The role of digital platforms in e-commerce food supply chain resilience under exogenous disruptions

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Abstract

Purpose – Operational risks can cause considerable, atypical disturbances and impact food supply chain (SC) resilience. Indicatively, the COVID-19 pandemic caused significant disruptions in the UK food services as nationwide stockouts led to unprecedented discrepancies between retail and home-delivery supply capacity and demand. To this effect, this study aims to examine the emergence of digital platforms as an innovative instrument for food SC resilience in severe market disruptions.

Design/methodology/approach – An interpretive multiple case-study approach was used to unravel how different generations of e-commerce food service providers, i.e. established and emergent, responded to the need for more resilient operations during the COVID-19 pandemic.

Findings – SC disruption management for high-impact low-frequency events requires analysing four research elements: platformisation, structural variety, process flexibility and system resource efficiency. Established e-commerce food operators use partner onboarding and local waste valorisation to enhance resilience. Instead, emergent e-commerce food providers leverage localised rapid upscaling and product personalisation.

Practical implications – Digital food platforms offer a highly customisable, multisided digital marketplace wherein platform members may aggregate product offerings and customers, thus sharing value throughout the network. Platform-induced disintermediation allows bidirectional flows of data and information among SC partners, ensuring compliance and safety in the food retail sector.

Originality/value – The study contributes to the SC configuration and resilience literature by investigating the interrelationship among platformisation, structural variety, process flexibility and system resource efficiency for safe and resilient food provision within exogenously disrupted environments.

Keywords E-commerce food supply chains, Digital platforms, Exogenous disruptions, Resilient operations, Industry case studies

Paper type Research paper

1. Introduction

Compound risks and disruptive events highlight supply chain (SC) vulnerability, even if tier-level stakeholders operate according to lean and globalised structures (Ivanov *et al.*, 2016). To this end, SC reconfigurability in terms of structural variety, process flexibility, business model evolution and resource efficiency are necessary for SCs (Dolgui *et al.*, 2020). In turbulent environments, as industries and technologies drive role diversity among involved SC stakeholders, the issues of resilience and efficiency become progressively more critical (Xu *et al.*, 2020). Indicatively, the COVID-19 pandemic had a pernicious effect on all manufacturing and logistics operations (Singh *et al.*, 2021), explicitly challenging the resilience of food SCs due to upstream and downstream disruptions and the interconnectedness with other networks (Ivanov and Dolgui, 2020).

In the UK, the COVID-19 pandemic severely impacted the food system due to nationwide stockouts that led to diminished supply capacity, challenging the ability of the retail and home-delivery echelons to fulfil the escalating demand (Power *et al.*, 2020). Contemporarily, UK dairy farmers discarded significant amounts of milk due to diminished demand from culinary business operations such as cafes, restaurants and offices following the coronavirus-induced lockdowns (Drury, 2020). Output losses in the aggregated UK accommodation and food services sector were estimated at 85% relative to the sector-wide baseline following the COVID-19 pandemic disruptions, ranking second only behind the education sector (Office for Budget Responsibility, 2020). Evidence from e-commerce businesses demonstrated the role of digitalisation, particularly digital platforms, in fostering resilience to disruptions such as the COVID-19 pandemic (Han *et al.*, 2022).

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Digital platforms, a constantly evolving phenomenon (Joglekar *et al.*, 2022), offer a medium that bridges the gap between producers and consumers through processes of disintermediation. For example, Facebook is a social media platform that has transformed how people interact and engage (Parker *et al.*, 2016). Payment platforms such as Alipay and Apple Pay are disrupting the financial industry, and platforms such as Uber and Airbnb heavily disrupted the sharing economy (Dablanc *et al.*, 2017; Parker *et al.*, 2016). In the food sector, digital platforms enable seamless and digitally connected e-commerce transactions (Cenamor *et al.*, 2017; De Reuver *et al.*, 2018). To a greater extent, food delivery platforms (e.g. Doordash and Uber Eats) and their environmental sustainability practices can influence the volume and value of transactions, depending on customers' attitudes and behaviour (Chan *et al.*, 2023).

The extant body of literature often regards SCs as a set of interconnected processes vulnerable to multidimensional risks (Wagner *et al.*, 2014). Research efforts have focused on assessing risks and SC resilience using network performance indicators such as eigenvector centrality, hub, authority, closeness and betweenness (Ledwoch *et al.*, 2016). However, such metrics often originate from graph theory (i.e. measure node centrality) and are relatively static in nature, without being able to capture the dynamic behaviour of disruptions and node responses. Furthermore, extant efforts explore myopic "risk-response" strategies that advocate the targeted allocation of constrained resources based on a single criterion and objective, following the main principles of the well-known Knapsack problem regarding the effective allocation of the available resources (Cox, 2012). Conversely, some studies focused only on contingency planning, seeking to calculate high-quality solutions in a short computational time about resource allocation (Moazeni and Collado, 2021).

Notwithstanding the importance of food SCs, a dearth of literature exists exploring the role of digitalisation in enabling/inhibiting such systems' resilience. To this effect, the objective of this research is to investigate the enabling role of digitalisation and, specifically, digital platforms in reconfiguring e-commerce food SCs towards resilience during major exogenous disruptions. Therefore, this study attempts to respond to the following research question:

RQ1. How may digital platforms reconfigure food supply chains for more resilient operations during exogenous disruptions?

A multiple case-study approach was used to respond to the enunciated research question. The research focused on established and emergent digital food platforms within a specific geographic region to ensure regulatory consistency. In particular, UK-based case studies were selected due to the breadth of maturity and prevalence of e-commerce food business operations during the timeframe of the COVID-19 pandemic. Furthermore, e-commerce food business operations have a significant social impact in the UK by fostering employment. For example, a single operator helped create 25,000 jobs in the UK restaurant sector within a few years (i.e. 2013–2018), with pre-coronavirus projections estimating an equivalent of about 70,000 restaurant jobs in 2020 (Basul, 2019). Data triangulation through expert interviews allowed us to develop further insights into network design adjustments for more resilient e-commerce food SCs.

The role of emerging technologies (e.g. platforms) in digital business transformation for operational excellence and sustainability is highly motivated (Akter *et al.*, 2022). This research contributes to the operations management literature by unveiling enabling mechanisms and their attributes for developing SC resilience via extensibility, product substitution and real-time order analysis within an evolving digital ecosystem. The underlined interplay dynamics within the "digital technology – supply chain" system structure for assessing operations-wise benefits is a prominent gap in the community (Sodhi *et al.*, 2022).

The remainder of this research is as follows. Section 2 outlines the research background pertinent to SC elements investigated in this study, namely,

- platformisation;
- structural variety;
- process flexibility; and
- system resource efficiency.

Section 3 describes the theoretical perspective and methodology applied to address the enunciated research query. Section 4 inserts the study results, whereas Section 5 discusses the research findings and proposes a conceptual framework. Finally, Section 6 concludes with theoretical contributions, practical implications, limitations and future research avenues.

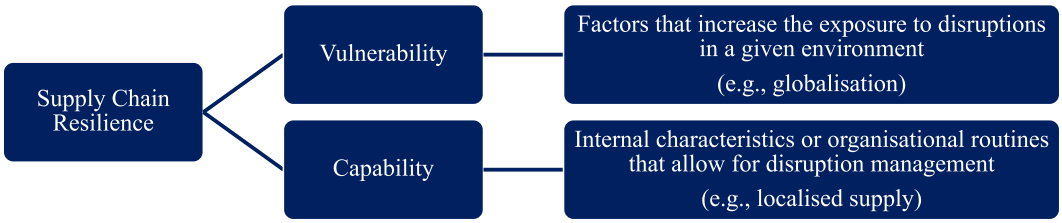
2. Research background and literature review

The digitalisation of the food sector, following significant disruptions and the subsequent operational needs of food business operators, motivates the restructuring of the pertinent SCs (Dolgui *et al.*, 2020). High-impact-low-frequency or catastrophic exogenous disruptions, similar to the COVID-19 pandemic, can potentially derail single- and multi-echelon SCs (Masys *et al.*, 2014). Indicatively, the Tohoku earthquake and subsequent tsunami in Japan in 2011 created issues related to the supply of automotive microcontroller units and had a detrimental impact on the domestic automotive industry due to the strategic choice of just-in-time inventory management and lean SC operations (Matsuo, 2015). Although SCs have encountered the challenges of high-impact-low-frequency disruptions, limited research in the extant literature has focussed on the enabling role of digital technology in managing resultant food sector discontinuities for improved resilience.

2.1 Supply chain resilience

SC resilience is an organisation's function of situational awareness and ability to absorb internal/external disturbances while upholding its operations (Fraccascia *et al.*, 2018) and managing fundamental susceptibilities and adaptive capacity in a complex and dynamic environment (Kamalahmadi and Parast, 2016). The general notion of resilience focuses on the ability of SCs to attain their original state of normalcy; the latter concept has been extended into two categories, i.e. vulnerabilities and capabilities, as depicted in Figure 1 (Sheffi and Rice, 2005; Tang and Tomlin, 2008).

Figure 1 Resilience concept in SCs



Source: Adapted from Chowdhury and Quaddus (2017)

2.2 Supply chain disruption management

Motivated by the necessity to investigate the role of digital technologies in food SC resilience, this research embraced the concept of low-certainty-need SCs developed by Ivanov and Dolgui (2019). A low-certainty-need SC perspective refers to maintaining network resilience in multiple risk scenarios without pre-defining risk contexts (e.g. inventory). The low-certainty-need SCs notion is particularly pertinent to complex supply networks as:

- disruptions tend to propagate through multiple oppressional echelons, known as the ripple effect; and
- low-probability high-impact events tend to have a long-term structural impact on SCs, such as the inventory build-ups in the semiconductor industry that amplified the impact of the 2001 downturn (Akkermans and van Wassenhove, 2018).

Ivanov and Das (2020) confirmed digital technologies' significance in developing low-certainty-need SCs where greater flexibility can be introduced into brick-and-mortar (i.e. conventional) SCs, potentially leading to improved disruption management. Low-certainty-need SCs enhance process flexibility because of the more straightforward implementation of changes (Ivanov and Das, 2020). Nevertheless, Ciulli *et al.* (2019) identified circularity holes (i.e. "missing linkages between waste generators and potential receivers") in food SCs due to a lack of technological (platform) integration that could propel network effects (Parker and Van Alstyne, 2005). Overall, innovative digital platform technologies provide an avenue for developing low-certainty-need SCs that are better adapted to manage disruptions (Li *et al.*, 2020).

Reconfigurable SCs, in this resilience context, refer to a network designed in a resilient, efficient, sustainable and digital manner that is progressively dynamic, responsive, adaptable, data-driven and capable of swift structural changes in cyber and physical spaces (Dolgui *et al.*, 2020). Nonetheless, the nurturing capability of addressing circularity holes, associated with digitalisation, implies that diverse feedstock specifications, quality attributes and geographical dispersion of the related sources and markets drive SC reconfiguration (Srai *et al.*, 2018). To this effect, SC disruption management for high-impact-low-frequency events requires analysing four research elements:

1 platformisation;
2 structural variety;
3 process flexibility; and
4 system resource efficiency.

2.2.1 *Platformisation*

Technological innovation continues to advance with the resultant shifts in business models causing substantial restructuring across SCs (Kapoor and Vij, 2018). In addition, longer, fragmented and more complex food SCs introduce increased challenges to effective operations management (Birkie *et al.*, 2017). Consequently, digital platform-based business-model development is increasingly essential, provided that digital infrastructure enables better collaboration of SC tiers than more linear network configurations (Hahn, 2020; Parker *et al.*, 2016). Digital infrastructure extends the collaboration among SC actors by enabling a reduction or elimination of middlemen and "gatekeepers" in contemporary markets, a phenomenon referred to as disintermediation (Parker *et al.*, 2016). The emergence of digital platform business models has helped facilitate germane ecosystem characteristics such as direct transactions, data flows and shared added value between suppliers, retailers and end-users. Thus, digital platformisation refers to the process by which firms transition from a traditional, linear SC business model to a platform-based business model whereby bidirectional data flows enable mutual value-creation and exchange among network actors.

In the e-commerce food sector, digital platforms allow for real-time searching and order placement from retailers (e.g. groceries and packaged goods, recipe boxes), restaurants (e.g. pre-prepared food delivery) and consumer-to-consumer interactions (e.g. meal sharing) within the platform ecosystem (Ciulli *et al.*, 2019). Such disintermediation of processes, transactions and actors induces horizontal value-creation and network effects whereby additional platform elements allow the connection and elevated collaborative value for existing stakeholders (Hein *et al.*, 2020). Given the interoperability of actors within a platform ecosystem, a reduced need for maintaining large amounts of inventory exists (Parker *et al.*, 2016). Reduced inventory is particularly pertinent in the food sector as maintaining low-level stock is beneficial considering the associated cost savings and the perishable nature of food supplies. Although considered counter-intuitive to the just-in-time approach, the latter approaches' financial and consumer health impacts are particularly advantageous (e.g. reduced food wastage and improved consumer experience and product freshness) where product quality and obsolescence are considered.

Furthermore, digital technology integration catalyses food SC transformation (Kapoor and Vij, 2018), allowing a broader portfolio of product choices and personalisation in line with a societal shift towards greater convenience and instant gratification (Dablanc *et al.*, 2017; Mallinson *et al.*, 2016;

Kapoor and Vij, 2018). Transitioning from centralised to more agile, last-mile delivery and vertical production systems is also pertinent (Behnke and Janssen, 2020). Moreover, rapidly evolving environments indicate the importance of SC agility to address responsiveness issues in highly dynamic and customisable markets, with subsequent benefits for food access, consumer experience and efficiency. Table 1 summarises the characteristics of digital platforms.

2.2.2 *Structural variety*

In a dynamic changing operations environment, SCs have to manage risks by balancing performance (e.g. inventory level, capacity utilisation and responsiveness) while improving data flows, materials distribution and transactions, allowing for diversification, decentralisation and localisation (Chopra and Sodhi, 2004). To this end, SC design (e.g. critical nodes), typically related to structural SC formation, is vital in ensuring robustness and resilience in the emergence of SC complexity and uncertainty considerations (Dolgui *et al.*, 2018). Structural variety may be achieved through rearrangement and component reallocation/change to rapidly adjust supply and production capacities alongside functionality in response to unforeseen disruptions and acting towards improved digital SC management during crisis periods (Ivanov and Dolgui, 2019).

Structural SC properties critically impact networks' robustness and resilience (Scheibe and Blackhurst, 2018). In principle, from a semantic-level analysis perspective, SC structure is denoted by network graphs that unfold the underlying interdependencies between SC robustness, flexibility, adaptability and resilience (Ivanov *et al.*, 2017). Evidence demonstrates that different structural variations have a crucial impact on SC performance for various risk attitudes of decision-makers (Yoon *et al.*, 2018).

Digitalisation, resilience, sustainability and structural variety frame the context of reconfigurability strategies with digital SCs to prevent inflexibility and surplus in SC design through progressively data-driven market responsiveness (Dubey *et al.*, 2018). In e-commerce food SCs, enabling elements such as improved supply-demand mediation, increased responsiveness and efficient operations include the amplified omnichannel interactions between digital food platforms and SC management practices. To this end, digital platforms enable cross-sector partnerships and leverage network effects to propel waste recovery and bridge circularity holes across SCs, hence establishing the concept of circularity brokerage (Ciulli *et al.*, 2019).

2.2.3 *Process flexibility*

The difficulty of predicting and managing factors associated with external SC disruptions (e.g. timeframe) suggests that process flexibility is necessary. To this effect, e-commerce in food SCs enables significant flexibility in operations (Ciulli *et al.*, 2019; Ivanov and Dolgui, 2019). Digital technologies introduced into brick-and-mortar SCs can provide greater flexibility, potentially leading to improved disruption management (Ivanov and Das, 2020). Resilient SCs in multiple risk scenarios without the need to pre-define risk contexts (e.g. inventory) enhance process flexibility because of the more straightforward implementation of changes (Ivanov and Das, 2020). Nevertheless, Ciulli *et al.* (2019) identified circularity holes in food SCs due to a lack of technological platform integration. Overall, literature evidence confirms that digital platform technologies provide an avenue for developing flexible SCs better adapted to manage disruptions (Li *et al.*, 2020).

Chopra and Sodhi (2004) further explored the significant possibilities associated with e-commerce food provision. The difficulty of predicting and managing factors associated with exogenous SC disruptions, such as the types of disruption and magnitude (i.e. timeframe, locale and food SC actors affected), suggests further developments are still required.

2.2.4 *System resource efficiency*

Resilience correlates to resource efficiency. Research evidence pointed out that if a company cannot use its resources efficiently, the ability to incorporate changes diminishes (Bottani *et al.*, 2019). Additionally, companies usually have to balance resilience and efficiency because resource utilisation in an efficient manner can reduce and minimise the ability of food companies to respond to disruptions (Umar *et al.*, 2017).

In food SCs, efficiency can be increased by reducing food waste, allowing firms to maximise their profits based on improved resource utilisation (Rohm *et al.*, 2017). Nevertheless, given the severity of food waste globally, modern food systems require substantive solutions. According to the Waste and Resources Action Programme, almost 10 million tonnes of food waste is generated annually in the UK from food manufacturing,

Table 1 Characteristics of digital platforms

Characteristic	Description	Reference(s)
• **Modularity**	Purely technical artefacts, extensible codebase, with a digital ecosystem consisting of multiple third-party modules	Tiwana *et al.* (2010)
• **Interoperability**	Software-based codebases in which shared core functionality enables interoperability among these modules and facilitator interfaces	Ghazawneh and Henfridsson (2015)
• **Compatibility**	Shared set of technologies, architecture, services and components to serve the diverse group of actors and create value	Gawer and Cusumano (2002); Gawer (2014)
• **Network effects**	Multisided marketplaces, where value is created through interactions, enable the multiplication and replication of traditional market activities	Still *et al.* (2017)
• **Disintermediation**	Incorporate e-commerce marketplaces and extend to interactive ecosystems, leading to disintermediation and network economics	Parker *et al.* (2016)
• **Integration**	Online, multisided marketplaces bridge the gap between digital and physical processes and activities	De Reuver *et al.* (2018)

Source: Authors' own work

retail and wholesale companies, of which ~70% was fit for human consumption (WRAP, 2019). Furthermore, Power *et al.* (2020) outlined the potential that the COVID-19 pandemic would have in increasing UK food insecurity and subsequent negative externalities such as diet-related health inequalities. Therefore, there is a need for real-time solutions that can minimise such negative impacts (i.e. food waste) and improve efficient and resilient operations. Concerning efficiency, the notion of circularity brokerage can be integrated (i.e. system resource efficiency) (Ciulli *et al.*, 2019).

To summarise, extant literature explores explicit dimensions, such as SC resilience, SC disruption management, efficiency and digital platform technologies. The aggregation of the presented four elements provides for the development of a distinct context, namely, one that examines core themes of SC resilience and efficiency but also applies to a digital SC (i.e. digital platform) context. Therefore, this research expands upon a necessity for exploration of major SC disruption (e.g. COVID-19 pandemic) where challenges such as resource constraints (i.e. high-impact-low-frequency events) in tandem with the interplay between digital technologies (e.g. digital platforms, artificial intelligence (AI), internet of things (IoT) and analytics) and their evolving impact on each of the aforementioned four individual areas remain underrepresented (Sodhi *et al.*, 2022; Akter *et al.*, 2022). Table 2 summarises these four areas, along with highlighting key definitions and components for each of the framed elements.

3. Methodology

A multi-layered research design was adopted to ensure rigour (Saunders *et al.*, 2009). The research philosophy and approach relevant to this study are specified in the following subsections.

3.1 Research philosophy

This research used an epistemological, interpretive stance to explore the relationship between theory and practice (de Vries, 2020; Eisenhardt, 1989). Due to limited specific data surrounding digital food platform contributions to resilience in times of disruption, the interpretivism paradigm helped to obtain a range of perspectives that contribute to understanding the role of digital platforms as technology innovation in food SCs (McChesney and Aldridge, 2019).

Interpretive research assumes that study evidence and conclusions stem from explanations of information obtained from different participants and sources (Žukauskas *et al.*, 2018). Such a paradigm allows researchers to obtain a detailed perspective on the subject under investigation. The research process involved the review of subject-related literature and the gathering and triangulation of primary data in deriving meaningful outcomes (Golafshani, 2003). This involved the development of key research themes from existing theoretical knowledge and empirical observations.

3.2 Research approach

Considering the exploratory positioning of this study, the collection of qualitative data to link research objectives, questions and units of analysis are consistent with the interpretive qualitative research approach within epistemological techniques (Langley and Abdallah, 2011). This approach involved subject-related literature, data collection and triangulation (Golafshani, 2003). Figure 2 summarises the research approach flowchart detailing the steps adopted to conduct this study.

3.2.1 Industry case studies

A multiple case study approach was adopted to allow for comprehensive insights and achieve research credibility (Yin, 2013). Considering the dynamic nature of the COVID-19 pandemic, the case study approach facilitated the collection of recent and relevant data from primary stakeholders (Power *et al.*, 2020; Yin, 2013) and helped capture a breadth of the underpinning complexities of the phenomenon, hence contributing to high practical relevance (Baxter and Jack, 2008).

Data collection was conducted through semi-structured interviews (one interview conducted per case with the relevant C-level executive). Drawing on the conceptual framework, twelve questions aligned with key framework elements were used to explore individual case scenarios. The UK food sector served as the research context, with digital food platforms within the UK food SCs landscape being the central unit of analysis. Specifically, evidence from three established (i.e. platformised) food business operators with proven e-commerce operations (Case #1 to Case #3) and four emergent (i.e. platformising) food business operators with developing e-commerce operations (Case #4 to Case #7) was incorporated as part of our multiple case study, ensuring a variation in terms of stages of evolution of the involved cases.

Case interview questions (inserted in Table A1 in Appendix 1) incorporated four key research elements:

1. platformisation;
2. structural variety;
3. process flexibility; and
4. resource efficiency.

Table A2 in Appendix 1 summarises the industry case studies' background and data collection process, including respondent positioning within each organisation, interview length and validation processes.

3.2.2 Data triangulation

Our study rigour relies on the Gioia method, a qualitative methodological approach to developing data analysis that meets trustworthy research standards (Gioia *et al.*, 2013). The Gioia methodology has been used in pertinent digitalisation studies to capture relevant and recurrent concepts over interviews (Denicolai and Previtali, 2023). In particular, for data triangulation purposes, multiple industry case study evidence, company documents, second-order themes using coding and multiple instances of the same phenomena following the Gioia method and emerging operational framework were tested by seven experts.

Semi-structured interviews were used to better understand perspectives and preferences regarding the key phenomenon, with the potential for more personalised, detailed responses to specific questions. Interview questions were shared with all experts prior to the interviews to ensure clarity, understanding and subsequent consent for the process. The experts' interview protocol is provided in Table A3 in Appendix 2.

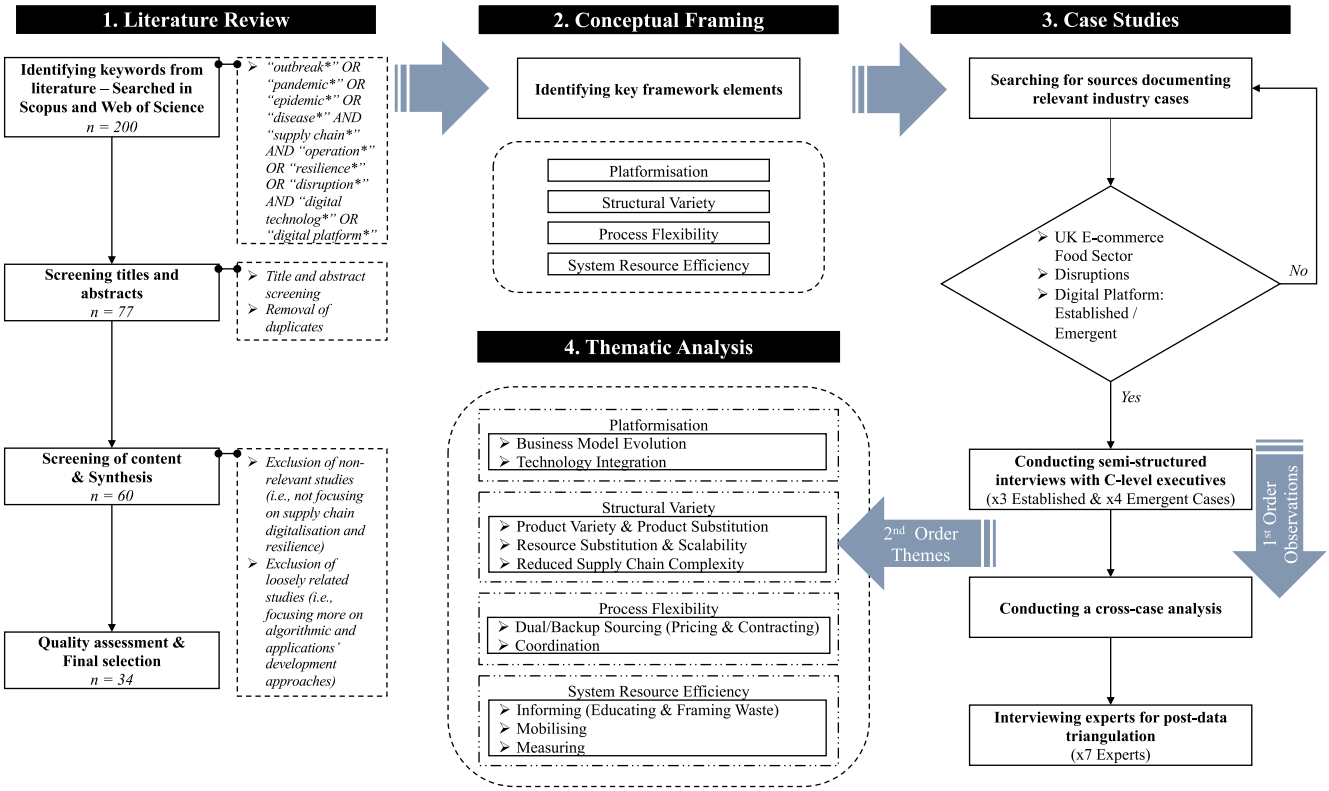
Interviews with seven experts were conducted, who are affiliated with distinguished UK academic institutions, organisations and the technology/food industry. The selected experts represent significant areas of expertise, proficiency and

Table 2 Summarised literature review findings with topic-based components

Topic	Definition	Relevant literature components	Key authors
Element 1: Platformisation	Platformisation refers to the process by which firms (e.g. food business operators) may transition from a traditional, linear SC business model to platform-business-models whereby bidirectional interactions enable mutual value-creation and exchange among SC actors	• An extensive transformation is occurring in food ecosystems, presenting a plethora of benefits for SC actors, food safety and access (i.e. resilience and efficiency) • Bidirectional data flows enabling mutual value creation and exchange among network actors • In the e-commerce food sector, digital platforms allow real-time searching and order placement, inducing horizontal value creation and network effects • Digital platform-based business model development is increasingly essential, allowing better collaboration and disintermediation in supply chains	(Akter *et al.*, 2022); (Behnke and Janssen, 2020); (Cenamor *et al.*, 2017); (Chan *et al.*, 2023); (Ciulli *et al.*, 2019); (Dablanc *et al.*, 2017); (De Reuver *et al.*, 2018); (Dolgui *et al.*, 2020); (Hahn, 2020); (Han *et al.*, 2022); (Hein *et al.*, 2020); (Ivanov and Dolgui, 2019); (Ivanov and Das, 2020); (Joglekar *et al.*, 2022); (Kapoor and Vij, 2018); (Li *et al.*, 2020); (Mallinson *et al.*, 2016); (Parker *et al.*, 2016)
Element 2: Structural variety	Refers to a breadth of interchangeable raw materials, components and products available within an interactive platform ecosystem required for procurement to intermediates or final customers. Reduced complexity and unified SC interactions aid in reducing the need for "certainty" throughout a SC network	• In a dynamic environment, supply chains must manage risks by balancing performance and efficiency while improving data flows, materials distribution and transactions • Achieved through rearrangement and component reallocation/change to adjust supply and production capacities in response to disruptions • Crucial for robustness and resilience, with different structural variations impacting supply chain performance • Different structural variations crucially impact supply chain robustness and resilience	(Akter *et al.*, 2022); (Dolgui *et al.*, 2018); (Dolgui *et al.*, 2020); (Chopra and Sodhi, 2004); (Ivanov and Dolgui, 2019); (Ivanov *et al.*, 2017); (Scheibe and Blackhurst, 2018)
Element 3: Process flexibility	Refers to the ability of production, sourcing and transportation systems in SCs to change/adapt in line with dynamic environments. Backup and dual-sourcing, product substitution and production capacity with coordination have been identified as major elements of SC flexibility	• Necessary due to the difficulty of predicting and managing factors associated with external SC disruptions • Enabled by digital technologies introduced into brick-and-mortar supply chains, providing greater plasticity for improved disruption management • Resilient supply chains enhance process flexibility by simplifying the implementation of changes in multiple risk scenarios • Necessitated by the difficulty of predicting and managing factors associated with external supply chain disruptions • Enabled by digital technologies in food supply chains, providing flexibility and contributing to improved disruption management • Need for process flexibility in supply chains to facilitate adaptability to turbulent environments	(Ciulli *et al.*, 2019); (Dolgui *et al.*, 2020); (Ivanov and Dolgui, 2019); (Li *et al.*, 2020); (Xu *et al.*, 2020)
Element 4: System resource efficiency	System resource efficiency is defined as the correlation between resilience and the efficient utilisation of resources, particularly in the context of minimising food waste and addressing circularity holes to enhance overall efficiency and resilience in food supply chains. A mechanism whereby digitally enabled linkage (e.g. among waste generators and potential receivers) is formulated to inform, mobilise and integrate circularity holes within SC operations aiming to increase resource efficiency (i.e. reduce waste)	• Resilience is correlated with resource efficiency, with efficient resource utilisation reducing the ability of companies to respond to disruptions • In the context of food supply chains, reducing food waste is a key aspect of improving resource efficiency • Circularity brokerage, integrating system resource efficiency, addresses circularity holes, contributing to more efficient and resilient operations • Resilience correlates with resource efficiency, where efficient resource utilisation is essential for incorporating changes • In the context of food supply chains, improving efficiency involves reducing food waste and addressing the severity of global food waste issues • The concept of circularity brokerage is integrated into system resource efficiency, contributing to more sustainable and resilient operations	(Akter *et al.*, 2022); (Bottani *et al.*, 2019); (Ciulli *et al.*, 2019); (Dolgui *et al.*, 2020); (Umar *et al.*, 2017); (Power *et al.*, 2020); (Rohm *et al.*, 2017); (Sodhi *et al.*, 2022); (WRAP, 2019)

Source: Authors' own work

Figure 2 Research approach flowchart



Source: Adapted from Ho *et al.* (2022)

exposure to potential ecosystem development pathways from which valuable, practicable recommendations could be divulged and serve as an initial roadmap to developing resilient food SCs. The experts' salient points are inserted in Table A4 in Appendix 2. The expert interviews helped triangulate and refine the gathered data and further comprehend the resilient SC ecosystem development. In this regard, a comparison of experts' perceptions alongside cross-case analysis about the influence of digital food platforms on reconfiguring food SCs for greater resilience occurred.

3.2.3 Data analysis

The data analysis approach used in this research is aligned with a systematic approach, e.g. grounded theory, by applying all interpretative steps to assure credibility, dependability, confirmability and transferability (Kaufmann and Denk, 2011). Specifically, qualitative thematic analysis was used in the retrieved primary data to derive themes and insights through using the NVivo-12 software. Descriptive, thematic and structured coding (i.e. framework analysis) were incorporated to maximise the reliability of the analysis regarding the given context, as further outlined in the literature (Braun and Clarke, 2006; Edwards-Jones, 2014).

Data stratification was performed to extract first- and second-order themes via analysing the food business operators' transcripts using the NVivo-12 software. An in-depth cross-case analysis was performed, whereby key individual industry case findings were synthesised to develop well-rounded and meaningful conclusions inclusive of individual contexts (Crossman, 2020). Data saturation occurred in line with suggestions by Saunders *et al.* (2018).

4. Results

This multiple industry case study research helped explore the impact of digitalisation on building food SC resilience amidst exogenous disruptions.

4.1 Food business operators

Food business operators were investigated in terms of the four key framework elements deriving from the literature, i.e. platformisation, structural variety, process flexibility and resource efficiency. These elements are exemplified below.

4.1.1 Platformisation

Platformisation was conceived as a business model evolution with technology integration. Case #1 experienced a consistent increase in application usage during the initial lockdown period (consumer listing increased by >30%), partly due to both unsold food supplies from local businesses needing redistribution and due to higher food surplus at the consumer level. Low asset ownership and specificity meant that when initial SC disturbances arose due to the COVID-19 pandemic, Case #1 was able to rapidly grow its user base, adding to an already loyal platform community. In parallel, Case #1 upscaled services and operations due to its interactive platform business model, enabling rapid resource provisioning in line with demand: "Our

digital-first approach has greatly aided our day-to-day operations, especially when tackling disruption-related food provision challenges. Seamless platform integration has offered our organisation a whole array of benefits".

Case #2 used a hybrid-business model whereby partner self-delivery business comprised approximately 80% of order fulfilment. Pre-pandemic, Case #2 focused solely on demand-matching and relied on food providers (i.e. restaurants) to provide their own logistics services to customers upon ordering via Case #2's digital platform. This operation mode differed notably from alternative food order aggregators; however, at the time of data collection, Case #2 had evolved to provide up to 20% order fulfilment via proprietary delivery means. Therefore, Case #2 achieved a considerably higher EBITDA than other food order aggregation platforms: "We are an interactive marketplace aiming to provide a convenient medium for consumers to visit any time of the day and find all that the local area has to offer". March 2020 saw increased mergers and acquisition activity with other established delivery platforms, allowing further growth into another 20 countries. To this effect, the onboarding of >300 businesses in approximately three to six months was observed, with many exclusive (e.g. fast food) entrants to the market resulting in the strengthening of lunchtime offerings.

Case #3 used a "gig economy" logistics-based business model to offer customers restaurant and grocery item deliveries. Case #3 implemented new e-commerce features/capabilities and services, i.e. service expansion to groceries and spearheading safe food provision through platform-to-user/partner interaction. Earnings were up to 35% commission per order, depending on courier type. Furthermore, multi-technology integration such as predictive analytics and AI ensured that the experience of the customers, restaurants and delivery partners could be augmented.

In addition, Case #4 upscaled the operations via a third-party platform (i.e. Facebook) as the e-commerce marketplace, where previously, Case #4 created an advertisement page on the platform prior to the COVID-19 crisis: "Having begun offering non-digitalised services to local consumers locally, we quickly saw the huge benefits compared to previously time-consuming and difficult operations".

Due to the imposed mobility restrictions throughout the lockdown periods, the original model of Case #5 about event catering was no longer viable. Case #5 highlighted the business model transformation, where day-to-day operations were significantly hindered as the workforce could no longer operate given the restriction of operating in a single, non-commercial premise (not purpose-built). Nevertheless, Case #5 successfully integrated several previously unexplored technologies in the digital platform infrastructure. A business model shift from physical-first event catering to digital-first food fulfilment resulted in greater flexibility concerning menu trials and product options (including product provenance considerations). Using integrated forecasting and in-application voting services resulted in a 60% increase (June 2020) in user interactions and a substantial advancement in the quality and quantity of collected operational data, both predictive and post-order.

Case #6 experienced a disruption-driven business model shift from single-source, physical-first event organising to multi-sourced digital-first food/service provision. This shift improved food business operators' functionality concerning platform-user communication (i.e. signalling availability and alternative options) and user-platform interaction (i.e. product personalisation). Disintermediation of food SC actors (i.e. supermarkets and individual caterers directly with users) was thereby enabled. Additionally, Case #6 took a step further, where integration of analytical capabilities was used to manage orders efficiently due to the higher availability of information.

Case #7 began as a market stall, which extended to events in surrounding areas, then began supplying to local cafes: 3–4 regular café partners as of July 2020. Therefore, the COVID-19 pandemic significantly affected the brick-and-mortar operations of Case #7. Operations are now predominantly e-commerce-based, with physical market sales also occurring. This operational shift from solely physical operations to incorporating platform technology (i.e. event caterers to e-commerce food operators) offers contactless delivery and collection services. Case #7 also integrated data management software, allowing for a more seamless product offering.

4.1.2 Structural variety

Structural variety was observed in the investigated cases in the form of product variety and substitution, resource substitution and scalability and reduced SC complexity. Case #1 adopts a simplified interchangeable supply, meaning that although business supplier retention is high, the uptake of new suppliers is also growing. Ensuring a mix of long- and short-term supplier contracts contributes to resilient and responsive operations. Secured contractual agreements in tandem with a fast-growing voluntary workforce (i.e. rapidly mobilised) have meant considerable growth during the pandemic. In addition, an exponential increase in product listings (i.e. >10,000 listings) was observed in a single day, which occurred for the first time since inception. In this vein, Case #1 added new channels to its digital platform to support homemade food and crafts: "User interactions and overall digital approach offered through our platform have meant that we have a wide variety of volunteers in a range of age groups, the majority of which tend to be young adults and university students who are amazing at sharing information and coordinating timely food pickups".

Case #2 elaborated a unique business model compared to similar market actors; Case #2 is not primarily a logistics platform but allows other partners to serve customers, giving them more freedom directly. Of the 45,000 partners listed on the platform, Case #2 experienced an initial sales reduction of around 50% following the initial COVID-19 pandemic outbreak, driven by:

- partner restaurant closures; and
- office closures and subsequent decline in lunchtime orders.

Case #2 added more product offerings, amounting to more than 150–170 different cuisine types, with more focus attributed to smaller food business operators than many similar-sized competitors. Indicatively, about 5,000–7,000 new restaurants joined the platform from March to September 2020. Following this initial decline in sales, Case #2 realised around 30%–40% growth because of the improved operations due to the digital platform development as data was gathered to optimise the order processes for customers and restaurants.

Case #3 has a flexible/interchangeable supply due to demand-driven resource supply ("gig economy" workforce), resulting in minimal redundant resources given partner flexibility. Case #3 reduced downtime by adapting day-to-day operations and incentivising partners to adhere to government regulations. Although Case #3, like many other food business operators, experienced an initial order volume decline following the coronavirus-related measures in March 2020, Case #3 onboarded approximately 1,400 additional partners. In particular, Case #3 expanded partnerships with grocers and supermarkets and introduced service delivery of groceries, packaged goods and hot meals. As a result, Case #3 exhibited an annual revenue growth of around 650%.

Case #4 noted that a highly interchangeable supply base increased customer retention by providing a broader product variety (e.g. bakery goods and packaged confectionaries) through local business collaborations (i.e. a local bakery). The expansion of collaborations allowed customers to experience a greater choice and variety of quality products and enabled additional delivery and operational options (e.g. through shared last-mile delivery services). The analysis of demand and order fulfilment empirical data also illustrated that certain bakery items were most popular with new and returning customers during the COVID-19 pandemic-induced disruption. The richness of acquired data allowed Case #4 to expand upon bakery items and include several health and well-being items requested via user feedback. Such data-enabled experimentation led to significant improvement in the consumer experience. Additionally, Case #4 noted that baking ingredients such as flour and yeast were in short supply during March–April 2020. This shortage led Case #4 to explore alternative supply sources and expand procurement of high-demand items, thus corroborating product/service offerings' adaptability.

Case #5 experienced limitations in facilitating an in-situ workforce due to COVID-19 pandemic restrictions and low asset ownership (i.e. commercial kitchen facilities), leading to reduced product offerings and menu rotations. Although supply localisation received increased importance given the product's freshness, durability (e.g. reduced wastage from product obsolescence) and higher efficiency in terms of time and cost, Case #5 reported greater difficulty in sourcing fresh produce for the usual variety of menu rotation. This challenge, however, led to a streamlining of product offerings based on improved data collection and heuristics (i.e. order hotspot identification), resulting in a higher-demand menu and increased revenues. Product differentiation and added user functionality increased demand for personalised items and menu collaborations.

In Case #6, following A/B testing, i.e. a simple randomised controlled experiment, in which three trial products were compared, initial demand trends were ascertained using the data-rich platform infrastructure supporting product personalisation and preferences. This substitution of key service-based offerings was possible due to disruption-related government guidelines (i.e. social distancing). Customers were positively inclined to support local businesses, thus allowing Case #6 to gather feedback, proceed to necessary service improvements and increase its customer base. The interviewed representative in Case #6 stated: "The lockdown saw a large shift in consumer behaviour, leading to increased order volume and value. This, along with a growing customer base, enabled us to gather and act upon feedback more effectively and allowed us to focus more on the products and service our customers want, such as personalised orders".

For Case #7, the use of digital platforms resulted in providing services to a broader range of customers, a significant increase in the number of menu items offered to customers and an expansion to four commercial establishments. Case #7 also diversified the workforce, hiring digital marketing expertise to provide a more seamless experience. In Case #7, post-platformisation, the procurement order time was reduced, equalling less than three days, whereas previously, the equivalent time was up to seven days in some cases. In particular, it was stated: "We have added six more dishes to the menu since going digital. Real-time orders mean we have more time to prepare and plan any menu changes well in advance and according to availability".

4.1.3 Process flexibility

Process flexibility revolves around the potential for dual/backup sourcing (involving the proper pricing and contracting arrangements) and coordination. Case #1 successfully operates with other SC actors who cannot commit to sales. It uses application-based data/heuristics targeting certain products of interest (i.e. short expiry dated products – efficiency and sustainability improvements to food waste management): "Collaboration with a major supermarket to distribute 'wonky' vegetables in an extra 300 stores has been another milestone for us [Case #1] and has helped us expand our operation and mission of reducing food waste exponentially". The platform has allowed the rapid assembly of voluntary workforce/teams to orchestrate safe and efficient food pickups from local food business operators with surplus stock (particularly pertinent given the time constraints surrounding food obsolescence). For instance, restrictions due to the COVID-19 pandemic resulted in large-scale disruptions to physical restaurant operations. Consequently, a sudden increase in demand for food redistribution services from several large-scale producers of rapidly perishable foods (e.g. dairy produce) was noted as local businesses attempted to minimise large-scale losses (e.g. financial and food losses from product obsolescence). Case #1 successfully disintermediated regular wholesale actors by coordinating over 50,000 nationwide volunteers to redistribute vast product volumes quickly. Though statistics and forecasting cannot accurately predict future demand, they help change business strategies to cater to the changing market needs. Constant platform-consumer interaction/feedback alongside A/B testing aided in process development whereby minimal resource redundancy was required given Case #1's ability to pivot and adapt to changing environments with ease: "Although there was this initial surge of activity, the agility and ability to pivot quickly and relatively easily meant that we were able to meet increasing demand effectively". Case #1 charges a small fee to the businesses for required training and support to successfully carry out the operations, but an immense communication facility on the platform helped collaborate with over 500 businesses to provide food services rapidly: "A high degree of flexibility involved with the platform approach means we [Case #1] can almost "hack" customer behaviours and experiment with different approaches to encourage platform

loyalty and ensure we are maximising our purpose and profit-driven approach". Therefore, Case #1 was able to adapt quickly to changing customer needs, behaviours and SC conditions.

Case #2 faced difficulty convincing the non-movers/late movers to join the platform. Case #2 is now working on optimising the business for delivery by onboarding partners and supporting them because they: "... saw a massive surge in demand, particularly from independent restaurants who had not traditionally done take away because those, of course, were the ones that were mostly the hardest hit during Covid-19". Case #2 invested in platform commission reduction (>£1m) for restaurants, leading to reduced platform usage costs. Furthermore, Case #2 uses digital tools such as the "circle of demand" to optimise operations (i.e. localised demand-sensing). Case #2 provided financial support to independent couriers and swiftly collaborated with the government to communicate all necessary regulations in partnering restaurants.

In Case #3, self-employed ("gig economy") delivery partners are assigned work based on real-time demand. Several new services and offerings following the onset of the COVID-19 pandemic were also introduced, namely:

- Updated application functionality with improved user integration and order visibility through an improved alert functionality for partners and customers.
- Expanded partnerships with grocers and supermarkets by adding delivery of groceries and packaged goods alongside hot meals and increased "dark kitchens" utilisation.
- Added safety functionality following disruption-driven government advice and additional delivery partner training for altered delivery mode (i.e. contactless delivery and drop-off).

Case #4 used shared delivery/logistics with partners onboarded to the platform (i.e. confectionary suppliers). Case #4 highlighted the role of digital platform operations in facilitating richer customer/supplier data, thus providing granularity in line with demand-supply availability (e.g. in the case of bottlenecks surrounding the availability of baker's flour and yeast). The digitally-enabled collection of data helped timely identify current stakeholder needs and requirements, allowing for seamless strategic responsiveness (e.g. alternate supplier sourcing) to rectify disruptive episodes. Leveraging partnerships and technology-enabled data access meant that Case #4 could adapt strategic approaches according to real-time customer and supplier needs.

In Case #5, employee numbers significantly fell during the pandemic due to government guidelines and regulations concerning health and safety. As a result, the general operation initially slackened; however, the shift towards e-commerce food provision helped to negate the related detriment and maximise capacity utilisation. Given the demand and opportunity due to furloughed employees, the operation was taking place outside holiday periods. The latter shift was also intended to be the case moving forward following the COVID-19 pandemic disruption-driven changes. Process variability was achievable via direct sourcing from suppliers, wherein operations were managed based on customer demand. Geo-netting tools improved operational efficiency since planning was based on real-time location data. The aforementioned added user functionality enabling personalisation and collaboration on menus.

Case #6 focusing on world food cuisine, while previously occupying two people, became a team of five partners following the upscaling of operations post-COVID-19 pandemic onset. The partnership with third-party confectionary suppliers allowed Case #6 to be in a position where it could fulfil all demand requirements, e.g. events ranging from small, highly personal baby-showers to more high footfall anniversaries, among others. Furthermore, user-feedback-based services aided in providing an "A-Z party bundle", including food and non-food items, such as party bags and an extended menu. Furthermore, Case #6 has a flexible (seasonal) product offering (e.g. fruits and vegetables), thus maximising accessibility and reducing negative externalities (i.e. air miles). Preference is given to sourcing raw materials from local farms and producers enabled by accurate demand-forecasting abilities.

In Case #7, process variability was achieved by localising suppliers and focusing on pre-booked orders. Real-time orders and delivery mapping increased time flexibility associated with preparing and planning menu alterations (based on supply availability) well in advance: "Before Covid-19, essential materials were purchased from supermarkets and cultural and niche shops. Given the situation, we diversified and developed partnerships with more suppliers of cooked goods so that we could provide a wider range of hot goods while also freezing minimal amounts as backup supply and having no deadstock [...]". Case #7 further added that it managed to accomplish higher process flexibility due to the use of digital platforms for analytical capabilities and further incorporating them to enrich its product portfolio and procure more efficiently. Additionally, flexibility was achieved by an increase in the number of suppliers, higher localisation and a higher ability to interchange the suppliers.

4.1.4 System resource efficiency

System resource efficiency regards informing about waste availability, measuring and mobilising for fostering exploitation opportunities. Case #1, a volunteer workforce of more than 25,000 active users and rapid adaptability facilitated by digital data flows and easily accessible application alerts and marketing, significantly supported food waste redistribution before product obsolescence. The continuous connectivity critically benefited Case #1 by allowing rapid (human) resource provisioning. Case #1 praised the importance of such connectivity for the continuation of operations during the pandemic as it allowed for unparalleled agility and responsiveness in operations (i.e. collecting surplus food from suppliers in a timely fashion) and concerning the recruitment of new volunteers. Case #1 was able to coordinate the required human resources in a few minutes via instant alerts/messages on the platform and swiftly enact necessary operations: "The immediacy of using a digital platform really helped us to react quickly and stand out; especially among local businesses and supermarkets that we were collaborating with". A near-zero inventory model helped Case #1 to improve overall SC efficiency and subsequent resilience, given that Case #1's flexible operations enable seamless and rapid transformation according to contemporaneous situations. The near-zero inventory model in Case #1 mainly regards fresh produce (i.e.

maximum of one day) and frozen produce (i.e. maximum of three days). Statistics showed that Case #1 shared over 5.4 million portions of food and saved over 720 million litres of water, corroborating the success and business growth of Case #1 following the onset of the COVID-19 pandemic.

Case #2 effectively developed and successfully integrated several technologies to analyse location-based consumer behaviour feedback to monitor demand better. Case #2 uses extensive data analytics across multiple regions, which led to the identification of dinner time delivery (i.e. 17:00–23:00) as prime order time. Case #2 also collaborated with the Sustainable Restaurant Association to raise food waste awareness. Furthermore, Case #2 invested in educating partner restaurants and platform users by providing blogs (i.e. recipes for surplus food) and up-to-date information on cooking oil recycling initiatives.

Case #3 uses a smart/intelligent algorithm to aid decision-making regarding deliveries to restaurants and estimated time for preparation, hence maximising food delivery efficiency and profits for both platform and restaurants. Case #3 also collaborated with Veolia for food waste management in the UK. As some restaurants tried to survive during the pandemic, the delivery app helped monitor demand (i.e. eliminating dead stock through promotional means) and minimise waste by connecting customers with restaurants. Furthermore, Case #3 added another feature called Table Service that allowed customers to use the app to place restaurant orders, thus improving system efficiency.

In Case #4, the prime reason that allowed the firm to minimise waste was through improved leveraging of consumer demand and supplier capacity/stock/offerings data, matching grocery suppliers with (increasing) demand during the UK lockdown periods. Therefore, the digital platform allowed placing orders to suppliers after the demand was expressed (i.e. no standing inventory). In addition, Case #4 invested in cold-chain facilities to cater to a broader customer base and product offerings (i.e. chilled meats). Case #4 also implemented bulk discounts on the leftovers/unsold goods. Notably, Case #4 focused on diverting the leftovers to charities. This strategy became possible because of the continued expansion of geographic ambitions within a few weeks (i.e. scalability benefits): "When I first experienced a lot of unsold stock, I linked up with several local charities and community support initiatives, namely the Hardship Fund, Gratitude and Gift – different organisations which work with local families in need".

Case #5 operates a third-party platform and gathers information related to users and their preferences. However, the extent to which Case #5 integrated analytics was limited due to its small size. Geo-netting tools helped adapt to changing customer needs and demands, thus increasing marketing and system efficiency. Better-targeted marketing via the platform and other digital mediums allowed Case #5 to reduce waste by providing only best-selling products, in line with reducing costs. For food waste management, Case #5 declared: "We have implemented weekly pre-booked orders, which allowed us to know exactly how much food to order/make. We only buy what we have orders for; this means we have very little dead stock and, therefore, less wastage than ever before". Additionally, the provision of lower prices and special bundle deals helped ensure faster product sales so that the waste was minimised. However, platform functionality was challenging due to a lack of purpose-built technology. Nevertheless, data-enabled supply enabled the location-based product offerings and improved digital marketing efficiency, resulting in a 7% reduction in overhead costs over five weeks (i.e. due to decreased rent and advertising costs).

Case #6 used an efficient order-fulfilment process through waste-minimisation (zero-food waste operation) facilitated by omnichannel ordering and pre-ordering. Case #6 realised reduced operating costs in the form of weekly savings of up to £50 due to weekly waste reductions (packaged food/beverages and other consumables).

Finally, Case #7 would distribute to people experiencing homelessness with minimal waste, given that demand could be predicted with greater accuracy via digital applications. Case #7 added: "We have implemented weekly pre-booked orders, which allowed us to know exactly how much food to order/make. We only buy what we have orders for; this means we have very little deadstock and, therefore, less wastage than ever before". Since the COVID-19 pandemic outbreak, operations occurred daily, with orders taken from Monday to Thursday ahead of collection or delivery. Furthermore, Case #7 helped store non-perishable items at home (e.g. spices) instead of taking limited resources to markets. All these strategies and technology implementations increased efficiency in operations and resulted in a significant waste reduction and little deadstock.

4.2 Cross-case analysis

A cross-case analysis revealed key thematic observations for the established (Table A5 in Appendix 3) and emergent (Table A6 in Appendix 3) food business operators. The analysis enabled the capture of crucial resilience and efficiency-related capabilities revolving around the four key elements, i.e. platformisation, structural variety, process flexibility and system resource efficiency.

All examined cases (Case #1 to Case #7) acknowledged that platform-based e-commerce food business operations provided many restaurants options to diversify product/service offerings and maximise business success while reducing negative impacts concerning food waste. Established and emergent food business operators (particularly Case #1 and Case #4 to Case #7), which otherwise would not have had the wherewithal to build/use the required technology to operate safely, legally and efficiently, could operate and reach new business milestones under severe pandemic-related restriction. Additionally, all seven experts highlighted digital platforms' importance and multi-faceted role in propagating SC resilience. For instance, Expert #3 stated: "Greater diversification and collaboration are needed to increase agility and responsiveness to external disruptions. This includes cross-tier assimilation regarding food provenance, delivery, and risk reduction in response to change".

Technological advancement facilitates better-connected SCs. The investigated cases had varied reactions to the platform coordination aspect, where it was noted that efficiency in operations significantly improved (e.g. Case #5 to Case #7) in tandem with considerable improvements to resilience during disruption. Alternatively, Expert #3 to Expert #7 denoted the first-mover advantage of companies digitalising their operations in the lockdown, highlighting the importance of platformisation.

Expert #2 stated: "Platforms have a unique connection with food businesses. This is something to be exploited by local authorities and regulators in the future, especially in areas of business monitoring, both direct and indirect platform governance and incentivising food standards through required hygiene ratings, for example".

Overall, Case #1 to Case #7 successfully adapted business offerings and strategies (e.g. localised supply) to meet disruption-driven demand, strengthening relationships with key suppliers for higher process flexibility. Furthermore, the responses obtained from the involved experts confirmed that digital technologies and platform implementation increase the flexibility of operations.

5. Discussion

The development of digital food platforms provides opportunities to support effective SCs, disruption management and safe food provision. The research findings confirm that digitalisation facilitates data and information flows to enable upstream and downstream SC visibility, resilience, product safety and consumer trust, thus supporting decision-making for improved operations (Tsolakis *et al.*, 2021). Notably, research identifies that proactive measures, such as expanding the supplier base and diversifying the product/service portfolio, play pivotal roles in enhancing the agility of supply chain strategies, enabling firms to respond promptly to market demand disruptions (Ho *et al.*, 2022). This research further provides primary evidence supporting the notion that platform business models are crucial in ensuring firm viability during disruptions such as the outbreak of the COVID-19 pandemic (Anderson *et al.*, 2022a, 2022b).

5.1 Digital platforms for food supply chain resilience

Technology has a fundamental role in advancing societies in the digital era by improving global food provision (Frederico *et al.*, 2019). Advanced technologies and better-connected users are vital to the future development of the food sector, particularly in environments where crises significantly strain food SCs. Digital platforms can significantly increase food access and offer consumers a disruption-resistant medium for e-commerce food consumption. However, to this day, food SCs remain vulnerable to disruptive events, with almost a third of edible food being wasted and high-impact-low-frequency events contributing to further detriment (Govindan, 2018). Food SC resilience is challenging given the sector-wide complexity, network length (e.g. globalisation) and dynamic demand fluctuations in contemporary markets. The COVID-19 pandemic portrayed the potential operations disturbances from SC disruptions and indicated contributions that digital platforms are perceived to play in a recovering market.

Empirical evidence corroborated that firms in all investigated industry cases (i.e. Case #1 to Case #7) were significantly affected by the global-reaching disruptions caused by the COVID-19 pandemic. However, as divulged from the cross-case analysis, established and emergent food business operators benefitted from a short operational downtime following government lockdown measures. Small-scale food business operators (i.e. Case #4 to Case #7) appeared to adopt digital platforms relatively quickly to ensure continued service and food provision. On the contrary, the benefits for the larger and more established platform operators (i.e. Case #1 to Case #3) were significantly less during exogenous shocks of great magnitude.

A collaborative strategy was apparent in established digital food platforms in Case #1 to Case #3 (e.g. local food eateries and multinational food sector incumbents) and in emergent operators in Case #4 to Case #7 (e.g. bakeries and cafes). Following the pandemic-induced SC disruption, all operators swiftly upscaled and transformed operations to propose a greater target customer base and diversify their product/service offerings (i.e. adding packaged food delivery boxes and incorporating delivery and collection services). In particular, operators in Case #1, Case #4 and Case #6 extended this upscaling to incorporate new/more non-food offerings, denoting the ease of scaling business operations via the platform model.

Additionally, Case #1, Case #2 and Case #3 presented key functionality contributions as an "interactive marketplace" whereby digital technologies aided in omnichannel consumer decision-making processes through implementing several customer-retention strategies such as gamification and real-time alerts. Such functionality-based contributions were explicitly apparent in all food business operators, expressed as the convenience of having access to alternative or substitute products (Case #4 to Case #7) and alternative providers (Case #1 to Case #3).

Interview data corroborated that Case #4 to Case #7 ensured the availability of at least two alternative products for sale at any given time. This approach allowed users to choose alternative items if specific ones were unavailable (e.g. supplementation of fresh sourdoughs and pitta bread in place of regular loaves). The homogeneity of such findings indicated the high-process flexibility. It is divulged that this flexibility, in part, is linked to the extensible and generative nature of platform operations, whereby a lack of long-term contracting and a variety of interchangeable suppliers meant that alternative/substitute product offerings were possible with relative ease.

By leveraging geolocation, platforms can directly connect consumers with local suppliers of goods and services, facilitating the exchange of offerings that meet specific customer needs. This supply-demand mediation fosters the creation of local communities or concentrated pockets of demand or "demand bubbles". For instance, food delivery apps can prioritise local restaurants based on a user's location, creating a cluster of consumers seeking nearby dining options. In-depth interviews in all case studies postulated that such functionality was inherently better suited to platform-based e-commerce than traditional brick-and-mortar food SCs. Nevertheless, questions still arise surrounding such platform-consumer transformations' longevity following the lockdown measures' lift. This argument is strengthened by the realisation that reductions in order volumes could weaken financial return and, subsequently, the prominence of digital food platforms.

Operators in Case #1 and Case #3 strongly exhibited the bridging of supply-demand actors through progressive platform-consumer interaction. In contrast, emergent food business operators (i.e. Case #4 to Case #7) illustrated consumer-platform interactions as dominant. Nevertheless, both platformisation generations indicated the successful facilitation of

bidirectional data flows and value co-creation regarding increased food availability, accessibility, improved consumer experience (recorded via user feedback) and efficient resource utilisation (e.g. food waste reduction). The latter benefits are perceived to be the case due to platform scalability, particularly in reference to the ability to coordinate and leverage network effects.

5.2 Framework

This research applied to the food SC context concepts surrounding disruption management for high-impact-low-frequency events, e-commerce digital platforms and systems thinking for resource management. The amalgamation of the concepts, primary evidence and a cross-case analysis of established and emergent food business operators revealed first- and second-order themes. Four distinctive but interrelated primary research elements emerged: platformisation, structural variety, process flexibility and system resource efficiency (presented as circularity brokerage).

Firstly, platformisation refers to the process by which firms (e.g. food business operators) may transition from a traditional, linear SC business model to platform-based business models whereby bidirectional interactions enable mutual value creation among SC actors. Secondly, structural variety indicates a breadth of interchangeable raw materials, components and products available within an interactive platform ecosystem required for procurement to intermediates or final customers. Platfromisation, in this sense, simplifies transactions, hence leading to reduced SC complexity. Thirdly, process flexibility implies the ability of sourcing, production and transportation operations to change/adapt in line with dynamic environments. Backup and dual-sourcing, product substitution and production capacity with coordination have been identified in this research as significant elements of SC flexibility. Fourthly, system resource efficiency denotes the mechanisms that leverage digitally enabled linkages (e.g. among waste generators and potential receivers) to inform, mobilise and integrate circularity holes within SC operations to increase resource efficiency (i.e. reduce waste).

The digitalisation of operations provides the ability to dynamically adjust the supplier base and offer an extended product/service variety at scale to respond promptly to demand. Direct communication upstream and downstream of the SC chain due to platform technology fuels network effects and cross-side value creation. Additionally, SC stakeholders' platformisation fosters coordination, efficient resource utilisation and circularity. Figure 3 depicts the deriving conceptual framework underpinning e-commerce food SC resilience and its relation to digitalisation.

6. Conclusions

Studies on digitally enabled food SC resilience are fragmented, often myopically focusing on the farming or processing echelons. In contrast, our research considers control failures propagating downstream the food SC to the last-mile logistics, a body of literature that remains largely unexplored. This literature fragmentation is particularly relevant to digital food supply platforms and their impact on last-mile delivery models in the context of severe market disruptions. Motivated by this research gap, our study unfolded a cross-case analysis of established and emergent food business operators.

Our findings suggest the interrelationship between four key elements in e-commerce food SCs – platformisation, structural variety, process flexibility and system resource efficiency – which were previously considered independently within the context of major exogenous disruptions (i.e. the outbreak of the COVID-19 pandemic). The interplay of these elements allowed food business operators to rapidly reconfigure their supply, processing and go-to-market channels and flexibly offer product variety, hence continuing operations with minimal hindrance. A digital-enabled low-certainty-need SC approach could facilitate resilience through reconfigurable SC capabilities.

In response to the articulated research question, our study findings support the understanding of evolving transition pathways surrounding the digital platformisation of the e-commerce food SC sector, representing a dynamic process exhibited by established and emergent e-commerce food business operators. Reconfigurability of the SC for resilient operations during exogenous disruptions was observed to be informed by:

- Efficiency and productivity requirements of critical operations due to high-impact-low-frequency disruptive events.
- Business model evolution from linear to (delineated) platform models imposed by the emergence of digitalisation, necessitating the utilisation of diverse suppliers and developing portfolios of offerings.

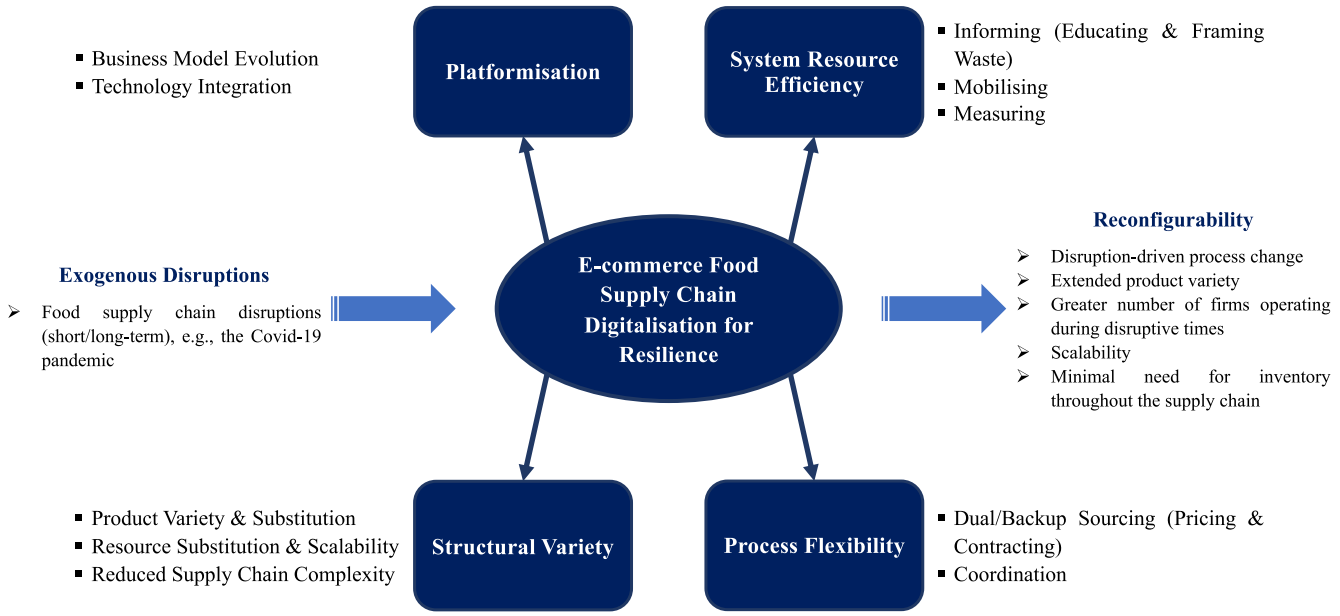
While traditional SCs in the last-mile delivery are focusing on narrow market segments and consumer requirements, digitalisation allows the realisation of unseen benefits in several areas, such as product variety, resource efficiency and customisation options, analogously to pharmaceutical value networks (Harrington *et al.*, 2017). Digital platformisation further activates third-party-based interactions through bidirectional data and information flows, thus facilitating value co-creation and exchange (cross-side value is a fundamental property of platforms) (Anderson *et al.*, 2022a). Overall, the primary case data and cross-field experts' opinion review (i.e. post-data triangulation) highlighted the increasingly prominent role of digital platformisation in shaping and implementing safe, resilient food provision in severely disrupted environments.

6.1 Theoretical contributions

A validated conceptual framework of e-commerce food SC resilience under major exogenous event scenarios is provided with particular relevance attributed to high-impact-low-frequency disruptions such as the COVID-19 pandemic. Theoretical contributions to knowledge are made in terms of structural, process and system platformisation attributes and how these, in combination, enhance operations resilience.

Firstly, digital platforms are well recognised for facilitating direct communication and data and information SC actors, enabling continuous functionality and service improvements amidst highly fluctuating environmental conditions. Therefore, platformisation allows timely product diversification and value-added service provision. Improved connectivity and functionality are enabled via the ability to use scalable, hybrid platform-based business models and extensible platform architectures from which effective supply-demand mediation and market sensing capabilities emerge in response to

Figure 3 Framework on e-commerce food SC digitalisation for resilience



Source: Authors' own work

exogenous disruptions, leading to prompt SC restructuring. The latter finding aligns with the proposition that in the dawn of severe disruptions, developing mechanisms and tools (e.g. digital platforms) and reconfiguring SC processes help improve resilience and ensure operational stability (Tsolakis *et al.*, 2023). Secondly, developing ecosystems where platform resilience-building capabilities are presented via advanced technology functionality and integration enables digital food platforms to offer dynamic and diversified product offerings via interchangeable supplier bases. Short- and long-term supplier contracts can range from about 3–12 months for established and around two to six weeks for emergent food business operators. Such attributes provide exceptional resilience during exogenous disruptions, with the ability to quickly onboard new supply partners, rapidly reconfigure supply, production, and go-to-market channels, and flexibly offer product portfolios based on near-real-time availability. Our study findings thus validate via real-world evidence that digital platforms can be valuable for sharing, securing and analysing SC data flows for supporting the decision-making process for cost-competitive resilience and sustainability across end-to-end operations (Bechtsis *et al.*, 2022).

Thirdly, where the involvement of multiple food SC actors had previously been deemed detrimental due to added complexity, and high-levels of inventory platform business models can act to facilitate collaboration among multiple food supply chain actors, mitigating complexity and enabling value co-creation without excessive product redundancy. Therefore, value is co-created and exchanged horizontally without requiring high-level product redundancy. External partners, enabled via an open platform architecture, contribute towards a collective food SC value-adding mechanism whereby the collaboration of actors can garner resiliency and efficiency through digital technology integration and circularity brokerage roles (Agnusdei *et al.*, 2023). Interchangeable supplier base, product personalisation and substitution and flexible resource utilisation and provisioning are considered significant drivers to enabling food organisations to remain agile, responsive and adaptable to disruptive environments where many incumbent firms, both small and large, often fail. Further, cooperation of ecosystem stakeholders and resource utilisation coordination emerged as recent contributions. Many established digital food platforms operate in varying levels of self-delivery, and several emergent food business operators use synchro-modal logistics on a peer-to-peer, shared logistics basis.

6.2 Practical implications

From a food platform practitioner perspective and the broader stakeholder community, this research builds on the unique interrelationship of resilience and its enabling structures, processes and system features required for transformation. Established platforms operate a self-governance mechanism providing a unique avenue for users, institutions and regulators to drive compliance and safety in the food retail sector through ecosystem inclusion and connection with smaller food business operators with whom food regulators would otherwise have little immediate contact. In this vein, in major disruptions (e.g. pandemics), platforms can effectively act as "gatekeepers" and flexibly onboard/offboard partners to ensure quality/safety compliance. Focusing on the identified first- and second-order themes, e-commerce food operators can absorb bullwhip and ripple effects from consumer behaviour and supply-demand shifts amidst disruptions.

Moreover, digital food platforms offer a highly customisable, multisided digital marketplace wherein platform members may aggregate product offerings and customers and share value throughout the network. Digital marketplaces also implicate the intelligent utilisation of finite resources due to considerably

improved demand monitoring capabilities. The proposed framework allows SC delineation, facilitated by digitisation/adoption of platform-business models while ensuring bidirectional data and information flows among participants through disintermediation.

6.3 Limitations

The limitations of this research provide stimuli for future studies. Firstly, this research constrained primary data collection to a UK context. Considering the challenges of global SC operations and the compounding disruptions ever-present, research into the digital operations and sustainability phenomena postulates more cross-sector-relevant research.

Secondly, considering the interpretive nature of this qualitative research, bias could be relevant given that a certain level of researcher interpretation of results occurred regardless. To mitigate this, using a second researcher/thematic coder or team could provide greater validity and reliability of results (Campbell *et al.*, 2013).

Thirdly, the lack of critique and diversity of perspectives could be pertinent to the research findings. To this end, leveraging the Delphi method could allow additional richness in the findings as re-expression of opinion and predictions is often encouraged, negating potential conformity and peer bias often associated with focus groups. Therefore, further study using the Delphi methodology can provide additional interpretive dimensions (Brady, 2015).

6.4 Future research

Research findings suggest a linkage between intrinsic digital food SC characteristics and resilience-building capabilities; thus, further research into this relationship could also consider upstream agri-supplier interfaces, manufacturing food processing and how these relate to downstream consumer connectivity. Provided the global and cross-sector relevance of food SCs, further explorations into the increasingly prevalent so-called "black swan" events related to natural disasters and climate change, fast-changing socio-political contexts, technology or cyber-security failures or changes in trade arrangements are necessary to be investigated. Indicatively, geographically dispersed food SC operations are often exposed to competing and coexisting policies arising from the incompatibility of incentives, standards and regulations imposed by local/national jurisdictions; hence, digital platforms could leverage public and private data and information sources to inform SC planning in a dynamic changing environment (Srai *et al.*, 2022). Finally, the SC digitalisation for resilience context is not unique to food systems; therefore, the research has broader generalisability to other sectors, such as health-care and service industries.

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Appendix 1. Multiple case studies

Table A1 Multiple case study interview questions

Framework elements	Interview questions for industrial case studies
• **Platformisation**	Describe the role of "platform X" in bridging the gap between food provision and current situational challenges. (*) What were the main reasons for implementing digital technology to provide food? How do these correlate to operations following the UK's COVID-19 pandemic lockdown? (*) How would you describe your main barriers to the adoption/usage of digital technologies? How have these been addressed?
• **Structural variety**	Please describe the "platform X" supplier base at present? What future developments (e.g. structural/technological) do you aim to integrate to meet demand and business objectives? How might these transform current operations, if at all?
• **Process flexibility**	What roles have digital platform technologies played in the development of current product/service offering? What data is collected from suppliers/partners and customers? How is this managed and leveraged to fit business goals?
• **System resource efficiency**	Does "platform X" use practices or strategies to help identify and mitigate food waste? If so, how? What effect has the COVID-19 pandemic had on resources and supply? What changes, if any, have been made to facilitate efficient operations during the pandemic? How would you describe your overall experience in food provision amidst the COVID-19 pandemic disruptions? Have upscaling services to meet rapidly changing customer demands been a major issue? (*)
• ***Context (*)***	How effective have primary risk management strategies been post the COVID-19 pandemic lockdown? How have these changed, given such supply chain disruptions? What are your views towards "platform X" operation post-COVID-19 pandemic?

Source: Authors' own work

Table A2 Industry cases' context and data collection process

Case ID	Case description	Data-collection process details
• **Case #1**	Founded in February 2015, Case #1 represents a purpose-built, medium-large application-based food-sharing platform. Operating in both business-to-customer (B2C) and customer-to-customer (C2C) spheres, Case #1 aims to facilitate better interactions among upstream and downstream stakeholders (i.e. both peer-to-peer and local food businesses to consumers interactions). This interaction facilitation is achieved by acting as a "gatekeeper" in the redistribution of surplus food from: brick-and-mortar businesses and consumers (C2C transactions). Monetisation takes the form of financial transactions between local food business operators and Case #1 (food business operator – platform), whereby businesses with excess supply pay Case #1 a fee for redistributing this surplus stock via several channels on the platform. Having recently exceeded 2.1 million users, Case #1 incorporates multiple specific application features, a primary function being fee-free C2C communication (i.e. product listings), sale and sharing of food/non-food items	1.75-h interview with business development manager; transcript notes and queries validated with the respondent and triangulated with platform CEO and COO via email interview/ discussions, company webpages, reports and official social media streams. External sources such as independent user reviews were also considered alongside researcher testing of platform functionality over two months
• **Case #2**	Given its entry into the UK market in 2006, Case #2 is considered a pioneer digital food platform offering a digital marketplace for consumers to conveniently explore and order food and drink supplies from a wide array of restaurants and cuisines using a single platform: "We are a marketplace that provides a place for consumers to find all that local restaurants offer and order food straight to their homes". Case #2 has a heritage in the self-delivery business, wherein partner restaurants fulfil most orders. Recent years have seen logistical development leading to a scenario where up to 20% of orders are fulfilled by Case #2. A centralised model consisting of one company, one brand and one IT platform ensures best practices across the organisation. Of the 45,000 partners listed on the platform, Case #2 experienced an initial dip in sales (approximately 50%) following the initial COVID-19 pandemic-induced government measures due to high volumes of partners ceasing operations	1.5-h interview with global restaurant and sustainability director; transcript notes and validation of critical points were carried out via email discussions, company website and annual report analysis
• **Case #3**	Case #3 was established in 2013 and has exhibited an annual revenue growth of around 650% yearly. Based on their location, customers can choose from various restaurant and cuisine options with business operations, including food delivery from restaurants to customers. The entire platform is based on the "Frank" algorithm that integrates several different technologies, including predictive technology, to ensure that the experience of the customers, restaurants and delivery partners can be enhanced. Case #3 is one of the UK's largest food platform delivery organisations and offers nationwide coverage with over 30,000 UK partner restaurants. Case #3 serves as an intermediary platform between customers and restaurants. Customers place/pay for all orders via an online application, which is conveyed to the participating restaurant	Secondary data case study of one of the largest UK food platforms: company reports, operational data, sales data (UK statistics) and official publicly available resources (i.e. official website and social media streams used alongside researcher platform functionality testing in the validation process)
• **Case #4**	A small/emergent start-up established in March 2020 and operating in grocery delivery since inception following the COVID-19 pandemic-imposed lockdown measures in the UK. Case #4 represents an example of disruption-driven platformisation of regular food business operators in the UK food sector, with rapid service and geographic upscaling being salient. The firm's founders identified the need to deliver fresh groceries and bakery items to UK customers as challenges arose surrounding "physical" shopping amidst the COVID-19 lockdown. The organisation's key focus involves providing higher quality food items to local communities delivered biweekly	1.5-h interview with the CEO, followed by a 1-h follow-up interview for results validation and usage statistics; company reports, website, product and primary platform usage data were used as external data sources

(***continued***)

Table A2

Case ID	Case description	Data-collection process details
• **Case #5**	Case #5 is a small-scale food provider focusing on delivering ethical, wholesome and healthy plant-based food to consumers. Case #5 also encompasses the idea of spreading culturally diverse, vegetarian and vegan food products by providing customers with a mix of traditional and fusion cuisine. Having approached the Prince's Trust In 2016, Case #5 began trading in 2017, primarily focusing on catering for events, festivals and special occasions during UK holiday periods. Operating from a single site, customer orders are solely taken via digital means (x2 third-party platforms) and fulfilled by four employees whose responsibilities range from ordering supplies to cooking and delivery processes	1.5-h video interview with Case #5 founder, validated via a 1-h follow-up interview and email correspondence; company reports, official webpages, order data and primary platform usage were also used for case validation
• **Case #6**	Case #6 is an emergent family-run business established in April 2019. Having begun trading before the COVID-19 pandemic disruption, Case #6 began operating with children's parties/ events in mind and offered products ranging from beverages, snacks and finger food alongside offering "animal cycle" entertainment (PonyCycles). As the business has grown, Case #6's consumer base has also expanded to offering products and services for a range of larger events (e.g. birthday parties, anniversaries and graduations). This trend led to further development and growing product/service offerings, including confectionaries, party bags, a wider range of finger foods and more extensive (i.e. hot food) event catering. As an emergent platform player, Case #6 aims to provide products and services eponymous with quality, safety and reliability while offering high customer satisfaction through partner-facilitated entertainment (internal and external collaboration) for all the family	1.5-h video interview with Case #6 CEO, followed by a 1-h follow-up interview, was conducted via video call; further email correspondence for case validation was conducted via external sources such as the official website, sales data and primary platform usage
• **Case #7**	Established in October 2018, Case #7 began operations as a small-scale caterer for events occurring fewer than twice a month. Following the COVID-19 pandemic, however, the operation expanded to a more digital sphere encompassing physical and digital markets through its e-commerce operations. Operations occur daily, with orders taken from Monday to Thursday ahead of collection or delivery. Operating from a single-site headquarters, Case #7 targets its customers by bringing cultural fusion foods to the masses and providing them with novel menus and combinations. The COVID-19 pandemic significantly affected the brick-and-mortar operations of Case #7. A transformation and growth from a single market stall and in-person catering events within the city centre (i.e. Hitchin) soon extended to diversified e-commerce operations, including customer collection and takeaway delivery orders alongside commercial supply to local cafes: 3–4 regular café partners as of July 2020	1.5-h video interview with Case #7 CEO, and 1-h follow-up interview with CEO and COO via joint video conference call; subsequent validation occurred via the official Case #7 website, product, order data and researcher platform functionality testing

Notes: CEO = Chief Executive Officer; COO = Chief Operating Officer; IT = Information Technology; NHS = National Health Service
Source: Authors' own work

Appendix 2. Experts' interview protocol

Table A3 Expert opinion input review – digital ecosystem development

A review of extant literature, operational data and cross-case analysis of industrial interviews suggest that the global COVID-19 pandemic has led to significant changes to the UK food provision and sector operations

The synthesis of primary evidence explores existing themes and practices concerning digital platform operation while extending this outlook to broader issues and a more extensive understanding of the wider ecosystem. The expert opinion input will serve to expand upon current knowledge and findings relating to the UK/developed economies in the areas mentioned below

Since digital ecosystems integrate several dimensions and stakeholders other than suppliers/partners, food providers (i.e. platform organisations) and consumers, the synthesis of evidence will further extend attention to more institutional, technological and regulatory development in digital ecosystems

The experts' interview protocol is divided into four sections focusing on different but related themes, namely,

A. Digital food platform evolution
B. Supply chain resilience
C. Food sector regulation
D. Food supply chain restructuring and transformation

A. Digital food platform evolution

Digital e-commerce platforms provide new opportunities for mediating supply and demand, which is particularly important during supply network disruption. Initial case results suggest the following key factors in their development:

- Process and resource flexibility (supplier base and resource provisioning)
- Disruption-driven process change
- Food waste reduction
- Firm-level adaptability and responsiveness
- Supply-demand mediation (product offerings, bidirectional data flow and consumer experience)

1. To what extent would you agree with the importance of the above factors? Please elaborate and reference any other key factors you may think relevant
2. Analysis suggests several positive and negative consequences of digital platform implementation in e-commerce food supply chains. Please elaborate on these and/or other key sector challenges:
1) Food safety/regulation
2) Food availability and access
3) Food waste

B. Supply chain resilience

3. Which aspects of digital platform implementation relating to supply chain resilience would you expect to be of most benefit and/or detriment for effective and efficient operation during times of disruption (e.g. service times, inventory and food waste reduction)?
4. What technological and/or management process innovations could better support supply chain agility and responsiveness of digital platforms amidst supply chain shocks?

C. Food sector regulation

5. How may current regulations and policy support/hinder digital platform food operations?
6. What are the opportunities for collaboration between food supply chain actors, the UK food regulators and policymakers to accelerate development and leverage sustainable food provision?

D. Food supply chain restructuring and transformation

7. How would you describe the investments and assets needed for the operation and performance of digital platforms in the future?
8. What are the provisional and/or long-term transformations triggered by external disruptions (i.e. COVID-19)? How might these be leveraged for future sustainable operations?

Source: Authors' own work

Appendix 3. Cross-case analysis

Table A4 Expert interviewees' salient points

Expert ID	Industry/area of specialisation	Interview salient points
• **Expert #1**	UK Food Regulatory Body/Digital Platform Liaison Lead	– Digital food platforms can have an inbound and outbound disintermediation role between regulators and (smaller/emerging) firms – Digital food platforms provide a unique avenue for regulators to drive compliance in the food retail sector – Digital food platforms can help local and national authorities drive compliance and standards – Firm-level flexibility and resource provisioning are the most critical capabilities for resilience and efficiency – Smaller, emergent firms are generally more agile – due to several reasons, such as potentially lower foreign direct investments or investments of their own – do not have the same background
• **Expert #2**	UK Food Regulatory Body/Head of Analytics and Chief Economist	– A strong interconnected nature of digital food providers exists – Many benefits lie in encouraging the self-governance aspects of digital food platforms in the UK food supply chains (i.e. incentivising high food standards as platform entry requirements for local food businesses) – One of the major challenges is reassuring that e-commerce firms are following the rules and regulations – The UK imports a high percentage of food. Developments like Brexit will further disrupt the global food supply chains and stress food business operators more
• **Expert #3**	Academia/Industry 4.0 Adoption and Technology and Entrepreneurship	– Significant supply chain process changes occurred due to global disruption (i.e. in procuring physical goods). It now makes sense to short-term source contracts where it previously was not a viable option – Transformation of public health/consumer behaviour as well – not only is there greater resource scarceness on the supplier level, but an added more significant challenge in the procurement (i.e. social distancing, particularly for those most vulnerable) – Gig economy workforce allows for greater flexibility in general operations. Process and resource flexibility (e.g. driven by the necessity of higher food scarcity/demand consumers willing to pay more)
• **Expert #4**	Industry/Serial (angel) Investor, Digital Start-up Innovator and Author	– Digital food platforms provide considerable headway in integrating technologies such as process monitoring and predictive analytics (e.g. for demand-sensing) – Digital platform technology can be particularly relevant and valuable in identifying, quantifying and reducing food waste in the UK and global markets – Need for greater regulation compliance is apparent as keeping pace with the rapid scale of digital food platform transformation is challenging
• **Expert #5**	Academia/Operations Management, Food Supply Chain and Resilience	– Digital platforms have evolved primarily to look at how to match supply and demand and create admissions – Digital platforms give visibility and foresight (e.g. through platform ecosystem involvement and bidirectional interactions) previously inaccessible to smaller firms – Although digital food platforms offer users product/service diversification, the physical element and experience of in-person dining cannot be diminished. However, this notion is refuted depending on whether consumer/consumption behaviour will undergo considerable transformative or long-term change
• **Expert #6**	Academia/Director, School of Logistics; further experience in Operations and Supply Chain Management	– Collaboration and integration of systems regarding suppliers, manufacturers and other actors are essential – Digital platforms can help find replenishment and in conducting reliable demand forecasting – Technology heavily incorporates the management of time and process – Small suppliers require protection for further sustainable ecosystem development
• **Expert #7**	Industry/Principal Consultant, Digital Supply Chain	– Support diversification and collaboration to reduce risk and increase system capacity to respond to change is important – Interconnectedness and interoperability are necessary – when food business operators are better connected with their supply chains, supply-demand signals flow more smoothly – Food waste incurs higher costs for inbound members, thus affecting margins and subsequent consumer prices

Source: Authors' own work

Table A5 Cross-case analysis of established food business operators

First-order observations (established platform food business operators)			
Case #1	**Case #2**	**Case #3**	**Second-order themes *(emerging constructs)***
Framework element 1: Platformisation			
• Case #1 uses a commission-free business model with low asset ownership and a predominantly voluntary workforce • A consistent increase in consumer listings (>30%) during the initial lockdown period (i.e. March 2020) was observed	• Hybrid (restaurant self-delivery) business model (~80% of orders fulfilled by partners). Before entering delivery logistics (in 2018), UK self-delivery was running at an EBITDA of 55 points • Core strength development in dinner-time orders (i.e. 17:00–22:00) expanded to lunchtime orders following large-scale onboarding of >300 large fast-food businesses (including some exclusive food business operators)	• Logistics-based business model (i.e. fulfilling most delivery orders) • During disruptive periods, new e-commerce capabilities and services, particularly service expansion to groceries and packaged goods • Spearheading safe food provision through a platform to partner interaction • Use a commission of up to 35% per order, depending on the courier type	*Business model evolution* • An extensible platform architecture aiming to accommodate changing service providers wherein increased service/product procurement occurs • Business model-driven growth • Hybrid business models with multiple go-to-market channels (with or without self-delivery logistics delivery)
• Interactive platform incentivisation and gamification strategies (user leader boards, competitions, badges and share summaries) • Exploitation of primary and third-party digital marketing • Near-zero downtime (<3 days) following COVID-19 pandemic lockdown measures	• Data gathered with a focus on optimising the order processes for the customers and the restaurants • Improved application operation development • Wider implementation of last-mile robotics (delivery) • Continuous development and self-governance of marketplace interactions • Provides support and significant sales, marketing and technological optimisation for individual food business operators	• Predictive analytics and AI to ensure the positive experience of the customers, restaurants and delivery partners • Reduced downtime via adapting daily operations and incentivising partners to adhere to government regulations (safe operation)	*Technology integration* • Leveraged consumer data and feedback to continuously improve functionality and service offerings • Rapid process restructuring following initial restrictions to the COVID-19 pandemic in the UK • Ecosystem development via support for smaller food business operators joining the platform ecosystem through account management (sales, marketing and technology) and optimisation previously unachievable for emergent firms
Framework element 2: Structural variety			
• Unprecedented user activity (>10,000 user listings per day) due to a flexible and diversified operating model • Continuous A/B testing of additional platform features based on user feedback (i.e. new channels to support the C2C sale of user-made food and crafts • Products procured according to available surplus	• Onboarding of >300 businesses in a three to six-month period • About 5,000–7,000 new restaurants joined the platform from March 2020 to September 2020 • Offering of >150–170 different cuisines	• Onboarded 1,400 additional partners following the UK's COVID-19 pandemic-imposed lockdown • Expanded partnerships with grocers and supermarkets • Introduction of service delivery of groceries, packaged goods and hot meals	*Product variety and product substitution* • Strong extensible nature (i.e. product – SKU – variety) given swift process/operating model adaptions in-line with demand-supply fluctuations • Expanded partnerships • Increased consumer choice and convenience

(***continued***)

Table A5

First-order observations (established platform food business operators)			
Case #1	**Case #2**	**Case #3**	**Second-order themes *(emerging constructs)***
• Leveraging a voluntary workforce to cater to specific strategies, categories and foods of interest (i.e. short-expiry-dated products)	• Extensive service offering growth of >150–170 different cuisines, giving customers greater convenience and choice	• Additional 1,400 partnerships allowing customers to have an array of product varieties to choose from, and improved in-app recommendations based on previous order history and AI-generated alternatives	*Resource substitution and scalability* • Increased workforce flexibility (i.e. dynamic "gig economy" workforce) • Reduced order turnover time
• Offering multiple channels of C2C sales efficiently • Leveraged volunteers reduced contractual complications • Surplus-defined supply of products	• Effectively managing an excessive number of actors	• Effectively managing an excessive number of actors	*Reduced supply chain complexity* • Offering multiple products in an efficient manner • Leaner ordering processes
Framework element 3: Process flexibility			
• Application-based data heuristics (i.e. short-expiry dated products) automatically assign priority and advertisements on the application as suggestions • Short- and long-term supplier contracts	• Investment into platform commission reduction (>£1m) for restaurants and subsequently reduced platform usage costs to allow a more forgiving ecosystem • Short- and long-term supplier contracts	• "Gig economy" workforce whereby self-employed delivery partners are assigned work based on real-time demand • Increased "dark kitchens" utilisation	*Dual/backup sourcing (pricing and contracting)* • Mixed partnership strategy incorporating both short- and long-term supplier contracts • Greater accuracy of application-based (user and order) data collection and usage, encompassing data heuristics
• Improved bidirectional connectivity (consumers-suppliers) via direct application alerts • Additional functionality (consumers can request required items and organise contactless collections), increasing network economics and consumer satisfaction	• Swift collaboration with government sources and lobby groups to communicate all necessary government advice in partner restaurants	• Updated application functionality with improved user integration and order visibility through order and recommendation alerts for partners and customers • Added safety functionality (i.e. contactless delivery and drop-off) and guidelines for all partners/customers	*Coordination* • Updated application functionality with improved user integration • Improved consumer experience through continuous feedback, platform-user coordination and feature evaluation
Framework element 4: System resource efficiency			
• Near-zero inventory model: fresh produce – maximum one day, frozen produce – maximum three days; investment into the cold chain • Higher (B2C and C2C) food waste redistribution statistics (>10,000 listings in a single day) • >5.4m portions of food shared and >720m litres of water saved	• Education to partner restaurants and platform users by providing blogs (i.e. recipes for surplus food) and up-to-date information on cooking oil recycling initiatives	• Discounted meals on surplus and redistributed food to NHS • Used bicycle deliveries constitute most of the partner logistics • Published articles on food poverty and partnering with the UK Department for Environment Food and Rural Affairs (DEFRA) (committed to waste reduction)	*Informing (educating and framing waste)* • Educational instigating behavioural change (food businesses and consumers) • Demand sensing heuristics • Near-zero inventory model
• Rapid human resource provisioning allowed ample surplus produce to be redistributed promptly • Nationwide flexible, voluntary workforce meant near-zero operational downtime	• Collaboration with the Sustainable Restaurant Association to spread and encourage food waste awareness through multichannel interactions	• Partnership with Veolia for waste management services designed to build a circular economy and preserve scarce raw materials	*Mobilising* • Elimination of dead stock through charitable or promotional means • Streamlined order fulfilment through dynamic demand-driven human resource provisioning

(***continued***)

Table A5

First-order observations (established platform food business operators)			
Case #1	**Case #2**	**Case #3**	**Second-order themes *(emerging constructs)***
following the COVID-19 pandemic onset as human resources were coordinated accordingly in real time	• Near-zero operational downtime following the COVID-19 pandemic onset	• Flexible/interchangeable supply due to demand-driven resource provision ("gig economy" workforce) • Minimal utilisation of redundant staff/resources given partner flexibility	• Minimal redundancy (i.e. dynamic supply-base and resource utilisation) given dynamic shifting of the workforce leading to swift time to recover • Digital tools and monetisation strategy
• Innovative digital marketing and educational schemes to incentivise sustainable purchasing and consumption habits • Reduced negative externalities through active parametric monitoring • Monetisation strategy based on local food businesses completing transactions to redistribute food waste	• Successful integration of several technologies to analyse location-based consumer behaviour feedback to monitor demand better • Use digital tools (i.e. AI and geo-localisation) to optimise operations (i.e. localised demand sensing) • Transfer of surplus food to third-party waste distribution platforms	• Improved demand forecasting, helping to minimise waste • Introduction of table service, allowing customers to use the app to place their orders in restaurants • Transfer of surplus food to third-party waste distribution platforms	*Measuring* • Digital marketing • Integration of location-based technologies and educational schemes • Local valorisation of waste

Source: Authors' own work

Table A6 Cross-case analysis of emergent food business operators

First-order observations (emergent platform food business operators) Case #4	Case #5	Case #6	Case #7	Second-order themes *(emerging constructs)*
Framework element 1: Platformisation				
• **Inclusion of third-party platforms due to disruption-driven business model shift** • **Increased network effects leading to rapid service expansion to five more postcode areas (over four months)**	• Business model shift from physical-first event catering to digital-first food fulfilment • >60% increase (June 2020) in user interactions via existing and newly introduced digital channels	• Disruption-driven business model shift from single-source, physical-first event organising to multi-sourced digital-first food/service provision	• Bidirectional food supply chain interactions with the disintermediation of upstream actors • Elevated platform-consumer communication, propagating a more seamless consumer-platform experience • Reduced procurement order time	*Business model evolution* • Disintermediated business models • Digitalised platform-based supply • Streamlined order management
• **Order system integration for improved food-order convenience and reduced lead and fulfilment times** • **Challenges with increased feedback functionality resulting in delayed responses**	• Greater and more accessible product/service personalisation • Expanded online presence and marketing via third-party-platforms to offer equal online presence where previously unsuccessful	• Integration of analytical capabilities to manage orders efficiently due to higher quality data • Contactless delivery and collection services • Flexible omnichannel communication whereby value-addition occurred two-fold, i.e. via improved consumer experience and closed feedback loop	• Rapid service expansion leading to a more significant online presence and nationwide partnerships with third parties (i.e. cafes and eateries) • Integrated digital customer and order data management software	*Technological integration* • Improved accessibility to data-driven functionality • Multi-party integration and ordering policy
Framework element 2: Structural variety				
• **Expansion-driven collaboration with new delivery partners offering a range of temperature-sensitive products (i.e. cold chain)** • **Temporary reduced workforce availability (due to coronavirus disease)** • **Collaboration with third-party food business operators leading to additional product availability** • **Short supply of baking ingredients (i.e. flour and yeast) during March–April 2020, leading to investigation of alternative supply sources and expanding the procurement of high-demand items**	• Limitations in facilitating an in-situ workforce due to COVID-19 pandemic-imposed restrictions and low asset ownership • Streamlining of product offerings occurred • Product differentiation and added user functionality increased demand for personalised items and menu collaborations	• Diversified from limited finger foods to providing a menu of >12 main meals and party bundles • Product offerings expansion, including the additional sale of packaged goods • Flexible product offerings (e.g. fruit and vegetables) • Maximised accessibility and reduced negative externalities (i.e. air miles) • Critical service-based offerings could be substituted due to disruption-related government guidelines (i.e. social distancing)	• Increased menu (six additional main dishes), service offerings (i.e. delivery and collection options), and expansion to four commercial establishments • Workforce diversification with using additional digital marketing expertise • Personalised goods (customer-facing functionality development) Introduction of "cook at home" range due to critical ingredient shortages (reduced menu due to stock visibility issue)	*Product variety and product substitution* • Demand-driven streamlining of product offerings • Diversification through product bundling/aggregation • Limitations in facilitating an *in situ* workforce and low asset ownership • Product differentiation and added user functionality • Reduced order turnover (operations cycle) and consumer experience
• **Highly interchangeable suppliers and greater product variety (baked goods, confectionaries)** • **Service local expansion (i.e. additional service availability such as expansion to South and North London)**	• Localised supply and reduced lead times, providing greater product quality, durability, consumer satisfaction and overall efficiency (i.e. time and cost)	• Following initial A/B testing and three trial products, ascertained initial demand trends using the data-rich platform • Addressing specific product personalisation and preferences	• Order turnover time reduced from >7 days in some cases to <3 days • Process variability via supplier localising and an operating model switch to order pre-booking	*Resource substitution and scalability* • Structural efficiency through reduced complexity (i.e. localised supply) Interchangeable supply base

(*continued*)

Table A6

First-order observations (emergent platform food business operators) Case #4	Case #5	Case #6	Case #7	Second-order themes *(emerging constructs)*
• **Mobilising local actors**	• Mobilising local actors	• Enabling leaner processes	• Enabling leaner processes	*Reduced supply chain complexity* • Mobilising local actors
Framework element 3: Process flexibility				
• **Gradual increase in short-term supplier contracts, as well as an increase in more non-conventional suppliers** • **Acquisition of +4 short-term contracts through collaboration with local brick-and-mortar food providers (during March–June 2020)**	• Dynamic/increasing product offerings – expanding variety and choice for consumers • Demand-based direct-sourcing from suppliers disintermediating >3 previously used retailers	• Increased sourcing from local farms and producers • Partnership with a third-party supplier offering additional confectionaries and decorations	• Incurred small financial losses due to a lack of backup sourcing for a best-selling pre-cooked product, leading to three days of order cancellations due to a lack of stock visibility (consumer-food business operators)	*Dual/backup sourcing (pricing and contracting)* • Ability to adapt product portfolio based on supply-demand fluctuations • Processes to enable short-term supplier and workforce contracts
• **Shared logistics with partners (i.e. confectionary suppliers)** **Improved e-commerce functionality concerning platform-user communication and user-platform interaction** • **Planned logistics development and partnerships (with two large logistics providers)**	• Use of geo-netting tools for improved operational efficiency based on planning deliveries to locations that the business can serve • Team expansion (e-commerce expertise)	• User-feedback-based service change • Provision of an "A-Z party bundle", including an extended menu of food and non-food items such as party bags • Team expansion (food preparation, delivery and e-commerce expertise)	• Real-time orders and delivery mapping leading to increased time flexibility associated with preparing and planning menu alterations (based on supply availability) well in advance • Team expansion (e-commerce expertise)	*Coordination* • Real-time order analysis by geography • Continuous feedback (e.g. product/promo evaluation) • E-commerce and logistics development
Framework element 4: System resource efficiency				
• **Real-time order acquisition** • **Minimal inventory/deadstock held onsite** • **Implemented bulk discounts on** • **leftovers/unsold goods** • **Lack of purpose-built application**	• Frequent overbooking due to a lack of purpose-built technology	• Efficient order-fulfilment process through waste-minimisation (zero food waste operation) facilitated by omnichannel ordering and pre-ordering	• Implemented weekly pre-booked orders, allowing the accurate estimation of the food to order/make	*Informing (educating and framing waste)* • Real-time order acquisition, omnichannel ordering and pre-ordering
• **Linking with several local charities and community support initiatives, namely, the Hardship Fund, Gratitude and** • **Gift – different organisations which work with local families in need**	• Reduced waste (i.e. packaging) through the elimination of intermediaries	• Split operations between two sites • Investment in human resources (i.e. digital marketing expertise, chef and two logistics partners)	• Distribution to people experiencing homelessness • Minimised waste given that demand could be predicted with greater accuracy before technology usage	*Mobilising* • Elimination of dead stock through charitable or promotional means and intermediaries • Higher accuracy and reduced time for complete order-fulfilment
• **Investment into cold-chain facilities to cater to a larger customer base and product offering (i.e. chilled meats)**	• Data-enabled supply targeting (location-based product offerings and improved digital marketing efficiency) • In total, 7% reduction in overhead costs over five weeks (i.e. rent and advertising costs)	• Customer-based growth (i.e. closed feedback loop) • Reduced costs of operation (overhead costs) • Weekly savings of up to £50 due to weekly waste reductions (packaged food/beverages and other consumables)	• Reduced food wastage (e.g. ingredients) due to a more seamless order-fulfilment process • Demand monitoring leading to the elimination of dead stock through promotional means	*Measuring* • Near-zero inventory model (fresh produce, maximum of one day; frozen produce, maximum of three days) • Investment into the cold chain • Improved demand monitoring leading to the elimination of dead stock • Data-enabled supply targeting

Source: Authors' own work

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