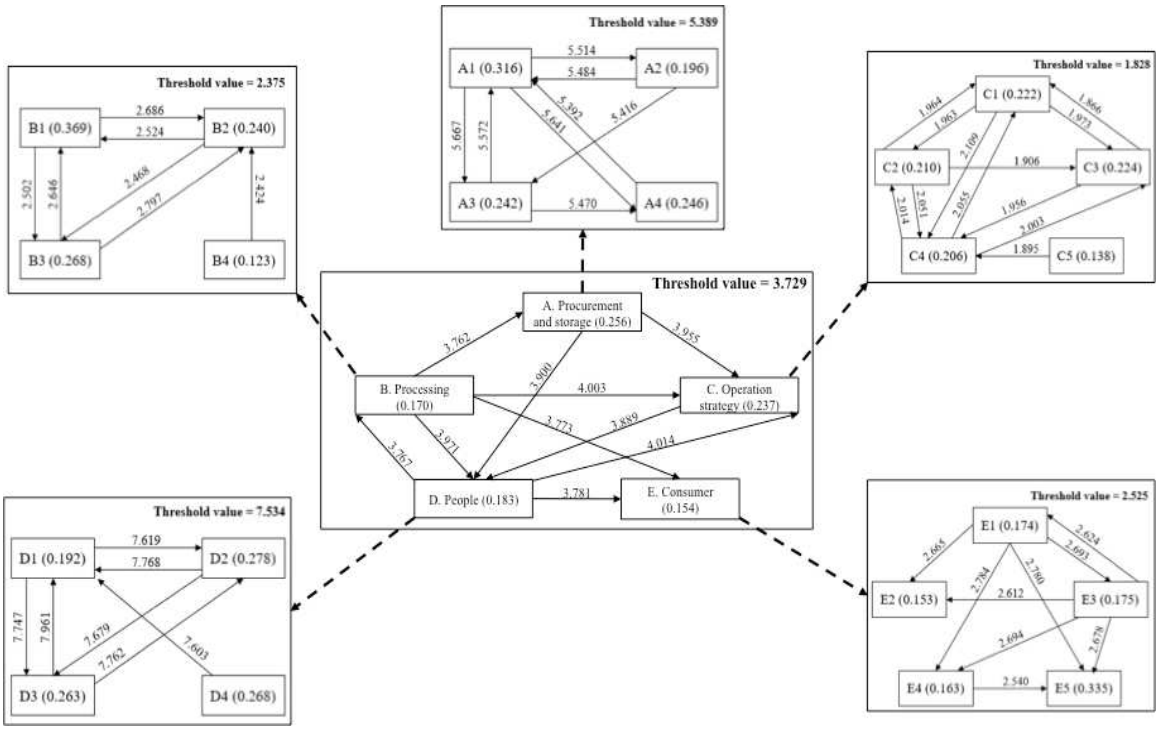

Figure 4. Cause and effect diagram for food waste enablers across all outlets in catering industry.

4.2 Coffee shops

AHP weights for each food waste enabler in coffee shops have been calculated using responses from seven business (Table 8). The procurement and storage have the highest weight of 0.23; with processing ranked as the 2nd highest factor leading to food waste in the coffee shop. Among sub-level enablers, difficulty in forecasting (A_1), cooking amount unawareness (B_3), poor waste management (C_5), unskilled staff (D_3) and different dietary preference (E_3) are the most crucial causes based on combined priority rankingwith weights of 0.352, 0.215, 0.149, 0.156 and 0.345. Enablers A, B and C are classified as causes. In A, difficulty in forecasting (A_1) is the most significant enabler with highest prominence and relation value.

Table 8. AHP weights, priority ranking, cause and effect for each enabler in coffee shops.

Level enablers	**AHP weight**	**D+R**	**D-R**	**Group**	**Priority Rank**	**Sub-level enablers**	**AHP weight**	**D+R**	**D-R**	**Group**	**Priority Rank**
A. Procurement and Storage	0.23	15.097	0.437	Cause	1	A_1	0.352	16.091	0.579	Cause	1
						A_2	0.26	15.149	-0.072	Effect	3
						A_3	0.247	15.618	-0.727	Effect	4
						A_4	0.141	13.691	0.22	Cause	2
B. Processing	0.19	15.448	0.625	Cause	2	B_1	0.409	14.319	-0.14	Effect	2
						B_2	0.204	13.909	-0.529	Effect	3
						B_3	0.215	14.698	0.751	Cause	1
						B_4	0.172	12.754	-0.083	Effect	4
C. Operation strategy	0.182	15.532	0.535	Cause	3	C_1	0.285	18.046	-0.509	Effect	3
						C_2	0.171	17.009	-0.057	Effect	5
						C_3	0.254	17.721	-0.82	Effect	4
						C_4	0.141	19.046	0.572	Cause	2
						C_5	0.149	18.515	0.814	Cause	1
D. People	0.205	16.575	-0.867	Effect	4	D_1	0.266	42.229	-0.011	Effect	3
						D_2	0.398	42.506	-0.732	Effect	2
						D_3	0.156	39.555	1.226	Cause	1
						D_4	0.18	42.237	-0.483	Effect	4
E. Consumer	0.194	16.446	-0.73	Effect	5	E_1	0.202	18.123	-0.002	Effect	2
						E_2	0.188	17.813	-0.102	Effect	3
						E_3	0.345	19.380	0.299	Cause	1
						E_4	0.121	17.814	-0.104	Effect	5
						E_5	0.143	17.191	-0.091	Effect	4

Figure 5 presents the holistic cause-effect diagram of the food waste enablers in coffee shops. Procurement and storage, processing and operation strategy are the dimensions that would influence people and consumer, without being affected by others. These two affected dimensions would interact with each other at a similar influence level. Noticeably, among the sub-enablers, unskilled staff (D_3) could be regarded as the root cause in its dimension because it would influence the other sub-enablers without being impacted.

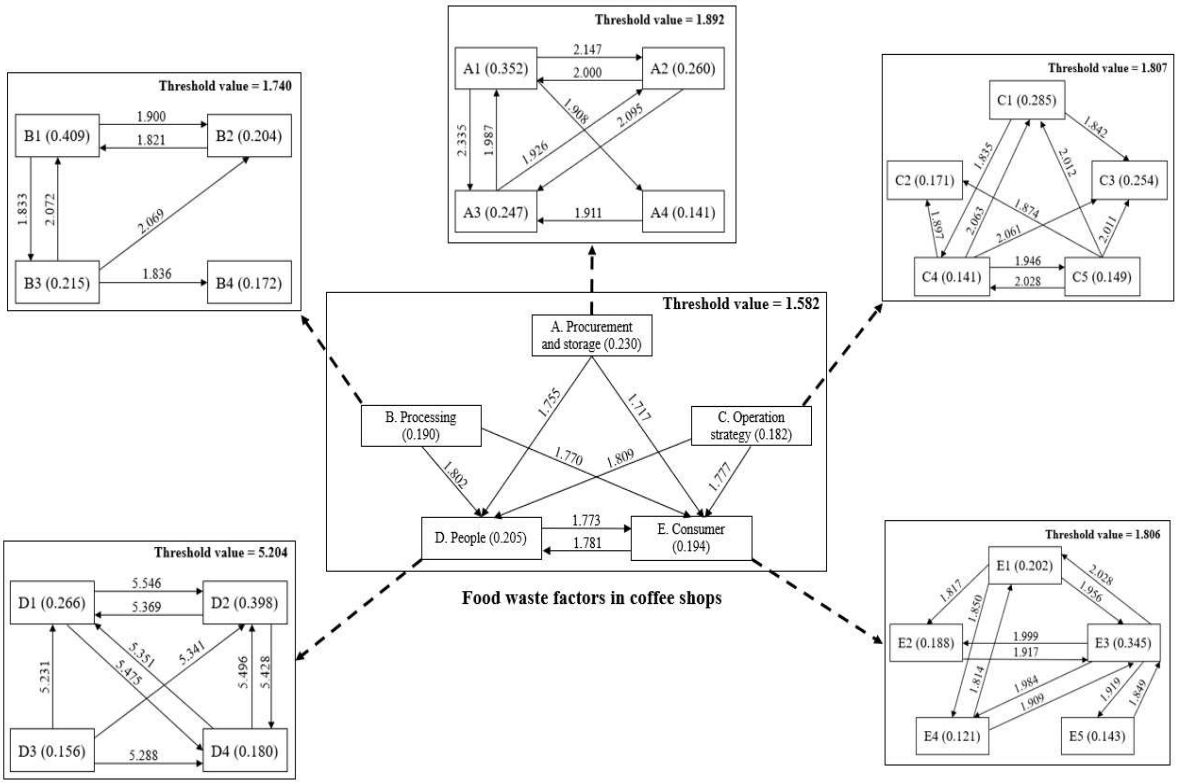

Figure 5. Cause and effect diagram for food waste enablers in coffee shops.

4.3 Takeaways

Table 9 presents the analysis and findings related to takeaways. The procurement and storage (A) is the most important contributor towards food waste at around 47% of the total weight. Difficulty in forecasting (A_1) and strict regulation (B_1) are effects. Procurement and storage (A) and consumer (E) enablers could be recognized as the causes leading to other enablers. For the sub-level, customer attitude towards food (E_1) has the highest prominence and relation values. Regarding the priority ranking (see Table 9), procurement and storage (A) is the priority level. Lack of purchase plan (A_2), cooking amount unawareness (B_3), poor facility layout (C_5), attitude towards food waste (D_4) and E_1 are the priority for each level.

Table 9. AHP weights, priority ranking, cause and effect in takeaways.

Level enablers	AHP weight	D+R	D-R	Group	Priority Rank	Sub-level enablers	AHP weight	D+R	D-R	Group	Priority Rank
A. Procurement and Storage	0.465	23.042	1.603	Cause	1	A_1	0.428	23.887	-1.407	Effect	4
						A_2	0.225	23.699	0.671	Cause	1
						A_3	0.196	24.77	0.483	Cause	2
						A_4	0.152	22.688	0.252	Cause	3
B. Processing	0.112	25.214	-0.228	Effect	5	B_1	0.399	11.444	-0.569	Effect	3
						B_2	0.129	12.501	-0.611	Effect	4
						B_3	0.364	11.902	0.745	Cause	1
						B_4	0.108	10.435	0.435	Cause	2
C. Operation strategy	0.197	24.523	-0.56	Effect	3	C_1	0.214	9.666	0.244	Cause	2
						C_2	0.208	8.897	0.004	Cause	3
						C_3	0.127	7.862	0.268	Cause	4
						C_4	0.233	9.324	-1.158	Effect	5
						C_5	0.219	8.473	0.642	Cause	1
D. People	0.157	25.14	-0.836	Effect	4	D_1	0.256	10.691	-0.871	Effect	3
						D_2	0.188	9.731	0.634	Cause	2
						D_3	0.251	10.037	-0.21	Effect	4
						D_4	0.305	9.909	0.447	Cause	1
E. Consumer	0.07	24.329	0.021	Cause	2	E_1	0.236	9.45	0.92	Cause	1
						E_2	0.149	8.547	-0.488	Effect	5
						E_3	0.267	9.2	-0.145	Effect	3
						E_4	0.1	8.772	0.095	Cause	2
						E_5	0.248	7.929	-0.382	Effect	4

Figure 6 presents the cause and effect diagram for takeaways and it is more complicated compared to other businesses. Procurement and storage (A) is shown as the core dimension influencing other dimensions but not affected by others. Among the sub-enablers, lack of equipment and tools (B_4) fully impacts on preparation residue (B_2), miscommunication (D_2) and attitude towards food waste (D_4) would affect staff mishandling (D_1) and unskilled staff (D_3). As for the influence level, the numbers on the arrow from A_3 to A_1, from B_3 to B_2 and from C_1 to C_4 are relatively higher in their level at 3.424, 1.864 and 1.212 respectively. This implies that forgotten and spoiled food (A_3), cooking amount unawareness (B_3), and inappropriate portion size (C_1) would strongly affect the difficulty in forecasting (A_1), preparation residue (B_2) and poor waste management (C_4).

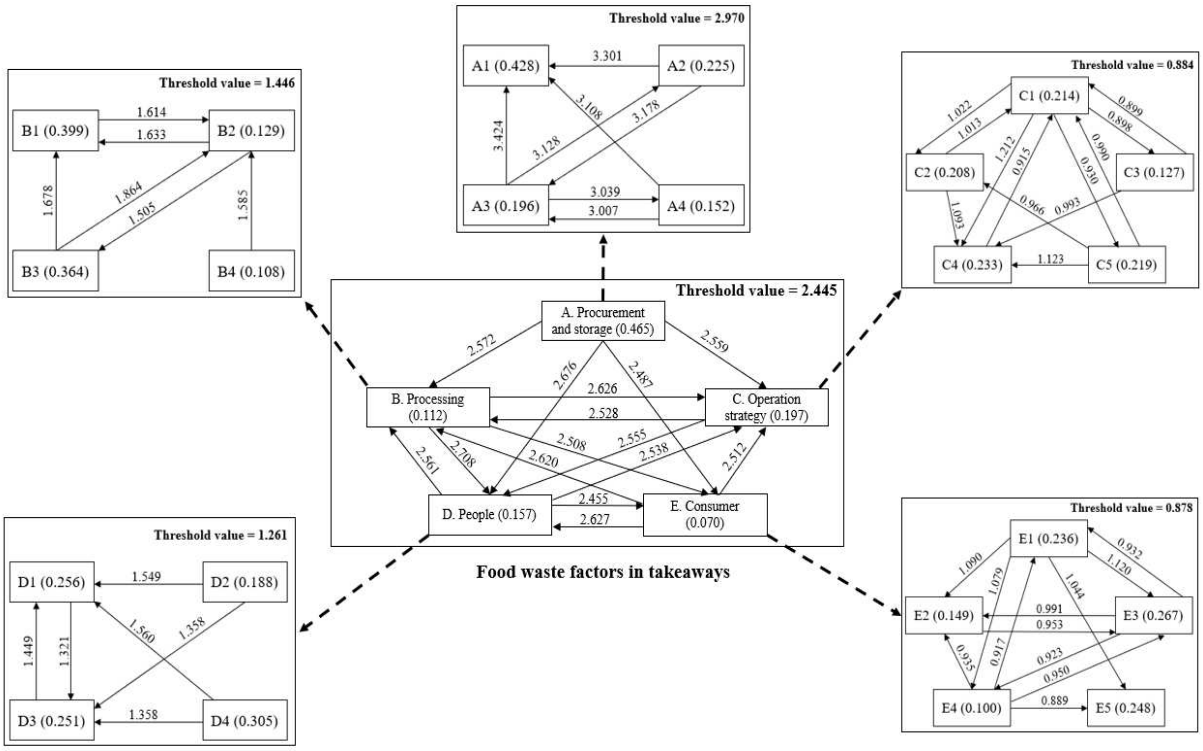

Figure 6. Cause and effect diagram for food waste enablers in takeaways.

4.4 Restaurants

Table 10 presents AHP/DEMATEL findings related to restaurants. Operation strategy has the highest AHP weight of 0.247. Over-stocking (A_4), strict regulation (B_1), large menu (C_3), unskilled staff (D_3) and over-ordering (E_5) also have the highest AHP weights for each dimension respectively. The analysis of cause and effect groups shows that processing (B) and people (D) play an important cause on other enablers and there is only one sub-factor grouped as an effect (preparation residue (B_2) and attitude towards food waste (D_4)). Processing is the dimension with the first consideration in restaurants due to its high cause weight (0.195) and priority ranking of 1. Within the sub-enablers, difficulty in forecasting (A_1), strict regulation (B_1), inappropriate portion size (C_1), unskilled staff (D_3) and customer attitude towards food (E_1) should be addressed first.

Table 10. AHP weights, priority ranking, cause and effect in restaurants.

Level enablers	AHP weight	D+R	D-R	Group	Priority Rank	Sub – level enablers	AHP weight	D+R	D-R	Group	Priority Rank
A. Procurement and Storage	0.217	20.253	-0.442	Effect	4	A_1	0.233	33.352	1.386	Cause	1
						A_2	0.173	33.303	0.16	Cause	2
						A_3	0.294	33.394	-0.415	Effect	4
						A_4	0.3	33.835	-1.131	Effect	3
B. Processing	0.195	19.953	0.577	Cause	1	B_1	0.306	10.824	0.054	Cause	1
						B_2	0.303	11.583	-0.685	Effect	4
						B_3	0.277	11.167	0.138	Cause	2
						B_4	0.114	9.077	0.494	Cause	3
C. Operation strategy	0.247	20.794	-0.879	Effect	3	C_1	0.208	15.48	0.248	Cause	1
						C_2	0.194	15.866	0.177	Cause	2
						C_3	0.245	14.811	-0.213	Effect	4
						C_4	0.235	16.298	-0.307	Effect	5
						C_5	0.118	12.259	0.096	Cause	3
D. People	0.182	20.067	1.344	Cause	2	D_1	0.147	41.936	0.425	Cause	3
						D_2	0.256	41.856	0.318	Cause	2
						D_3	0.326	42.419	0.376	Cause	1
						D_4	0.27	39.012	-1.119	Effect	4
E. Consumer	0.159	19.312	-0.6	Effect	5	E_1	0.155	20.954	0.58	Cause	1
						E_2	0.117	19.836	-0.151	Effect	5
						E_3	0.114	19.963	0.685	Cause	2
						E_4	0.196	20.809	-0.79	Effect	4
						E_5	0.419	21.971	-0.323	Effect	3

As shown in Figure 7, processing and people are root enablers that impact on others. However, it can be argued that decision-makers should target the people dimension prior to processing because people would affect processing while processing would not affect people. Hence, a slight discrepancy between this argument and the combined priority rank. This difference may be attributed to the higher AHP weight of processing than people, where processing is considered first when they both belong to a cause group. For sub-level enablers, difficulty in forecasting (A_1), lack of equipment and tools (B_4) and different dietary preference (E_3) are the causes that entirely affect others without being impacted. The high influence levels of cooking amount unawareness (B_3) on preparation residue (B_2) and A_1 on over-stocking (A_4) demonstrate the powerful causality of those enablers. Noticeably, the poor facility layout (C_5) neither has an impact on other enablers nor is influenced by others while it has been grouped as a cause. A possible explanation for this might be that C_5 impacts on others more than being impacted even though its overall relationship with other enablers is quite weak and would not be shown in the diagram.

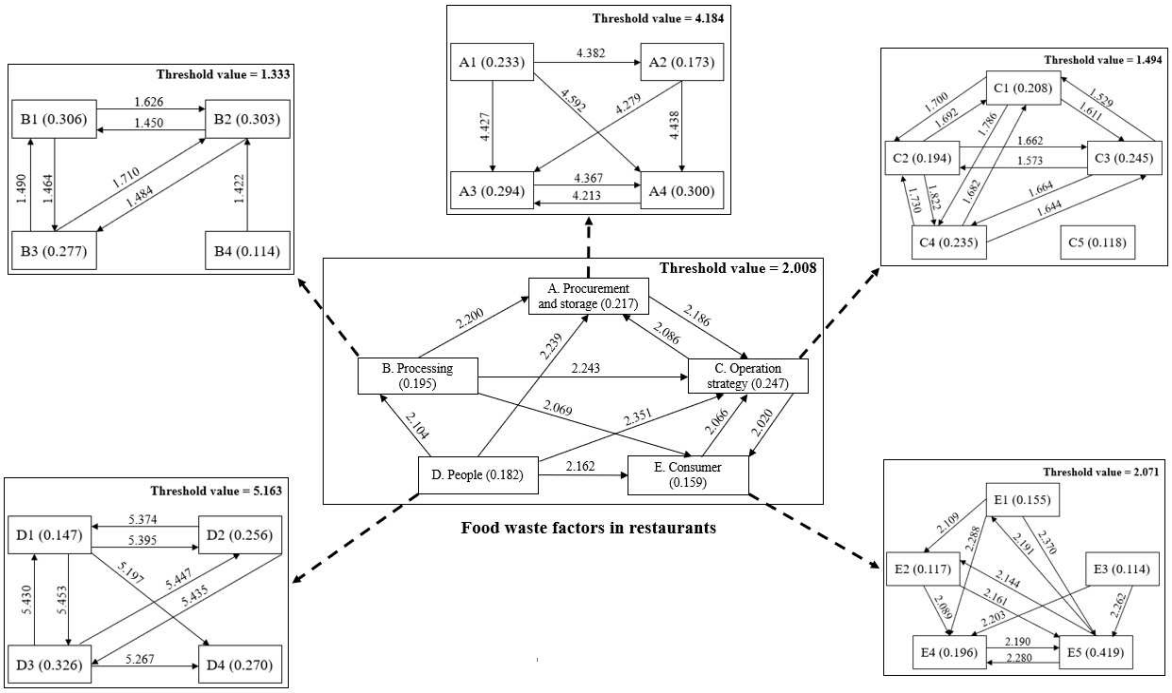

Figure 7. The cause and effect diagram for food waste enablers in restaurants.

4.5 Pubs

Table 11 presents the AHP/DEMATEL results related to pubs. Operation strategy (C) has the highest weight of 0.282 and it indicates relatively high importance towards food waste. For each sub-level, over-stocking (A_4), strict regulation (B_1), buffet-style (C_2), attitude towards to food waste (D_4), and over-ordering (E_5) have highest AHP weights, especially B_1 and E_5 with weight values of 0.405 and 0.481. Furthermore, combined priority ranking identifies the procurement and storage level as the most contributing factor towards food waste and should be addressed first and within sub-enablers, A_3, B_1, C4, D_4 and E_1 are priorities. Cause and effect groups illustrate that procurement and storage (A), processing (B) and consumer (E) are the causes and there is only one cause in the people dimension - attitude towards food waste (D_4).

Table 11. AHP weights, priority ranking, cause and effect in pubs.

Level enablers	AHP weight	D+R	D-R	Group	Priority Rank	Sub – level enablers	AHP weight	D+R	D-R	Group	Priority Rank
A. Procurement and Storage	0.231	16.463	0.67	Cause	1	A_1	0.331	18.062	-0.511	Effect	4
						A_2	0.144	15.918	0.084	Cause	2
						A_3	0.165	16.596	0.788	Cause	1
						A_4	0.36	17.685	-0.361	Effect	3
B. Processing	0.138	16.522	0.241	Cause	3	B_1	0.405	21.456	0.157	Cause	1
						B_2	0.259	19.762	0.15	Cause	2
						B_3	0.231	19.844	-0.523	Effect	4
						B_4	0.105	19.446	0.216	Cause	3
C. Operation strategy	0.282	17.288	-0.421	Effect	4	C_1	0.18	13.87	-0.173	Effect	5
						C_2	0.276	13.388	-0.452	Effect	3
						C_3	0.237	14.23	-0.843	Effect	4
						C_4	0.194	14.234	0.445	Cause	1
						C_5	0.113	10.487	1.024	Cause	2

D. People	0.164	16.775	-0.819	Effect	5	D_1	0.16	12.388	-0.109	Effect	4
						D_2	0.264	12.153	-0.644	Effect	3
						D_3	0.267	13.773	-0.26	Effect	2
						D_4	0.309	11.939	1.014	Cause	1
E. Consumer	0.185	13.061	0.328	Cause	2	E_1	0.103	18.062	0.709	Cause	1
						E_2	0.157	16.89	-0.042	Effect	4
						E_3	0.103	17.292	0.564	Cause	2
						E_4	0.156	17.186	-0.382	Effect	5
						E_5	0.481	16.504	-0.849	Effect	3

Figure 8 presents the relationships between enablers and sub-enablers. It is worthy to note that the consumer dimension neither affects other dimensions nor is impacted by others. Procurement and storage influence relatively the operation strategy (1.961) in pubs. As for the sub-enablers, forgotten and spoiled food (A_3) and poor facility layout (C_5) are the cause enablers that only affect others, while over-ordering (E_5) is the effect factor that is only impacted by others. The influence level of strict regulation (B_1) on cooking amount unawareness (B_3) is quite high compared to others (2.814).

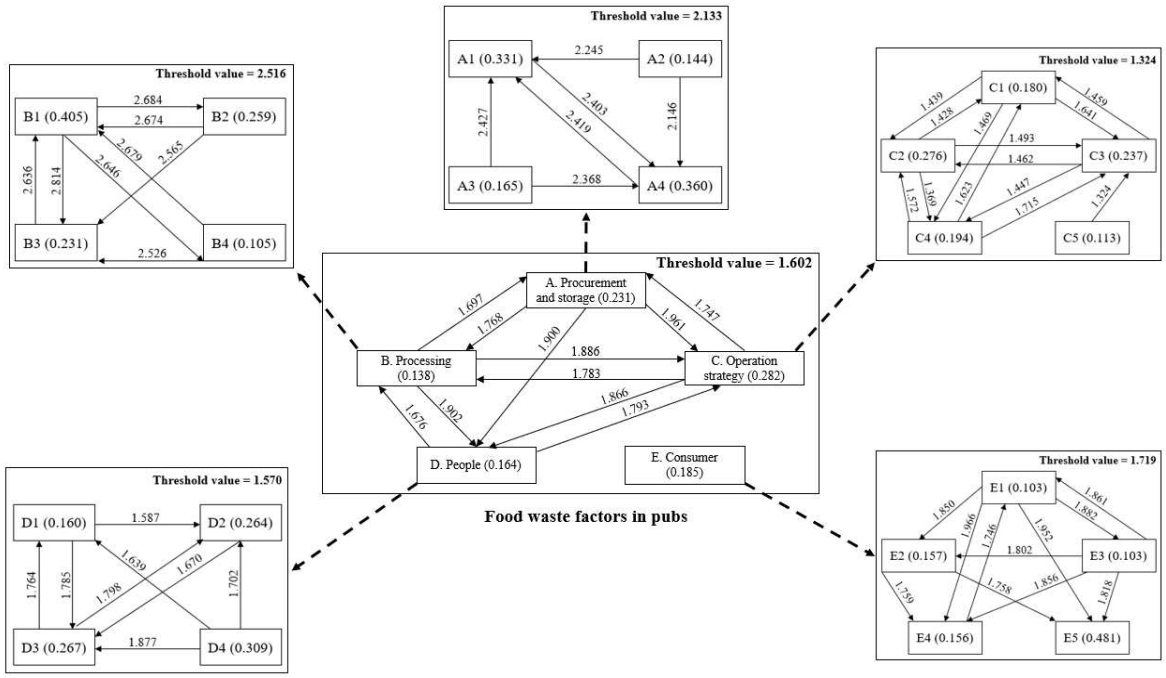

Figure 8. The cause and effect diagram for food waste enablers in pubs.

5. Discussion

Tables 12 and 13 present a summary of the findings across all businesses (G) in the catering industry and for individual outlets to allow a cross-business comparison for coffee shops (CS), takeaways (T), restaurants (R) and pubs (P). The table presents AHP weights, cause or effect classification and combined priority ranking. The values

highlighted in both tables support discussion presented in this section and emphasize results that will help decision-makers to prioritize their improvement efforts, by targeting the most influential levels first.

Cross-comparison among businesses: AHP weights represent the business opinions towards the importance of each food waste enabler. When considering all businesses (G), the procurement and storage level revealed the highest weigh (0.256) followed by operation strategy (C) (0.237), people (D) (0.183), processing (B) (0.17) and consumer (E) (0.154). The results indicate that food waste causes in the procurement and storage level play a paramount role and should be addressed by decision-makers as a priority. At sub-level analysis, coffee shops and takeaways have similar views for the difficulty in forecasting (A_1) enabler when considering AHP weights. One of the reasons for that grouping can be the size of businesses where the majority of coffee shops and takeaways are micro-companies while the size of restaurants and pubs can be bigger, which might suggest that similar business size models could have similar attitudes towards food waste. DEMATEL classifies food waste enablers as causes and effects where cause enablers should be targeted as a priority with urgent attention. It is worthy to notice that some enablers are causes in three food outlets but regarded as the effect in others. For example, lack of purchase plan (A_2), lack of equipment and tools (B_4) and customer attitude towards food (E_1) are causes in takeaways, restaurants and pubs while it is an effect in coffee shops.

Table 12. Level enablers summary.

Level	AHP weight					Group					Priority rank				
	G	CS	T	R	P	G	CS	T	R	P	G	CS	T	R	P
A. Procurement and storage	0.256	0.23	0.465	0.217	0.231	C	C	C	E	C	1	1	1	4	1
B. Processing	0.17	0.19	0.112	0.195	0.138	C	C	E	C	C	2	2	5	1	3
C. Operation strategy	0.237	0.182	0.197	0.247	0.282	E	C	E	E	E	3	3	3	3	4
D. People	0.183	0.205	0.157	0.182	0.164	E	E	E	C	E	4	4	4	2	5
E. Consumer	0.154	0.194	0.07	0.159	0.185	E	E	C	E	C	5	5	2	5	2

C – cause; E – effect

The combined priority rank demonstrates which food waste enablers should be regarded as a conclusive determinant and should be addressed first (Tables 12, 13). Procurement and storage level is the priority for majority except for restaurants where processing takes precedence. Furthermore, takeaways should focus on the lack of a purchase plan and pubs on forgotten and spoiled food. At the processing level cooking amount unawareness should be considered first in coffee shops, takeaways and strict regulation is the priority for restaurants and pubs.

Table 13. Sub-level enablers summary.

Level enablers	Sub-level enablers	AHP weight					Group					Priority rank				
		G	CS	T	R	P	G	CS	T	R	P	G	CS	T	R	P
A	Difficulty in forecasting (A_1)	0.316	0.352	0.428	0.233	0.331	C	C	E	C	E	1	1	4	1	4
	Lack of purchase plan (A_2)	0.196	0.260	0.225	0.173	0.144	C	E	C	C	C	2	3	1	2	2
	Forgotten and spoiled food (A_3)	0.242	0.247	0.196	0.294	0.165	E	E	C	E	C	4	4	2	4	1
	Over-stocking (A_4)	0.246	0.141	0.152	0.300	0.360	E	C	C	E	E	3	2	3	3	3
B	Strict regulation on safety and quality (B_1)	0.369	0.409	0.399	0.306	0.405	E	E	E	C	C	3	2	3	1	1
	Preparation residue (B_2)	0.240	0.204	0.129	0.303	0.259	E	E	E	E	C	4	3	4	4	2
	Unaware of cooking amount (B_3)	0.268	0.215	0.364	0.277	0.231	C	C	C	C	E	1	1	1	2	4
	Lack of equipment and tools (B_4)	0.123	0.172	0.108	0.114	0.105	C	E	C	C	C	2	4	2	3	3
C	Inappropriate portion size (C_1)	0.222	0.285	0.214	0.208	0.180	C	E	C	C	E	1	3	2	1	5
	Buffet style leading to over-taking (C_2)	0.210	0.171	0.208	0.194	0.276	E	E	C	C	E	4	5	3	2	3
	Large menus (C_3)	0.224	0.254	0.127	0.245	0.237	E	E	C	E	E	3	4	4	4	4
	Poor waste management (C_4)	0.206	0.141	0.233	0.235	0.194	E	C	E	E	C	5	2	5	5	1
	Poor layout of facility (C_5)	0.138	0.149	0.219	0.118	0.113	C	C	C	C	C	2	1	1	3	2
D	Staff mishandling (D_1)	0.192	0.266	0.256	0.147	0.160	E	E	E	C	E	4	3	3	3	4
	Miscommunication between management & staff (D_2)	0.278	0.398	0.188	0.256	0.264	E	E	C	C	E	3	2	2	2	3
	Unskilled staff (D_3)	0.263	0.156	0.251	0.326	0.267	C	C	E	C	E	2	1	4	1	2
	Attitude towards food waste (D_4)	0.268	0.180	0.305	0.270	0.309	C	E	C	E	C	1	4	1	4	1
E	Customer attitude, values and behaviours towards food (E_1)	0.174	0.202	0.236	0.155	0.103	C	E	C	C	C	2	2	1	1	1
	Random customer purchase (E_2)	0.153	0.188	0.149	0.117	0.157	E	E	E	E	E	5	3	5	5	4
	Different dietary preference of customers (E_3)	0.175	0.345	0.267	0.114	0.103	C	C	E	C	C	1	1	3	2	2
	Considering food unattractive (E_4)	0.163	0.121	0.100	0.196	0.156	E	E	C	E	E	4	5	2	4	5
	Over-ordering (E_5)	0.335	0.143	0.248	0.419	0.481	E	E	E	E	E	3	4	4	3	3

C – cause; E – effect

Procurement and storage: Across the sector (G), in CS, T and P it has been discussed that the focus should be on procurement and storage and this finding is consistent with Charlebois et al. (2015). However, in our study, restaurants regard procurement and storage as 4th priority (see column 14 for combined priority rank, in Table 12) but it does not mean that restaurants can ignore this factor because the AHP weight is the second highest for restaurants. The lower priority rank may be attributed to the interrelationship of five dimensions, where the procurement and storage factor in the restaurants is more susceptible to other cause enablers compared to other types of business. This suggests that restaurant managers should address this factor after other cause enablers.

Difficulty in forecasting (A_1) is the conclusive determinant in G, CS and R. This enabler could lead to over-stocking and forgotten and spoiled food (Charlebois et al., 2015; Derqui et al., 2016), which is also supported by our findings. The management implication is that CS and R could collect and analyse relevant historical data to improve their forecasting ability and prevent food waste effectively (Priefer et al., 2016). However, the findings from T and P illustrate the implication in a different direction. In takeaways, the determinant cause of food waste is lack of a purchase plan instead of difficulty in forecasting. The purchase plan is an important aspect that strongly impacts on food waste generation in the industry (Baldwin, 2012; Charlebois et al., 2015). This finding reveals that managers in takeaways should purchase the raw material with appropriate planning and organizing to reduce inventory surplus.

Processing: The findings support the literature that processing plays an important role in food waste generation (Derqui et al., 2016; Priefer et al., 2016). For restaurants, it has the highest rank and for G, CS and P, this level takes second and third priorities. Regarding sub-enablers, unawareness of cooking amount is the most contributing factor towards food waste in G, CS and T, while the strict regulation in restaurants and pubs. For most coffee shops and takeaways, the food (e.g. sandwiches, chips, fried chicken) is often pre-done before customers coming, but most restaurants and pubs tend to follow the "make to order" principle and confirm the exact cooking amount in advance, which is probably why unawareness of cooking amount has a higher impact on coffee shops and takeaways. Furthermore, unsuitable food due to preparation residue, over-cooked food and food waste due to lack of equipment and tools would be disposed of due to existing food safety regulations (Charlebois & Hielm, 2014). Therefore, the managers in restaurants and pubs should focus on (1) targeting the root causes of food waste and reduce them accordingly; and (2) establishing a treatment plan to handle waste (i.e., overproduction) that can be used as, for instance as pet food or compost (Betz et al., 2015).

Operation strategy: For G, CS, T and R, the operation strategy level is positioned as 3rd in the priority, whereas pubs consider this dimension as 4th. Papargyropoulou et al. (2016) discuss that restaurant operations are one of

the main food waste drivers, and our study indicates that operation strategy is important and should not be ignored and addressed in order of priorities. Inappropriate portion size seems to be the most critical factor for the sector (G) and restaurants, and it is consistent with Betz et al. (2015). This suggests that restaurants can deal with excessive size by adapting the portion size to customer needs (Sakaguchi et al., 2018). For CS and takeaways, poor facility layout is the main factor for food waste generation, and our findings are different to the study by Derqui et al. (2016) where kitchen design and layout in the restaurant was not an important contributor to food waste. Panisello & Quantick (2001) discuss that the poor facility layout may hinder communication or service of the food, leading to food waste. In pubs, poor waste management is the main waste factor; therefore designing effective waste disposal practice could be beneficial. Poor waste management is also seen as the least important factor across the sector (G), takeaways and restaurants. This result reveals that food waste management would not be identified as the main factor in the sector, which might indirectly illustrate why food waste management has not received enough attention.

People: This level mainly refers to the food waste enablers related to the staff and for G, CS and T, it is ranked as 4^{th}, whereas it comes 5^{th} for pubs. Restaurants have a different view where people dimension should be taken into account as a second priority. This difference may imply that the staff enablers have a stronger impact on the restaurants than other types, thus restaurants should be more concerned with staff enablers to minimise the food waste effectively. The literature also discusses that staff enablers contribute considerably towards the food waste in the catering industry (Baldwin, 2012; Charlebois et al., 2015).

Usually for the business, collecting and recycling food waste can be costlier compared to disposal, thus staff are allowed to throw away food waste into the general bins without any further action (Gustavsson et al. 2011). Our findings indicate that attitudes toward food waste are the main cause of waste when some food could have been reused rather than disposed of. Takeaways and pubs should raise staff awareness related to sustainability through staff training and appropriate actions. In CS and R, the unskilled staff is a major contributor to food waste where staff mishandling and miscommunication in the workplace should be improved through essential staff skills training.

Consumer: This level considers food waste enablers that come from customers. Across the sector (G), CS and R, it is identified as the last priority for consideration, where customers might not be crucial to minimise the food waste in the context of this study. Considering sub-enablers, different dietary preferences are a conclusive determinant across the sector (G) and for coffee shops. This could increase the difficulty in determining procurement, preparation and cooking amounts (Baldwin, 2012). Noticeably, different dietary preferences are

objective enabler because food companies cannot control what customers would like to eat. For coffee shops, this cause can be handled by communicating with customers regarding serving size before preparing and cooking. In the other three business types, customer attitudes, values and behaviours towards food are considered as the primary cause of food waste which was supported by Lorenz et al. (2017). Companies should create customer awareness related to waste issues through active engagement. An unattractive food factor has low priority in this study, and it could be linked to the fact that most businesses are unwilling to admit that their food is not attractive.

6. Conclusions

The research presented a food waste mitigation methodology that should help businesses to design effective food waste prevention and reduction strategies. To this end, this paper aims to identify the main enablers of food waste and then guide managers to target root causes by conducting the cause-effect analysis. A hybrid AHP-DEMATEL approach is proposed to perform this analysis and to identify the relative importance of cause and effect enablers. This paper targeted the catering sector in identifying five levels (i.e., procurement and storage, processing, operation strategy, people and consumer). Data required for applying the AHP-DEMATEL approach was collected from 32 participants with management responsibilities from businesses in the catering sector in Wales, UK. Based on an application of AHP-DEMATEL approach, a holistic cause-effect diagram was developed to graphically illustrate the relationships among causes and effects of food waste. Those groups were also prioritized and sequenced vis-à-vis their relative importance from practitioners' perspectives.

6.1 Theoretical and managerial implications

This research provided an original contribution both to the academic research field and to practitioners. The proposed methodology used multi-criteria decision-making methods and provided new insights into major food waste enablers when considering the level of importance and causal relationship simultaneously. It presented a holistic cause-effect analysis for food waste enablers and evaluated and compared the importance of interrelationships and assessed the priorities among various food waste factors. This study, for example, shows that the procurement and storage is the cause of food waste for all outlets except for restaurants where this enabler is an effect. The same observation is for processing in the takeaway. Poor facility layout is the only cause across all outlets that indicate its strong impact on operation strategy. The cause-effect analysis played a key role in the identification of where to design future strategies to mitigate food waste for different types of businesses. It would not be possible to achieve without the use of MCDM methods. The AHP method hereby helped in revealing the most important food waste enablers; that might guide the strategies and priorities towards food waste mitigation.

Furthermore, the DEMATEL method allowed to perform cause-effect analysis for all food waste enablers and sub-enablers towards understanding the interrelationship among them and accordingly, categorize them as cause enablers and effect enablers. The identified cause enablers are prioritized based on the AHP outcome. Therefore, it can be argued that the research methodology presented in this paper can be re-visited by scholars in food waste management to explore root causes of food waste for different sectors and at different stages throughout the supply chain. In addition, it could also benefit researchers in sustainable supply chain management to undertake cause-effect and relative importance analysis of a particular topic's enablers. This methodology can also be used to categorize enablers of supply chain resilience as causes and effects and then prioritize targeted causes based on their weight. Similarly, this could improve the management and decision making of outsourcing risks.

From an industrial marketing perspective, the results will support the design of a more effective sustainable marketing strategy, continuous development and commitment to a greener corporate image. This methodology could also be used to analyse causes and effects of traditional criteria (e.g., cost, and quality) and green criteria (e.g., green resources, and low carbon footprint) to understand consumers' commitment towards greener products. The research contributions inspire B2C and B2B firms towards more dedicated food waste mitigation and reduction strategies in the downstream supply chain, instead of strategies that might lead to temporary enhancement as they direct both enablers and causes. Thus, arguably, this paper contributes to the causes-effects analysis literature, not merely in proposing the AHP-DEMATEL methodology, in targeting the food waste, but also in exploring how this methodology leads to an in-depth analysis of a multifaceted causes-effects industrial marketing or supply chain problems orchestrated by a holistic, instead of compendious, methodological-analytical tactic.

For practitioners, the proposed methodology could help food businesses to recognize the levels of importance and interrelationships of various enablers that exist in different dimensions. By understanding degrees of importance and interrelationships, the business could assess the priority of food waste enablers in each dimension. In doing so, companies can design effective strategies to reduce waste by targeting the most significant causes instead of dealing with all the causes at the same time. For example, the research outcome demonstrated that decision makers in all outlets except for restaurants would be encouraged to address food waste causes in the procurement and storage as the first priority as they revealed the most relative important causes. Decision makers should also notice that some enablers could be either causes or effects based on the considered sector/business type. In this work, for instance, they should target lack of purchase plan, lack of equipment and tools, and customer attitude towards food in takeaways, restaurants and pubs and ignore them in coffee shops as they represent as

effects in the latter. In the same context, the results showed that for restaurants, processing has the highest importance, and for coffee shops and pubs it had second and third priorities. Also, the procurement and storage enabler turned out to represent one of the most effective factor in restaurants. It is well known that resources are scarce in this sector, as a large proportion of companies are considered as micro-businesses or SMEs. Therefore, addressing the most crucial factors of food waste could reduce food waste issues with limited resources and create the maximum value for the business. The developed methodology could be applied as a strategic tool in daily operations to prevent food waste in advance by managing and controlling the major causes.

6.2 Future research avenues

Future research can include different actors in the entire supply chain. The proposed food waste mitigation approach could be used to undertake cause-effect analysis for food waste enablers at a business-to-business level between, for example, suppliers and distributors, between suppliers and food manufacturers or between distributors and foodservice providers. This may help to identify further correlations and relationships among food waste enablers throughout the supply chain that can be addressed via a more integrated supply chain management. This approach will help to establish visibility throughout the supply chain towards food waste mitigation via shared food waste enablers. Difficulty in forecasting was identified as a cause enabler, thus it would be beneficial to undertake analysis of the relationship between current forecasting and inventory management approaches to understand links between food waste and supporting strategies. This could lead to the development of revised forecasting/inventory management techniques to mitigate food waste accordingly. On the people level, mishandling and unskilled staff were highlighted as an enabler of food waste where additional training and investment is required. The cost analysis between training costs and food wasted could be another area of exploration. Another research avenue could explore the behaviour of customers and managers in different cultures to allow further transferability of the findings presented.

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