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Communication

Sustainable Food Delivery

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Abstract: Food delivery service has grown rapidly in recent years and exploded during the pandemic. However, the single use packaging of food delivery generated a huge amount of wastes and emissions. This article assessed the economic feasibility and environmental impacts of a green food delivery system, where a company focuses on the distribution and collection of reusable food containers and tableware. To find the answer, a survey was conducted to estimate the willingness to pay for extra service charge among young Millennials, and a scenario-based analysis was performed to a case study region in Cambridge, Massachusetts. Results show that the green food delivery system can be self-sustained or even profitable solely by charging $1 from the customers. However, the actual positive externality of the system, estimated as CO2-eq emissions avoided, is only around 1% of the total operating cost, and 3-10% of the profit, making the system not efficient in terms of sustainability. The illusion of this system being "green", however, may be taken advantage of by companies as advertisement and make profit by manipulating students' willingness to protect our environment.

Keywords: Sustainability, Food Delivery, Reuse&Recycle

1. Introduction

Ordering food with a few clicks on apps like UberEats and Grubhub has gained popularity in recent years and exploded during the COVID pandemic. However, as such service grows viral, its environmental impact becomes concerning. Meituan, one of the leading food delivery platforms in China, delivered more than 27 million food orders per day and contributed approximately 1.6 billion tonnes of packaging waste in 2018 [1]. In Europe, over two billion disposable takeaway containers are used every year [2]. In Australia, the single-use packaging from online food delivery led to 5,600 tonnes of carbon dioxide equivalent (CO_2-eq) emissions in 2018 and is projected to increase two-folds by 2024 [3]. As food delivery becomes a considerable business market, adopting “green” approaches to deliver food is in urgent need to reduce the environmental footprint of this convenient service.

Multiple attempts have been tried from different perspectives to cut the carbon emission associated with food delivery. In China, for instance, electric bikes have become the best transportation for food delivery, which is more expedient and energy efficient than cars in the busiest parts of cities. However, this may be only applicable to regions similar to Chinese cities: high population density, and short delivery distances from restaurants to customers. With the US Federal Aviation Administration recently approving rules for delivery services to people's homes, drone food delivery has swept the USA in 2021. This option has a lower environmental impact than ground-based delivery methods, including diesel trucks, trucks powered by natural gas or even electric vans [4], especially when the drone battery is charged by renewable energy. However, large-scale implementation of this delivery approach requires further technology development. Meanwhile, food delivery apps have also strived to improve sustainability of food delivery via various policies and options that aim to reduce the life-cycle emissions. Uber Eats, for example, waives delivery fees for customers who order from a range of restaurants that require shorter delivery routes, which allows one driver to pick up multiple deliveries and reduce time on the road. DoorDash, another delivery app, has a policy that restaurants default to not including tableware with food order, which saves the waste from single-use tableware.

Recently, the number of reusable food packaging solutions has been growing, mostly in forms of providing reusable tableware and containers to various takeout food sellers and collecting through deposit systems, and some has entered dining service areas such as those in university campuses [5]. Historically, deposit systems have been functioning well for beer and dairy bottles, for example. But the distinct challenge for modern food delivery is that tableware and containers are circulating among hundreds or thousands of restaurants and an even greater number of customers, possibly leading to a very complex and expensive operating cost. One such example with early success is Loop, an online shopping service platform who delivers high-margin personal care and cleaning products through resistant reusable bags and pick-up in the next order. However, whether or not a similar business model can be feasible for food delivery remains an open question to be answered.

This study aims to assess the economic and environmental outcomes of a new sustainability business that focuses on the distribution and collection of reusable containers and tableware for food delivery. In its simplest form, this business could be a third-party company cooperating with food delivery apps and the restaurants that on one hand lease or provide free reusable food delivery kits (e.g. tableware, containers and bags) to restaurants, and on the other hand collect, clean and sanitize used delivery kits for later use. When orders come in, the restaurants will put the food in these reusable containers and deliver it to the customers by food delivery apps as normal. When customers finish eating, they can put the used reusable packages in a collection system set up by the company. The restaurants should be willing to participate since there’s no extra cost for them and it mostly likely reduced their cost on delivery containers.

Some variants of this business model have emerged, but their economic feasibility and environmental impacts are elusive. For example, Ozzi, an U.S. company who offers reusable containers and collection systems suggested participant restaurants can save nearly $70,000 annually compared with using disposable units (assuming 300,000 units annually purchased at a relatively high price of $0.3 per unit). However, this calculation didn’t consider external costs such as dishwashing and labor. Also, they have not discussed whether or not the extra carbon emission of running this system will outweigh the savings from reducing single-use units. In addition, several other questions to be answered: How much service fee can be charged to reimburse the operating cost? Can this business survive without external funding support? What's the emission throughout the system? Are the environmental benefits meaningful compared to the operating cost?

2. Materials and Methods

2.1 Study area and spatial analysis

Among the many possible service areas, the dorms within university campuses are likely to be the most feasible because of its high population density of young Millennials who tend to be "green" consumers [6]. Here I use food delivery from the hundreds of restaurants in Cambridge, MA, to the on-campus student dormitories at Harvard and MIT as a case to investigate the economic and environmental outcomes of green food delivery with reusable tableware and containers (Figure 1a). I set up two scenarios with the first scenario (S1) having a third-party organization/company build a warehouse for cleaning and sanitizing close to Cambridge, and the second scenario (S2) having the warehouse located in a suburban area for a lower rental cost but slightly more travel distance.

Restaurant locations (i.e., latitude and longitude) are extracted from the Points of Interest (POI) categorized as 'restaurant', 'fast food', and 'food court', which are available at OpenStreetMap (http://download.geofabrik.de/north-america/us.html). The two warehouses are manually selected from a LoopNet (https://www.loopnet.com/), a website specialized for renting commercial properties. The first warehouse I selected is at about 2.5km from the centroid of Cambridge at a cost of $25.75/sf/year, and the second at about 7.5km away at a lower cost of $14/sf/year. For each trip, the driver will set off from the warehouse and stop by restaurants to deliver sanitized tableware and containers or by dorms to pick up used ones, and finally return to the warehouse. The routes are determined by searching the nearest stop (i.e. the minimal cartesian distance from one stop to the next, for simplicity) sequentially in R. Next, the vehicle driving distance connecting all stops is estimated using the Google Distance Matrix API (https://developers.google.com/maps/documentation/distance-matrix/overview). The Distance Matrix API is a service that returns the estimated travel distance and time for a matrix of origins and destinations along the roads with given departure time and transportation mode. The departure time is set as 10 AM EST on October 20, 2020, and the transportation mode is set as 'driving'.

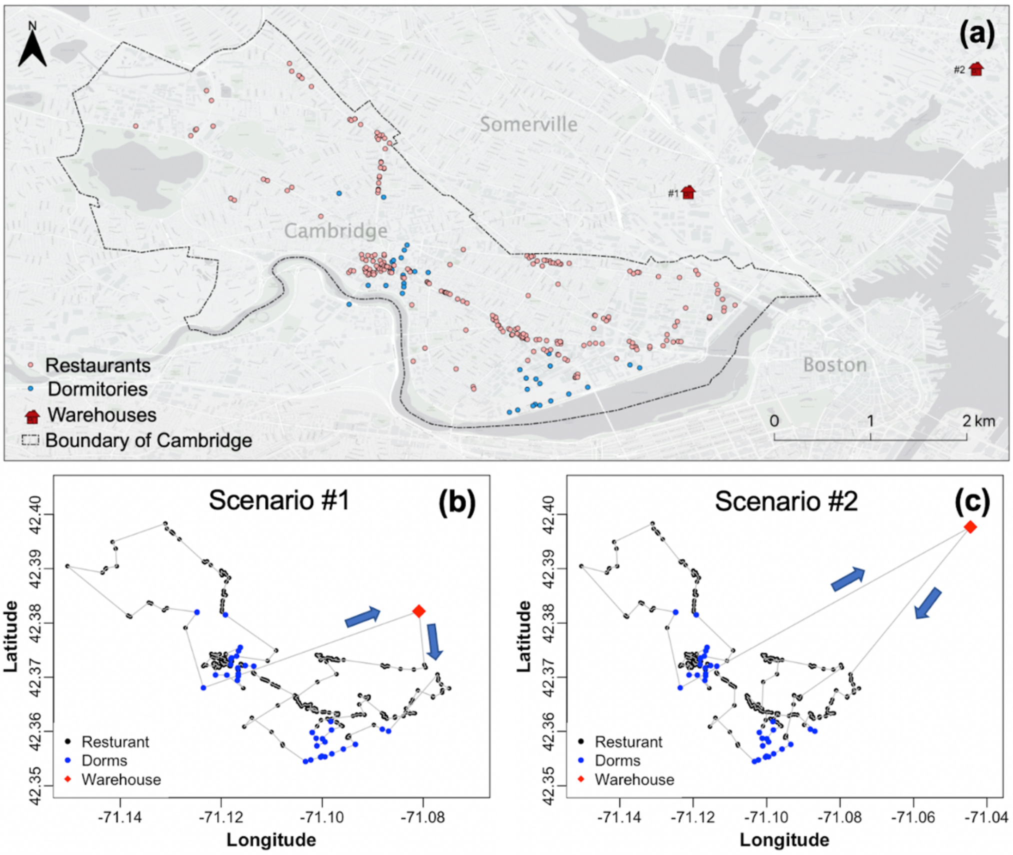

Figure 1. Study area, points of interest, and routes for collecting and re-distributing reusable food packaging under two scenarios.

2.2 Questionnaire survey

To answer the willingness to pay extra for reusable containers, a survey was conducted via SurveyMonkey to collect feedback of the target market. Until the 13th of August 2020, 272 responses were collected from multiple countries, including the U.S., China, the UK, Canada and Australia. Among these, 126 U.S. responses mainly from the New England region are used for the scenario analysis. The samples are mainly high school and college students, making the data collected representative for the research question.

The first survey question to ask is: do you mind carrying food containers and tableware to a recycle box in front of the dorm after finishing the food. This survey question helps to assess how many students are likely to participate in this green food delivery program. The second survey question is: are you willing to pay more for a more sustainable delivery system. This information is crucial for determining whether the customers can cover part of the cost of the new system. If the answer is yes, the next question will be “how much more are you willing to spend”. The respondents will be given choices from a range between 0-10 US$. This is a reasonable assumption compared with the per delivery cost for food ($20-30) and delivery service fee ($1.89 to $3.45 depending on delivery apps [7]. The potential amount of extra money one can get from the customers is essential in calculating if this new business model can survive or not.

2.3 Scenario analysis of economic and environmental outcomes

The cost for a third-party operated green food packaging delivery system mainly includes expenses on renting the warehouse, driver’s and on-site worker’s salary, fuels, and environmental cost associated with emissions from transportation. A number of fact-based assumptions were made for generating the estimates. The warehouse was assumed to be a 2,000 square feet facility, with rental cost specified in the previous section. Salary for driver and on-site work was assumed at $22/hr and $20/hr, which is roughly the national average salary for these two occupations. For fuel cost, this analysis assumed that the third-party driver uses a light-duty truck, and the fuel efficiency driving in the urban area is 19 mile per gallon. This driver will take 3 round trips per week. The social cost associated with climate change (e.g. due to emissions of CO_2, CH_4 and N_2O) and non-climate change (e.g. caused by NH_3, NO_x, PM2.5, SO_2, VOCs) damages were obtained from [8], a guidebook for quantifying the full costs and benefits of different transportation modes. At the current CO_2 price of about $50 per tonne, the average climate change damages cost $0.02/mile and non-climate change costs $0.015/mile.

The income mainly comes from two sources. First, service charges to customers were assumed to be $1 per delivery. As will be shown in section 3.1, this rate was above the acceptable threshold by the majority of young customers. However, this may reduce food delivery orders from people who do not feel comfortable with greater than $1 service charge (about 30% of the survey respondents), but some may continue to use the service for a variety of reasons. Therefore, I exclude service income from this group of people by 50%. Second, CO_2 emissions that are avoided due to reusable food delivery packages brings economic income to the society. For this category, the best recent estimate I found is by Arunan & Crawford (2020) for Australia, who reported that packaging-related GHG emissions range from 0.15 to 0.29 kg CO_2-eq per order, depending on food types. I used the average of 0.22 kg CO_2-eq for calculation. Finally, the number of food delivery orders need to be estimated in order to calculate the annual total service charge income and emissions avoided. The best information I found is a survey by [9], who reported out of 2928 surveyed US consumers ages 18+, 19% of them ordered food delivery service with 1-2 times, 10% with 3-4 times, 5% with 5-6, 2% with 7-8 times, 2% with 9-10 times, and 3% with more than 11 times in the past 90 days. The weighted average for annual food delivery orders is thus 6.32 per year.

This may be an under-estimate because [9] found the age group of 18-29, many of whom are college and university students, used more food delivery than other age groups.

3. Results

3.1 Willingness to pay for green delivery

Among the 272 responses collected, approximately 88% of participants said they definitely or probably wouldn't mind carrying their food containers to a recycle box in front of their dorm after finishing the food they ordered (Figure 2a). This high percentage indicates green food delivery has a good potential at university dorms. Regarding the willingness to pay, about 81% of respondents are willing to pay 0-5 US$ more (0 is not included) for reusable food containers with 29.4% willing to pay 0-1 US$ more (0 is not included) , 34.9% willing to pay 1-3 US$ more and 19.9% willing to pay for 3-5 US$ more (Figure 2b). Nobody answered 0 [10]. This high percentage of willingness to pay for reusable food packages is close to a recent survey estimate by GreenPrint's Business of Sustainability Index that 75% of Millennials are willing to pay more for an environmentally sustainable product [11]. The distribution of monetary preference on service charge also suggests that the service charge for reusable tableware and containers should be set around $1 to attract the majority of students. In short, the target markets are willing to act on this incentive if it won't dramatically increase their cost on online food ordering.

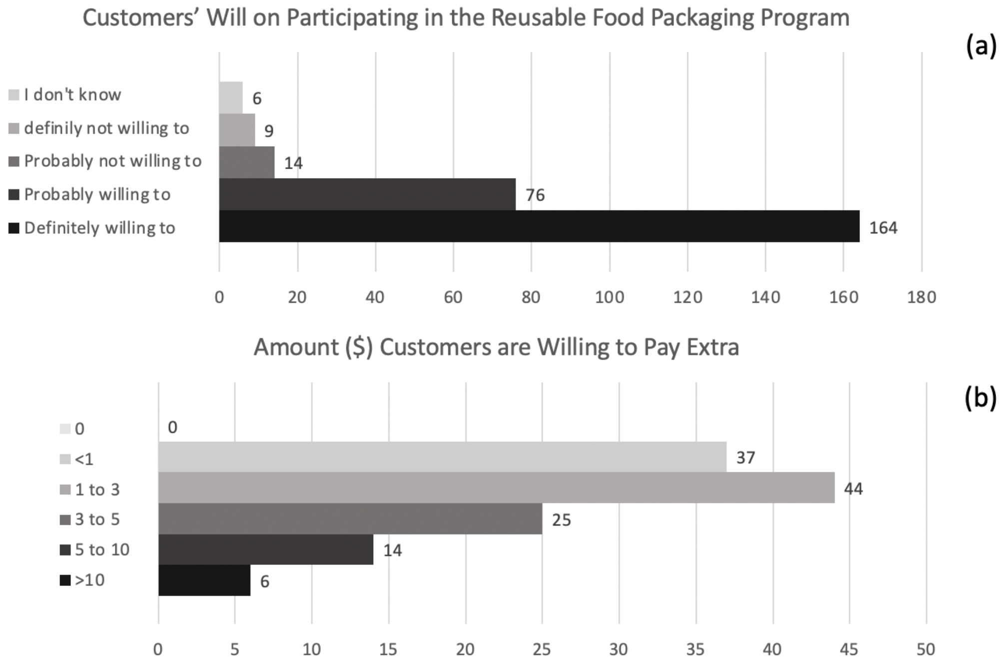

Figure 2. (a) Willingness to participate in green food delivery programs. (b) Willingness to pay for extra service charge for reusable food packaging. Data used in the figure can be retrieved from citation [10].

3.2 Environmental and economic outcomes of green delivery

Results showed that the cost of facility rental and labor to operate a reusable food packaging service is much higher than the environmental cost (Table 1), accounting for 97.7% and 96.7% of the total annual costs of $92,307 and $68,963 under S1 and S2, respectively. The climate change and non-climate change damages costs associated with vehicle emissions are almost negligible under both scenarios. The same conclusion is true even increasing the current CO2 price from ~$50/tonne to the more aggressive $200/tonne proposal, suggesting the green food delivery service does have very small inherent environmental costs.

On the other hand, the $1 service charge applied to each meal delivery with reusable tableware and containers could bring considerable annual income of $105,587, just based on on-campus housing students in the two Universities. Another income source is the carbon emission avoided by saving single use food packaging and tableware. In total, 21.1 tonnes of CO2-eq emissions can be avoided, which values $1,077 with the current CO2 price of $51/tonne. As such, the dollar value of environmental benefits achieved through the green food delivery service is only about 1% of the total operating income. Although 21.1 tonnes saving of CO2-eq seems to be a surprisingly low number, it is reasonable when comparing to a recent estimate of 5,600 tonnes of annual CO2-eq emissions caused by disposal of single use packaging from online food orders in Australia [3]. There's no doubt that our society should significantly reduce single use food packings, but this scenario analysis casts doubt on whether or not many publicly advocated "green solutions" are addressing meaningful problems or in the right way.

The net margin of green food delivery service is $14,357 and $37,701 for S1 and S2, respectively (Table 1), suggesting it can be a self-sustained or even profitable business. However, the budget sheet in Table 1 revealed a counterintuitive fact that green food delivery, regardless of the benefits being advocated by environmentalists, is a solution that solves the ~$1,000 problem of single use tableware and containers by triggering nearly 70 to 90 times more cost. But because of the considerable net margin, commercial entities may take advantage of the public's willingness, especially among young Millennials [6], to pay for environmental sustainability to generate profit. If the green food delivery customers can be extended beyond the on-campus living students in the two Universities to all workers in the Cambridge region, the net margin would be even more attractive since the dynamic cost increased by more users is relatively a small fraction compared with the static cost.

Table 1. Detailed cost and income analysis.

Items	Assumption	Scenario 1	Scenario 2
	Cost		
Facility	Rent 2000 square feets warehouse for cleaning and storing tablewares and containers	$25.75×2000 = $51,500	$14×2000 = $28,000
Labor (driver)	4 hrs per trip with $22/hr rate	$22×4×3×52 = $13,728	$88×3×52 = $13,728
Labor (on-site)	Unpack, machine operation 8 hrs with $20/hr	$20×8×3×52 = $24,960	$20×8×3×52 = $24,960
Fuels	Light-duty vehicle with 19 mile per gallon fuel efficiency in the city, fuel at $3.3 per gallon	$3.3×61.76/19×3×52 = $1,674	$3.3×66.33/19×3×52 = $1,797
Air pollutions	Social costs of climate change (i.e. CO_2, CH_4 and N_2O) and non-climate change (e.g. NH3, NO_x, $PM_{2.5}$, SO_2, VOCs) damages. On average, $0.02/mile for climate change damages costs, $0.015/mile for non-climate change costs[1]	1.32×($0.02+$0.015)×61.76 ×3×52 = $445	1.32×($0.02+$0.015)×66.33 ×3×52 = $478
Subtotal 1		**$92,307**	**$68,963**
	Income		
Service fee	$1 charge to customers for reusable tableware and containers but reduce the frequency of ordering food delivery by 50% among some students.	$1×19586×6.32×0.706+ $0.5×19586×6.32×0.294 = $105,587	
	$0 charge to restaurants to attract participation		$0
CO2 avoided	Social cost for avoiding CO_2 from single use food delivery tableware and containers. Assume 0.2 kg CO_2 per deliver food[2]	$51×0.2/1000×19586×6.32×(0.706+0.5×0.294) = $1,077	
Subtotal 2			**$106,664**
Net margin	Income minus cost	**$14,357**	**$37,701**

[1] Data from "Transportation Cost and Benefit Analysis: Techniques, Estimates and Implications", chapter 5.10. Updated by March 20, 2020. Accessed from: https://www.vtpi.org/tca/tca0510.pdf.

[2] The median estimates by Arunan & Crawford (2020).

The estimations in this study are inevitably associated with uncertainties. For example, the upfront equipment (e.g. dishwashers) and some operating cost (e.g. utility bills) of running this green food delivery service has not been explicitly considered, which may add to the cost. The fuel efficiency and gas price may vary widely depending on the travel time. Social costs of climate change and non-climate change damages could also vary significantly [12]. On the income side, how the added service charge would affect students' behavior on ordering delivery food is unknown and require more survey-based data to quantify. Regardless of these uncertainties, the major findings in this study are unlikely to change because the capital cost and margin is greater than the environmental benefits by orders of magnitude.

4. Discussion

Based on the survey and scenario analysis, the conclusion is somewhat counter intuitive. First, the green food delivery business can be self-sustained or even profitable solely by charging one extra dollar from the customers. Surprisingly, the actual positive externality of the system, estimated as CO2-eq emissions avoided, is only around 1% of the total operating cost, 3-10% of the profit, making the system not efficient in terms of sustainability. The illusion of this system being "green", however, may be taken advantage of by companies as advertisement and make profit by manipulating students' willingness to protect our environment.

For the sake of pursuing sustainability, other solutions must be proposed and studied. For example, instead of having a company that runs this entire system, each school can operate their own systems and students won't be charged for this service. This approach can potentially reduce the carbon emission due to transportation, reaching out to more students in each school and greater student participation without an extra cost. Furthermore, other than containers, food waste is another critical source of CO2 emission. About 50% of the food is wasted in the U.S., and the burning/decomposing of these wasted food generates substantial CO2 and CH4 emission. Increasing and improving waste recovery and processing infrastructure will help significantly divert waste from landfill, possibly delivering substantially greater impacts than simply promoting a reusable food packaging system.

5. Patents

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Conflicts of Interest

The authors declare no conflict of interest.

References

1. Zhong, Raymond, and Carolyn Zhang. *Food Delivery Apps Are Drowning China in* Plastic, 28 May 2019. New York Times.
2. *Less Polluting but Too Light, Styrofoam Sparks Recycling Debate.* Available online: news.cgtn.com/news/3d3d674d3345444e31457a6333566d54/index.html. Accessed 29 Oct. 2021.
3. Indumathi Arunan, Robert H. Crawford, *Greenhouse gas emissions associated with food packaging for online food delivery services in Australia*, 2021. Resources, Conservation and Recycling, Volume 168
4. Stolaroff, J.K., Samaras, C., O'Neill, E.R. et al. *Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery,* 2018. Nat Commun 9.

5. Patricia Megale Coelho, Blanca Corona, Roland ten Klooster, Ernst Worrell, *Sustainability of reusable packaging–Current situation and trends*, 2020. Resources, Conservation & Recycling, Volume 6.
6. Naderi, I. and Van Steenburg, E., *Me first, then the environment: young Millennials as green consumers*, 2018. Young Consumers, Vol. 19 No. 3, pp. 280-295.
7. *Consumer Fee Comparison: Food Delivery Companies*. Available online: www.kinetic12.com/newsroom/consumer-fee-comparison-food-delivery-companies/. Accessed 30 Oct. 2021.
8. Litman, T., *Transportation cost and benefit analysis: Techniques, estimates and implications*, 2016.
9. *Food Delivery Apps: Usage and Demographics — Winners, Losers and Laggards*. Available online: www.zionandzion.com/research/food-delivery-apps-usage-and-demographics-winners-losers-and-laggards /. Accessed 30 Oct. 2021
10. Yuqing Mao, Available online: https://www.exploratiojournal.com/green-food-delivery-for-campus/ , Accessed 30 Oct. 2021
11. Green Print. *Business of Sustainability Index,* Mar. 2021. PDF.
12. Carleton, Tamma and Greenstone, Michael, *Updating the United States Government's Social Cost of Carbon*, January 14, 2021. University of Chicago, Becker Friedman Institute for Economics.