

Review

# Review of Online Food Delivery Platforms and their Impacts on Sustainability

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**Abstract:** During the global 2020 COVID-19 outbreak, the advantages of online food delivery (FD) were obvious, as it facilitated consumer access to prepared meals and enabled food providers to keep operating. However, online FD is not without its critics, with reports of consumer and restaurant boycotts. It is, therefore, time to take stock and consider the broader impacts of online FD, and what they mean for the stakeholders involved. Using the three pillars of sustainability as a lens through which to consider the impacts, this review presents the most up-to-date research in this field, revealing a raft of positive and negative impacts. From an economic standpoint, while online FD provides job and sale opportunities, it has been criticized for the high commission it charges restaurants and questionable working conditions for delivery people. From a social perspective, online FD affects the relationship between consumers and their food, as well as influencing public health outcomes and traffic systems. Environmental impacts include the significant generation of waste and its high carbon footprints. Moving forward, stakeholders must consider how best to mitigate the negative and promote the positive impacts of online FD to ensure that it is sustainable in every sense.

**Keywords:** online food delivery (online FD); sustainability; economic impacts; social impacts; environmental impacts

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## 1. Introduction

Economic growth and increasing broadband penetration are driving the global expansion of e-commerce. Consumers are increasingly using online services as their disposable income increases, electronic payments become more trustworthy, and the range of suppliers and the size of their delivery networks expand.

Online to offline (O2O) is a form of e-commerce in which consumers are attracted to a product or service online and induced to complete a transaction in an offline setting. An area of O2O commerce that is expanding rapidly is the use of online food delivery (online FD) platforms. All around the world, the rise of online FD has changed the way that many consumers and food suppliers interact, and the sustainability impacts (defined by the three pillars of economic, social and environmental [1]) of this change has yet to be comprehensively assessed. Part of the difficulty in assessing its impact has been that scholars are approaching this topic from a range of different disciplines. Thus, the objectives of this review are threefold: (1) To conduct an interdisciplinary review that brings together academic research on the broad range of areas impacted upon by the increased use of online FD; (2) to discuss the opportunities and challenges these impacts pose; and (3) to highlight the opportunities for action by all stakeholders, including online FD industry practitioners, policy-makers, consumers, and academics, to maximize its positive and reduce its adverse impacts. Before presenting the review, it is important

to overview the online food delivery sector (Section 2) to help contextualize the results outlined in the review (Sections 4–6).

## 2. Overview of the Online Food Delivery Sector

### 2.1. E-commerce Market Size

The e-commerce market has experienced strong growth over the past decade, as customers increasingly move online. This shift in how consumers shop has been driven by a wide range of diverse factors, some being market or country dependent, others occurring as a result of worldwide changes. These changes include: an increase in disposal income, particularly in developing nations; longer work and commuting times; increased broadband penetration and improved safety of electronic payments; a relaxing of trade barriers; an increase in the number of retailers having an online presence; and a greater awareness of e-commerce by customers [2].

The strongest growth of e-commerce over the last few years has occurred in China, where, in 2019, sales were worth US\$1.935 trillion—an amount which was more than three times higher than that spent in the United States (US\$586.92 billion), the second largest market. On its own, China represents 54.7% of the global e-commerce market, a share nearly twice the market share of the next five highest countries (US, UK, Japan, South Korea, Germany) combined [3]. The rise of e-commerce in the Asia-Pacific region is demonstrated in Table 1, which highlights the massive increase in the amount spent during key online shopping days between 2015 and 2019. Of particular note is the US\$38.4 billion spent on Singles Day (11.11) in the Asia-Pacific region in 2019, an amount which is more than double the total sum of the US\$9.4 billion spent on Black Friday in North America and much of Europe and the US\$7.4 billion spent on Cyber Monday in North America. The leading e-commerce platforms worldwide differ by region and include platforms which are now household names, such as Amazon (U.S.), Alibaba (China), and Flipkart (India).

**Table 1.** Regional sales value of featured online shopping days from 2015–2019 [4].

Sales volume (US\$ billion)	2015	2016	2017	2018	2019
Black Friday (North America and much of Europe)	2.7	3.3	5.0	6.2	7.4
Cyber Monday (North America)	3.1	3.4	6.6	7.9	9.4
Singles Day (Asia-Pacific region)	14.3	17.8	25.3	30.8	38.4

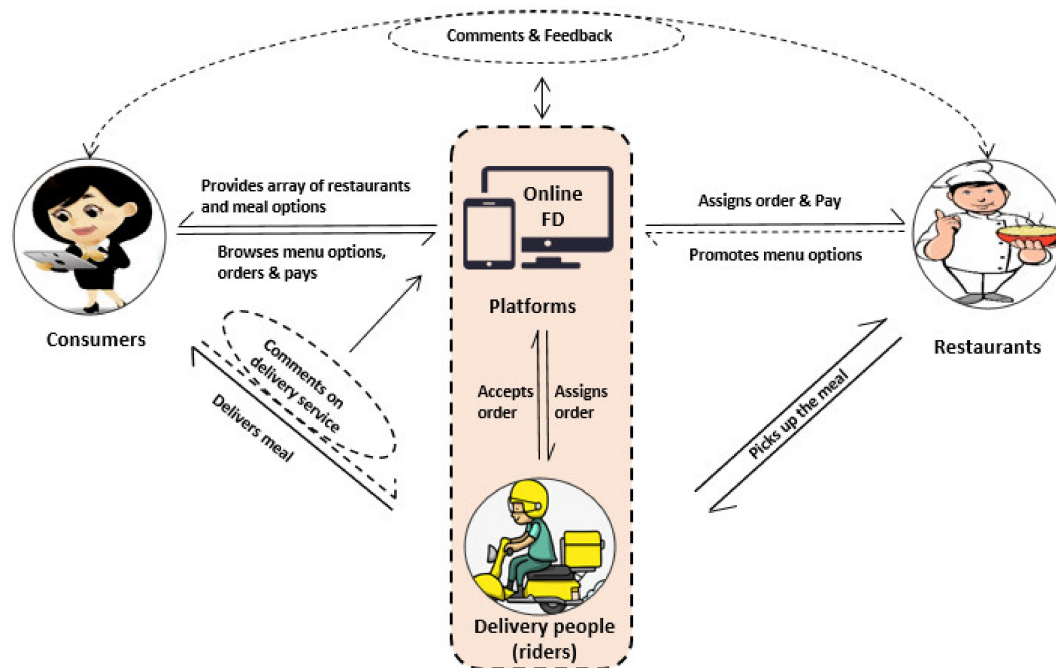
### 2.2. Online to Offline Business and Online FD

The rapid growth of e-commerce has spawned many new forms of business, such as B2B (business to business), C2C (customer to customer), B2C (business to customer), and O2O (online to offline) [5,6]. The business of O2O is a marketing method based on information and communications technology (ICT) whereby consumers place orders for goods or services online and receive the goods or services at an offline outlet [7,8].

One of the significant developments driving the O2O commerce explosion has been the proliferation of smartphones and tablets and the development of infrastructures to support payment and delivery. In 2019 there were 5.2 billion smartphone connections, and by the end of 2020, it has been predicted that half of the people in the world will have access to mobile internet services [9].

O2O services have emerged in various fields, including the purchase of diverse product and service categories, such as food, hotel rooms, real estate, or car rentals [10]. Online FD refers to the process whereby food that was ordered online is prepared and delivered to the consumer. The development of online FD has been underpinned by the development of integrated online FD platforms, such as Uber eats, Deliveroo, Swiggy, and Meituan. Online FD platforms serve a variety of functions including providing consumers with a wide variety of food choices, the taking of orders and the relaying of these order to the food producer, the monitoring of payment, the organization of the delivery of the food and

the provision of tracking facilities (Figure 1) [11]. Food delivery applications, or ‘apps’, (FDA) function within the broader context of online FD as they enable the ordering of food through mobile apps [12].



**Figure 1.** The functions associated with online food delivery (FD) platforms. Arrows indicate movement of information or logistic; lines indicate necessary routes; dotted lines indicate optional routes.

### 2.3. Online FD Providers and their Delivery System

Food delivery providers can be categorized as being either Restaurant-to-Consumer Delivery or Platform-to-Consumer Delivery operations [13]. Restaurant-to-Consumer Delivery providers make the food and deliver it, as typified by providers, such as KFC, McDonald’s, and Domino’s. The order can be made directly through the restaurant’s online platform or via a third-party platform. These third-party platforms vary from country to country, and include examples, such as Uber eats in the U.S., Eleme in China, Just Eat in UK, and Swiggy in India. Third-party platforms also provide online delivery services from partner restaurants which do not necessarily offer delivery services themselves, a process which is defined as Platform-to-Consumer Delivery.

Online FD requires highly efficient and scalable real-time delivery services. Restaurants can use existing staff for self-delivery, such as the use of waiters in some small restaurants or they may use specialized delivery teams who are specifically employed and trained for this role, as is seen with some of the big restaurant brands, such as KFC, Domino’s, and Xibei. Alternatively, restaurants can employ crowdsourcing logistics, a network of delivery people (riders) who are independent contractors, a model that provides an efficient, low-cost approach to food delivery [14]. Online FD platforms can either be responsible for recruiting and training professional delivery people, or they may also resort to crowdsourcing logistics, using delivery people who are not necessarily employed by the online FD platform. Professional delivery people are usually trained, and at least part of their salary is guaranteed, while a portion is commission-based. In contrast, the independent delivery people who are frequently known as “riders” are paid on a commission (per order) basis (Figure 2).

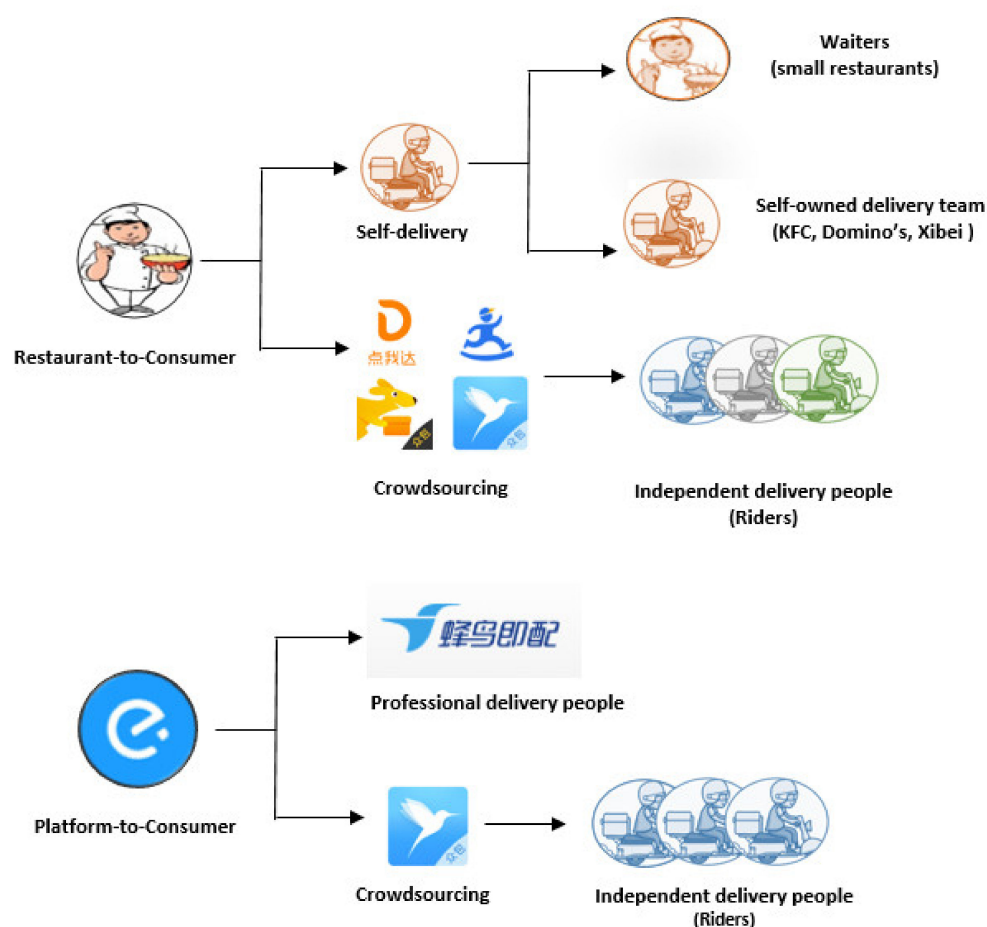


Figure 2. Online FD delivery retailers (Eleme in China, for example).

#### 2.4. Growth of Online FD Worldwide

The rise of online FD is a global trend with many countries around the world having at least one major platform for food delivery (Table 2). China leads the way in market share for online FD, closely followed by the US with the developing markets of India and Brazil, showing rapid (> 9% compound annual growth rate (CAGR)) growth.

The online FD industry has been very proactive in the way it develops new markets and cultivates consumers' eating habits. For example, in 2018, a promotion campaign by the India-based online FD company Foodpanda offered consumers large discounts, which resulted in Foodpanda increasing the number of users by a factor of 10 [15]. Moreover, in 2018, Eleme in China, spent three billion yuan (US\$443 million) over three months in a successful marketing strategy to increase its market share to more than 50 percent of the Chinese market [16]. Despite online FD being very strong in some regions, as a whole across the world online FD is in the early stages of market development, and it will require considerable investment to fund promotions and campaigns and to provide subsidies to participating restaurants [17–21]. For example, a restaurant may hold a campaign on an FD platform, in which a consumer obtains ¥8 as a discount if the total amount ordered reaches ¥20. In fact, this discount may only cost the restaurant ¥2, as it will receive a ¥6 subsidy from the FD platform (the actual rules may vary from one platform to another [22]). Such an approach is beneficial for a restaurant because it will attract more consumers and orders. It is crucial for the future of online FD to cultivate consumers' eating habits by introducing them to the choosing and purchasing of food online. By providing consumers with the option of having a meal at a cheaper price or by providing other services, such as

free delivery, online FD platforms and providers are encouraging consumers to abandon cooking at home or going out to a restaurant to eat.

**Table 2.** Revenue of the Online FD segment in major countries [13].

Country	Forecast Revenue in 2020 (in million US\$)	Annual Growth Rate (CAGR 2020–2024)	Market's Largest Delivery Segment	Volume of Market's Largest Delivery Segment in 2020 (in million US\$)	Leading Platforms
China	51,514	7.0%	Platform-to-Consumer	37,708	Meituan, Eleme
US	26,527	5.1%	Restaurant-to-Consumer	15,631	Grubhub, Uber Eats, Doordash
India	10,196	9.5%	Restaurant-to-Consumer	5401	Foodpanda, Swiggy, Zomato, Uber Eats
UK	5988	6.5%	Restaurant-to-Consumer	4115	Just Eat, Food Hub, Deliveroo, Hungry House
Brazil	3300	9.5%	Restaurant-to-Consumer	2033	iFood, HelloFood

Worldwide online FD is becoming increasingly well accepted and embraced by young adults, and nowhere is this trend more evident than in China. A survey in 2019 of 1000 university students in Nanjing, revealed that at least 71.45% of them had used online FD for at least two years and that 85.1% of them used online FD more than once a week [23]. Online FD has been reported to be popular with Chinese university students because it saves time (50.35% of 141 students in Hebei, China), is convenient (44.35% of 124 students in Jiangxi, China), and is able to provide options that were tastier (39.52% of 124 students) or simply different from canteen meals (36.17% of 141 students) [24,25]. Of course, different populations around the world have different opportunities to purchase food online owing to cultural, technological and economic reasons and these differences can be responsible for the differing rates of uptake of online FD seen around the world. By way of comparison to China, for example, a 2019 survey of 252 Greek university students aged 18–23, reported that most of them cook at home and rarely eat out or have food delivery (45.6%), while others mostly eat at the student restaurant or cook at home (23.4%), with only 21% of the students surveyed stating that they had food delivered [26].

### 3. Methodology

Understanding the economic, social, and environmental sustainability impacts of online FD required an in-depth and interdisciplinary review of recent literature. More than 60 documents were identified on 'online food delivery impact(s)', using the following research engines: Scopus, Web of Science, Google Scholar, and China National Knowledge Infrastructure (CNKI). The broad range of databases searched was due to the interdisciplinary nature of the research question and the desire to search in two languages. Importantly, in addition to journal articles, the research scanning also included books and book chapters, government policies, reports, working papers, and other grey literature sources. Given the newness of the online FD sector, our initial searches revealed that a systematic review of the academic literature was not possible as there was simply not enough published on the sustainability impacts to enable hard and fast conclusions about the state of the sector to be derived. Consequently, a rather more exploratory approach was adopted that identified topics worthy of further exploration and sought to showcase these to encourage future research.

Source material published between 2010 and 2020 that were available in either English or Chinese (language) were included. While our study aimed to understand the impacts of online FD globally, the decision to include both Chinese and English language articles was made because the online FD sector is most developed in China, and therefore, online FD in China has received the most academic attention to date. Indeed, the results of our search showed that most of the literature on online FD reported on FD within a Chinese context.

To analyze and synthesize the findings from the studies we employed a narrative synthesis [27], which is a flexible approach which allows the reviewers to be reflective and critical [28] when reporting on the studies included in the review [29].

#### 4. The Impacts of Online FD

The impacts of online FD was organized according to the three pillars of the sustainability framework (Figure 3) and discussed in Sections 4.1–4.3.

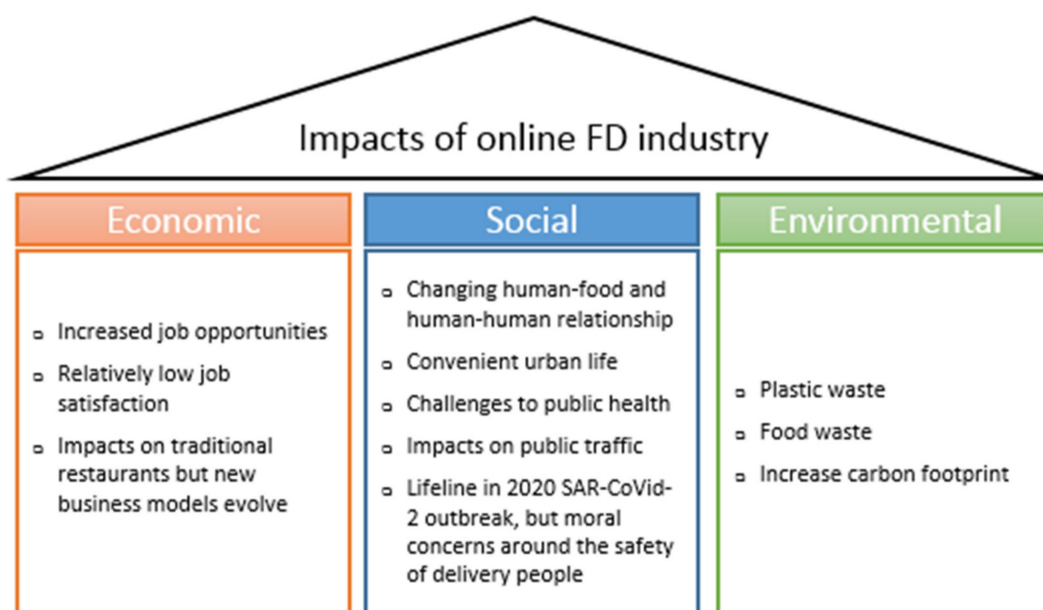


Figure 3. Message house of the impacts of online FD.

##### 4.1. Economic Impacts

The rise of the online FD industry has provided job opportunities for many people across a range of types of employment including as chefs and administrative staff in restaurants, delivery people or as programmers behind the Apps/online platforms. In addition, the online FD industry has been a bonanza for support industries, including companies that make, sell or service electric bicycles, and companies involved in the making and distribution of food packaging. The large online FD platforms employ many thousands of workers, with Meituan and Eleme in China, employing around 1.17 million people to work as delivery people [30]. Likewise, Swiggy in India has 17 thousand delivery people [31], and the US-based online FD company Uber Eats has over 10 thousand employees [32].

While there is no doubt that the online FD industry has provided many jobs, especially in the delivery sector, there has been concern expressed about the poor working conditions that delivery people are subjected to, including the standardized nature of their job, their high workload, the limited training many receive and the risks they experience to their personal safety during the process of delivering the food [33,34]. These limitations mean that while many job opportunities exist for food delivery people, job satisfaction is often low, and there is a high attrition rate [18].

The online FD industry has also directly impacted the traditional restaurant industry, and many restaurants have had to change how they operate in order to stay in business. As the online FD industry started to gain a foothold, traditional restaurants with a physical storefront noticed a decrease in in-store dining and foot traffic as more and more of their customers began ordering food online and eating it away from the restaurant, normally either at their home or their place of work. Consequently, many food businesses, which did react quickly enough to this change in customer demand, by embracing online FD, suffered a decline in profitability [35]. As discussed above, when first starting online FD,

a restaurant may initially do very well, and obtain many more customers and orders (due to the online FD platform running promotions and providing subsidies). However, overtime a restaurant's profit may reduce, owing to the provision of fewer subsidies or the requirement to pay a higher commission to the online FD platform. This reduction in profit can be more marked for small restaurants that do not have the bargaining power of the larger online FD providers [36,37]. Increases in the cost of commissions can lead to restaurants looking for other online FD platform providers, which can be difficult to find in markets where individual online FD platforms have a virtual monopoly, or restaurants may choose to no longer be involved in online FD [38]. In addition, there have been reports that online FD platforms may put undue costs onto small restaurants, such as making them or the delivery people liable for refunds for delivery errors—even if the restaurant or the delivery person was not at fault [39]. In general, however, for many restaurants, online FD is an important way for them to get in contact with consumers and to obtain sales [40]. This point was especially evident during the lockdown that occurred in 2020 owing to the occurrence of SARS-CoV-2 virus, with online FD being credited for enabling many food businesses to survive [41].

In regions where online FD industry is well developed, food businesses have realized that they can reduce their dining area, therefore, saving costs associated with the provision of space and that this space can be used to provide more room for their expanding online FD services. The ultimate manifestation of this trend is the development of so-called ghost kitchens (also known as cloud kitchens or dark kitchens) which have become relatively common in the UK, US, and India [42–45]. These food delivery businesses do not have a physical storefront at all, and online orders are their only source of income. Dispensing with a physical storefront has many advantages for restaurants including a reduction in the cost associated with premises, reception and wait staff, the ability to virtually limitlessly increase the diversity of menus, concepts or even brands, the ability to run multiple websites and to provide a diversity of dining experiences catered for by one kitchen [46]. In addition, such kitchens can capitalize on the advantages of scale enabling them to invest more in streamlining delivery management thereby enabling them to get the food to the consumer in a more timely and cost-effective manner.

Despite that apparent advantages of ghost kitchens, concerns have been raised about how effectively ghost kitchens can be regulated. In China, for example, the occurrence of several well-reported food safety issues [20] resulted in the China Food Drug Administrative (FDA) announcing in 2017 that all online catering providers should obtain a business license and own a physical storefront which must operate under the supervision of local FDA [47]. Interestingly, despite this proclamation, there still appears to be interest in ghost kitchens in China [48].

#### 4.2. Social Impacts

Online FD impacts the relationship between consumers and their food by changing the way consumers obtain, prepare and consume food. In turn, these changes impact the human to human relationships, which has led to considerable debate on whether online FD enhances or reduces the quality of family time and community interactions.

Traditionally, family members communicated with each other and enjoyed the comfort of each other's company while undertaking the mundane aspects of food-related family life—such as shopping for groceries, and preparing and cooking food in their home [49,50]. Indeed, in some instances, it has been reported that married Korean women are less likely to use online FD because they believe they have a moral obligation to prepare meals for their families [10]. In contrast, other studies report that online FD is seen by some Chinese [51] and UK [52] consumers as being a way to quickly and easily provide meals which consequently enables them to spend time with their family. For example, a qualitative study in Guangzhou (the largest city in South China) of people aged between 18 and 35, who order takeaway meals at least once per week found that they used online FD as it enabled them to enjoy the comfort of their home and still partake in the foods and lifestyles they enjoyed, without the stress associated with the buying and cooking of food [51].

There is no doubt that online FD can save time otherwise spent on grocery shopping, cooking or cleaning up afterwards. According to the research carried out by the Research Centre for Network Economy and Knowledge Management of the University of Chinese Academy of Sciences, at least 48 minutes is saved by each online FD order [53]. The qualitative study from Guangzhou found that at least two hours a day could be “saved” by choosing to use online FD and that these consumers liked to order on online during their commute, so that they could relax and enjoy the food on their arrival home [51].

A news reporter who interviewed white-collar workers in Shanghai, China, reported that many workers feel that they are expected to work at a fast pace, and they believe that they have no time to go out for lunch. Online FD, especially if ordered in conjunction with colleagues, saves them time and promotes better communication as they are able to share their mealtimes together, discussing which restaurants and meals to order online and chatting with each other while eating [54]. In Italy, the Just Eat Observatory, witnessed a 137% increase in orders, for delivered lunches in 15 Italian cities in 2017, which they attributed to employees increasingly ordering and eating meals that are delivered directly to their offices [55].

There are differing views on how online FD impacts social relationships between friends. In a study of 365 students at Ningxia University, China, it was found that 34.2% of the students choose to order online because they had no one to go out for a meal with; the author’s assumption was that university students were unwilling to socialize [56]. In the qualitative research from Guangzhou, it was also reported that some early-career people, who despite sharing a flat with other people, prefer to order food and eat it alone in their room [51]. This practice has been put down to the fact that many young people in China lead independent and individualized lives and are unwilling to socialize. In general, it has been reported that people tend to share food only with close family members, such as young couples who live together, colleagues who work together, or students who live together in dormitories [51,52,54]. Therefore, online FD provides people who wish to eat alone the opportunity to do so without compromising on taste, quality or value, while also providing groups that wish to eat together the chance to share food and split the delivery fee.

In addition, online FD provides access to a wide range of meal options for those who wish to eat late either owing to work or lifestyle choices. For example, Eleme reported that in 2018, between 21:00 and 24:00, more than 170,000 lamb skewers, 100,000 beef skewers and 70,000 chicken burgers were consumed in Shanghai. Most late-night orders came from the CBD and hospitals (presumably due to people working overtime or patients who were hungry outside of the hospital’s regular meal-times) [54].

By increasing food availability and choice and decreasing the barriers to consumption of price and effort, online FD poses an inevitable challenge to the public health system by promoting a sedentary lifestyle. It does this by enlarging the range of the food environment. Traditionally, a neighborhood food environment encompassed approximately 1.6 km, equivalent to a 20-min walk from the home, workplace, or school. With online FD, the range of food service can extend out to 10 km and potentially much further [57].

Moreover, often the community food environment is filled with unhealthy options. For example, a survey in Xi Hu district, Hangzhou, China found that the availability of “unhealthy” food outlets was four times greater than that of “healthy” outlets, and while 41.86% of the total food outlets provided food-delivery services; fast-food restaurants comprised 65.53% of these providers [58], thereby increasing the likelihood of exposure to unhealthy food choices available in fast-food settings [59–62]. In addition, by making the obtainment of food effortless, requiring only a few touches on a keyboard to have food delivered to the doorstep, online FD could potentially be promoting a sedentary lifestyle which is harmful to health. Researchers have expressed their concerns that food delivery apps could have negative health impacts for Americans [63]. Further, a study of 1220 university students in Beijing, China, found that a high frequency of online delivery food consumption was associated with a non-medical major, a preference for high fat and high sugar foods, physical inactivity and not surprisingly a high BMI, with 11.6% of the students surveyed being overweight or obese [64].



As discussed above, online FD has provided employment opportunities for many FD workers, however, this opportunity has also impacted traffic systems by increasing congestion on the roads. Owing to the online FD platform's commission and management systems, the delivery people often race against the clock to meet delivery deadlines and to obtain higher commissions which can, thereby, impact road safety as riders may ignore traffic lights and fail to ride to road conditions, increasing the possibility of traffic accidents [65,66]. For instance, in Nanjing, China, over the first six months in 2019 there were 3,357 traffic accidents involving food delivery electric bicycles, resulting in 2584 injuries and three deaths [23]. In order to control the traffic problems associated with food delivery, some university campuses in Jiangsu and Anhui province in China prohibited delivery vehicles from entering their campuses—a move that more than half (51.69%) of the students supported [67].

On a more positive note, online FD and delivery people provided a critical lifeline during the 2020 COVID-19 pandemic for the tens of millions of people quarantined at home. Online FD not only provided meals, but also employment for the people who prepared or delivered the food [41,68]. Most major online FD platforms adapted their food delivery apps so delivery people and consumers did not have to come into face-to-face contact during this time. Contactless lockers were also installed at hospitals so food could be left securely by delivery people and unlocked by medical staff using a QR code [69,70]. Moreover, under the lockdown conditions imposed in some country owing to the pandemic, many people's meal choices shifted from eating out or venturing out to buy groceries and cooking at home, to the online ordering of prepared food. For example, many essential workers started or increased their use of online FD so that they could dedicate more time to their work. During this time some online FD platforms reached out to their communities in various ways, such as platforms in China where they thanked medical staff for their commitment to the cause by handing out free meals [69,71].

In addition to receiving positive media attention by carrying out social deeds, the COVID-19 pandemic raised a number of moral concerns, including the appropriateness of letting delivery people expose themselves to the risk of infection, especially when they are in low paid, not very secure jobs [41]. In addition, in some countries as restaurants started to open again, there was public debate about the high commissions (up to 35%) charged by online FD providers, such as Uber eats [36], and there was a public movement to more directly support restaurants by ordering and picking the food up directly from them. In addition, in the US, some online FD providers were sued during the COVID-19 pandemic for allegedly exploiting their dominance in deliveries to impose fees through higher menu prices [72].

#### 4.3. Environmental Impacts

One of the most pressing environmental concerns evident from the dramatic increase in online FD is the sheer volume of plastic waste generated and how to deal with it. The effectiveness in which different countries are dealing with the plastic waste generated by online FD is dependent on how well developed their recycling infrastructure is and the speed at which online FD has grown. In China, for example, on the back of an increase in online FD, the total volume of packaging waste went from 0.2 million metric tons in 2015 to 1.5 million metric tons in 2017 [73]. It has been estimated that the waste generated from online FD in China in 2016 was 1.68 Mt, including 1.33 Mt of plastic waste and 0.35 Mt of wooden chopsticks [74]. A less obvious waste associated with online FD is the spent batteries from the electric bikes of the food delivery riders. In 2016, 19,507 batteries (including 17,285 lead-acid batteries) were consigned to waste. In China, in 2016, the electricity used during vehicle charging and in dealing with the waste generated was estimated to have an indirect GHG emission of 73.89 Gt CO<sub>2</sub>eq [74]. In 2020, in many parts of the world the use of single-use, disposable food packaging increased owing to the COVID-19 pandemic, as many consumers believed single-use packaging was safer and more hygienic [75].

As online FD packaging wastes in China are normally contaminated with food residues, and therefore, have a low residual value, they are frequently mixed with other municipal solid waste (MSW) and disposed of by either sanitary landfilling (62% in 2016, national average), incineration (32%) or illegal dumping and open burning (6%) [73]. In China, it is reported that 65% of cities have been

surrounded by municipal waste and 25% of them have very limited space available for landfilling [76]. In addition, in some big cities in China, an emerging environmental problem is the sight of office buildings being besieged by online FD waste. In contrast, in countries with more developed waste management systems and where the increase in online FD has not been as fast as experienced by China, the plastic waste has been relatively well managed, and it has received relatively little academic attention. For example, in the UK, in 2018, takeaway containers only account for 5.1% of littered plastic items, far behind cigarette filters (31.9%) and wet wipes (31.9%) [77].

In China, despite it being academically acknowledged that online FD is causing huge environmental challenges [78], there is little apparent concern being shown for this issue by either policy-makers or consumers. This is in part due to the fact that only 1% of the plastic in municipal waste comes from food delivery [73], and the government is consequently putting more effort into dealing with other plastic waste, such as plastic bottles and bags [79]. Meanwhile, for ordinary consumers, although they are aware of the environmental impact, they seldom think about how food and food-related wastes are produced, and many do not consider keeping leftover food for future meals or think to reuse the meal boxes, plastic bags or disposal chopsticks [51]. Only 21.1% of 884 university students surveyed in Changchun, China, in 2019, separated food and containers after consumption with 67.2% of them throwing leftover food away in the containers [80]. The study indicated that lack of knowledge was the main reason for this occurring, and only a few of the students (6.4%) clearly understood how to separate the wastes. To some extent, the lack of civil facilities (including a lack of recycling bins) contributes to this problem. Research among white-collar workers in office buildings in Chengdu, China, reported that if separate recycling bins were not provided, consumers ended up putting all of their waste into a single bin, even if they believed they should separate the wastes [81].

However, both the government and the online FD sector are starting to take action to mitigate against plastic waste. The 'Implementation Scheme for the Classification of Municipal Waste' published by the Chinese government in 2017, clearly stipulates that 46 cities across China should implement a mandatory classification system for municipal waste. By the end of 2020, the recycling rate of municipal waste in each city must reach more than 35% [82]. Shanghai was the first city to implement this system in July 2019, and it has subsequently seen the percentage of municipal solid waste going to landfill decreased from 41.4% in 2018 to 20% in 2019 [83]. The online FD sector is also exploring ways to improve its sustainability credentials. For example, Meituan in China launched the "Green Hill Plan" in 2017 and upgraded it to the "Green Hill Partner Program" in August 2018. This program, which has the goal of uniting its partners to protect the environment, has funded the planting of trees in Yunnan and Gansu [84]. Moreover, in China, the online platform Eleme now provides the consumer with the option of "disposable cutlery not needed". However, it has been noted that even if the consumer chooses the "disposable cutlery not needed" option, many restaurants will still provide them in the whole meal kit because it is less time consuming than distinguishing between who needs cutlery and who does not [79]. In a similar vein, platforms in the UK have been cutting down on the automatic provision of cutlery, with reports that a "utensil opt-in" rather than "opt-out" is more effective [85].

The extent to which food waste caused by online FD is contributing to the global burden of food waste is a matter of debate, because while consumers tend to over order and discard food, the counter-argument is that restaurants are more efficient at preparing food, and hence, there is less waste if the meals are prepared in restaurants. Obviously, an ideal outcome would be to achieve the benefits afforded by restaurant preparation without food waste occurring at the consumer end.

Food waste because of online FD is often associated with companies setting a 'minimum price' requirement which means consumers pay for more food than they need or try to order food with roommates in order to meet the 'minimum price' for free delivery services. This incentive to order more results in uneaten food being discarded, especially when consumers are unwilling or unable to store the leftovers because they do not want to have same meals again, or have the hassle of taking it home with them from the office, or they cannot store it because they live in dormitories, and are therefore, not allowed to have fridges within their rooms for example [51]. Secondly, compared with

ordering in a real restaurant where a range of sensory cues are available to the consumer, such as the aroma and sight of the food, it is very difficult for consumers using online FD to make the correct assumption about the portion size, as well as the taste. This means that online FD food is more likely to be discarded owing to its unexpected poor taste or unexpected large portion size. A survey conducted in Changchun, China, showed that 90.1% of 884 university students surveyed left half of their food uneaten [86].

A counter-argument is that food waste is decreased when using online FD, as online FD generates less waste than cooking at home or eating out in a restaurant. According to a qualitative study of 19 households in the UK in 2012, home cooking in some cases resulted in the production of more food than people need, and therefore, food ended up being wasted [87]. Food waste is also of serious concern when eating in restaurants. In China, a 2017 survey covering 3557 tables in 195 restaurants across four case cities reported that approximately 11kg/cap/year food waste was generated in restaurant-dining, which was similar to that generated by Western countries. This high level of food waste has been acknowledged in the literature as being in part, due to the Chinese cultural value of “mianzi”, in which over-ordering is seen as an important part of hospitality [88]. When using online FD, food waste can be reduced by ordering expensive food, which comes in smaller portion sizes, thus, still meeting the ‘minimum price’ requirement for online FD whilst receiving an amount of food that can reasonably be eaten [51].

Given the increase in public concern regarding the high levels of waste created as a result of online FD, stakeholders in the sector are starting to take action, so as to become part of the solution rather than simply the creator of the problem. The sector consists of incredibly powerful platforms with access to real-time location-based data. Leveraging this power, in 2018 Door Dash in the United States introduced a social impact program to tackle hunger and food waste by using its network of restaurant partners to match uneaten prepared food with hungry people. In another example, Seamless in the U.S. partnered with the No Kid Hungry program whereby customers had the option to round up their online FD payment to provide meals to children facing hunger. Further, Postmates rolled out a program in Los Angeles and 19 other U.S. cities in which participating restaurants are able to use their food delivery app to have excess or unwanted food taken to a local shelter [85]. Some food rescue organizations in the U.S. have begun leveraging crowd-shipping to transport surplus food more efficiently from donors to food-insecure recipients. However, the success of such initiatives relies on achieving a critical mass of donor and crowd-shipper participation [89].

In addition to plastic and food waste, another environmental issue that cannot be overlooked is that online FD creates a massive carbon footprint. In a 2019 study in China, focusing on the life cycle impact assessment of packaging from online FD, the data from 35.61 million orders from one online FD platform across eight cities was assessed in conjunction with 334 sets of packaging samples from the restaurants, including boxes, bags, chopsticks, cups and straws, etc. Taking Beijing as example, the authors discovered that online FD produced 0.1185kg of waste solids and 0.68 kg CO<sub>2</sub> eq/kg Global Warming Potential (GWP) from each order and that the manufacturing and disposal of packaging, accounted for 45% and 50% of the total environmental impact, respectively, making these the major environmental impacts across the whole industry. The delivery stage (including delivery from the manufacturer to restaurant, from delivery people to consumer, from consumer to disposal unit) only accounted for 5% of the environmental impact. The most serious environmental impact in this new industry is solid waste pollution, followed by water pollution, resource consumption and air pollution [90].

Online FD industry is desperately exploring ways to try to improve its image, including the use of bicycles and electric bikes, and even drones, to deliver food. Not only will this help to improve the environmental impacts of delivery, but it will also serve to reduce road safety problems. Currently, some delivery providers use cars or motorcycles which generate exhaust fumes, which contribute to air pollution. Scientists have recommended that food delivery operators use cargo-bikes, because they are quiet, emission-free, and less disturbing for citizens [91]. Drone food delivery is also less polluting because drones use batteries. Even though there are potential problems associated with using drones for food delivery, such as time risks, performance risks and psychological risks [92], researchers still believe that

drone-based delivery could reduce CO<sub>2</sub> emissions in the delivery service, and therefore, may be worth the other risks [93]. These low-carbon transportation innovations can contribute to reducing greenhouse gas emissions, and so many food service companies are already preparing for the commercialization of drone food delivery services, such as Yogiyo in Korea and Domino pizza in New Zealand [94].

## 5. Discussion

### 5.1. Practical Implications

In order to ensure the long-term sustainability of this sector, action must be taken now to magnify the positive impacts whilst mitigating the negative ones.

**Practitioners:** To improve economic sustainability by improving staff retention, online FD providers may need to adjust the rules of delivery time with delivery people's benefits and safety in mind. In terms of social sustainability, online FD platform providers could help to tackle the food waste problem by exploring ways to better communicate with their consumers about appropriate portion sizes and to avoid pressuring or unduly incentivizing consumers to over purchase. With regards to environmental sustainability, the online FD industry should consider working with both packaging producers and the restaurant sector to explore options for the development and use of more sustainable packaging materials.

**Policy-makers:** Policy-makers should consider how to better regulate to ensure appropriate working conditions for delivery people which could result in lower attrition rates, and therefore, improved economic sustainability. In terms of enhancing social sustainability, policy-makers could raise public awareness of sustainability and healthy eating habits through education. More importantly, they could work on clarifying the rights and responsibilities of each stakeholder in waste management (e.g., waste management companies, online FD companies, and consumers) by improving relevant policies and regulations. Regarding environmental sustainability, policy-makers could encourage the packaging industry to develop new packaging material through incentives, such as taxation, subsidies, and industrial support.

**Consumers:** Ordering wisely and eating healthily would reduce the chance of wasting money by purchasing food that is not consumed and avoid the potential negative health outcomes associated with overconsumption, providing both economic and health benefits. In terms of enhancing the social sustainability of online FD consumption, users could be encouraged to order and share food with colleagues or flat mates to enhance social bonds. To make their own contributions to environmental sustainability, users could separate food and packaging waste after finishing the meal.

### 5.2. Limitations and Future Research Directions

As with any study, this review is subject to several limitations which must be acknowledged. Firstly, while the scope of the review was global in nature, the fact that the online FD sector is more developed in China meant that a large proportion of the referenced articles included herein are concerned with online FD in China. Future research that explores online FD in non-Chinese contexts will be critical to the success of this sector as it rapidly develops globally. Secondly, a notable limitation in being able to generalize findings from the studies to date is that the target populations for many of the existing studies have been university students. Therefore, future research should consider the much broader actual market by including a diverse range of representative participants in studies. Thirdly, a systematic review of the literature was not possible given the limited academic work available. As this is a burgeoning academic field, we encourage future researchers to adopt a systemic approach to understand the sustainability impacts of online FD.

In particular, future research by academics should be focused on each of the impacts of online FD, identified in this review to help provide deeper insights into why the impact is occurring and how this can be either promoted or mitigated. Research to date has overwhelmingly focused on the attributes of online FD and consumer's motivation and behaviors for using food delivery services,

as well as on online FD business models. A notable gap in the literature is that there has been very little work conducted with regards to food waste in relation to online FD services. This is surprising given the burgeoning attention food waste is receiving in many other food-related fields. Future work in this area could consider not only how much food is wasted owing to online FD, but also what practical steps or interventions could be taken to reduce this waste. As aforementioned, there are already initiatives underway to tackle waste reduction by distributing surplus food to hungry people. However, academic research is required to investigate the impact of such actions and to explore how to scale these for greater effectiveness.

## 6. Conclusions

This review has outlined a large array of impacts from online FD that are affecting a range of stakeholders in different ways, as summarized in Table 3. While an attempt has been made to categorize the impacts as being either ‘positive’ or ‘negative’, in reality, an argument could be made for each impact to be categorized differently. For example, during the COVID-19 crises, online FD had a positive impact in that it allowed people to source food without leaving home (i.e., a positive impact for consumers), but using online FD at this time did mean greater exposure for delivery people (i.e., a negative impact for delivery people).

**Table 3.** Summary of positive and negative impacts of online FD on the three pillars of sustainability.

Sustainability	Impacts	For most Stakeholders		Difficult to Categorize
		Mainly positive	Mainly negative	
Economic	Increased job opportunities	√		
	Relatively low job satisfaction		√	
	Impacts on traditional restaurants but new business models evolve			√
Social	Changing human-food and human-human relationship			√
	Convenient urban life	√		
	Challenges to public health		√	
	Impacts on public traffic		√	
	Lifeline in 2020 SAR-CoVid-2 outbreak, but moral concerns around the safety of delivery people			√
Environmental	Plastic waste		√	
	Food waste			√
	Carbon footprint		√	

To conclude, this review has made three key contributions. Firstly, it is the first interdisciplinary review that brings together academic research on the broad range of areas impacted by the increased use of online FD. Secondly, it has discussed the opportunities and challenges these impacts pose. Thirdly, it highlights the opportunities for action by all stakeholders, including online FD industry practitioners, policy-makers, consumers, and academics, to maximize its positive and reduce its adverse impacts. The future of online food delivery is exciting, and in order to ensure the sector develops in a sustainable manner which serves the interests of all stakeholders involved, we must continue to reflect on what is happening, and question if things could be done better.

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