



## Discussion

## Why is the generation of packaging waste from express deliveries a major problem?



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## HIGHLIGHTS

- Packaging waste increased since the booming of express delivery service.
- Packaging waste has become a serious environmental issue.
- E-commerce and COVID-19 exacerbated the generation of packaging waste.
- Key environmental insights on research, policies and education are suggested.

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## ABSTRACT

The rapid growth of the express delivery industry resulted in the explosion of packaging waste with a wide range of direct and indirect environmental consequences. Until recently, little attention was given to this topic, but e-commerce and the associated growth of packaging waste exploded with the COVID-19 pandemic. Even though the phenomenon is only little to moderately documented, the waste problems in express delivery are recognized and caused by excessive packaging, lack of recyclability of the packaging material, and the low motivation of consumers to recycle. Key research, policy, and educational actions to reduce the environmental impacts of the fast-growing express delivery industry are discussed in this short discussion article.

The anthropogenic technological advancements of the 21st century fueled the development of e-commerce and online retailing, making the delivery service industry increasingly popular, especially in densely populated cities. Express delivery industry quickly became an emerging service sector, and the fast-paced standard of living in certain countries even led to the expansion of round-the-clock delivery services. However, the growing demand for express delivery services resulted at the same time in many countries to an increase in packaging waste (Escursell et al., 2021). For example, Kim et al. (2022) found that e-commerce in Korea generates 4.8 times more packaging waste than offline shopping. It is roughly estimated that packaging accounts for approximately 46% of global plastic waste

(You et al., 2021), putting increasing pressure worldwide on the management of municipal solid waste (MSW). The treatment of packaging waste has undoubtedly become a significant fraction of the recycling of MSW, and recovery and recycling rates are alarmingly low. For example, the recycling rate of China's express packaging materials is less than 20% (Fan et al., 2017). However, the proportion of packaging plastic waste within MSW varies widely around the world depending on the waste management infrastructure and collection-recovery-recycling systems of each country, for example, if the informal recycling sectors are involved or not (Karak et al., 2012). Asia is the largest packaging consumption market in the world and the biggest contributor to global plastic waste, mainly generated by China and India, followed by North America and Western Europe (Lebreton and Andrady, 2019). It is worth mentioning that Asia is also the main recipient region of plastic waste in the world, with China,

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Thailand, Indonesia, Vietnam, Malaysia, and the Philippines as leading countries. In 2018 China banned importing 24 categories of solid waste, including plastics, resulting in a dramatic decline in plastic waste imports, but unfortunately leading to an increase in imports to other Asian countries (Huang et al., 2020; Wen et al., 2021).

Online retailers use various packaging materials to prevent food and non-food products from being damaged during transportation. It explains why more packaging materials per product are generated, compared to offline shopping (Regattieri et al., 2019). Express delivery packages come in many sizes, shapes, and weights and consist of synthetic resin films and sheet materials, plastic trays and containers, expanded polystyrene (PS) or PS foam, material that after use ends in the bulk of packaging waste. Although they are not considered hazardous, they have a major impact on the environment and human health as: (1) the release of environmental pollutants in the manufacturing processes and transportation (e.g., greenhouse gas emissions), incineration for energy recovery (e.g., dioxins, furans), and the disposal and storage of these materials in open dumpsites and/or controlled landfills (e.g., Verma et al., 2016; Fan et al., 2017; Su et al., 2020; Lin et al., 2022); (2) their daily use creates huge amounts of this type of waste, including their distribution in the terrestrial and marine environment (Villarrubia-Gómez et al., 2018; Hahladakis, 2020); and (3) many packaging wastes contain non-degradable or refractory materials (e.g., polyvinyl chloride (PVC), polyethylene (PE), polypropylene (PP), polystyrene (PS)), so the environmental contamination by these products is persistent over time. Due to the fierce price competition, the use of virgin and/or low-quality packaging materials to reduce costs is preferred by most of the express delivery service industry, and this notwithstanding the recyclability of packaging plastics is largely dependent on their quality (Hahladakis and Iacovidou, 2018). Furthermore, some packaging materials contain potentially toxic substances that can seriously affect human health (Hahladakis et al., 2018), so packaging made from recycled materials is preferentially used for secondary packaging due to high levels of contaminants (Suciu et al., 2013).

Transportation is also a key issue in the packaging cycle. The use of fuel-powered motor vehicles (e.g., trucks, cars, motorcycles) by packaging manufacturers, express delivery services, and waste management companies generates daily greenhouse gas emissions, especially carbon dioxide (CO<sub>2</sub>). Currently, the use of artificial intelligence (AI) algorithms is reducing vehicle mileage and saves fuel consumption. Emerging technologies, such as autonomous or hybrid cars, or cars powered by hydrogen or biofuels provided by the fleet market, will further help to reduce the impact of transportation (Escursell et al., 2021). Given the convenience of e-commerce, this economic activity will become more popular in the future, creating the need to address the associated increase in traffic, and associated herewith the rise in CO<sub>2</sub> emissions.

The sheer size of disposable containers, bags, and utensils that come with each package (i.e., overpackaging) adds to the environmental concern of the express delivery sector. Usually, each express order requires multiple packaging materials, including paper, corrugated boxes, woven bags, styrofoam, bubble filling, plastic, envelopes, invoice statements, and promotional flyers. Tape, cord, and staples are most commonly used to seal the packaged material to which the express waybill is attached. While many packaging materials, such as corrugated boxes can be recycled or reused, the majority of packaging wastes from express delivery have a low residual value and might be contaminated by food residues, thereby ending in the urban solid waste streams. Those streams, after material recovery (if any), are traditionally destined for landfilling, incineration, illegal dumping, and open burning (Duan et al., 2019). In general, anything that is not recycled or recovered from packaging waste represents a loss of non-renewable natural resources (e.g., fossil fuels and forests) and other inputs used in the life cycle of the packaging materials. Even if waste is destined for energy generation through incineration, this outdated strategy does not encourage recycling and waste reduction.

Despite the great environmental risk posed by packaging waste, it remains a major challenge to reduce and recycle packaging materials and promote the use of green materials such as biodegradable plastics (see Flury

and Narayan, 2021). Currently, few studies examine the environmental impacts of the booming express delivery industry. No rigorous estimates exist on the amount, variety, and environmental impacts of packaging waste generated by the express delivery industry, especially in economic emerging and developing countries. Many of these countries cannot establish a comprehensive express packaging recycling system because of the lack of policies, funds, and civic awareness. Nevertheless, in many developing countries, an important but controversial system for the recovery of materials is through the informal recycling sector (Wilson et al., 2006). Recycling rates (collection, separation, and recycling) through the informal sector in different cities around the world range between 10% and 40% (Wilson et al., 2012; Linzner and Salhofer, 2014), however, much of this work is carried out by untrained-unskilled vulnerable individuals (including women, children, and elderly people) who act, most of the time, outside of any governmental capacity and/or authority, which exposes them to increased health risks (Wilson et al., 2006). Therefore, it is an urgent problem to construct an efficient express package recycling system suitable for national scale conditions. Only a few scholars explored this issue. Yang et al. (2021) constructed and compared three express packaging recycling models based on the behavioral characteristics of multi-stakeholders and national policies, which is a beneficial exploration for constructing efficient express packaging recycling models in developing countries. However, such studies are still relatively scarce, and a systematic and profound exploration is still needed.

Until recently, little attention was paid to these issues, but the exponential growth of e-commerce fueled by the COVID-19 pandemic has increased our reliance on express delivery services. To restrict the spread of the pandemic, governments applied remote working, closure of the hospitality and tourism sector, and quarantine, which created the need for home deliveries of food, life, and other products (de Oliveira et al., 2021). Since the outbreak of the pandemic, e-commerce has gradually been adopted as normal consumer behavior, and as a result, more packaging materials will passively or actively be used by city dwellers (Guthrie et al., 2021). In addition, the COVID-19 pandemic has given rise to an immense generation of personal protective equipment waste (i.e., face masks, gloves, disinfectant wipes, protective suits, etc.) and medicines, including their packaging (Benson et al., 2021), which exerts increased pressure on urban waste management and raises concern over environmental pollution. Chen et al. (2021) and other scholars have noticed the environmental problems caused by the sudden increase of medical waste and actively explored efficient actions to treat them, which provides a useful reference for medical waste treatment measures, a hot issue for future research. Therefore, to handle packaging waste correctly and safely, a universal action plan, rather than some provisional acts and temporary policies, ought to be developed. Key and main actions discussed by the authors and others (Pinos et al., 2018; Song et al., 2018; Duan et al., 2019; Escursell et al., 2021) are summarized next, and categorized as environmental research, environmental policies, and environmental education (Fig. 1). It is hoped that the challenges associated with packaging waste management will be addressed over time.

Environmental research supported by reliable data is needed to generate knowledge and tools to tackle the packaging problem. Some key topics are: (1) life cycle assessment (LCA) to assess impacts of packaging waste in its use and management (Fig. 2), including the evaluation of different packaging waste treatment scenarios to determine appropriate management strategies and optimize composite packaging separation and recycling designs; (2) using green packaging materials involving the biotechnological development of reusable containers, less toxic materials, biodegradable and compostable materials, accompanied by the circular bio-economical assessment of the green packaging transformation of the express delivery industry; which plays a critical role in tackling multiple environmental issues like climate change, increasing population (i.e. growing demand of products through delivery services), and limited non-renewable natural resources; (3) evaluation of the willingness of the delivery companies to adopt new strategies and consumers' perception of these changes; consumers' perceptions are important for interventions to be effective, such as the incorporation of new eco-friendly green packages, where the key

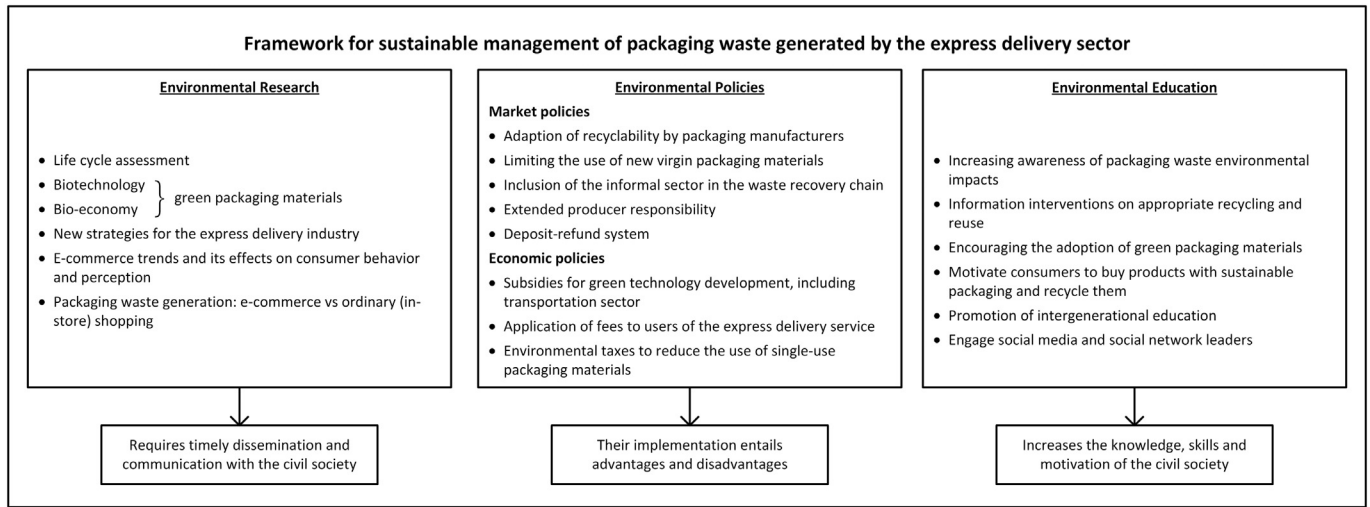


Fig. 1. Outline of key actions for management of packaging waste.

factor is to empower consumers with solution-oriented products; and (4) generation of reliable data to fill the literature gap on packaging materials in e-commerce compared to offline shopping. Even more important is the timely communication and dissemination of research findings among the civil society, this will increase citizens' awareness and knowledge, which can lead to an improvement in urban waste management, promoting a willingness to collaborate because they know they will benefit from it.

Environmental policies addressing mandatory national standards for the recycling and disposal of packaging materials are presented in the following two main groups.

- **Market policies:** (1) including recyclability as a criterion in the industrial standards for packaging products in express delivery will help to promote the packaging industries to massively recover recycled materials and incorporate them into their production chain; (2) limiting the amount of new virgin packaging materials that can circulate in the domestic market will help achieve higher recycling rates by increasing the demand for recycled packaging materials; (3) integration of the informal sector into waste management planning by governmental entities will contribute to smart packaging waste management by training those individuals to

increase waste collection, separation, and recycling rates and to provide them with protective equipment to reduce health risks; (4) establishing the extent of the producer's responsibility, encompassing the producer's responsibility for reducing packaging size and avoiding overpackaging, promote recycling, and properly treating and disposing of post-consumer waste; (5) implementing a deposit-refund system which is a mechanism that allows the reuse of packaging avoiding that it ends up in landfills. This system needs to commit local authorities and the express delivery sector as main stakeholders to be actively involved in defining parameters such as management institutions, deposit amount, material owner, among others.

- **Economic policies:** (6) subsidizing and stimulating the development of green technology or equipment for the collection and transport of materials for recycling and reprocessing companies; governments that subsidize green technology can benefit from its development, as long as the subsidy programs are well designed, and contributes to reducing the carbon footprint, water, energy, and waste as compared to traditional technologies; (7) the government can also consider collecting disposal fees from consumers ordering express delivery; and (8) applying environmental taxes for companies that refuse to replace single-use corrugated boxes and plastic bags by green alternatives that can be used multiple times. In

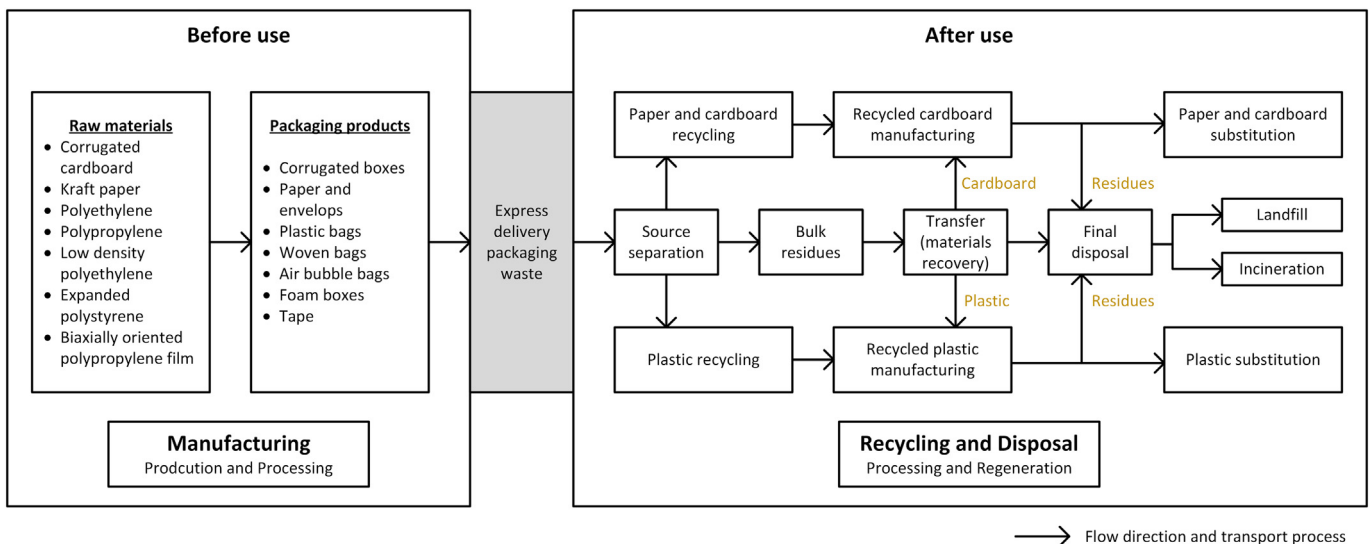


Fig. 2. Life cycle of the packaging and packaging waste. Adapted from Su et al. (2020) and Lin et al. (2022).

both (7) and (8), environmental taxation seeks to incorporate the prices of negative externalities in the generation of package materials to guide production and consumption decisions in an eco-friendlier framework. In general, all these actions may come with increased costs for express delivery service providers in the short term, but in the long term, social responsibility will lead to comparative advantages in a highly competitive market. However, it should be noted that despite clear environmental and social advantages (e.g., less atmospheric pollution, higher recovery rates, and employment generation), some measures have disadvantages such as high capital requirements (the process is not always cost-effective), short life of biodegradable packaging materials, legal reforms, stakeholder coordination, among others, aspects to be evaluated beforehand.

Environmental education is a useful instrument to promote citizens' green behaviors regarding express packaging waste and the development of a sustainable lifestyle. Some key educational programs are: (1) dissemination of public awareness of the environmental consequences of post-consumer packaging materials; it is generally accepted that citizens with higher environmental education will have a better understanding of the state of environmental sustainability in urban metabolism; (2) information interventions will have a positive effect over packaging waste management by promoting recycling and reuse strategies, such as a decrease in packaging consumption (less packaging waste), and an increase in the recycling rates; (3) the promotion of the use of green packaging materials based on biodegradability and recyclability characteristics; consumers emotionally process green advertising to elicit positive changes in behavior (see Martínez-Fiestas et al., 2015); (4) the promotion of intergenerational education; the integration of seniors, adults, youth, and minors in environmental education activities expands the number of residents who are informed since people of different ages learn about each other's knowledge, experiences, skills, perceptions, and promote actions focused on finding an individual or collective solution to combat the problem of packaging waste; and (5) engage social network leaders, having an impact on their social circles due to their distinctive qualities within their network, and use social media to spread the circular economy strategies for reducing waste in general. Benefits such as the skills and knowledge acquired through environmental education will help improve people's participation in environmental programs and activities for packaging waste management, motivating them (especially university students and social leaders) to generate new ideas and solutions to current packaging problems.

In sum, e-commerce and the express delivery sector became an everyday part of the modern lifestyle, with an evolution strongly influenced by the COVID-19 pandemic. The pandemic changed consumer behavior drastically from offline to online shopping, leading to an increase in packaging waste and in finding cost-effective solutions for the associated environmental problems.

#### CRediT authorship contribution statement

**Juan Pinos:** Conceptualization, Investigation, Writing – original draft, Visualization. **John N. Hahladakis:** Writing – review & editing. **Hong Chen:** Writing – review & editing.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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