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DOI: 10.1002/tie.22259

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WILEY

Toward sustainable express deliveries for online shopping: Reusing packaging materials through reverse logistics

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Abstract

The COVID-19 pandemic has led to an increase in online purchases, which has inevitably raised the demand for express delivery packaging materials (EDPMs). This study proposes a reverse logistics reuse framework that extends the EDPM life cycle by drawing on insights and conclusions from a review of the literature on supply chain management and materials science to achieve a sustainable e-commerce system. A key benefit of reverse logistics is its effectiveness in exploiting opportunities for resource reuse, which is preferred to recycling. By extending service life through resource optimization, recycling, and recovery processes, the novel reuse framework based on reverse logistics can be implemented with minimal changes to existing forward logistics systems, potentially leading to more sustainable online shopping. This study proposes a novel combination of reusable packaging materials and reverse logistics as a viable and more environmentally friendly practice, in line with circular economy goals.

KEYWORDS
circular economy, packaging materials, recovery, recycle, reuse, reverse logistics

1 | INTRODUCTION

The COVID-19 pandemic has brought changes to our everyday lives, notably an increase in online purchases. Home-based shopping for groceries and other essentials became popular during the pandemic and remains so after it (Jefferies, Cheng, & Coucill, 2020). According to a survey conducted in Singapore, Malaysia, and South Korea, more than 30% of consumers in each country responded that they made online purchases several times a month during the pandemic (Rakuten Insight, 2020). After the pandemic, consumers in emerging economies shifted significantly toward online shopping, which increased single-use plastic waste, such as carrier bags, containers, and eating utensils (Simachaya, 2020; United Nations Conference on Trade and Development, 2020).

The ability to purchase a product in the comfort of one's home and have it delivered to one's doorstep is not something new. In the 1980s and 1990s, the system of ordering products over the telephone in response to magazine and television advertisements dominated mail-order sales. Later, with the growth of internet services, the general population's opportunity to shop online emerged in 1995 when Amazon introduced online book retailing services in the United States (Mellahi & Johnson, 2000). Internet-based online shopping malls began to develop rapidly around the world in the 2000s (Kuah & Wang, 2017). Mobile shopping also expanded because of the growth in smartphones, which allows for more commerce through mobile telephony. Livestreaming e-commerce, which is gaining popularity in the United States and China, is also attracting attention as a part of the future of e-commerce (Kharif & Townsend, 2020).

Although the form of commerce has changed, the method of product delivery has not radically altered. Single-use packaging materials, such as corrugated boxes, plastic bags, and bubble wrap, have been the mainstays of packaging for almost all products purchased online (Figure 1). Therefore, it is reasonable to assume that the growth

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FIGURE 1 Common packaging materials for online orders. *Source*: Authors [Color figure can be viewed at wileyonlinelibrary.com]

in online shopping and the consumption of packaging materials are highly correlated.

There are increasing concerns about the environmental and social burdens that result from the widespread employment of single-use products, and reducing this practice has been a much-discussed objective for decades (Kalina & Tilley, 2020). Single-use plastic packaging has been preferred for reasons of health, safety, and convenience without due consideration of its environmental impact (Grodziska-Jurczak, et al., 2020). As Su et al. (2020) asserted, "the booming of online shopping and rapid increasing of express deliveries has led to the consumption and scrap of a large number of express delivery packaging materials (EDPMs) and caused the phenomenon of 'over packaging.'" For instance, Figure 2 shows the rise in the number of express delivery packages from 2015 to 2019 in China, the world's most populous country and one of its largest online shopping markets (Kuah & Wang, 2017).

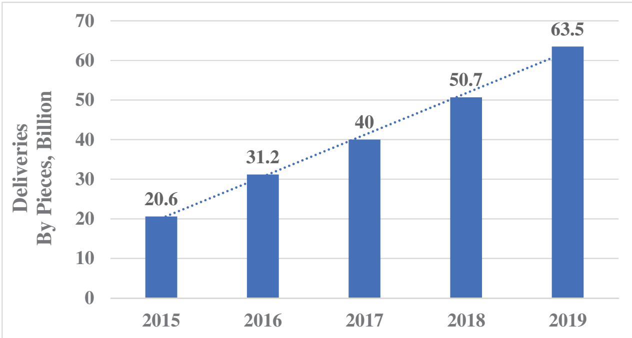

FIGURE 2 Growing express delivery business in China from 2015 to 2020. Adapted from National Bureau of Statistics of China (2020) [Color figure can be viewed at wileyonlinelibrary.com]

The packaging materials used can be divided into commonly used corrugated boxes, plastic bags, woven bags, foam boxes, file envelopes, bubble wrap, and taping materials (Chueamuangphan, Kashyap, & Visvanathan, 2020). Two China-based studies in 2017 and 2018 found that the corrugated box was the most widely used material in the express delivery sector, followed by plastic bags (Figure 3). These statistics give cause for concern about their environmental impact. Over the past 10 years, the annual revenue of China's Alibaba Group, one of the largest e-commerce companies in the world, has grown by over 70 times (Statista, 2020). The glut of packaging waste has conspicuous and negative impacts on the environment, as online retailers tend to overuse packaging materials for safety reasons (Chueamuangphan et al., 2020). Furthermore, only about 5% of plastic packaging waste in China is currently being recycled (Stanway, 2019).

The packaging waste problem is not confined to China or even to Asia. The steady growth in online shopping, driven by the ever-increasing popularity of the internet, is exacerbating the packaging problem even in the United States and Europe. In the United States, online sales are led by Amazon and are expected to double within the next decade, representing nearly 25% of U.S. retail sales (Allington, 2018). Meanwhile, the quantity of packaging waste generated per capita in the 28 EU countries is increasing steadily: their use of corrugated boxes, plastic boxes, and wooden crates has grown over the years (Figure 4).

If EDPMs are used excessively and not disposed of correctly, they will have a significant adverse impact on the environment. For example, plastic packaging takes 400–500 years to degrade in nature (Weber et al., 2008), and a substantial amount of it ends up in the ocean every year, seriously affecting the marine environment (Geyer, Jambeck, & Law, 2017; United Nations, 2017). When it is burned or buried, toxic chemicals are released into the air or soil (Ilyas, 2018). Meanwhile, the manufacture of cardboard packaging accounts for about 22% of the total carbon impact of online purchases (Weber et al., 2008). Thus, besides emphasizing aspects of recyclability and compostability (Boesen, Bey, & Niero, 2019), attention should also focus on the deployment of circular economy processes, such as reverse logistics, which would help improve resource use efficiency.

Reverse logistics "is not limited to the collection and aggregation of products and material but extends to value-adding activities such as sorting, separating, reprocessing, and remarketing" (Lacy, Long, & Spindler, 2020). Therefore, such activities embrace the management of products, their packaging, and waste returns followed by recovery, reuse, or recycling activities. Reverse logistics, especially for online retailers, becomes a major factor not only for environmental reasons but also for retaining a stable customer base (Geisendorf & Felicitas, 2018). Esposito, Terence, and Khaled (2018) proposed a reverse logistics system for the recovery of waste—disparate items such as mobile phones, packaging, and inkjet cartridges—utilizing existing postal services to create a circular economy system. Inspired by this study and to address a global problem, we propose a framework to address the online shopping packaging waste problem through reuse of express delivery shipment packaging and reverse logistics.

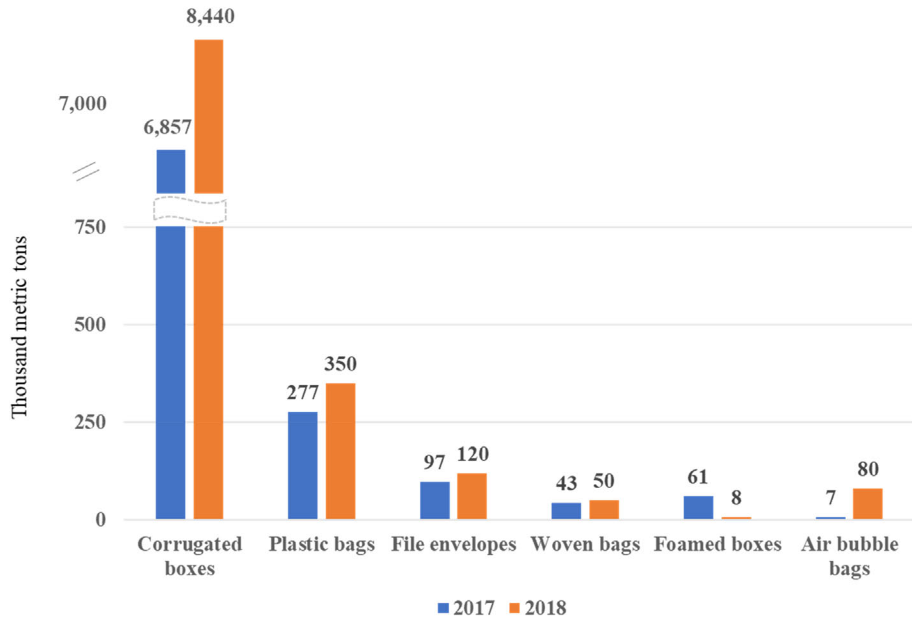

FIGURE 3 Usage of express delivery packaging material (EDPM) in 2017 and 2018. Adapted from Duan, Song, Qu, Dong, & Xu, 2019 and Su et al. (2020) [Color figure can be viewed at wileyonlinelibrary.com]

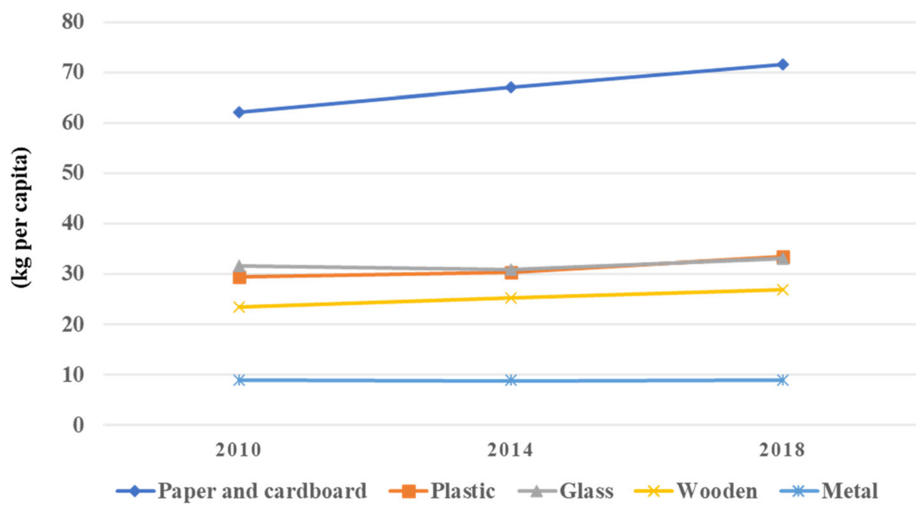

FIGURE 4 Packaging waste generated by packing material in EU-28. Adapted from Eurostat (2020) [Color figure can be viewed at wileyonlinelibrary.com]

We contend that the reuse of packaging materials through reverse logistics makes online shopping and delivery activities more sustainable.

2 | REVERSE LOGISTICS AND ONLINE SHOPPING

2.1 | Multiple objectives of reverse logistics

Reverse logistics has attracted attention as a strategic tool that can meet customers' demands while simultaneously conferring economic benefits and improving corporate social image (Agrawal, Singh, & Murtaza, 2015; Govindan, Palaniappan, Zhu, & Kannan, 2012). It has evolved over the years from solely being a reverse flow of goods (P. R. Murphy & Poist, 1989; Pohlen & Theodore Farris, 1992; Rogers & Tibben-Lembke, 1999) into multiple duties or objective systems embracing environmental, economic, and social aspects (Carter & Ellram, 1998). Its main goals are twofold: first, to minimize wasted resources through reuse and recycling; and second, to be a value-added process for meeting customers' demands, whether for product returns or through recycling.

Bernon, Tjahjono, and Ripanti (2018) proposed using reverse logistics to facilitate the circular economy. The successful management of product returns is, in fact, product recovery, and is associated with waste management (Srivastava, 2008; Thierry, Salomon, Nunen, & Wassenhove, 1995). Manufacturers and retailers are sometimes legally obliged to take back and recycle products at the end of their service life (Walther & Spengler, 2005). Bal and Satoglu (2018) examined a reverse network design for waste electric and electronic equipment (WEEE) to achieve multiple objectives of minimizing costs and environmental effects while managing its legal targets. Dedicated collection points should be provided to facilitate the return service (Assavapokee & Wongthatsanekorn, 2012; Fiksel, 2012; Li &

Tee, 2012). Chen, Pan, Wang, and Zhong (2017) proposed using final consumption points as collection facilities and spare capacity in taxis to transport returned online goods back to retailers. In eastern Slovenia, a transportation system was optimized to enable more efficient reverse logistics for collecting industrial packaging waste from large retailers (Lisec, Antić, Campuzano-Bolarín, & Pejić, 2018). Bing, Bloemhof, Vorst, and J. (2014) designed a sustainable network to deal with household plastic waste collection in the Netherlands, where efficiency, cost reduction, and sustainability were the principal objectives.

2.2 | Challenges of reverse logistics

Reverse logistics faces challenges similar to those for forward logistics in terms of capacity, infrastructure, and information handling (Lacy et al., 2020). To assess whether the objectives of reverse logistics have been met, these challenges can be categorized into three phases: planning, implementation, and control (Plaza-Úbeda, Abad-Segura, Burgos-Jiménez, Boteva-Asenova, & Belmonte-Ureña, 2021). Reverse logistics encompasses value-added activities such as testing, sorting, refurbishing, recycling, and redistribution (Ellen Macarthur Foundation, 2016). These activities compel manufacturers to concentrate on planning and implementation before undertaking reverse logistics. Therefore, trained personnel are needed to proactively establish standards and processes to enable reverse logistics (Plaza-Úbeda et al., 2021). Effective communication is another critical factor for reverse logistics. This may involve asset visibility, real-time information updating, and package tracking issues. Communication with customers, suppliers, and vendors becomes an essential part of meeting customers' needs and coordinating the operations of the reverse logistics chain (Bag, Gupta, & Luo, 2020; Huscroft, Hazen, Hall, Skipper, & Hanna, 2013). Another layer of complexity relates to the unpredictability of supply (Lacy et al., 2020). Manufacturers frequently face challenges in controlling the quantity, quality, and timing of returned products (Sundin & Dunbäck, 2013). Although facets of information technology such as Big Data and Cloud can help manufacturers to accurately analyze returned products, the capabilities that support reverse logistics are still significantly lagging, creating severe challenges (García-Sánchez, Guerrero-Villegas, & Aguilera-Caracuel, 2018).

2.3 | Online shopping and the existing delivery structure

With the increase in the amount of business-to-business (B2B) and business-to-consumer (B2C) e-commerce, traditional fulfillment responsibilities, previously borne by consumers at physical stores, have been transferred to retailers. This final extension of the supply chain, bringing products to customers' homes, has added a layer of complexity to the distribution system. However, Xing, Grant, McKinnon, and Fernie (2011) found that successful online retailers tended to deliver consistently and reliably. They had a first-mover advantage and were often equipped with the latest technology and technical expertise in logistics. For example, through Big Data technology and collaboration with various delivery partners, Cainiao Network successfully developed a smart logistics system across China (Falcone, Kent, & Fugate, 2020). Cainiao's successful use of automation, algorithms, and digital networks suggests that it is worth examining the possibility of further resource recovery and optimization in the context of online shopping.

3 | MATERIALS, RECYCLING, AND REUSE

3.1 | Packaging materials

Packaging materials play an essential role in assuring that products are delivered safely and in an acceptable condition to customers. Equally, customers see packaging materials as necessary for their online purchasing experience. However, once customers receive the goods, EDPMs are discarded with regular household domestic waste (Figure 5). Some of the discarded packaging materials will be recycled, but many will end up in landfills or incinerators. Duan et al. (2019) estimated that close to 90% of the EDPMs from online shopping deliveries are corrugated paper boxes and plastic delivery bags.

3.1.1 | Corrugated paper boxes

Corrugated paper boxes are lightweight, highly customizable, and renewable. They have a simple composition and are made mainly of wood fiber and a small amount of starch-based adhesive. Their physical structure is an advanced composite sandwich panel, which leads to low density and anisotropic mechanical performance. The most common type of corrugated box in e-commerce has a single-walled structure, with a fluted sheet sandwiched between two sheets of facing material known as liners (Figure 6a). Due to increased awareness of sustainable manufacturing, a higher proportion of fiber recycled from waste and old corrugated boxes is

FIGURE 5 Packaging materials discarded together with standard domestic waste. *Source*: Authors [Color figure can be viewed at wileyonlinelibrary.com]

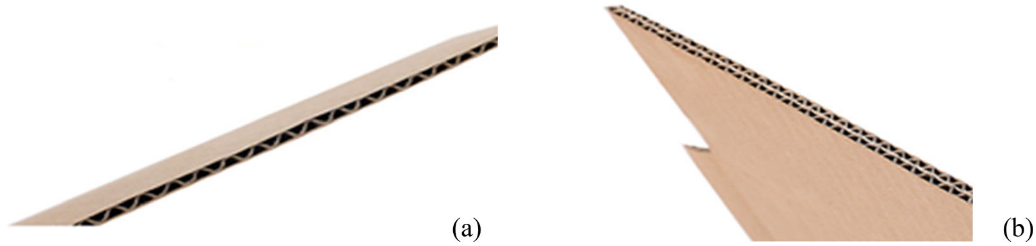

FIGURE 6 Corrugated box structure with (a) a single wall and (b) double walls. *Source*: Authors [Color figure can be viewed at wileyonlinelibrary.com]

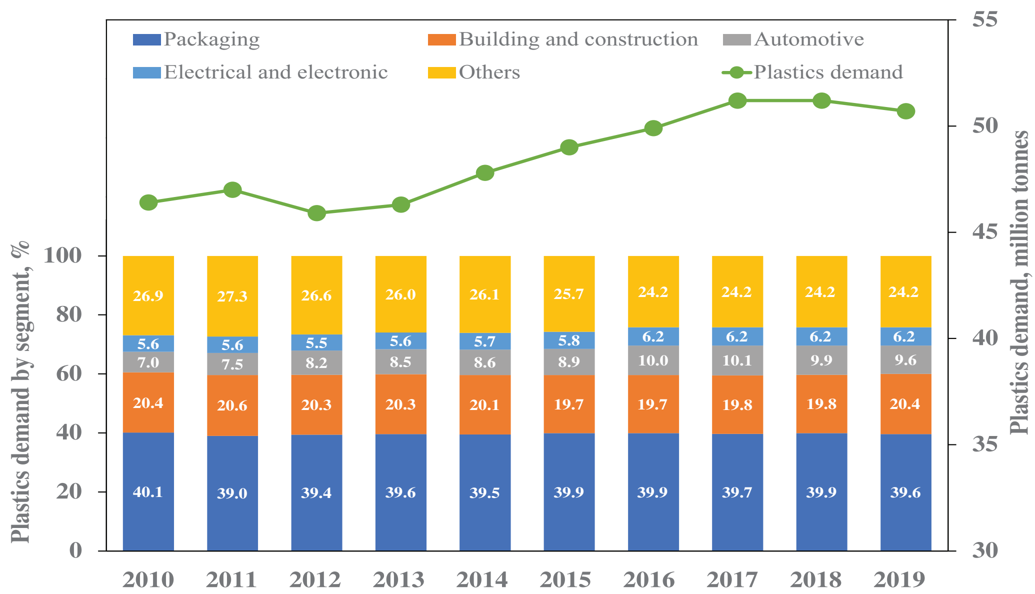

FIGURE 7 Plastics demand in Europe from 2010 to 2019 and its distribution by industry segment. Adapted from Plastics Europe (2021) [Color figure can be viewed at wileyonlinelibrary.com]

used in place of virgin wood fiber (Adamopoulos, Martinez, & Ramirez, 2007; Watkins, 2012). Some liners are even made of 100% recycled pulp (Rahmaninia & Khosravani, 2015). To attain the same specification as their virgin fiber counterparts, these boxes are slightly thicker to compensate for the lower mechanical strength of the recycled fibers (Watkins, 2012). If greater strength and stability are required, particularly for heavy-duty packaging, a double-walled structure can be used; it contains two layers of fluted sheet sandwiched between three liners (Figure 6b). Various combinations of flute profiles can be specified for this double-walled design, which further increase the versatility of this popular packaging material.

3.1.2 | Plastic packaging materials

Global plastics production in 2019 was 368 million tonnes, and about 51 million tonnes was consumed in Europe (Plastics Europe, 2021). There was a steady increase in demand for plastics in Europe from 2010 to 2018 (Figure 7), and the sectoral distribution of that demand was consistent. By far, packaging represented the largest end-use market, with a commanding 40% share over the last decade. Similarly, plastic was also a popular packaging material in China (Figure 3).

Plastic has various attractive properties suitable for packaging purposes: light weight, durability, and relative ease of mass-production in customized shapes at low cost. Besides the five most common plastics, that is, polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC), other options are also readily available and adaptable for various packaging needs (Groh et al., 2019). Plastic is compounded with different chemical additives to improve its properties and allow it to be processed into products with enhanced performance and appearance. Additives range from plasticizers, lubricants, antioxidants, and pigments (Al-Malaika, Axtell, Rothon, & Gilbert, 2017; J. Murphy, 2001) to advanced additives like nanoparticles for antimicrobial function (Palza, 2015) and improved biodegradation of plastic waste (Kumar & Maiti, 2016).

3.2 | Recycling and reuse considerations

Life cycle assessment (LCA) is an established systematic method that considers environmental and other potential impacts of a product's life, from cradle to grave. In the case of EDPMs, this may include consideration of their manufacture to the final disposal of waste. LCA studies can indicate better or alternative materials for the intended purpose and identify different options for recycling or disposal (Kaab, Sharifi, Mobli, Nabavi-Pelesaraei, & Chau, 2019; Perugini, Mastellone, & Arena, 2005).

3.2.1 | Recycling of corrugated paper boxes

Previous LCAs of corrugated paper boxes suggested that recycling is much more environmentally friendly than incineration or landfilling (Denison, 1996). Similar findings were supported by a 2006 report by the European Environment Agency, which aimed to provide a solid basis for the European Commission's policymaking in the management of paper and cardboard wastes (Villanueva, Wenzel, Strömberg, Viisimaa, & Skovgaard, 2006). A more recent LCA by the National Council for Air and Stream Improvement (2017) reported a 35% reduction in global warming potential of producing one tonne of corrugated packaging in the United States between 2006 and 2014, driven by reduced dependency on fossil fuel and a higher recycling rate of end-of-life corrugated packaging. According to the American Forest and Paper Association (2019), the average recycling rate of corrugated packaging was 92.3% between 2017 and 2019. In 2018, more than 50% of old corrugated cardboard (OCC) cartons were reused as feedstock to produce more corrugated boxes (Fibre Box Association, 2019). Rising e-commerce deliveries and a drop in OCC exports have further encouraged U.S. paper mills to use more recycled paper and OCC in their papermaking process. For every tonne of wastepaper being used as a replacement for virgin wood fiber in papermaking, at least 30,000 L of water and 3,500 kWh of electricity can be saved, and air pollution can be reduced by 95% (Bajpai, 2013).

3.2.2 | Recycling of plastic packaging materials

Commercial plastic products have a wide range of working life spans before they are discarded as waste. Geyer et al. (2017) noted the estimated average lifespans of three main plastic products: less than a year for plastic packaging, over a decade for automotive parts, and several decades for plastics used in building and construction. Post-consumer plastic waste collected annually has increased from 24.7 million tonnes in 2010 to 29.1 million tonnes in 2018 in Europe (Figure 8), where over 61% came from the packaging sector from 2016 onwards. It is evident that recycling, which increased by 33% between 2010 and 2018 in Europe, has been the preferred option followed by energy recovery via incineration and landfill. The 50% decline in landfilling over this period highlights Europe's ambition to achieve a circular economy and society. In the EU, per Directive (EU) 2018/852, the Packaging and Packaging Waste Directive 94/62/EC was amended to include higher recycling targets for materials commonly found in packaging waste; for plastic, the targets were set

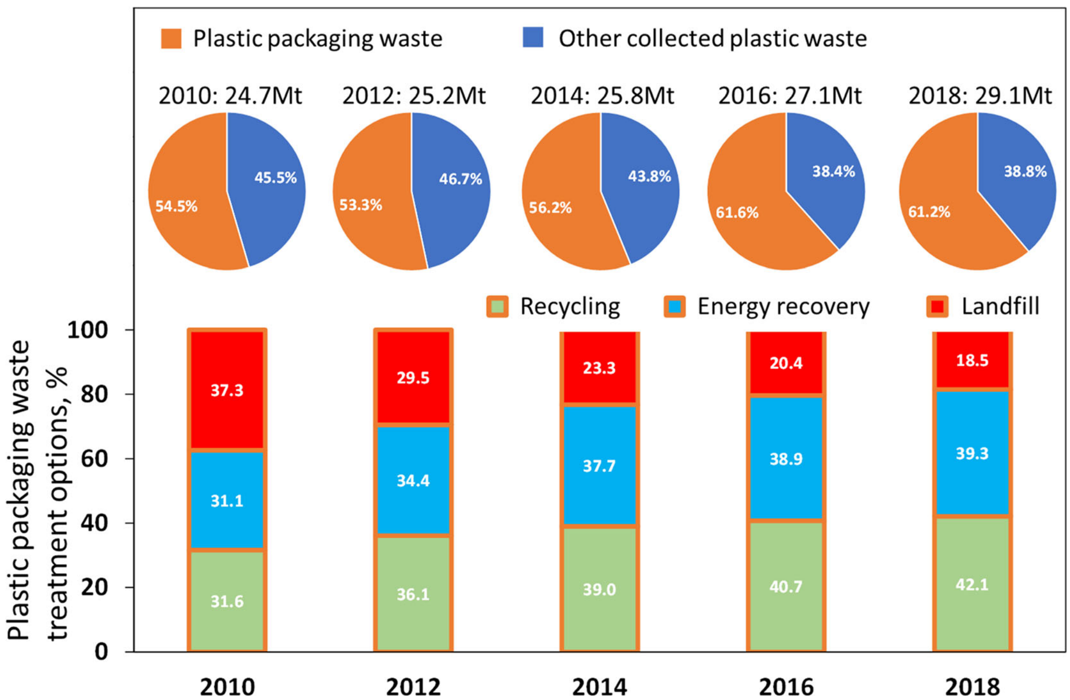

FIGURE 8 Plastic waste collected in Europe from 2010 to 2018 and waste treatment options. Adapted from Plastics Europe (2021) [Color figure can be viewed at wileyonlinelibrary.com]

at 50% by 2025 and 55% by 2030 (Directive, 2018/852). It is worth noting that energy recovery does not count toward the attainment of such recycling targets. Thus, greater effort must be devoted to improving the existing recycling approach, which is mechanical recycling in the case of plastics (Garcia & Robertson, 2017).

Mechanical recycling of plastics is a multistep process involving waste collection, sorting, cleaning, shredding, and remelting the plastic into granules. An LCA reported that mechanical recycling required far less energy than using virgin PE and PET in the production of containers for liquids (Arena, Mastellone, & Perugini, 2003). However, the purity of the waste stream input is critical because each plastic has its own unique chemical structure, melting temperature, and processing parameters. Coprocessing of common packaging plastics, such as PP, PET, PE, and PVC, will result in an immiscible blend (Ragaert, Delva, & Van Geem, 2017) with inferior properties (Ajitha & Thomas, 2020). Hence, an efficient collection and sorting system is essential for separating individual plastic types; otherwise, more packaging waste is destined for energy recovery.

3.2.3 | Reuse of packaging materials

The minimization of the use of packaging materials is one of the most effective measures for protecting the environment (Ahamed et al., 2021). While total elimination of EDPMs usage is not possible, direct and secondary reuses are becoming more important options for environmental conservation (Edwards & Fry, 2011; Muthu, Li, Hu, & Mok, 2011; Yaman, 2020). By reusing EDPMs, waste can be reduced and its life cycle extended, which potentially reduce negative impacts on the environment (Hazen, Cegielski, & Hanna, 2011).

Many would agree that packaging materials, especially corrugated boxes, are generally still in good and usable condition after the delivery process. Previous studies have also reported that reusable plastic containers are more environmentally friendly (Lee & Xu, 2004; Levi, Cortesi, Vezzoli, & Salvia, 2011; Raugei, Fullana-i-Palmer, Puig, & Torres, 2009; Ross & Evans, 2003; Singh, Chonhenchob, & Singh, 2006), and this was further supported by an LCA focusing on a confined waste management system within a modern city (Ahamed et al., 2021). Furthermore, Abejón, Bala, Vázquez-Rowe, Aldaco, and Fullana-i-Palmer (2020) have shown that reusable plastic crates for food packaging applications are more environmentally friendly than single-use cardboard boxes. In contrast, a study by Koskela, Dahlbo, Judl, Korhonen, and Niininen (2014) found that with a strict recycling protocol, corrugated cardboard boxes could be a better choice than reusable plastic crates. Although there are some uncertainties about the best packaging from an environmental perspective, it can consistently be seen that whenever there are opportunities to reuse these materials for multiple delivery cycles, they may have a significantly positive impact on the environment.

4 | THE REUSE FRAMEWORK

Waste prevention and product reuse should be prioritized before recycling or disposal (Gharfalkar, Court, Campbell, Ali, & Hillier, 2015). Given that the discarded EDPMs might still be in good condition, their potential should be fully evaluated. Thus, we propose a reuse framework based on a reverse logistics system for online order fulfillment to exploit opportunities for resource recovery and to ensure that online shopping is more environmentally friendly and sustainable. The proposed framework extends the existing forward logistics model to enable reuse, resource optimization, recycling, and recovery, in line with the vision of a circular economy. When the customer receives the parcel at their home or at a designated collection point, they can return the used packaging material (e.g., cardboard boxes, plastic crates, and/or bubble wrap) in a reverse logistics loop, as shown in Figure 9. Packaging materials can be returned immediately or on a different day. Return efforts could be rewarded through the form of cash incentives, discounts for future purchases, or other forms of motivation to encourage participation in the return process.

Transport optimization for pickup and delivery services plays a vital role in the proposed framework. The spatial distribution of these services relative to courier depots, the availability of a finite fleet of vehicles, and the carrying capacity per vehicle determine the complexity of forming an efficient closed-loop supply chain. Determination of the best vehicle route for achieving high productivity, low carbon emissions and satisfying customers' demand is the primary target of reverse logistics management; these factors have been collectively studied under an operational research topic known as the vehicle routing problem (VRP).

For the proposed reuse framework, which consists of delivering a customer's order and picking up used packaging materials, VRP variants with integrated backhaul features are thus necessary. They can be executed through three strategies: (1) delivery first, pickup second; (2) mixed deliveries and pickups; or (3) simultaneous deliveries and pickups (Nagy & Salhi, 2005). Although strategy (1) is the easiest to implement, it is inefficient in the use of vehicle storage capacity as the pickup service only commences once all deliveries have been completed. The used packaging materials are light and can easily be rearranged with the linehaul loads on the vehicle. In addition, some materials are compressible or foldable, and require little storage space. For more efficient transportation, the mixed-mode strategy (2) is optimal, as the used packaging materials can be picked up in any sequence. Some customers may have both delivery and pickup requirements at the same time and prefer to be served at their appointed time slots; the simultaneous delivery and pickup strategy (3), coupled with the time window feature, would be the best option for this. However, pickup frequency, time slots, and quality of the used packaging materials are likely to be stochastic, potentially causing a high fluctuation in inventory levels. Therefore, with the aim of achieving a balance between inventory gluts and shortages, inventory management has been integrated with VRP analysis (Andersson, Hoff, Christiansen, Hasle, & Løkketangen, 2010; Vidal, Laporte, & Matl, 2020).

It is important to note that the quality of the used packaging material varies, as each parcel may have been stored or treated differently. In addition, reuse will further degrade and age the packaging materials with each accumulated cycle of reuse. Thus, the quality characteristics of the collected used EDPMs significantly influence the success of the proposed reuse framework. Hence, a comprehensive set of quality criteria that considers the requirements of all

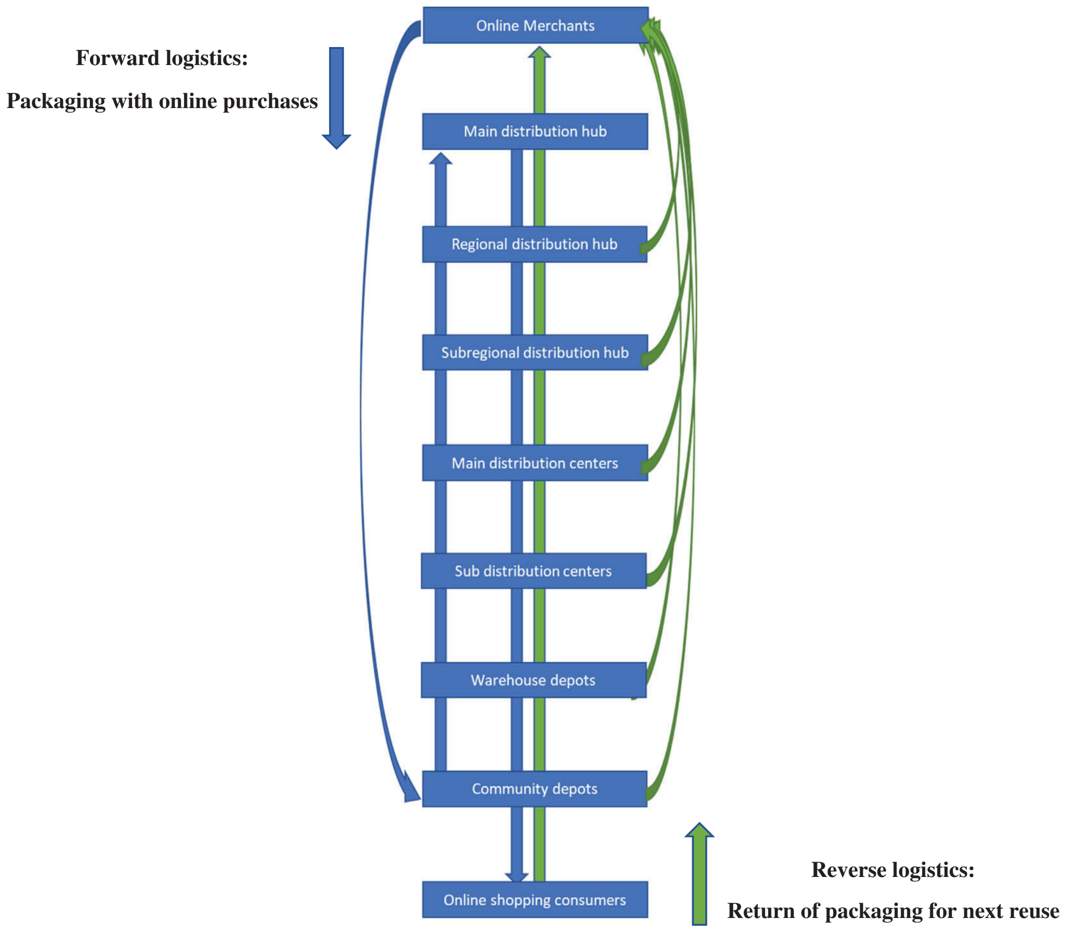

FIGURE 9 Reusable packaging framework for online shopping delivery [Color figure can be viewed at wileyonlinelibrary.com]

stakeholders must be established before reusing EDPMs. Apart from apparent structural or functional failures of the packaging material, other defects, such as cosmetic scarring, smudges, and marks, should also be considered. Once the rejection criteria are established, there should be multiple inspection points within the framework. The packaging materials should be assessed for their condition, cleaned, and sterilized before being circulated for reuse on the next delivery.

The proposed framework could be implemented within a single courier express organization, such as DHL and FedEx. However, the framework could ultimately be adopted throughout the industry through a loose form of cooperation between multiple courier companies. Although the current standard packaging materials are suitable for reuse in multiple delivery cycles, their design and specifications may not be optimal for this purpose. Therefore, further work is needed to optimize the design. This would boost the sector's efficiency and help reduce the waste created by accumulation of used packaging materials. Changing habits and established practice is always a challenge when introducing new sustainable processes (White, Habib, & Hardisty, 2019). Nevertheless, creating support for a change initiative could help ensure a higher take-up rate and endorsement by the consumer of this greener practice. Gaining acceptance and support for the proposed framework from courier companies, consumers, and merchants would be essential.

5 | MANAGERIAL IMPLICATIONS AND LIMITATIONS

This proposed framework will help minimize waste and contribute to the concept envisaged: a circular economy for express delivery of online shopping packages. The key benefit of the proposed framework is the utilization of the existing delivery system with minimal additional cost and effort for recovery of packaging materials. Express delivery service providers could capitalize on return runs after deliveries by collecting packaging materials for reuse in future deliveries. Before adopting the framework, stakeholders and managers must be clear about the following requirements and challenges.

First, express delivery organizations need to establish the necessary infrastructure for cleaning, sorting, and quality assurance of the reused packaging materials. This may include considering how to optimize the use of current and additional resources to support the collection and redistribution of materials. Effective communication and involvement of all stakeholders are both a challenge and a success factor for our framework of reverse logistics. Consumer participation also plays a vital role in its success; thus, campaigns to increase awareness of the benefits of reusing packaging materials should be given top priority. Consumers' awareness of waste recycling is on the rise. Thus, the campaign should build on that desire and provide easily understandable information to engage, educate, and positively change consumers' behavior toward reusing packaging materials. In addition, guidance on the proper handling of packaging materials, such as removal and storage, should be readily available to preserve the reuse potential of EDPMs.

Second, it may be necessary to establish a "reuse logistics partnership." Stakeholders from manufacturers, logistics companies, research organizations, and academia should form a joint consultative group with the regional government to institutionalize reverse logistics practice through mutual cooperation. Capacity requirement planning for reverse logistics becomes ever more important when combining forward and reverse logistics. Algorithmic solutions have been proposed to reduce not just routing and pickup stations, but also the frequency of pickups based on input–output analyses of these deliveries. These efforts are expected to play a leading role in the efficient operation of a sustainable logistics system, with the development of related technologies, including a data-driven collaboration platform.

Third, it is important to consider the introduction of a verification and certification system that is well acknowledged by the logistics industry for the reuse of packaging materials. The system should include clear evaluation criteria established by the joint consultative group. The effectiveness of the certification system can be strengthened by providing benefits to certified manufacturers and consumers who partake in the scheme. Lastly, it is worth noting that government-led support, such as subsidies and tax incentives for stakeholders, could further expand the voluntary participation of the private sector.

However, the current proposed framework is not without limitations; notably, it is still at a conceptual stage. It has been developed based on knowledge gleaned from the literature and our expertise in sustainable materials, operations management, and the circular economy. The framework may need to be refined and adapted according to location-specific contexts and policies. The current conceptual framework may not have addressed in complete detail the human or material resources required to realize the framework. Nevertheless, these limitations may be opportunities for future research.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

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How to cite this article: Lai, N. Y. G., Kuah, A. T. H., Kim, C. H., & Wong, K. H. (2022). Toward sustainable express deliveries for online shopping: Reusing packaging materials through reverse logistics. *Thunderbird International Business Review*, 1–12. https://doi.org/10.1002/tie.22259