The Impact of E-commerce Last-mile Delivery on Environmental Sustainability

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Abstract. Along with the increasing number of people holding the tool of purchasing what they want online, logistics operation has become gradually prosperous in recent years. Here comes the serious problem of carbon emission during the delivery process. Although some countries have already paid attention to such a phenomenon, the issue of the extra release of carbon dioxide does not be resolved completely. This paper introduces and analyses the conditions of carbon dioxide emissions during the last-mile delivery and aims to analyze the switch of customer expectations and specific LMD processes. This work makes use of data collection, survey methods, and simulation to mainly get analysis on the topic. The results of the paper showcase that first delivery, return delivery, delayed delivery, and failed delivery all contributes much to the accumulation of carbon dioxide emissions while presenting solutions that have their own benefits and defects. The results invite people to reflect on solutions to improve the present situation on delivery and help to encourage people's initiatives of creating better living conditions for the next generation.

Keywords: e-commerce industry, last-mile delivery, customer expectation, environmental sustainability, carbon emission.

1 Introduction

In the digital area, internet-related businesses have been flourishing across the globe, with the internet increasingly recognized as a platform for commercial transactions [1]. This has led to a surge in electronic commerce, or e-commerce, drawing considerable attention from researchers, especially as the share of online shopping continues to grow in overall consumption [2]. E-commerce encompasses a broad spectrum of online shopping activities for goods and services, often utilizing computer-mediated networks for transactions that involve ownership or rights to use those goods and services [3]. Unlike traditional offline shopping, e-commerce enables customers to place orders from anywhere. The online search function within this shopping model allows for convenient inquiries about product information and facilitates purchases from any part of the world. Additionally, it offers global shipping services, delivering goods directly to consumers' homes, particularly in densely populated urban areas [4]. However, the last journey of delivery, known as last-mile delivery, has been linked to significant environmental pollution [5].

The primary emphasis of this paper lies in assessing the environmental sustainability implications of last-mile delivery in the realm of e-commerce, along with investigating potential remedies. The following section will provide an extensive summary of last-mile delivery and freight services in e-commerce, delving into their corresponding environmental effects.

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Following this summary, additional concepts regarding last-mile delivery will be explored, ranging from its emergence to current solutions. This part will be further subdivided into four key areas. Then, in the main body of the paper, data will be employed to analyze the issues identified in the literature review concerning last-mile delivery. Finally, the paper will propose innovative ideas to address the environmental problem existing in last-mile delivery, integrating perspectives from government systems, consumer expectations, and logistics company distribution networks.

2 Literature Review

The last-mile delivery constitutes a segment within urban freight transport [6]. It represents the final leg of the business-to-consumer delivery process, involving the direct delivery of products to end customers, often at their residences.

Because of the greater popularity of online shopping in recent years, an increasing number of packages must be delivered with a higher frequency and lower consolidation [7]. Nevertheless, transportation companies focus on maximizing their profits and consumer satisfaction; they generally ignore the negative impact on urban areas bought by increasing road deliveries, especially in terms of environmental impact [6]. The logistic service provided by transportation companies, closely related to last-mile delivery, is considered the major contributor to increasing emissions, and the emissions are expected to rise by one-third in the future, followed by higher amounts of vehicle miles traveled [5].

Before the data analysis, it is essential to have a comprehensive understanding of concepts related to last-mile delivery. From the literature review, last-mile delivery will be introduced into four parts based on existing literatures: 1) emergence of last-mile delivery----consumer expectation, 2) major pollution produced by transportation delivery, 3) the main factors in last-mile delivery which cause the environmental impact, 4) existing solutions.

2.1 The emergence of last-mile delivery---- consumer expectation

Customer satisfaction is the psychological state after their needs are satisfied. It is also regarded as a value judgment of whether the consumer is satisfied with the services and products. And the psychological reaction of consumer satisfaction is produced by their perception, and expectation of service [8]. In e-commerce, logistics companies are required in recent years to respond to rising customer expectations regarding delivery time and service [9]. And that last-mile delivery had become the primary customer expectation in the food and grocery sector. Last-mile delivery, as a value-add service, is willing to pay more money by the consumer when they are satisfied with this delivery service [10].

2.2 Major pollution produced by transportation delivery

The freight flow in urban areas is growing dramatically as more significant demands for consumer online shopping contribute to a higher frequency growth of vehicle movements in urban areas [5]. Consequently, issues related to transportation in densely populated regions become more apparent, encompassing concerns like greenhouse gas emissions, carbon dioxide output, sound disturbances, and traffic congestion [11].Greenhouse gas (GHG) emission created by the transport sector can be determined to take charge of about 20-25% of global greenhouse

gas emissions[12]. As previously mentioned, the primarily widely used mode of transport for last-mile delivery is just road freight transportation. Last-mile delivery also plays the most significant role in carbon dioxide emissions, which on average, contributes 32% of total carbon dioxide emissions related to e-commerce [13].

2.3 Factors in last-mile delivery to cause the environmental impact

The final stage of delivery is considered a significant hurdle for e-commerce industry leaders and their expansion efforts, primarily due to various inherent factors. Ranging from delayed delivery time to return of the express packages, for example, requires logistics companies to deliver two or more times, which induces additional transportation costs, labor force, and carbon dioxide emission [7]. Meanwhile, failed delivery is also a leading contributor to increased environmental pollution. The failure of delivery is attributed to the fact that the customer cannot sign for an express parcel when the order is delivered. Thus, it also requires additional trips entailing more carbon dioxide emissions for delivering the packages [4].

2.4 Existing solutions to reduce pollution

In view of environmental pollution contributed by the last mile delivery, some existing pieces of literature have proposed innovative and environmental-friendly solutions [14-16]. According to the research, some innovative ideas can be found to reduce carbon dioxide emissions during last-mile delivery, such as establishing consolidation centers (consolidating parcel flows in cities) and formulating regulations for freight transportation (e.g., restricting the traveling of 6freight vehicles at a specific time of day). Plus. The use of more low-polluting vehicles in last-mile delivery would also mitigate environmental pollution, and the low polluting vehicle contains electric delivery vehicles, Deliver, delivery drones, which have the typical characteristics with high efficiency and low carbon-dioxide emission [15]. The relevant solutions mentioned above are only to replace traditional transport vehicles or to place restrictions on freight vehicles' road accessibility. And this paper is more inclined to evaluate a comprehensive group of solutions to reduce the carbon emissions generated by the last mile delivery, by combining the government system, consumer expectations, and logistics company distribution model.

3 Discussion Analysis

3.1 CO2 emission of last-mile delivery in recent years and future trend

With the growing concern for the environment, CO2 emissions have become one of the most scrutinized environmental issues in the world. According to the International Energy Agency (IEA), in 2018, global road transportation is responsible for 29.4% of total CO2 emissions, which is one of the major sources of carbon dioxide emissions [17].

In road transport, the last mile delivery is a very important part. Although, as its name suggests, this part of transportation does not include a lot of distance, according to statistics, the last mile is responsible for 50% of CO2 emissions of all delivery vehicles globally [18]. As the second-largest e-commerce market in the world, the United States, CO2 emissions of last-mile delivery have reached 41,00000t CO2 in 2020, more than the entire European Union's combined last-mile emissions [18].

Since most of the express delivery companies have not disclosed their carbon emissions of last-mile delivery in recent years, this analysis refers to the CO2 emissions of the last mile per package (204g) in 2020 according to the calculations in "Secret Emissions of E-commerce" and the total annual packages in the United States according to the Package Shipping index[18], coming up with a rough estimation of the total carbon emissions generated by the last-mile delivery in the United States from 2019-2022.

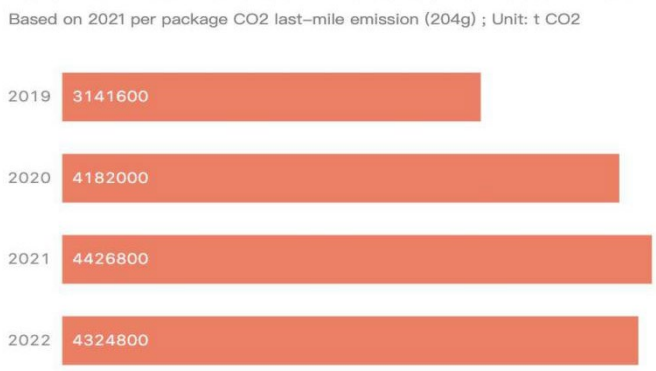


Figure 1. 2019-2022 Estimate Last-mile Carbon Emission in US.

The data in figure 1 suggests that if the 2020 level of CO2 emissions per package is maintained in last-mile delivery (204g), the environmental impact caused by the last-mile delivery will increase year by year due to the popularity of e-commerce and increasing customer expectations of last-mile delivery. However, due to the impact of the pandemic, the number of packages shipped in the U.S. decreased in the year 2022, which contributed to a reduction in the carbon emissions from last-mile delivery in the same year. However, according to the parcel index's projections for the period afterward, it's believed that the short-lived downward trend in 2021-2022 will be immediately countered by an upward trend if there is no appropriate way to reduce the carbon emissions of last-mile per parcel. With e-commerce gaining market share and offline shopping fading out of the market, The World Economic Forum (2020) projected that the number of freight vehicles for express delivery will increase by 36% by 2030 in urban areas, which will subsequently result in an increase by 32% of delivery emission [19].

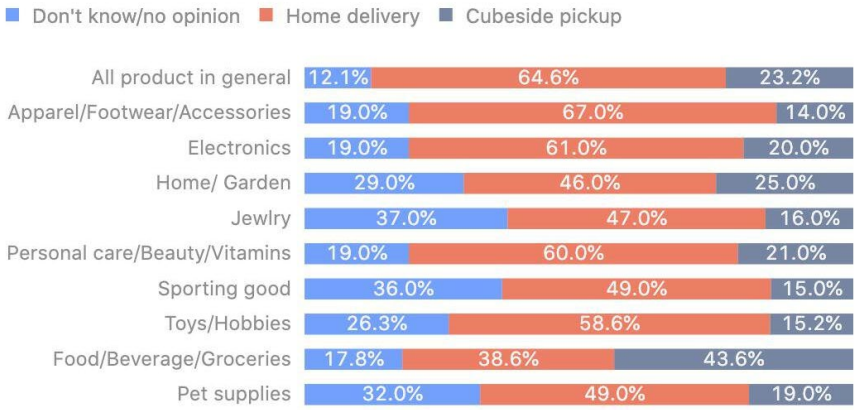
3.2 Different Sections of LMD Contributing to environment devastation

3.2.1 Consumer delivery tendencies play a big role in last-mile delivery

An important reason why the last mile is so important in express transportation is consumer delivery tendencies. Due to the increase in time spent in commuting to daily work, attending to family responsibilities, or keeping up with school assignments, one-third of people in the last five years believe their free time has become less [20]. This also means that people's quest for convenience in everything has increased, including the desire for online retailers to offer more convenient services.

This quest for convenience has led to a result: home delivery is still a top choice. According to figure 2, which is about customer preferences on methods of pick-up or delivery in 2022, 64%

of people preferred home delivery based on the free shipping services that online retailers are now offering. And, when looking at people's propensity for delivery of different types of consumer goods, for almost all types of goods, people preferred home delivery over others [21]. This also means that in the current social climate, the last mile is hard to avoid based on consumers' delivery tendencies and the free delivery services offered by online retailers.



Note:Source: Pitney Bowes BOX poll

Figure 2. Preference on Methods of Pick-up or Delivery [21].

3.3 Three segments of last-mile delivery

3.3.1 First Delivery

The first and foremost component of last-mile delivery is first delivery, which maintains the transportation of buses and vans. The amount of CO2 emissions per typical drop rises from 181g for initial 100% delivery to a maximum of 271g in the worst scenario, calculated from the emissions produced of one ordinary household first delivery. With an average of 120 drops per usual 50km round, a successful initial delivery released 181g of CO2. First delivery could be divided into two major factors: the number of items carried and the type of transportation used. Normally, most first deliveries only carry one item, which would be able to increase the number of items per drop. This is mainly associated with the current problem that online retailers send packages regardless of the size of it. In the case of small items like books, CDs, and DVDs, which have an average of 1.4 items per drop, each item contributes to 137g of CO2 emissions. As for clothes and household items, an average of 2.5 items per home delivery is estimated, with each item accounting for 72g of CO2 [22].

In terms of transportation tools used in the first delivery, different tools cause varied amounts of carbon emissions, which is revealed by figure 3. One essential delivery scenario is trip chaining, which helps to rationalize personal tripping. However, browsing trips would have an adverse effect, which would double or triple emissions during online shopping. Average estimate for a combined trip would be able to produce 1,069g of emission. Through data analysis, it is investigated that car travel remains the worse delivery option in the first delivery.

In the following diagram, it's clearly illustrated that browsing and trip accomplished by cars are the most severe conditions in terms of carbon emission during first delivery.

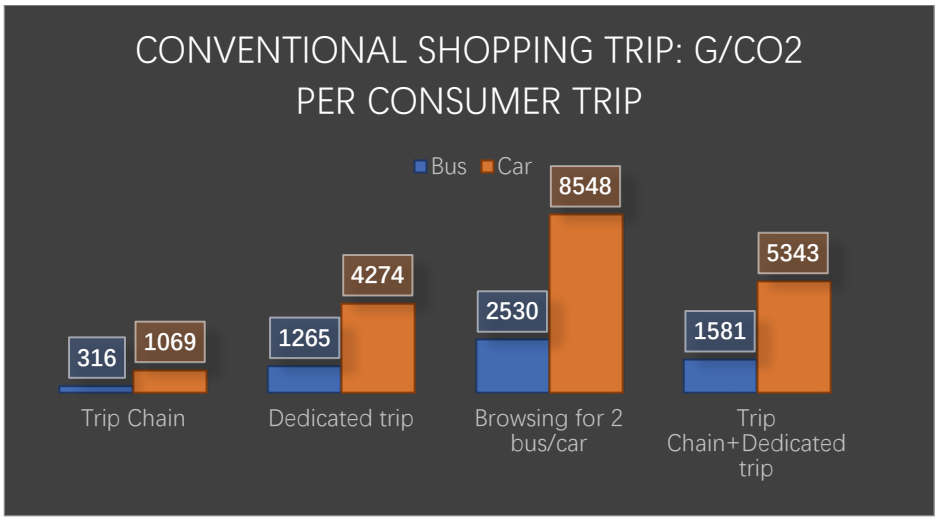


Figure 3. Conventional shopping trip: g/CO2 per consumer trip.

3.3.2 Return Delivery

Furthermore, another major contributor to environmental harm caused within last-mile delivery is return. Essentially, the problem of return delivery currently goes well beyond financials. One of the reasons that makes a return so devastating is its ability to cover multiple fields of harm. After the pandemic, increasing the return rate for goods on online shopping casts a tremendous amount of negative impact on environmental sustainability through increased carbon emission, plastic waste, and landfill accumulation. However, the most crucial and quickened impact always results in the field of carbon emission. A study carried out by Optoro, a company specializing in reverse logistics solutions, reveals that annually in the United States, 5 billion pounds of returned products are disposed of in landfills, and the transportation of returns leads to the emission of 15 million metric tons of carbon dioxide [23]. This certain amount of CO2 presented is enough to power half a million homes for one year, according to the CEO of Easysize. Navjit Bhasin, CEO and Founder of Newmine, emphasized at the Coresight event that from the moment a product is manufactured, it has a significant sustainability impact, encompassing aspects like carbon emissions and packaging [23]. When a return occurs, this impact essentially doubles. Another thing to be noticed for return is that many e-commerce companies nowadays view return as a normal cost of operating a business and have not started implementing strategies to combat the harm it casts on sustainability, despite the huge environmental issue return caused. According to Table 1, which reveals the top causes of retail returns, the major five reasons for customer returns focus on product quality and description mismatch, fitting issues, wrong items, and arriving damages, which are all able to be mitigated and improved by online retailers and delivery companies.

Table 1. Top Causes of Retail Returns [23].

Category	Rank	Shoppers' Reason for Return
Controllable	1	Product quality not as expected
Controllable	2	Color/product description mismatch
Controllable	3	Issues with product fit
Controllable	4	Wrong item sent
Controllable	5	Product arrived damaged
Controllable	6	Product arrived later than expected
Uncontrollable	7	Bought to try

Note: Source: 2021 State of the Industry Report: Retail Returns, by Incisiv/Newmine

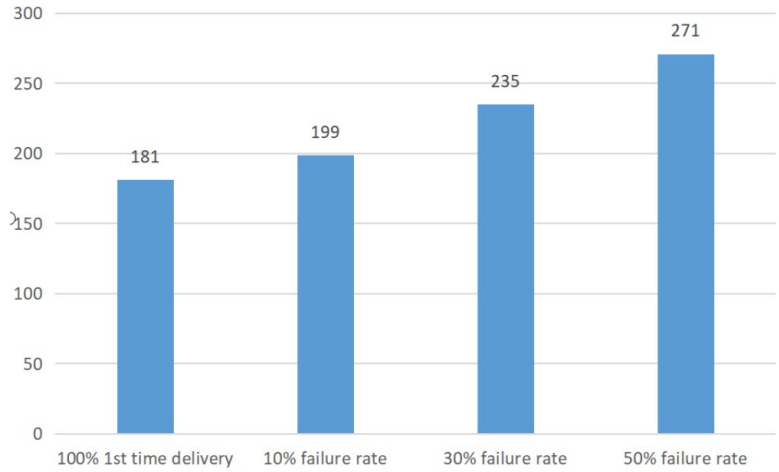
3.3.3 Delayed & Failed Delivery

One of the major contributors to e-commerce's severe environmental footprint is delayed delivery. A delayed e-commerce delivery occurs when the seller fails to fulfill the order within the initially promised estimated delivery time for the purchased good or service. The overall increasing popularity of e-commerce delivery is the consequence of its ease and speed. Delays in delivery, thus, will discourage that beneficial comfort of online ecommerce by causing the following problems: potential customer dissatisfaction, intense carbon footprints, and threats to the business's viability. Delayed delivery should be analyzed through the cause of it, which sometimes could be inevitable. In terms of inevitable reasons, weather anomalies and peak season are the major ones, which could go up to six times the normal sales and further due to low stock, slowly updated inventories, and wrong orders. In terms of evitable reasons, delayed delivery could be concluded to inadequate planning, incorrect customer information, labor shortages, and supply chain disruptions.

When analyzing the delayed delivery impact, it could mainly be distributed into the sector of environment and customer expectations. When a package is delayed with inaccuracies in last-mile delivery, it could cast a disastrous impact on customer satisfaction. Missed or delayed deliveries lead to dramatically increasing emissions typically during the process of redeliveries. If the initial delivery attempt fails, subsequent redelivery attempts or customers traveling to the depot to collect the package result in carbon emissions. Environmental specialists approximated that, due to one billion missed deliveries each year, the overall carbon emissions from redelivery amount to 3,742 metric tons. This is equivalent to the loss of 9,050 trees over a span of 58 years [24]. With such a significant number of harms caused, it makes delayed and missed delivery a hazardous factor of carbon emission, and further resolutions are required.

Failed delivery is a serious issue during the process of goods carrying, which causes much pollution. With the expansion of online shopping, logistics companies are increasingly only paying attention to whether the products are received by customers owing to consumers have their own expectations and hope that logistics companies can bring them a sense of satisfaction for receiving convenient service. If people do not receive the package within the specified time, such kind of failure of delivery not only causes inconvenience to both retailers and customers but also leads to detrimental effects on the environment. What causes this failure is that if there is no one at the address while the customer gives mandatory requirements to delivery companies

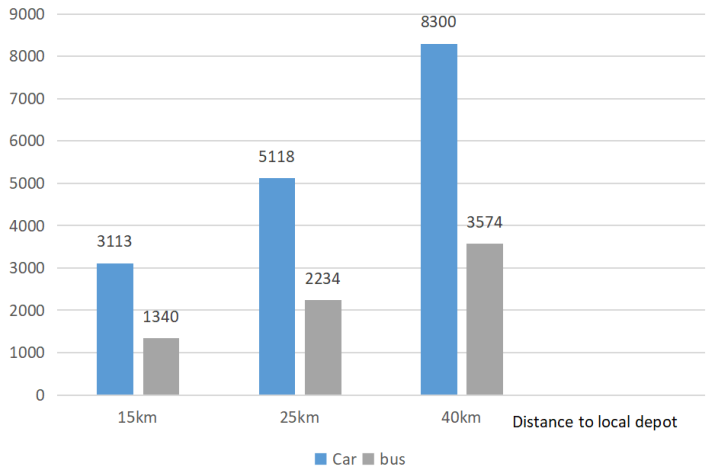
to get items to designated locations, it is possible to bring this failure that the carrier will leave time at this place to try more times. Definitely, it is a waste of time. But the fact is that there is little chance for carriers to stay around a single place for a great deal of time. Always many physical distributions must be done in a limited time, thus they will drive in trucks to other distinct places. After almost 24 hours [22], the carrier will go back to the original area to make an effort to contact the buyer. The time wasted on the road can be relatively severe. What's worse is that trucks usually get exhaust gas emitted, and such a situation will result in the intensification of carbon dioxide emissions. Research results based on a model of carbon emissions from [22],



Note: source: made by Whiteing, A, University of Leeds.2009

Figure 4. First time van-based delivery: Emission (gCO2) per drop [22].

According to figure 4, which illustrates the emission per drop with different delivery failure rate, when the delivery is efficient in the beginning, the emission of carbon dioxide per drop is up to 181 grams. For example, if there are ten delivery tasks and one of the ten is unsuccessful, the gram of carbon dioxide emission would increase up to 199 grams. While there exist failures of 3 of 10, 235 grams of CO2 would be released. Ultimately, the failure rate attains 50 percent, together with the total amount achieved at 271 grams. Clearly, digital evidence from Edward's research reveals that failed delivery could actually put influence on the release of carbon dioxide. Moreover, actually, when recipients do not obtain their commodities, carriers will put their goods somewhere else. These carriers will leave pieces of notice to their customers and the information on those cards would be: this matter has been already left to their neighbor; the product has been placed somewhere outside the destination; this item has been delivered back to the warehouse of the recipient, and in this case, the customer could make a connection with the seller to ask for further transportation with extra charge or the carriers themselves just go back to the storehouse to get what they buy online.



Note: source: made by Whiteing, A, University of Leeds.2009.

Figure 5. Emissions (gCO2) per consumer trip to a local depot to collect a missed delivery [22].

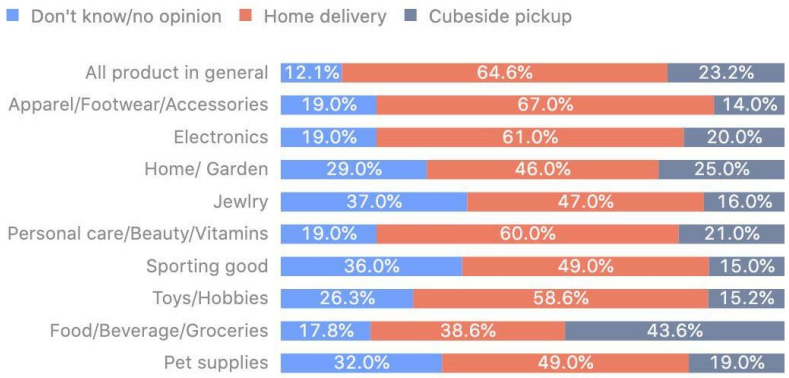
On hectic urban roads, local depots are standard configurations. It is commonly believed that one local depot will appear over a few miles. Owing to a failed delivery, some recipients would drive back to the warehouse to pick up their items. From Figure 5, it showcases obviously that when the longer the distance away from the depot, the more carbon dioxide emissions will be released. From 15 kilometers to 40 kilometers, whatever cars or buses have an apparent upward trend: cars have an amount of 5167 grams of rising from 15km to 40km for a single stroke and buses rise from 1340 grams to 3574 grams. Such kind of emissions released day by day would bring damage to the atmosphere and exacerbate the greenhouse effect [22]. The emission of carbon dioxide from the burning of fuel like gasoline during transportation is the second-leading origin of carbon dioxide pollutants. Such source explains 31% of all the American carbon dioxide emissions and 26% of all the released greenhouse gas emissions [25]. 78% of carbon emissions, which have raised concerns about harmful consequences on ecosystems, are from high-way transportation. From 1990 to 2005, the proportion of all the transportation greenhouse gas emissions to total emissions has increased from 24.9% to 27.3% [26]. Recently, scientists together have developed some models to deal with such kinds of issues. Electronic technology like UAV or EV are widely used during the session of delivery.

4 Reference Policy

4.1 Packages & CDP

Recently, scientists have already come up with some ideas to deal with the problem of inconvenience during the process of delivery. An option involves delivering the package to a safe storage container, which may be built into the residence, affixed to its outer walls, or provided in the form of a communal storage unit [22]. Another popular one is CDP—collection/delivery point. This approach has its own mode of operation. Just like storage boxes,

CDP truly has somewhere to leave with packages. It seems that such kind of solution could really eradicate this issue since it truly decreases the amount of carbon dioxide [22]. However, although logistic companies leave this part of the path to get the goods to their customers, the customers are not actually willing to carry their products through a long way.



Note: Source: Pitney Bowes BOX poll

Figure 6. Preference of Method of Pick-up or Delivery [21].

The fact that people are more likely to have home delivery services rather than picking up products in other places of their own in general (64%>23%) could be viewed in the from figure 6, which illustrates customers' preference of method of delivery for different products. Of course, such an approach of having a specific place to deliver goods is really helpful to the reduced amount of carbon dioxide emission, but from the perspective of customers, it is not the best one to be put into effect.

4.2 Electric delivery truck（electrifying road transport）

In addition to this, electrifying road transport for last-mile delivery trucks is also an existing effective measure to reduce last-mile carbon emissions. In recent years, major logistics companies have moved towards the electrification of the sustainable development of the road: UPS makes a promise to purchase 10,000 electric vehicles in order to deliver, and the company has also launched an electric trucking program to reduce carbon emissions [27]; USPS has committed to deploying 45,000 electric vans by 2028, claiming that van purchases between 2026-2028 will be 100% electric [28].The shift from conventional to electric trucks can indeed be effective in reducing CO2 emissions during transportation, which could save about $750 in costs of fuel when people drive every 15,000 miles, but the upfront investment costs are high, so support as well as incentives from government agencies are needed. Lowering carbon emissions is an overall goal government wants to achieve, despite local government or higher-level regulators. The U.S. IRA bill issued in August 2022 announced a subsidy of up to $7,500 per vehicle for medium-duty electric trucks [29]. This subsidy is an incentive to electrify freight trucks in the U.S.: the USPS received $3 billion from the IRA bill to invest in electric vehicles [28].

Even so, the electrification of freight trucks faces an unavoidable problem: a lack of infrastructure. In the U.S., both electric passenger cars and freight trucks face a lack of infrastructure. However, because of the dependence of electric freight trucks on infrastructure, such as charging stations, infrastructure development is a very important part of promoting the electrification of freight trucks. John O'Leary which is the CEO of Daimler ---the leading manufacturer of the US heavy-duty truck---claimed that the current production capacity of electric semi-truck is about 2000 trucks annually and doubling that number to 4000 would not be a hard thing, but in terms of electric vehicle deployment, infrastructure is slowing down their pace [30]. The lack of charging infrastructure is a big problem across the U.S. As of March 2023, according to bumper statistics, over 51,000 public EV charging stations were right up there with more than 131,000 plugs. But that leaves the U.S. with fewer than three charging ports for every 10,000 people [31]. The challenge will be even greater for large fleets of freight trucks, which require more infrastructure than passenger cars: more powerful charging posts and a charging station that enables a few trucks to charge simultaneously. The construction of this kind of electric freight trucking infrastructure faces a process of site selection, construction, and government approval," all means that current delivery times are measured in years, not weeks or months," said John O'Leary [30].

4.3 Consumer revolved

A key stakeholder not discussed above for decarbonization funding is consumers. For background information, currently, consumers have a huge preference for green transportation along with low carbon emission choices; however, customers are not entirely notified that which delivery companies are using green transportation. An increase in the e-commerce industry occurs simultaneously as consumers consider sustainability as a core evaluation of shopping decisions. According to Sendcloud's 2021 investigation, green delivery plays an important part in the purchase decision for 74% of UK online consumers. Therefore, the first step for carbon emission solutions is to educate the customers to the greatest extent, which contains understanding the amount of emission harm they would be able to cost when making daily purchasing decisions, and the impact on the environmental sustainability of different ways of transportation, forming a comparison between traditional fuel tools and green transportations. Relich emphasized that consumers may not fully realize the extent of the negative environmental consequences. He suggested that retailers should prioritize handling returns due to their substantial financial implications, beginning with educating the customer.

However, a good aspect results in the consumer's willingness to change and mitigate. Researches have shown that if consumers are made aware of the results of their choices, majority of them would become willing to shift expectations. According to National Retail Federation and IBM's recent survey [32], approximately 6 in 10 consumers, which is 57% in total, were open to altering their shopping behaviors in order to lessen their environmental footprint. Furthermore, the figure rises to 77% for consumers who express that sustainability holds significance for them. However, it's doubtful whether consumers are willing to pay for changing their decisions. On the opposite side, McKinsey's recent research found that 70% of consumers surveyed among 1000 customers in Europe and the US would be paying an additional 5% to offset the environmental impact[33]. According to figure 7, which demonstrates different types of shoppers' willingness to pay for sustainable products, illustrates that Gen Z is the most

prevalent and higher-income shoppers, who are about to become the dominant consumer cohort soon.

Figure 7. Different Shoppers' Willingness to Pay for Sustainable Products [34].

Most consumers are reluctant to change their minds because online retailers are not transparent about carbon-neutral delivery options. Most companies do not disclose if a consumer chooses a green delivery option and how much emissions will be reduced and calculated. If consumers choose a green shipping service, they currently have no channel to verify the freight company, which means this green shipping option is just a "charitable donation." [35]. Therefore, increasing the transparency of green transportation is an issue that logistics companies should focus on. For certain e-commerce companies, click choices of whether using traditional fuel transportation or environmentally safe transportation presented on online shopping platforms would help its brands to align with customer demand stand and increase acquisition and customer loyalty since 91% want an "eco-friendly shipping" option at checkout [36]. Many major shipping providers now provide carbon-neutral delivery choices to varying degrees, and updates are frequently provided on their decreased carbon emissions. Aveda and Zalando are examples of companies using online platforms and social media to highlight dedication to more eco-friendly supply chains. Additionally, Asendia, particularly in the retail sector, is requesting information about the carbon impact of parcel journeys, and exploring options like "green delivery." Considering the fact that only 6% of DTC (direct-to-consumer) brands offered a carbon-neutral delivery option [36], there still requires long-term processes and effort to fully mitigate current freight companies' delivery structures.

5 Conclusion

The objective of this study is to analyze the environmental contamination resulting from the final stage of product delivery in the United States, as well as to assess the limitations of current remedial measures. The paper analyzes why the last mile is so important in the freight transportation chain and generates a large amount of carbon emissions from different perspectives, and evaluates the existing solutions in the United States to find out the shortcomings of the different solutions within today's U.S. society. As the research has

demonstrated, carbon emissions of last-mile delivery in the U.S. continue to increase from 2019-2023, and will still follow an upward growing trend in the following years. Although the existing solutions are expected to be effective in reducing carbon emissions from consumers, companies, and the government sides, there remain limitations resulting in those solutions due to the current societal situation in the U.S. as well as the state of the industry for logistics companies.

The main limitation of this study is due to the complexity of the transportation process included in the last-mile delivery, which only a rough estimate of last-mile carbon emissions can be made. Furthermore, according to the existing data, it is highly impossible to make concise and accurate statistics in terms of consumer preferences, and greater use of control groups is required to determine consumer preferences for green transportation in last-mile delivery. Long-term mitigation would be needed to change the aspect involved in consumer expectation, along with inevitable societal changes that would appear in the next generation. In terms of consumer prices and freight company's costs for switching to green transportation, the conclusion that meanwhile EV could reduce costs, certain amount of fees would be charged differently according to different initiatives that firms set for their consumers could be arrived. Finally, while this paper presents the limitations of existing solutions, it is unable to offer practically meaningful improvements without a comprehensive industry analysis of the entire U.S. political, energy, logistics, and online retailer landscape. This would be a fruitful area for further work.

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