Measuring CO_2 emissions from transportation in a UK retail returns supply chain

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Abstract

Traditionally, there have been three aspects associated with retail returns management: 1) returns avoidance; 2) processing returned products; and 3) disposal of returned items from a retailer's supply chain, at which point retailers generally consider the transaction has reached a conclusion for that individual product. An often overlooked fourth aspect, however, is around the environmental cost of retail returns, specifically the carbon footprint generated from moving returned products through second life retail distribution channels. This paper examines the case of returned general merchandise retail products — in particular, a UK reverse supply chain for homewares, furniture, white goods and other non-apparel items. It focuses on investigating the environmental cost by determining how much CO_2 is created during the return transport processes until a product is retained by a customer and not returned again. Two disposition routes for unwanted retail stock items are examined in detail: first, the more desirable option of premium processing and resale of returned or unwanted items; and second, resale of items that are beyond economic repair through an auction house. The case study presented determines the CO_2 emissions generated for each disposition route and highlights the inefficiencies that arise from the fragmented transportation of items sold via the auction house that lead to significantly increased carbon emissions.

Keywords

retail returns, CO_2 emissions, circular economy, sustainability, reverse supply chain, carbon footprint

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INTRODUCTION

This paper discusses general merchandising (GM) product processing and transportation, specifically within the reverse supply chain for UK homewares, furniture, white goods, sports equipment, etc. Previous research has studied the cost implications of retail returns;[1] however, this paper focuses on the environmental impact of returned items and the implications for the carbon footprint in terms of CO_2 emissions of several current available disposition routes. It will specifically consider the CO_2 emissions associated with each transportation leg of moving product between returns processing nodes, as depicted in Figure 1.

The typical retail returns supply chain illustrated in Figure 1 highlights the transportation legs between processing nodes. An unwanted product is returned by the customer either to a physical store or direct to a retailer's distribution centre (DC) for inspection and processing. From the DC, a returned item can take a variety of routes, depending on the product type. Non-apparel is most commonly reprocessed for resale either as pristine or refurbished product through a second life retail channel or sent to an auction house for sale at a significant discount. Occasionally, however, on inspection at the DC, it may be deemed that the returned item is faulty and therefore the retailer may decide to simply return the faulty products/warranty returns, or report and dispose of them, depending on the contractual agreement between the original equipment manufacturer (OEM) and the retailer.[2]

The case study presented in this paper focuses on the returned product journey as it enters the reverse supply chain after a product has been deemed to be of no further use to the retailer. For example, returned products, in addition

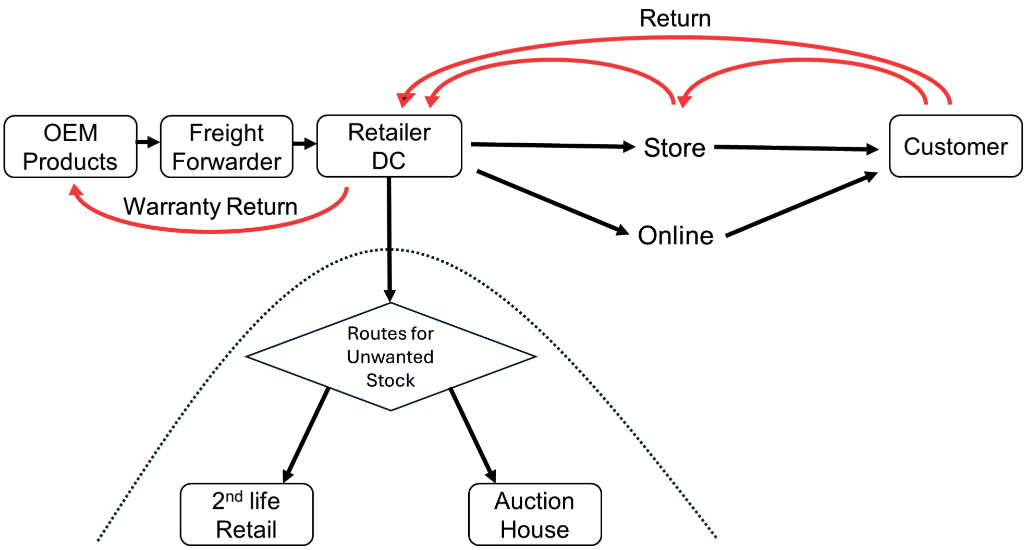

FIGURE 1 Typical retail returns process

to end-of-line or out-of-season products (eg camping equipment in the autumn), can be considered in this reverse supply chain. The focus is on measuring the CO_2 emissions for the transportation elements and does not include any processing emissions created by the retailer's DC, returns centres, specialist processing, warehousing and inventory holding activities.

As shown in Figure 1, a product is distributed to a customer in the first instance and is then returned either via a store or direct to a retailer's DC through postal services. A product could well go through this cycle several times before sticking with a customer, or eventually being sent to disposition routes outside the retailer's supply chain. On every arrow (Figure 1) there is an implied cost both financially and in terms of CO_2 emissions. This paper therefore concentrates on the area of Figure 1 that is below the dotted line, which incorporates two routes for unwanted stock.

Products bought online are said to be three times more likely to be returned compared with a 9 per cent return rate for an in-store purchase;[3] however, as will be explored in this paper, the CO_2 costs associated with returns for online purchases are higher than for products bought from traditional high street stores. Much previous research and UK logistics industry innovation has focused on the fashion supply chain, where return to good stock rates of over 95 per cent are commonly achieved.[4] Fashion is considered relatively easy to manage in terms of the reverse supply chain journey, as returned fashion products are easy to inspect, process, and can be repacked relatively cheaply and efficiently ahead of resale. In addition, if this processing is undertaken in the same location as the primary outbound logistics processing, the CO_2 emissions for returns are further reduced. Other product categories, however, are far more difficult to process (eg furniture, homewares, home electricals, etc.) with return to good stock rates being generally much lower and more sporadic. They can also be more expensive to purchase in the first instance (ie sofas, tables, etc.) and delivery tends to be more costly, requiring two-person delivery/two-person return. This in turn means that the percentage of stock that needs to be processed and managed outside the retailer's supply chain by third parties can be higher for these product ranges.

A case study was conducted in cooperation with ClearCycle, a small/medium enterprise (SME) in the northwest of England, which specialises in processing returned products on behalf of retailers. ClearCycle provides a data-driven stock liquidation and recommerce solution that uses market information to drive optimal product routing, refurbishment and pricing decisions, providing their clients with the best yield for returns and overstock. The majority of products they handle are reworked and resold, maximising the life cycle of retail goods.[5] The ClearCycle business model is designed to limit environmental impact: reduce landfill, optimise supply chain and provide intelligent packaging solutions, while prioritising reuse.

PRODUCTS FOR DISPOSITION

There are various recovery options for returned products which a retailer can take depending on the condition of the returned product and its packaging.[6] The preferred option for any product is to use it for its original purpose and resell as a pristine product, which is one of the three underpinning principles of the circular economy.[7] This is not always possible, however, for a variety of reasons, including damaged packaging, out-of-season or end-of-line products, bespoke items (eg personalised with initials), or unwanted products resulting from buyer remorse.

Once the decision has been taken that a product is no longer worthy to be sold by the retailer, there are a number of options available, all of which would see the removal of the product from the retailer's supply chain and be dealt with by a third-party company. Occasionally, products are sometimes processed by a specialist company for an additional fee, before being sold through secondary premium channels on behalf of the retailer. Alternatively, unwanted products are sold to third-party processors and thereby remove all of a retailer's liability. In the case of ClearCycle, unwanted returned products can then take a number of routes:

- Use the returned item for its original purpose — including use of any original marketing materials to promote the item through an online sales platform.
- Use for its original purpose, but it needs a minor repair — the repair is carried out by ClearCycle's trained staff and might involve regluing or touch-up of paintwork to meet the specification of the original product stock keeping unit (SKU). The blemish/repaired area in the product is photographed and clearly identified on promotional reselling materials. This includes details regarding the location of the blemish on the product so that a potential buyer can ascertain its visual effect on the overall product. This also helps to reduce the likelihood of the product being returned again.
- Send to auction — if the product is beyond economic repair, it is sent to an auction house, often as a bundle of items in pallet-sized lots.

Each option described has a cost implication for the retailer as well as an impact on CO_2 emissions. ClearCycle does not send any items for incineration or to landfill, but endeavours to ensure that all products are sold through an appropriate channel. This study focuses on two disposition routes for second life retail sales of returned products: first, sale as a premium returned product through a secondary channel, eg an online marketplace, and secondly, sale through an auction house, which could be for individual personal consumption or to sell on through market stalls, car boots, personal online channels, etc.

The returns DC is the starting point for the travel and carbon footprint calculations for the disposition of items through secondary sales channels. At the returns DC, a retail return item is received and temporarily stored, inspected, and then sent onwards through the reverse chain to complete its carbon footprint journey through second life retail using either a premium channel or an auction house.

PREMIUM DISPOSITION THROUGH SECONDARY CHANNELS

The CO_2 emissions associated with the retail return supply chain for the premium channel are calculated by segmenting the chain into transport legs between key nodes. ClearCycle provided various datasets and insight into the different journeys products made from their clients' DC to the ClearCycle facility, and through other distribution hubs, before the product was finally delivered to an end customer. This included the size and weight of products sold, distances each product travelled, the type of vehicles and fill capacity for individual trips, and fuel consumption by vehicle type and route.

The delivery channels were broken down into three distinct transport routes according to the size of the items (see Figure 2): small parcel delivery, large parcel delivery, and two-person delivery. For the purposes of calculating CO_2

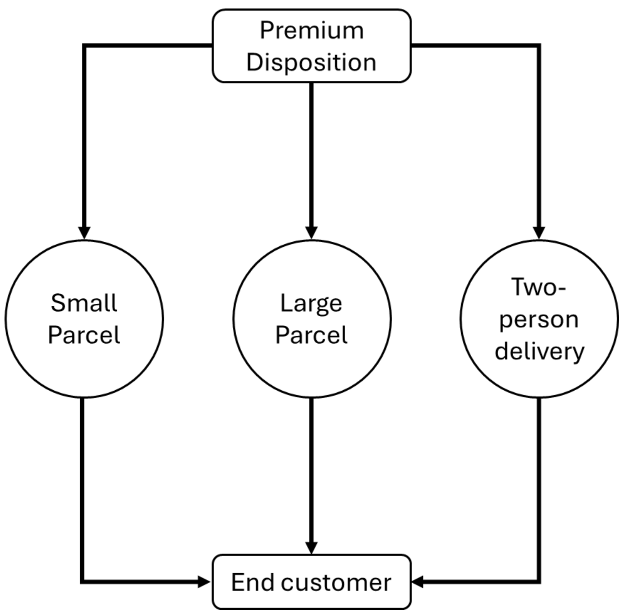

FIGURE 2 ClearCycle retail — premium delivery channels

emissions it has been assumed that a small parcel is delivered in a small or medium van with typical payload 500–1,200kg; a large parcel is delivered in a large van with a payload capacity of 1,200–1,500kg, sometimes referred to as '1.5 person delivery'; and two-person delivery is transported in at least a small truck, such as a Luton box van capable of carrying upwards of 3.5 tonnes, and requires handling by two people.[8]

These items are sold through an electronic back-to-customer (B2C) marketplace, therefore consumers have the right under distance selling regulations to return the item if not satisfied.[9] In addition, some items are rejected on delivery due to damage in transit, etc. Such items are then moved back to the returns processor for inspection before re-entering the disposition options. Examining the second life retail premium disposition options, the potential CO_2 emissions associated with each of the three transport routes were calculated using Equation 1. This calculation assumes the vehicles involved in the transport movements are diesel, and that burning a litre of diesel produces around 2.62kg of carbon dioxide,[9] and thus combining the above gives the carbon emissions per drop.

Equation 1: Calculation for average fuel efficiency

$$\text{Emissions Per Drop} = \frac{(\text{Average Distance Per Drop})}{(\text{Average Fuel Efficiency})} \times \text{Carbon Emissions Per Litre}$$

For the two-person delivery route, pallets are moved from ClearCycle's warehouse and reprocessing facility to the two-person delivery company on trucks, a distance of 258km. The number of pallets on each truck can vary up to a maximum capacity of 28 pallets. The warehouse and processing facility dispatch an average of 52.4 items per trunk on an average of 16.2 pallets.

Deliveries are made by a third-party logistics (3PL) company using box/curtain-sided trucks, with a fuel usage of 4.22km/l. Therefore, by calculating the average distance travelled by an item and the carbon cost of travelling that distance (Equation 2), it is possible to calculate the emissions per item (Equation 3).

Equation 2: Calculation for average distance per item

$$\text{Av. Distance Per Item} = \frac{(\text{Distance Travelled By Trunk})}{(\text{Av. Items Delivered in Trunk})}$$

Equation 3: Calculation for emissions per item

$$\text{Emissions Per Item} = \frac{(\text{Av. Distance Per Item})}{(\text{Vehicle Travel Per Litre Fuel})} \times \text{Carbon Emissions Per Litre}$$

The transport route is determined by the size of the item to be delivered to an end customer. Based on the above equations, the overall results for the item's journey between ClearCycle and the customer via the two-person delivery company are shown in Table 1. It should be noted that the ClearCycle to two-person delivery leg of the journey has been calculated based on an average number of items on a pallet.

Therefore, the overall average CO_2 emissions are 4.3kg per item. It should be noted, however, that this result is skewed by a significantly higher vehicle utilisation rate achieved by the small and large parcel delivery options that handle

TABLE 1 Results for ClearCycle to two-person delivery company

Metric	*ClearCycle to two-person delivery company*	*Two-person delivery to customer*
Road distance per Item	4.92km	45.9km
Fuel usage rate	0.24l/km	0.119l/km
CO_2 emissions per litre diesel	2.62kg/l	2.62kg/l
Emissions rate on road	0.621kg/km	0.311kg/km
CO_2 emissions per Item	3.1kg	14.3kg
Total	**17.4kg**	

26 per cent of the total items processed, compared with the less efficient two-person delivery option that handles the remaining 74 per cent of items, transported at 17.4kg CO_2 per item.

Parcelforce was used for 17 per cent of the deliveries attributed to the small parcel delivery route. The average emissions per parcel for Royal Mail (which includes Parcelforce) was 221g CO_2e; this is around half the 300–500g CO_2e average for UK parcel delivery companies.[11] The large parcels were delivered by various contracted express delivery companies as required, accounting for 9 per cent of all items delivered through ClearCycle's network. For both the small and large parcel delivery routes, an average per parcel CO_2 figure was provided by ClearCycle and used in our calculations. The CO_2 emissions for each of the delivery routes is summarised in Figure 3.

DISPOSITION BY AUCTION HOUSE

The second option for dispositioning returned products is the auction house route, shown in Figure 4. The returned product sold via an auction house is 'sold as seen' (not refurbished or repaired in any way), and often includes multiple products bundled together into one pallet-sized lot or equivalent. In practice, the quality and functionality of these items varies. The rationale for dispositioning through this route is that the product still retains some value to someone, even if it requires adaptation once purchased before it can be reused.

The majority of items purchased through the auction house are collected by the purchaser using a private vehicle. Although it is possible to arrange a delivery where an item is too large for transportation by private vehicle (eg a large sofa), the number of products taking this route is quite small and has not been included in the study. These products are sold outside the distance selling regulations[12] and are therefore non-returnable. Once a product or lot is collected from the auction house by the purchaser, this is the end of the CO_2 mapping journey for the item. While it is not possible to follow these items further, they may well be resold again through outlets such as car boot sales or personal online selling channels.

This study investigated an auction house in Greater Manchester whose lots included a wide range of products, encompassing everything from smaller one-off items to large pieces of furniture, white goods, building supplies and sports equipment. The fully managed service provided by the auction house includes physical storage of items before, during and following the auction until an item is collected, as well as an online auction service. The auction house is used to

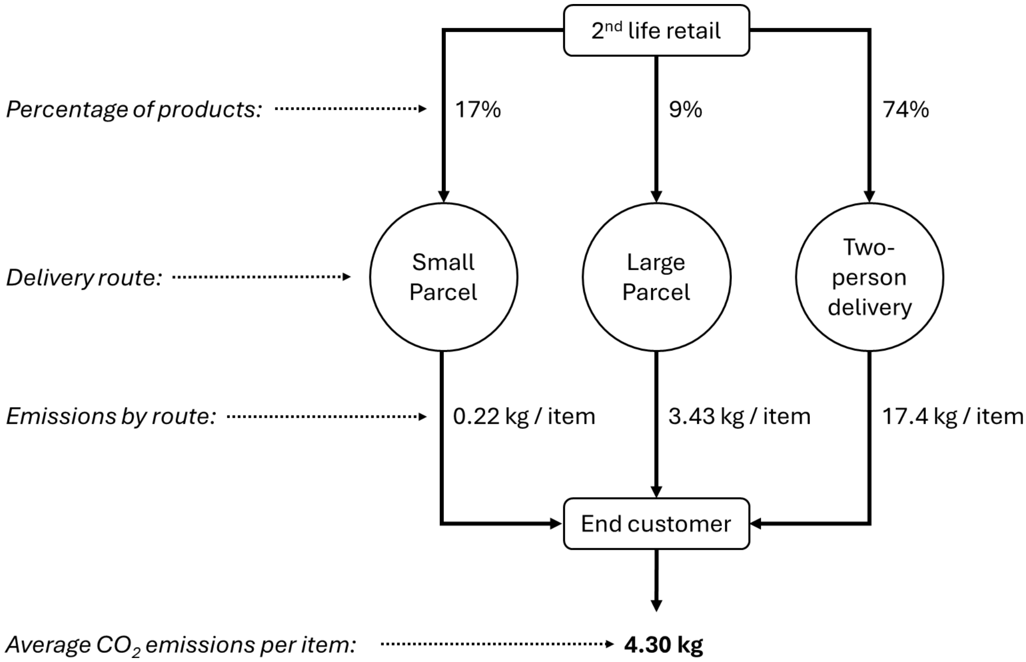

FIGURE 3 CO_2 emissions by delivery route

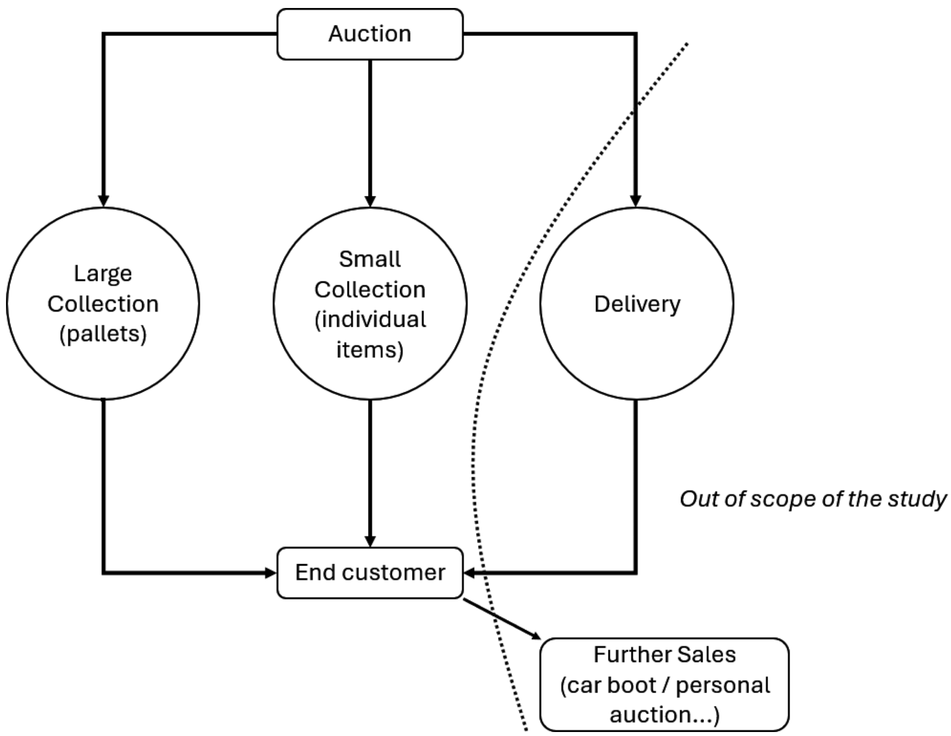

FIGURE 4 ClearCycle retail via auction house

disposing of unwanted products on behalf of retailers, return processors and others, through sales in live themed auctions each week. This route is often considered as the last disposition route for which a commercial return can be generated before the items are simply given away to charity or disposed of through landfill incineration.

This study considered auctions as lots, where a lot might be a single large item, a bulk purchase of smaller items or anything in between. The data examined, however, is provided as a single auction listing without further detail, irrespective of whether the lot comprises single or multiple items. For the purpose of understanding the travel incurred for collection of auctions won, this simplification of lots rather than items enables a CO_2 assessment without harming the integrity of the result. The CO_2 emissions associated with the auction disposition route therefore involves consideration for the purchaser travelling to the auction house to collect the lot, and assumes they take the lots to their purchase address using private vehicles (cars and vans).

CALCULATING CO_2 EMISSIONS FOR AUCTION HOUSE COLLECTIONS

Distances have been calculated based on the Euclidean distance between addresses, that is to say, 'as the crow flies'.[13] After establishing the Euclidean distance, a modifier was used to estimate the equivalent road travel distance. Originally defined as the 'deviation factor' of a road network, the assumed road distance between a pair of nodes is calculated. The ratio between the road distance and the Euclidean distance states that for most road networks, the deviation factor ranges from 1.2 to 1.6.[14–16] Given the topography of England, it was decided to use 1.3 as a conservative estimate in this study.

The study assumes that the origin and destination points of travel are the customer's address and the auction house respectively. It is feasible, however, that a customer collecting a lot will incorporate this trip as part of a longer trip chain. For example, a customer purchases a lot and travels from their home address, collects the lot but drops the lot at another location, before continuing to travel onwards elsewhere. Therefore, an assumption has been created around the use of 'trip chaining', which describes the effect of a customer performing multiple stops on a single journey, such as visiting a family member or stopping to purchase groceries at a supermarket as part of their journey. To account for this effect, a modifying function has been included. Research suggests[17] that around 10 per cent of journeys have multiple stops, and that in these cases there is a reduction of 20–50 per cent of road miles. Taking the mid value for reduction benefit of 35 per cent and considering this across 10 per cent of results means that this can be evaluated to an overall adjustment of 3.5 per cent across the entire dataset.

A further assumption is made to accommodate multiple auctions ending on the same day that are won by a bidder in the same postcode. It assumes the winning bidder is one individual customer and as such, they would collect the multiple lots from different auctions in a single journey. In these cases, the number of lots collected for that journey has been documented and used to attribute equal parts of the journey between lots collected, such that a 100km journey for two lots is equivalent to 50km per lot collected.

The dataset consisted of 15,144 records of delivery data for auction lots won. Following data cleansing, some records were removed due to incomplete information and some of the delivery addresses being outside the UK. In total, 15,129 usable records remained. When customers use their personal vehicle to collect an auction lot, it is assumed to be a petrol/diesel vehicle with emissions of 138g/km, which is equivalent to the average emissions rate for vehicles in 2020.[18] For the auction house route, 40 per cent of products are considered large collections (pallet-sized or equivalent), which may require a larger vehicle such as a small van, and the remaining 60 per cent are small collections or individual items. The results are summarised in Table 2.

DISCUSSION

In traditional forward supply chains, products are initially shipped in the most effective and efficient manner from the manufacturer or supplier through a centralised distribution system.[19] Essentially this consists of a consolidated vehicle load with maximum pallet fill, either in full containers or truck loads, to achieve increased transportation efficiency.[20] Once it becomes an individual SKU sold to an end customer, following a sortation process it is onward distributed in full cages on efficient trunking legs. At this point SKUs are either sent to a retail store where customers make an in-store purchase and then transport them home themselves, or for online sales, where they are delivered to the end customer, but in a consolidated full van load with other products being delivered as part of the driver's route.

TABLE 2 Results for auction house, customer collection

Metric	Result
Average Euclidean distance	66.0km
Estimated road network distance	85.8km
Estimated travel for collection	150.1km
Average lots collected per journey	1.32
Carbon emissions per journey	29.7kg
Carbon emissions per lot	26.0kg

For an unwanted or returned product, the journey becomes more complex, with several disposition routes[21] involving returns processors, and thus several transportation options, each contributing to the generation of CO_2 emissions. For each option to resell the returned product there is a decreasing level of efficiency associated with each transport leg until the product finally sticks with a customer, either as a resold pristine product, a secondary channel resale, or disposed of through an auction house. The sooner a disposition decision is made for an unwanted or returned product, the better the outcome for the retailer's bottom line and for the impact of CO_2 emissions on the environment.

This study has explored the CO_2 implications of disposition routes for unwanted products. It is clear that the sooner a decision can be made for any product regarding its future, both the costs[22] to the company and the CO_2 impact on the environment can be minimised; however, the scale of that impact does vary. From a financial perspective, there is a relatively linear trade-off in terms of the price a product can be resold for over time,[23] as can be seen in Figure 5.

Every time a returned product goes around the returns processing loop, the cost is approximately the same and these processing costs generally are incurred cumulatively. Each time a product is returned, however, the profit from resale is eroded, until it reaches a point where the profit has all gone and additional

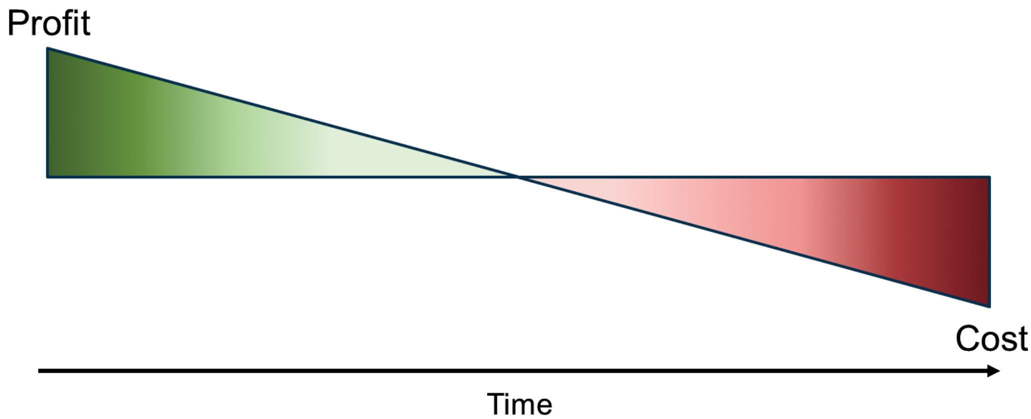

FIGURE 5 Trade-off between profit and cost over time

costs are being incurred to keep the product in the returns system.

From a CO_2 emissions perspective, the returns processing journey follows what could be described as a logarithmic pattern (see Figure 6). This is due to the decreasing efficiency created partly by the increasing number of transportation journeys associated with each transhipment of the product between stages of reprocessing and shipments to reach the final customer. In addition, the lack of consolidation of products on these transportation legs is a further contributing factor to this decreasing inefficiency.

CONCLUSION

Within this study, a product that is sold through a secondary return's processor channel was found to generate on average 4.3kg of CO_2, while a product disposed of through an auction house route was determined to generate approximately 26kg of CO_2. This is in addition to any emissions that were produced in shipping the product from the original manufacturer to the retailer and the initial pre-sale delivery from new. It is likely that the auction house sale route generates significantly higher CO_2 emissions because of the reliance on final customers (those purchasing the lots) to undertake the

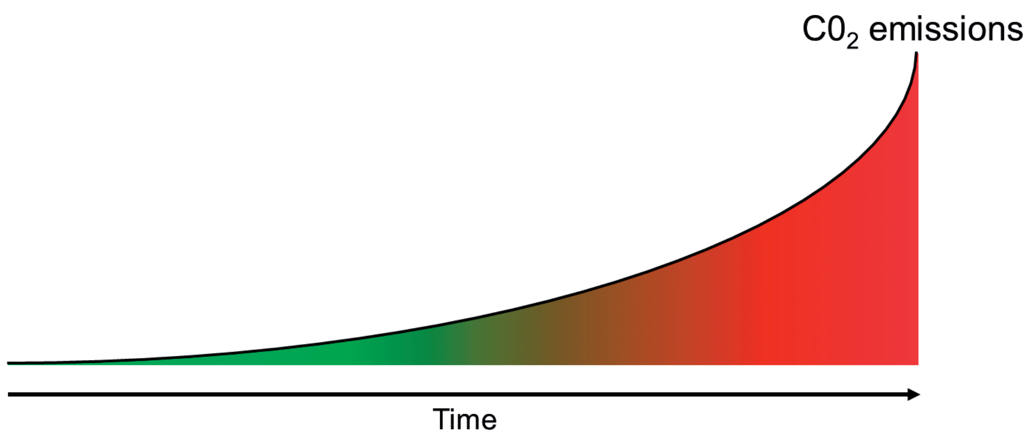

FIGURE 6 Increase in CO_2 emissions over time

last-mile distribution activities from the auction house themselves. Whereas the premium second life retail disposition option incorporates consolidated outbound deliveries to customers via three delivery routes.

The case study has shown that the ability to consolidate deliveries can greatly improve the efficiency of the transportation journeys, and this has a noticeable impact on the amount of CO_2 generated. The premium second life disposition route therefore benefits from the increased vehicle fill rates that are achieved by consolidation opportunities that the small and large parcel couriers provide. Even the two-person delivery route still maximises vehicle fill by achieving some degree of delivery consolidation. Such optimisation is simply not possible for single lots and items that are each collected on an individual basis from the auction house and transported in private vehicles.

The findings from this case study can serve as a basis for future studies examining the CO_2 generated from returns processing in a UK context. Returns processing is still a sector in its infancy, which has created a fragmented reverse supply chain. This translates into multi-site processing and (multiple) movements of returned items prior to their resale. This multi-site approach has led to increased transport emissions as items are transported between sites for processing and preparation for resale. This study has demonstrated the additional CO_2 emissions generated from unnecessary product movements. Therefore, the more times these items are transported around the reverse supply chain, the greater the emissions generated due to less efficient vehicle-fill rates resulting from the high volume of random one-off items requiring processing and their diseconomies of scale.

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