Carbon Auditing the 'Last Mile': Modelling the Environmental Impacts of Conventional and Online Non-food Shopping

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Executive Summary

Several internet retailers claim that it is better for the environment for consumers to shop online and have their goods delivered to the home than to travel to the shops. This report summarises the results of research which has compared the carbon footprints of online and conventional shopping. It focuses on the carbon intensity of "last mile" deliveries (i.e. deliveries of goods from local depots to the home) and personal shopping trips.

The research focused on the purchase of small, non-food items, such as books, CDs, clothing, cameras and household items. Several last mile scenarios were constructed on the basis of official government data, discussions with company managers and realistic assumptions derived from the literature. The analysis used representative data on home deliveries (related to drop density, distances travelled, vehicle type and fuel efficiency) and on consumer travel behaviour (related trip type, choice of transport mode, fuel consumption and the number of goods purchased). The calculation made allowance for home delivery failures (when no-one is at home to receive the goods), 'browsing' trips to the shops and the return of unwanted goods. No consideration was given to differences in CO_2 emissions in the upstream distribution channels because they do not differ between conventional and online channels.

Overall the research suggested that, while neither home delivery nor conventional shopping has an absolute CO_2 advantage, on average, the home delivery operation is likely to generate less CO_2 than the typical shopping trip. It was found that, on average, when a customer shops by car and buys fewer than 24 items per trip (or fewer than 7 items in the case of bus users) the home delivery will emit less CO_2 per item purchased. A typical van-based drop produced 181gCO_2, compared with 4,274gCO_2 for an average trip to the shops by car and 1,265gCO_2 for an average bus passenger.

This finding requires several qualifications, however, as it assumes that:

- the conventional shopping trip is a single purpose trip (i.e. there is no trip chaining);
- the online purchase is delivered successfully first time and is not subsequently returned; and
- the shopping trips and home deliveries are exposed to similar traffic conditions.

A further important finding was that CO_2 emissions per item for intensive / infrequent shopping trips by bus could match online shopping / home delivery.

On the basis of this evidence, the number of items purchased per shopping trip and the choice of travel mode are shown to be critical factors. The willingness to combine shopping with other activities and to group purchases into as few shopping trips or online transactions as possible is clearly important to minimise the environmental impact of both conventional (especially car-based) shopping trips and home delivery. Online retailers and home delivery companies could also apply several other measures to enhance the CO_2-efficiency of their logistical operations and gain a clearer environmental advantage.

Both consumers and suppliers need to be better informed about the environmental implications of their respective purchasing behaviour and distribution methods.

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CfIT	Commission for Integrated Transport
CO_2	Carbon dioxide
Defra	Department of Environment, Food and Rural Affairs
DfT	Department for Transport
FTA	Freight Transport Association
NAEI	National Atmospheric Emissions Inventory
RHA	Road Haulage Association
VED	Vehicle Exercise Duty

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1. Introduction

Consumer shopping behaviour is highly complex, *everyone* has to shop. And while the range of retail channels on offer has never been greater, modern-day pressures mean that shoppers are increasingly faced with external time constraints (Lewis & Bridger, 2000). Individuals have to make choices about how they apportion their time. Some consumers choose to shop in physical stores, while others, owing to convenience and other reasons, favour ordering online, for a third party to deliver the items to their home. Still others (probably the majority of consumers) use a combination of both conventional and online retail channels to acquire goods. The environmental implications of these shopping decisions are no less complex although, currently, people have no way of measuring the environmental merits of one shopping method against another.

Special consideration needs to be given to the "last mile" problem i.e. the final stage in the supply chain. The issue here is not just that this last link in the supply chain (from retailer / supplier to consumer) is the most visible; it can also be the most energy intensive. Browne *et al.* (2008) note that in the case of conventional shopping, personal shopping trips can use more energy than the entire upstream supply chain, even when production is included. Therefore, the relative carbon intensity of the so called "last mile" delivery (i.e. the final delivery to the customer) compared with the customer collecting goods from physical stores is of vital importance. Several past studies have examined this last mile delivery (European Information Technology Observatory, 2002; Abukhader & Jönson, 2003; Sarkis *et al.,* 2004; Farag *et al.*, 2006), although none have systematically compared consumer travel with freight delivery in terms of energy expenditure per delivery drop / item bought.

This report, taking into account the intricacy of consumer behaviour, attempts to model the carbon emissions associated with receiving goods delivered to the home by parcel carrier, compared with consumers making a trip to the shops to buy the products in-store. Several last mile scenarios are proposed based on publically-available data, discussions with practitioners in industry and realistic assumptions derived from the literature. Sensitivity analyses are then performed. It is hoped that the findings reported here will better inform consumers and suppliers of the environmental implications of their respective purchasing behaviour and distribution methods.

This new study adds to previous work in the following ways:

- It models the CO_2 emissions associated with van delivery for the last mile (from local parcel depot to the consumer's home);
- It models the impact of dedicated shopping trips (single purpose trips) versus trip chaining (multi-purpose trips) by consumers;
- It examines representative delivery scenarios related to distance, modal choice and product categories; and
- It considers the issue of returning unwanted goods.

The remainder of this report is structured as follows. In the next section, previous studies of the environmental impact of online shopping are briefly summarised. We then outline and explain the underlying assumptions to the analysis. Various scenarios are developed. Next, the methodology and data input values are described. These are followed by a presentation and discussion of the results. In the last section, overall conclusions are drawn and limitations to the model discussed.

2. Environmental impact of online shopping

Early retail forecasts from the turn of this century envisaged the demise of traditional 'bricks and mortar' stores at the expense of internet sales (Burt & Sparks, 2003). Yet, these (sometimes wild) predictions have not come to fruition, owing partly to the internet being regarded as an additional (complementary) retail channel rather than a direct replacement (substitute) for conventional shopping (Weltevreden & Van Rietbergen, 2007).

Nevertheless, some online retailers actively claim that internet shopping yields environmental benefits (Smithers, 2007). Equally, consumers seem to have a widely-held view that online purchases and home delivery are beneficial to the environment because they reduce personal travel demand (IMRG, 2008; Royal Mail, 2007). Such opinions are also prevalent among researchers. For instance, Rotem-Mindali & Salomon (2007, pp.178) point out that "studies of the impacts of teleshopping on transport usually assume that the delivery trip, by the retailer or a third party, to multiple customers is more efficient than individual trips".

On initial consideration one might assume that online shopping replaces conventional shopping trips. Where this occurs it is referred to as the substitution effect and would reduce overall travel (Visser & Lanzendorf, 2004). In 73% of cases DfT (2009a) reported that survey respondents said they would have visited an outlet to purchase a product had they not ordered it for home delivery. Weltevreden & Van Rietbergen (2008) in their review of online shopping found that the degree of trip substitution among online users varied considerably, with previous studies reporting between 12% and 78% of online shoppers making fewer shopping trips as a result of online purchases. This wide range was attributed to variations in methodology and the duration and geographical extent of data collection. On the assumption that customers do not make supplementary journeys in the time once devoted to shopping, Cairns *et al.* (2005) calculated that grocery home delivery vans in the UK could save as much as 70% of car-generated kilometres when used to directly replace car trips to the supermarket. In reality exact substitution is rarely achieved. Corpus & Peachman, (2003) found in their Australian study that in approximately a third of cases where internet purchases were made the physical trip would have occurred anyway, even if the internet transaction had not taken place.

Therefore, the environmental balance favouring freight transport to the home over traditional shopping methods is not as straightforward as it may seem. Adverse environmental effects may result from online shopping as people continue to use their cars *as well as* ordering online (these are referred to as complementarity effects). First, shoppers may continue to make trips to the shops for certain items. In the case of groceries, shoppers may prefer to buy fresh produce in-store (Citrin *et al.*, 2003), while having other goods (especially bulky and heavy items) delivered to their home (Cairns, 2005; Grunert & Ramus, 2005). Cullinane *et al.* (2008) reported that for students the physical convenience of not having to carry groceries was their main reason for shopping online. Second, additional physical trips to the shops may be generated as a result of the original internet purchase, as a consumer may wish to buy supplementary items in-store.

Several other aspects of the last mile delivery also appear to off-set any initial environmental gains. These include:

- Frequent purchases of small quantities generating numerous, relatively inefficient home deliveries (Kröger *et al.*, 2003; Mokhtarian, 2004);
- Customers' tendency to purchase separate items from several different web-based companies (each requiring separate delivery). Previously, goods would have been bought on one trip to the shops;
- Additional sortation requirements to combine multiple customers orders prior to delivery (de Koster, 2002). Some companies do not deliver the whole of a customer's multi-order in one trip because of the timing of the picking process;
- Additional trips being generated when the time saved by shopping online is converted into travel for other out-of-home activities by either the car owner or other members of the household (Gould & Golob, 1997; Cullinane *et al.*, 2008). As a result, there is an increase in total vehicle miles travelled (Mokhtarian, 2004), as on average leisure trips tend to be longer than shopping trips (DfT, 2007a);
- Internet-browsing encouraging people to go shopping for additional and/or supplementary purchases (Skinner *et al.*, 2004);
- Minimal travel savings for online shopping, when goods, if purchased via the conventional channel, would have been bought as part of an overall multi-activity trip;
- Additional freight movements being created in cases where customers previously walked or cycled to the shops;
- Failed deliveries when no-one is at home;
- Returns of unwanted goods; and
- Lower prices for internet purchases encouraging consumers to buy more.

In recognition of these issues, the present study models several different consumer trip scenarios.

3. 'Last mile' comparisons: background and assumptions

3.1. Online shopping

Methods of delivery

The vast majority of online purchases result in the physical movement of a small package (or single item) to an individual address (typically a consumer's home) by parcel carrier (RAC Foundation, 2006; Retail Logistics Task Force, 2001). In general, these deliveries are distributed from local parcel carrier depots, and consist of mixed loads in the back of vans. Volumes delivered are high: the leading parcel delivery carrier in the UK delivers some 300,000 parcels daily. Concern has been expressed about the environmental repercussions of this expanding home delivery market (Webster, 2007). Such fears are not unfounded. Total mileage travelled by vans has risen by 40% cent over the past 10-years in the UK, partly reflecting the growth in movement of smaller quantities of goods (although 'Goods collection and delivery' only represents a fifth of the total mileage) (DfT, 2009b). Nevertheless, fuel consumption has also increased correspondingly, as smaller vehicles consume more fuel per tonne-km moved than larger vehicles (DfT, 2003). They also produce more pollution, which is partly a reflection of the higher levels of urban driving undertaken.

As a result, there has been increased interest in the use of electric vehicles for home delivery, especially in the online grocery sector. Sainsbury's for example, plans to convert its entire online grocery delivery fleet to electric vans by 2010 (Sainsbury, 2007). Emissions for electric vans will also be assessed in this report, taking account of the environmental impact of the primary electricity generation (E4Tech, 2007).

Vans are not the only delivery vehicles employed by parcel delivery companies. The use of self-employed couriers has been on the increase recently (Beveridge, 2007). Several leading online retailers now use third party courier networks for deliveries. Couriers are not necessarily professionally-qualified drivers; rather they are often self-employed retired people or those with family commitments who can adapt to the flexible, part-time nature of this work. Deliveries are generally carried in the back of their private cars. Therefore, in addition to calculations for diesel and electric delivery vans, the implications of using couriers' private transport for home delivery will also be considered. Drops per round are varied to reflect the different types of vehicles and driving environments.

Traditionally, vehicle load factors have been measured with respect to weight. For vans in the home delivery sector the number of drops per round is more representative of vehicle utilisation than the total weight of the consignments. Rather than considering vehicle fill as a percentage of maximum permissible weight, parcel delivery companies are concerned with achieving high drop density rates per round by maximising the number of deliveries, a key productivity measure in this sector. The parameters of vehicle fill and empty-running are not therefore included in the analysis. All delivery drops are treated equally, regardless of when in the round they are actually delivered. This approach may be criticised, as those deliveries dropped first, it could be argued, should be apportioned less CO_2 than those items delivered later in the round. While correct in theory, assigning emissions based on the sequencing of delivery drops would be an almost impossible task.

Home delivery companies do not adopt a strategy of dropping off the heaviest (or bulkiest) loads first. Customer location is the main determinant of the loading / unloading sequence. Three other factors are likely to have a greater influence on the level of CO_2 emissions: the type of product carried, the chances of making a successful delivery first-time and the nature of the returns process for unwanted / damaged goods. These will be considered next.

Products purchased

Basic product characteristics, such as size, weight, perishability and fashion, not only determine the take-up and success of different product categories online (Burt & Sparks, 2003), but also the freight implications of their distribution (Hesse, 2002). This report focuses on non-food home deliveries. So far the mass market appeal of online grocery shopping has yet to materialise (Huang & Oppewal, 2006), whereas, lightweight products (such as CDs / DVDs and books) have traditionally been among the most popular purchases (DfT, 2009b), as they have the advantage over other products that customers do not feel the need to touch and feel these items before buying. Table 1 lists the product categories that online shoppers had bought in the previous 12-months. Clothing and households goods, in particular, recorded increased online sales over the last couple of years, while film and music purchases declined (Office of National Statistics, 2008), presumably reflecting the increased take-up of digital downloads (International Federation of the Phonographic Industry, 2009). Many small, lightweight items are dispatched by third party carriers in the UK, and as such form part of mixed loads in the back of vans.

Table 1: Internet purchases by adults in the last 12-months, 2006-2008 (requiring physical delivery)

Per cent	2006	2007	2008
Clothes or sports goods	37	38	42
Films, music	53	51	41
Household goods	24	39	40
Books, magazines or newspapers	37	35	37
Electric equipment	25	20	26
Computer software and upgrades	29	21	22
Food and groceries	20	20	19
Computer hardware	22	17	12
Other goods and services	11	8	8

Source: Office for National Statistics (2008) Internet access 2008: Households and individuals

Across the range of small, non-food consumer products typically bought online, the physical nature of the products has little effect on the energy intensity and carbon intensity of the delivery i.e. weight / density are not significant. The main variable will be the number of drops per round. Distinguishing between different product categories is not necessary other than designating whether the load consists of food or non-food items (heavy, bulky items (>25-kgs) are different, they require special two-man delivery and are excluded from the analysis).

Failed delivery

Increasingly many people are not at home to receive deliveries during the working day when most home delivery companies operate. Prologis (2008) reported that the number of working households increased by 22% between 1992 and 2006. As a result, parcel carriers must cope with the increasing incidence of failed delivery. Actual failed delivery rates among carriers vary considerably, Beveridge (2007) indicated a range between 2-30%, depending on the carriers' policies for dealing with 'no-one-at-home'. Some parcel delivery companies achieve very high first-time delivery rates as they are prepared to leave deliveries in alternative locations, such as with neighbours or in the garden shed (McKinnon & Tallam, 2003). While these places are often unsecure, the use of dustbins is now generally avoided owing to earlier reported mishaps! Other carriers require proof-of-delivery signatures, and consequently have a much higher delivery failure rate. As a result of different delivery arrangements, estimates of first-time delivery failure rates vary widely from 6 out of every 10 small-package deliveries (Retail Logistics Task Force, 2001) to a more conservative one in nine (IMRG, 2008). This study uses three failed delivery ratios. First, a first-time failure rate of 25% of deliveries, in line with findings by McLeod & Cherrett (2006) and Song *et al*. (2009); second, a 12% failure rate (assumed by Weltevreden & Rotem-Mindali (2008), and similar to the 11.5% failure rate identified by IMRG (2008)), and finally, a very successful first-time failure rate of 2%, achieved by parcel companies whose delivery drivers seek alternative locations at which to leave items, and couriers, who, having regular customers, get to know their clients' daily routines.

Returns

Typically, between 25-30% of all non-food goods[1] bought online are returned compared with just 6-10% of goods purchased by traditional shopping methods, although this varies widely among product groups (Nairn, 2003; Fernie & McKinnon, 2009). The environmental implications of these online returns are strongly influenced by both parcel carriers' returns policies and consumers' preferred habits. For instance, parcel carriers who collect returned items as part of their usual delivery round, and courier networks that offer to take back items when their representatives are next delivering in that area, generate very little additional mileage. In these cases, an allowance is made for collections within planned delivery drop-rates, and any additional energy use is subsumed within the overall delivery round.

The situation is complicated further by customers often having a choice of returns channels. For retailers with a high street presence, customers may choose to return items to a physical store. The popularity of this method depends on the number of high street stores operating such a returns policy. For instance, a high percentage of online supermarket clothing returns are handled through supermarkets, whereas some multi-channel retailers have very little returned to stores owing to their relatively sparse high street presence.

Alternatively, customers can send items back through the standard postal service. Where there is a choice between courier or postal services, approximately half of returns are via courier collection and half by post (Beveridge, 2007). Some high street retailers find that half their returns are to stores, and the remaining half split between courier collection and the post. The modelling undertaken for this stage takes account of these different returns options.

[1] Parcel return rates are higher, and may be between 37-48% (Beveridge, 2009)

3.2 Conventional shopping

There is no such thing as a 'typical' high street shopper. In creating characteristic shopper profiles consideration needs to be given to several key issues: how people travel to the shops, how frequently, what for and in what quantities goods are bought. However, obtaining such information can be problematic owing to a lack of behavioural data at the consumer level (Rotem-Mindali & Salomon, 2007). Locating readily-available information on shoppers' habits, especially at the micro-level is difficult, for while leading retailers undertake their own customer surveys, they are usually reluctant to release details publicly. Our analysis has relied mainly on government statistics available at the national level.

Dedicated shopping trips

The National Travel Survey, undertaken by the DfT, collects data on personal travel and travel behaviour over time which allows comparison between food and non-food shopping trips. Table 2 lists these average distances by transport modes. The National Travel Survey defines a trip as a one-way journey with a single main purpose, with outward and return halves of a return trip treated as two separate movements (DfT, 2007a). Therefore, an average dedicated shopping trip, where the sole purpose of the trip is for shopping, would require a doubling of the distances shown in Table 2. Average distances undertaken for non-food purchases are further than for food shopping trips, at 6.4-miles for car travel (car driver) and 4.4-miles for bus travel (DfT, 2009c). These trip lengths are used to represent average non-food shopping trips.

Table 2: Average trip length for non-food shopping by main mode, 2005-6 (one-way)

Mode	Average Distance (Miles)
Walk	0.7
Car / van (driver)	6.4
Car / van (passenger)	8.3
Other private	4.3
Local bus	4.4
Other public	12.5
All modes	**5.4**

Source: DfT (2009c) Personal communications: National Travel Survey

Most people travel to the shops by car (DfT, 2007a), regardless of the type of product that they intend to buy once there. Taking grocery shopping for instance, 86% of people drive to their chosen supermarket, often by-passing other nearer food stores en-route (Future Foundations, 2007), while for non-food shopping, half of people always travel by car and a further 18% sometimes travel by car to get to their shopping destination (CfIT, 2002). Car and bus travel are the two motorised transport modes most used by conventional shoppers, accounting for 72% of all shopping trips (DfT, 2007a). They are the only modes considered in this report. Rail is omitted as it is not a regular mode for shoppers (less than 1% of shopping trips are by rail) (DfT, 2007a). Walking and cycling have been also been excluded from the calculations, as both modes involve human effort (a category excluded from typical life cycle assessments), and neither emits easily-attributable CO_2 emissions. The environmental and social benefits of both are acknowledged, however.

Combined shopping trips

Trip chaining is a widely-used term to describe a combined trip. Although having no agreed definition, it can be described as a household's tendency to combine different activities during a single trip (Popowski Leszczyc & Timmermans, 2001). A trip segment represents the travel between a particular pair of activities (Primerano *et al.*, 2008). Often minor detours to a store can be incorporated into a much longer routine trip to or from somewhere else, with the shopping segment requiring little additional travel or effort on the part of the consumer. For example, it is estimated that 50% of Britons pass a superstore or convenience shop during their everyday routine (Future Foundations, 2007), and on occasion it would be sensible for them to combine this daily journey with some shopping en-route. Reinforcing this point, in a recent survey of neighbourhood shopping areas in Bristol, Sustrans (2006) found that 40% of car-based shoppers only visited a single store per trip, demonstrating the "drive-thru" nature of combined trips. The appeal to the consumer is that the marginal costs associated with the shopping segment of their journey can be negligible (Mokhtarian, 2004). The allocation of energy consumption related to the purchasing activity needs to be reduced accordingly (Browne *et al.*, 2008).

As a result, while headline calculations in this report refer to dedicated shopping trips compared with delivery to the home, it cannot be assumed that consumers *only* make single-purpose, single-stop visits to high street stores (Dellaert *et al.*, 1998; Thrill, 1986). As Brooks *et al.* (2008, pp.29) state: "the high incidence of multi-stop trips in empirically observed behaviour makes the single-stop assumption unrealistic"; most trips for shopping involve multi-stop activities either between different stores or between different activities, including shopping (i.e. from work to home, calling at shops on the way). Therefore, several different trip chaining scenarios are proposed here in addition to dedicated trips, where shopping is the primary purpose. When shopping is only a very minor component of the overall activity, as in the case of a supplementary, convenience shop, 10% of the overall distance will be allocated to the shopping activity.

Previous research has also examined differences in consumer behaviour by product categories. Popowski Leszczyc & Timmermans (2001) found in New Zealand a third of grocery shopping trips were multi-purpose trips (consumers still embark on a main weekly grocery shop, although they increasingly supplement this with top-up visits to the shops (Future Foundation, 2008)). In contrast, when clothes shopping (a good example of a high-order discretionary purchase), consumers are found to be less sensitive to opportunities for reducing travel costs by trip chaining (Dellaert *et al.*, 1998). Brooks *et al.* (2008) speculated that purchase frequency (and associated factors such as expense and perishability) is linked to the perceived enjoyment or importance of the trip type or destination. In other words consumers are more prepared to make shopping for expensive goods the main reason for a trip (and to travel further in order to purchase those goods) than they are for the purchase of lower order goods; shopping for clothes, for instance, is often the sole purpose of a trip.

Products purchased

Usually consumers visit more than one shop per trip especially when shopping for non-food products (Brooks *et al.*, 2008). Establishing the number of items consumers buy on each trip is far more problematic as individual retailers only have information about the number of products bought in their own stores, and not as part of the shopping trip as a whole. It seems that no information is collected about the overall quantities of goods bought per shopping trip. Therefore, in the analysis reported here we have had to estimate a range of values for this critical variable. It would clearly be preferable to have empirical data on the number and types of item bought on the shopping trips. In the absence of this information, however, calculations based on theoretical values still allow cross-channel comparisons of a ‘what if...’ nature.

It must also be remembered that some shopping trips do not result in a purchase. This is particularly the case when something specific is sought as the actual product may be out-of-stock. Fernie *et al.* (2008) in their recent fashion retailing study found average floor sales availability to be just 73%. Furthermore, some trips to the high street may be for information-gathering purposes only (comparison shopping). This ‘browsing’ category has been largely ignored by researchers owing to a lack of data (Moe & Fader, 2001), yet frequently a fact-finding sortie results in a later purchase (often online) (Skinner *et al.*, 2004). RAC (2006) reported that almost four out of five internet shoppers (78%) wanted to go to stores to look at goods before buying online, and DfT (2009a) recently reported that in almost a fifth of deliveries someone in the household had visited an outlet prior to purchasing the item online. The converse is also true, where people research the market online prior to the shopping trip. This permits some rationalisation of the shopping activity and related travel.

Informed by the above observations, the assumptions here are that for non-food items, a conventional shopper will make, on average, 1.1 trips to achieve a successful purchase on the high street (rising to 1.2 trips for clothes, and 1.3 trips for electricals and furniture), while a large proportion (possibly 40%) of online shoppers will make a browsing trip to stores before buying online. This assumption is based on half of those surveyed by the RAC (2006) who wanted to browse before buying online actually doing so.

4 Methodology

An excel spreadsheet has been constructed to compare the carbon intensity of home delivery and personal travel.

4.1 Emissions factors

Online shopping: Home delivery

Rather than relying on only one information source for freight-related emissions factors, emissions data from four key organisations are used:

1. *Defra's emissions factors for vans*[2] (Defra, 2008);
2. *NAEI emissions factors for vans:* Data for Euro II vehicles, and speeds of 40-kph (default speed), 20-kph (representative of average urban speeds) and 10-kph (worst case scenario) are applied (NAEI, 2008);
3. *RHA Cost Tables 2008:* Emissions factors are calculated from Defra values, based on average fuel consumption of 9.6km per litre (27 miles per gallon) for a van (RHA, 2008).
4. *FTA Distribution Costs 2008*: Emissions factors are calculated from Defra values, based on average fuel consumption of 8.9km per litre (25 miles per gallon) for a van (FTA, 2008).

Average emissions factors were derived for home delivery vans using the values from Defra, NAEI, RHA and FTA. This approach ensures consistency in any calculations. Alternative scenarios were constructed for electric vehicles, based on conversion factors for primary energy (E4Tech, 2007).

Conventional shopping: Consumer travel

Defra's emission factors (CO_2 per km travelled) for average car and bus journeys have been used to calculate emissions generated by travel to the shops (Defra, 2008). In the case of cars, additional calculations are presented for specific vehicle exercise duty (VED) bands, most notably a low emissions vehicle (Band A), a hybrid vehicle (Band B) and a high emissions vehicle (Band G). Band-specific emissions have been sourced from the Vehicle Certification Agency's records (www.vcacarfueldata.org.uk). E4Tech provides the emissions factor for electric vehicles (E4Tech, 2007).

[2] A van denotes a light goods vehicle up to 3.5-tonnes maximum permissible gross vehicle weight of van-type construction on a car chassis that operates on diesel fuel unless specified otherwise.

4.2 Transport considerations

Online shopping: Delivery rounds and drop characteristics for non-food

The home delivery calculations relate to typical conditions, with the underlining assumptions based on information derived from discussions with leading parcel delivery companies. For instance, accordingly to one of the largest UK parcel delivery carriers, a highly-efficient delivery operation would have a drop density of approximately 150 drops for a 60-mile delivery round, while a city centre-focused round usually covers about 25-miles to deliver approximately 110 drops on average. Delivering to rural areas would have higher mileage reflecting the greater distances between drops (typically 80-miles round trip), although with a lower drop density per round at approximately 70 drops. Couriers carry fewer deliveries again (at about 40), and their operation can add an extra link in the chain when local delivery is first to the courier's home in pre-sorted sacks (consisting typically of 13 deliveries each (Beveridge, 2007)), for onward delivery to customers. Alternatively some couriers go to the local depot to collect their allocated deliveries in person. In either case it is presumed that the total round mileage is 25-miles, either undertaken entirely by the courier or split between courier (10-miles) and delivery van (15-miles) carrying approximately 150 drops.

The assumption here is that each package delivered as part of a home delivery round weighs less than 25kg (the maximum permissible weight for a one-man delivery). Normally it will be considerably less than that for courier deliveries. Furthermore, there is no distinction made between the different types of products delivered; it is assumed that all items are treated equally in the delivery process.

Calculations of the number of items per drop have been performed. Initial results are shown for a single item per drop. However, a more realistic assumption, based on discussions with a leading book wholesaler is for each drop to contain either 1.4 items in the case of deliveries containing books / DVDs / CDs or 2.5 items for other non-food goods (clothes, household items) (Beveridge, 2009). Therefore, additional calculations for multiple items per drop are also included. Some online retailers have a dispatch policy where they delay distribution until all items purchased are available for delivery, while other online retailers prefer to send one item per package regardless of the number of goods ordered at the time of transaction. For direct comparison with conventional shoppers' behaviour, per item delivered is the preferred variable. The assumptions made about 'last mile' delivery are listed in Table 3 and represent the expert knowledge of those working in the industry or are derived from previous work in this area.

Table 3: Freight 'last mile' delivery: Assumptions

Assumptions	**Type of delivery round**	**Total distance (miles)**	**Drop density (deliveries per round)**
Van (<3.5-t)	City centre	25	110
	Average	50	120
	Efficient	60	150
	Rural	80	70
Courier (car-based)	City centre	25	40
Failed first-time deliveries	25% 12% 2%		
Returns (% of orders)	25% (40% for clothing)		
Method of return	Collection Postal services In-store		

Conventional shopping: Personal travel

For many people the car is the default means of getting to the shops. The average car driver makes a round trip of 12.8-miles for non-food shopping purposes). For bus passengers the average return journey to the shops for non-food items is slightly less at 8.8-miles (DfT, 2009c). The modelled consumer travel behaviour characteristics are listed in Table 4.

Table 4: Consumer travel and shopping behaviour: Assumptions

Mode	Journey trip	Round trip (miles)
Car	Local	2
	Average	12.8 [1]
	Distant	40
Bus	Local (urban)	2
	Average	8.8 [1]
	Inter-urban	40
	Rural	20
Browsing (as % of all shopping trips)	10% (average) 20% (clothes) 33.3% (furniture)	
Trip chaining (% of mileage attributed to shopping)	50% [2] 25% 10% (only applies to trips by car)	
Returns (% of all purchases)	8% [3]	

[1] DfT (2009c)
[2] Jespersen (2004)
[3] Fernie & Mckinnon, (2009)

5. Results and discussion

When focusing exclusively on the last link in the retail supply chain (from depot or shop to the home), home delivery by parcel carrier is often presumed to be more efficient than an individual travelling to the shops to buy the item in person. The results in Table 5 appear to support this supposition. Typically, one drop of 120 such drops on a 50-mile delivery round is apportioned 181gCO_2. This figure is derived from the four freight emissions factors outlined in Section 4 and is a drop's 'share' of the emissions produced during the overall delivery trip (181gCO_2 x 120 drops = 21,665gCO_2).

Assuming that a shopper using a standard car makes a round trip of 12.8-miles to the shops (national average distance for non-food shopping) solely for the purpose of buying one item, the trip would generate 4,274gCO_2 (all of which could be assigned to that one item). In this example, the CO_2 from personal car-based travel is 24 times greater than the CO_2 produced by a delivery drop as part of a typical freight round.

An alternative way of interpreting these results is that a person would need to buy 24 non-food items in one standard car-based trip for this method of shopping to be less CO_2 intensive than having one non-food item delivered (on the first attempt) to their home by a parcel carrier. For a VED Band A vehicle (99gCO_2/km) 12 non-food items would need to be purchased and for a mid-range Band G vehicle 31 items (270gCO_2km). A bus passenger, assuming average bus occupancy levels of 9.2 passengers for an 8.8-mile round bus trip, would need to purchase 7 or more non-food items to compete favourably with a home delivery.

The above calculations assume one item per drop for home delivery and only one item per shopping trip. Although some deliveries to the home do only contain one item (some online retailers only send items out individually regardless of order size), it would be more realistic to increase the 'items per drop' variable. With an average content of 1.4 items per drop (e.g. a typical book order) the CO_2 per *item* is reduced to 137g for home delivery. When a home delivery (e.g. for clothing and household goods) consists of 2.5 items, the CO_2 per item is 72g. These assumptions further increase the number of goods a conventional car-based shopper would have to buy in one trip to 32 or 59 non-food items respectively to contend with home delivery in terms of CO^2 efficiency. For bus travel a shopper would have to carry 10 or 18 non-food items respectively.

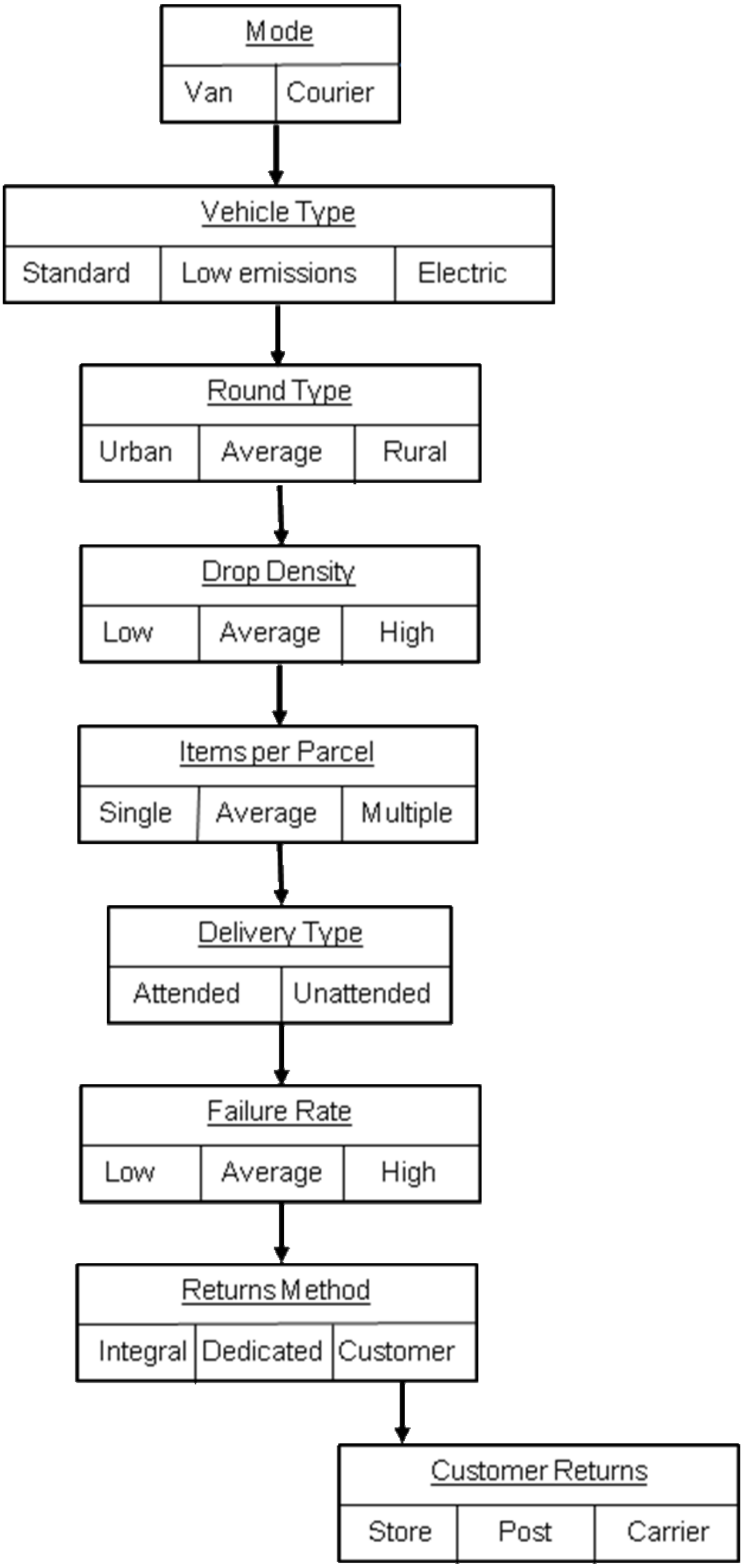
Table 5: CO_2 per average trip and per drop/item (parcel carrier / car / bus)

Delivery / collection method	**Total gCO_2 per trip**	**gCO_2 per item delivered / collected**
Standard delivery van (<3.5-t) (120 deliveries per 50-mile round trip)	21,665g	181g (per drop) 137g (1.4 items) 72g (2.5 items)
Car (dedicated shopping trip of 12.8-miles)	4,274g	4,274g (single item)
Bus passenger (dedicated shopping trip of 8.8-miles, assuming average patronage)(1)	11,641g	1,265g per passenger (single item)

(1) Defra (2007)

Although home delivery appears to have a strong environmental advantage over consumers' personal travel to the shops, this result requires several qualifications. The investigations only compare theoretical trips based on average values. No attempt has been made to incorporate conditional factors into the calculations for either channel. The last mile delivery is much more complex than these initial findings suggest (Figure 1). For instance, home delivery will vary by drop density (the number of delivery drops per round); failure rates (the number of failed first-time deliveries); distances covered (including type of road network), and the method by which unwanted items are returned. Equally, the type of home delivery vehicle used will affect the results quite considerably. These variants will be examined in the Section 5.1.

Figure 1: The online retail channel: Delivery options

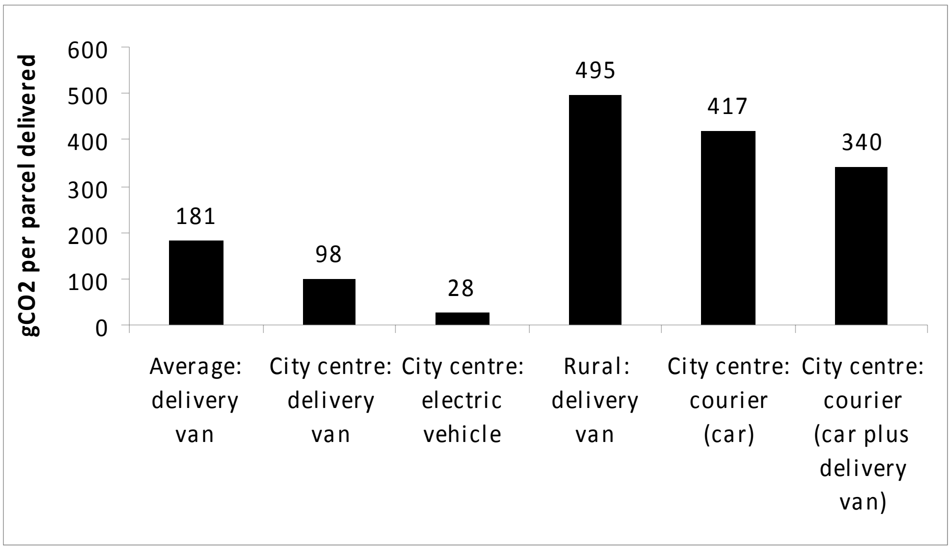


5.1 Online shopping

Drop characteristics

Deliveries in central urban areas are characterised by relatively high drop densities and relatively short delivery rounds. In this analysis, a city centre delivery round is defined as one covering 25-miles and delivering 110 non-food drops (these figures are based on typical values for a leading parcel delivery carrier in the UK). Using these values the gCO_2 emissions per drop (containing only a single item) average $98gCO_2$ compared with a typical value of $181gCO_2$ for a geographically non-specific round (Figure 2). To date, only a few companies use electric vehicles for non-food delivery. Employing this technology a city centre delivery drop by electric vehicle would be apportioned just $28gCO_2$. Similarly, assuming average item content is increased to 1.4 items per drop, a standard urban delivery would generate $70gCO_2$ per drop and an electric vehicle just $20gCO_2$ per drop.

Figure 2: gCO_2 per drop for average deliveries by round type



In rural areas typical delivery distances are greater (80-miles) and deliveries per round fewer (70 drops). As a result, a typical non-food drop (containing a single item) delivered to a rural address by standard delivery van would be allocated $495gCO_2$ (Figure 2), or five times the typical emissions for a city centre delivery. Parcel delivery carriers are far less likely to deploy electric vans to these outlying areas, for fear of these vehicles requiring a recharge while away from the depot. In summary, it appears that standard city centre deliveries produce just 20% of the CO_2 per drop that rural deliveries generate (when vans are the means of delivery).

Similar analysis is now performed for car-based deliveries. These 'courier' home deliveries (using a private car) have become increasingly popular among online retailers in recent years (Beveridge, 2007), yet with lower drop densities (of approximately 40-deliveries per 'round') and the use of relatively inefficient private vehicles, their CO_2 emissions per standard delivery (of 417g) are six-times the emissions of a city centre van-based delivery, *and* higher than typical emissions per delivery to rural areas. This assumes that couriers use their cars to collect deliveries in person from their local depot. When a delivery van undertakes part of the route first to the courier's home the CO_2 is reduced to 340g per drop. The relative inefficiency of car-based couriers for home delivery has not been highlighted previously. Nevertheless, courier-style deliveries are popular among both clients and carriers, as they achieve relatively high first-time delivery rates (couriers often have a regular customer base and therefore, become familiar with their customers' availability to receive deliveries). Additionally, couriers often combine deliveries with other activities, e.g. supermarket shopping or performing the 'school run' (Beveridge, 2009), thereby partly off-setting the relatively high emissions per courier drop.

Failed first-time delivery rates

Failed delivery is both uneconomic for a carrier (as redelivery has to be arranged most often at the carrier's expense) and inconvenient for the shopper (who has to ensure someone is available to receive the resent parcel). Various failed delivery scenarios are considered for both urban and rural areas, based on the following:

- a highly efficient 2% failure rate, achieved by some experienced couriers and van-based parcel delivery carriers who accept alternative drop-off arrangements when no-one is at home for first-time delivery;
- a 12.5% deliveries failure rate (considered to be an average to good failure rate for deliveries); and
- a 25% first-time failure rate, often experienced by those carriers requiring proof of delivery signatures. It was also the proportion of failed first-time deliveries noted by McLeod & Cherrett (2006) and Song *et al*. (2009).

Table 6: Emissions (gCO_2) per item including failed delivery rates

	100% successful first-time delivery	2% failure rate	12.5% failure rate	25% failure rate
Urban deliveries: gCO_2 per item	98g	100g	110g	123g
Rural deliveries: gCO_2 per item	495g	505g	557g	619g

Emissions of CO_2 per average city centre drop may increase from 98g for 100% first-time delivery to the worse-case scenario of 123g when one-in-four deliveries fail. Similarly, in rural areas CO_2 per drop increases from the standard 495g for no failures to 619g for a 25% failure rate (Table 6).

Most delivery companies schedule the repeat delivery for the next working day after the first-failed attempt, and as a result a high percentage of second attempts also fail, compounding the effects of the initial failed delivery. After a second failed attempt non-delivered goods are held at the local depot, and 'carded' customers (those receiving a failed delivery slip through the letterbox) have to visit the depot in person to collect the item. Around 3% of all home delivery recipients make a trip to collect an item left at a post-office, depot or outlet (DfT, 2009a).

Returns

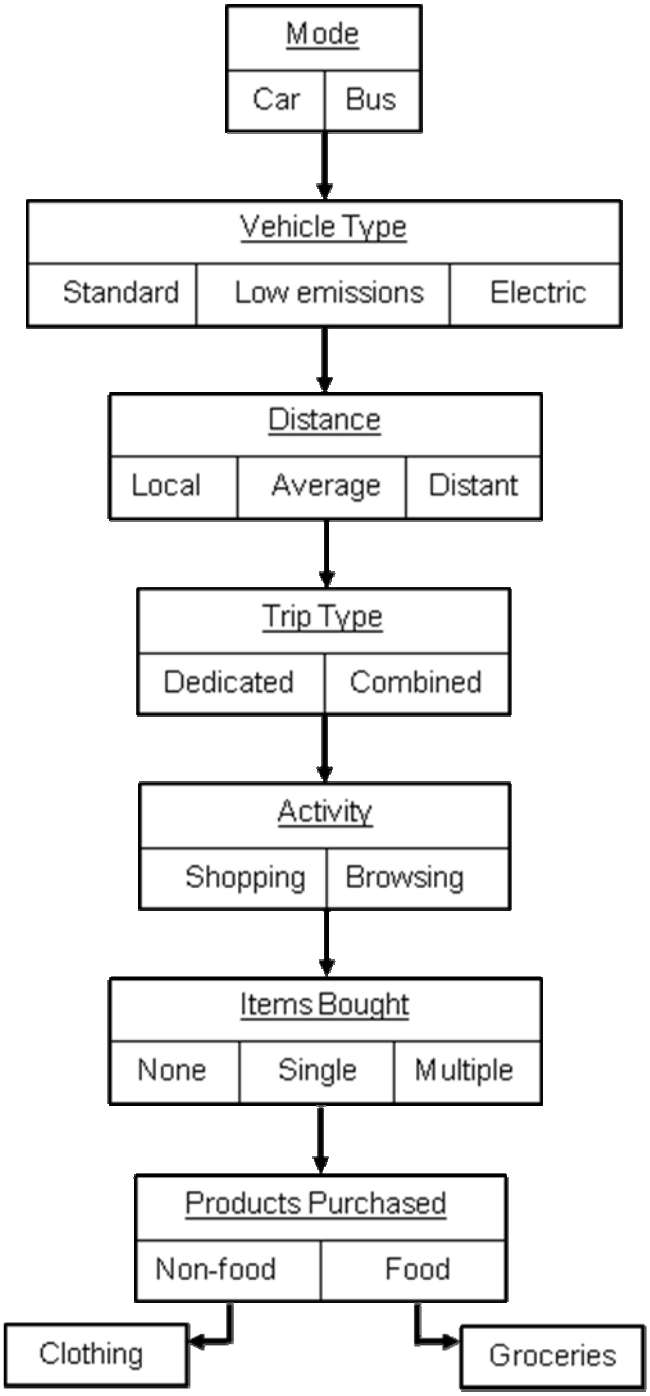
As explained in Section 3.2, the returns process for unwanted goods can take a number of forms. When a parcel carrier schedules collections into an outbound delivery round the gCO_2 per collection / item is effectively the same as per delivery. However, when alternative arrangements are made (either on the part of the consumer or the carrier) more complicated calculations are necessary, and these are examined in the next section.

5.2 Conventional shopping

Consumer travel and shopping behaviour

The model also captures much of the variability in consumer shopping behaviour. Some shoppers make dedicated trips to shops when shopping is their only intention, while others may choose to combine shopping with other activities as part of a trip chain. Additionally, both online and conventional shoppers frequently choose to inspect items in stores (prior to buying either in-store or online), and may make several trips to do so. When shoppers wish to return unwanted items, they often have a choice of returns methods. Figure 3 gives an indication of some of the choices available to the conventional shopper.

Figure 3: The conventional retail channel: consumer choices



Dedicated trips (solely for the purpose of shopping)

Distance travelled by a consumer to the shops is an important consideration. There has been criticism that people all too readily jump in their cars for short distances; to illustrate, over a fifth of journeys of less than a mile (a walk-able distance) are undertaken by car (DfT, 2007b)). This 2-mile round trip by car would generate 1,336gCO_2 (to be distributed equally among the items bought). When the same journey is undertaken by an urban bus, assuming average bus patronage, each passenger would be allocated 317gCO_2 for their share of total emissions.

The above analysis compares emissions for short trips, average distances and trips for dedicated shopping 'days out' are considerably longer. An average car-based journey to the shops of 12.8-miles round trip (Defra, 2007) would produce 4,274gCO_2, and when an electric vehicle is the mode of travel, the shopping trip would be responsible for 1,586gCO_2 (or approximately a third of the emissions produced by a standard car). For the shorter average 8.8-mile return journey by bus the CO_2 emissions per passenger are 1,265g.

In the case of longer shopping trips of some 40-miles return, for example, when a conventional shopper makes a dedicated trip to a neighbouring large town / city other than where they usually shop or someone in a rural area travels to their main town centre, the trip by car would emit 13,358gCO_2, and an express bus service and rural bus would produce 5,751gCO_2 and 4,198gCO_2 per passenger respectively.

Making a special dedicated trip to a distant high street shop by car is over 70 times less efficient in carbon terms, at 13,358 gCO_2, than having an item delivered first-time to a consumer's home at 181gCO_2 (assuming the item is kept by the online customer). A round trip by bus of 40-miles for a single purchase would be between 23 and 30 times less efficient. These comparisons assume only one conventional shopping trip is required to make the purchase.

Browsing (a shopping trip involving no purchases):

A certain number of shopping trips will end in no purchase, owing to:

- the consumer failing to decide which item to buy;
- the particular good sought being unavailable; or
- the consumer having no intention to purchase anything, using the trip for information gathering purposes only.

In these cases, the unsuccessful trip needs to be factored into the calculations. On the assumption that one in ten shopping trips for a particular product results in no purchase, the gCO_2 in each of the above dedicated shopping trips would increase by a factor of 1.1. Nevertheless, at a *personal* level, a shopper's CO_2 trip-related footprint would double to take account of a second journey to the shops. So while total emissions for a 'browsing plus purchase' average car trip would be 4,701gCO_2, (4,274gCO_2 x 1.1) for the individual undertaking the second journey it would be 8,548gCO_2.

Trip chaining

Trip chaining is a further consideration. Rather than making dedicated visits to shops solely to buy a product, a consumer may choose to acquire the item as part of a larger shopping expedition when many items are bought, and / or to combine the shopping trip with other activities. Some possible emissions consequences (for the high street shopper) are illustrated in Table 7. The combined trip assumes that shopping-related mileage is a quarter of the overall trip mileage (25%).

Table 7: Implications of shopping trip type on CO_2 emissions

Trip type	Items bought	Mode of transport	gCO_2 per item
DEDICATED	Single item (1 item)	Car Electric car Bus	4,274 1,586 1,265
	Multiple purchase (5 items)	Car Electric car Bus	855 317 253
BROWSING (2 trips to shops: one for browsing, one for purchase)	Single item (1 item)	Car Electric car Bus	8,548 3,172 2,530
COMBINED (shopping 25% of trip mileage)	Single item (1 item)	Car Electric car Bus	1,069 397 316
COMBINED then DEDICATED (25% of mileage: initial browsing followed by dedicated trip to buy an item)		Car Electric car Bus	5,343 1,983 1,581
COMBINED (grocery shopping: distance 7.12-miles*)	Multiple (50 items)	Car	48

*Average round trip distance to a supermarket (Future Foundation, 2007)

Often people are quite surprised when they are made to recall the number of separate shopping trips that they make during the course of a week (King *et al*., 2009). From the above table it can be seen that the most efficient ways to purchase and collect a product would be either as part of a much larger shopping trip when many items are bought at the same time (for instance from a large supermarket when bulk grocery shopping) or to reduce the number of separate trips and unnecessary journeys to the shops by combining shopping with other activities (trip chaining). Any consolidation of shopping activities is to be encouraged.

Bus travel can compete with home delivery in terms of CO_2 efficiency. During peak leisure times (e.g. on a Saturday afternoon) when occupancy levels are high and most non-food shopping occurs, from an environmental point of view, bus travel is an effective method of collecting shopping. For example, assuming a shopper travels the average distance (8.8-miles) by bus, in the company of 29 other passengers, and buys 5 items, each purchase would be allocated a share of just 78gCO_2, less than that for a city centre home delivery (98gCO_2). Encouragingly for the environment, most shoppers (63%) state that they would have no difficulty getting to the shops by public transport (DfT, 2005); bus travel for shopping purposes needs to be promoted.

Returns

The actual gCO_2 per online order will very much depend on not only the number of delivery attempts by a parcel carrier but also the method by which unwanted items are returned by the customer to the retailer. Two scenarios are considered. First, an average home delivery when the delivered item proves not suitable and is returned by the customer via the parcel delivery company's collection procedure; and second, when the customer returns the item directly to the retailer's high street store. As already noted, the original home delivery would be allocated 181gCO_2, although, additional emissions would be accrued in the returns process. These are now examined.

The most efficient returns method is when a parcel carrier modifies their outbound schedule to collect returns as part of the standard delivery round. In this case the integrated returns collection is allocated 362gCO_2 (twice the CO_2 of an outbound drop), as the unwanted item has the combined emissions of an outbound and return trip (in effect two outbound deliveries).

In the case of an online shopper opting to return an item to a high street store, the CO_2 would be 4,455gCO_2 (181gCO_2 plus 4,274gCO_2), calculated on an average car-based round trip (12.8-miles). Owing to convenience many shoppers opt for this method, although ideally the returns trip should be undertaken at the same time as other activities, as part of an overall trip chain, or alternatively, the item should be returned when the shopper intended to shop at those premises anyway.

5.3 CO_2 emissions: Last mile versus upstream activities

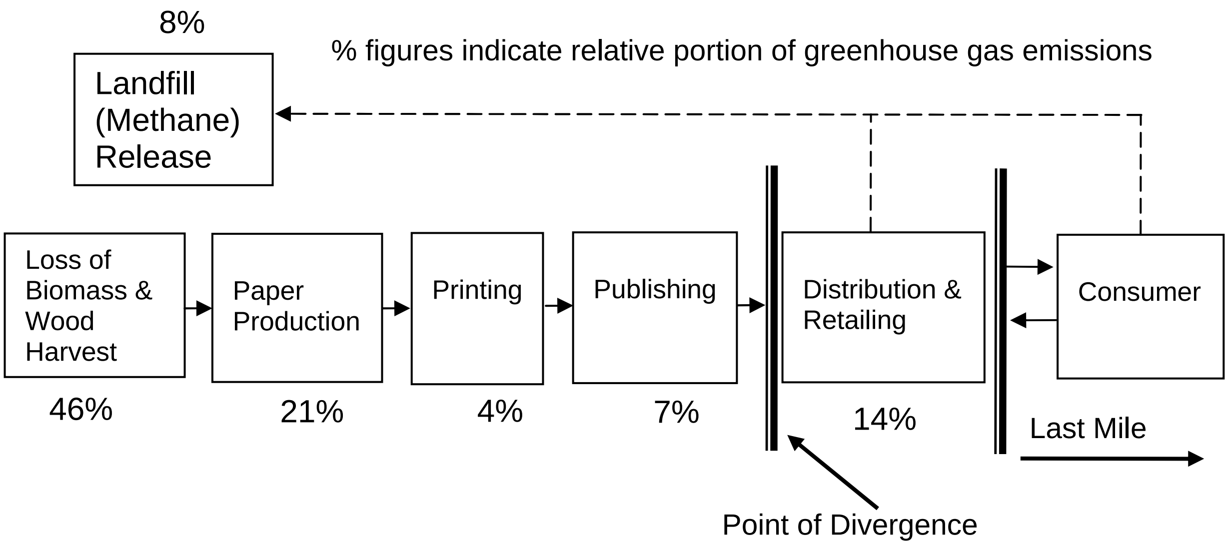
It is not only on the last link that the online and conventional retail channels vary. The structure of their upstream supply chains also differ and this too will affect their relative carbon footprints. Ideally, one should compare the carbon intensity of the two channels as far back as the point in the supply chain at which they diverge because up to this point the amount of CO_2 emitted will be common to both channels. This would allow us to put differences at the carbon intensity of last mile operations into context. Do they dominate the calculation or are they relatively insignificant when judged in relation to total CO_2 emissions across the 'end-to-end' supply chain?

While the majority of assessments to date have been for food-related items, several organisations have calculated the CO_2 emissions of particular non-food products across their respective supply chains (Borealis Centre for Environment & Trade Research, 2007; Browne *et al*., 2005; Carbon Trust, 2008; Carbon Trust, 2006; Green Press Initiative, 2008). Most of these life cycle assessments found that raw materials, packaging (where relevant) and manufacturing accounted for the vast majority of emissions. Distribution and retail, on average, emitted a relatively small proportion of emissions (between 6 – 14%).

Few studies, however, have compared the energy consumption of consumer travel and home delivery with energy use further upstream in the supply chain. Jespersen (2004) conducted telephone interviews to establish consumer travel behaviour when purchasing rye bread from retail shops. Assumptions for trip chaining (50% of an average 5km trip was for shopping) and for the weight of goods purchased (20kg) were made. His findings revealed that the consumer transport content was greater than all other transport connected with the production and distribution of the bread. Browne *et al.* (2006), in investigating the various stages of the production and distribution of jeans, noted the energy used for a dedicated consumer shopping trip (of 11-km) was approximately the same as that used in transporting the product from the jeans factory (based in the USA or Turkey) to the UK port, despite the huge differences in journey lengths. Similarly, Weber *et al.*, (2008), when comparing the energy use and CO_2 emissions generated by both the online and conventional distribution of an electronic flash drive, found that approximately 65% of total emissions for traditional retailing came from the customer trip to and from the retail store.

As noted earlier, when comparing the environmental impacts of conventional and online retail channels, analysis upstream of the last mile transport link need not extend to the point of production. The point at which the online and conventional retail channels diverge can be used to define the upstream boundary for the CO_2 comparison. Figure 4 illustrates the relative importance of this distribution and retail stage for the book supply chain, based on findings from Green Press Initiative (2008); both the point of divergence and the last mile delivery are highlighted. Another study of the US book supply chain calculated that each book was responsible for 4.02kg (8.85lb) of CO_2 (Borealis Centre for Environment and Trade, 2007). On that basis, distribution and retail would account for approximately 600gCO_2 per book. No distinction was made in either US study for energy use in the different types of retail distribution channels.

Figure 4: Stages of book production and distribution



Source: derived from Green Press Initiative (2008)

An earlier study by Environmental Resources Management (2002) compared the emissions of the online and high street sales routes for a pair of trousers. The study, conducted on behalf of Marks and Spencer, found slight energy savings for the online channel owing to greater energy use in high street stores and consumer travel, although the savings amounted to less than a 1% reduction in the energy burden across the life cycle of a pair of trousers[3]. The report concluded: "E-commerce has been shown to provide a marginal energy benefit with regards to the life cycle burden of clothing" (p.25).

The calculations in this report and available published evidence suggest that emissions from car-based shopping trips can far exceed those from distribution operations back along the supply chain. It is likely therefore that the environmental comparison of online and conventional shopping channels will be dominated by what happens at the local level. Differences in CO_2 emissions between car-borne shopping trips and home deliveries are likely to be much more important determinants of the respective carbon footprints of online and conventional shopping than differences in upstream logistical operations as far back as the point at which the two distribution channels diverge.

[3] Supply chain calculations for a pair of trousers included energy consumption associated with end use by the consumer. Consumer care, involving washing and ironing of the product, accounted for three-quarters of all energy use.

6. Conclusions

This report summarises the results of a comparative study of CO_2 emissions for the home delivery and conventional shopping trips. While this so-called 'last mile' has received considerable attention from researchers, none of the previous studies have attempted such a comparison on a per trip, drop or item basis. Several scenarios were investigated, and wherever possible representative values, derived from national statistics, previous research or industry practice, were applied to different freight and consumer trips.

Numerous factors influence emissions from home deliveries. They include: drop densities (the number of drops per delivery round); the distance and nature of the delivery round; the type of vehicle used; and the treatment of failed deliveries and returns. On average, when a customer buys fewer than 24 items per shopping trip (or fewer than 7 items for bus users) it is likely that the home delivery will emit less CO_2 per item purchased. These findings several require qualifications, however. They assume:

- the car-based trip was solely for the purpose of shopping (no other activity was undertaken during the course of the trip);
- the purchase ordered online was delivered successfully first time;
- the shoppers was satisfied with the purchase and did not return the item;
- home deliveries and shopping trips were made over average distances; no allowance was made for different types of road network or traffic conditions, and
- only the last mile and not the upstream supply chain has been considered in the analysis (although reference has been made to previous studies of the relative environmental impact of upstream activities).

For home delivery, emissions per drop or per item were obviously affected by the number of deliveries during a round. This drop density, in turn was partly a reflection of the nature of the delivery round. In urban areas van-based deliveries within city centres were found to produce half the CO_2 emissions of an average, geographically non-specific round, owing to the compact nature of the area served and the relatively high drop densities, while emissions from deliveries to rural areas were more than twice the average (at 492gCO_2). Dedicated deliveries by courier in urban areas emitted surprisingly large amounts of CO_2 per drop (417g) indicating the environmental inefficiency of using a car as the delivery mode (though it is acknowledged that car-based couriers have the opportunity to combine deliveries with other trip chaining activities). Overall, when the incidence of failed deliveries was factored in, emissions per drop rose by as much as 25% for this type of delivery.

The environmental implications of consumer behaviour have been illustrated by a series of different shopping scenarios. Having already established that a standard home delivery for a non-food item would be allocated 181gCO_2 various dedicated, combined and browsing-only shopping trips were compared. From the modelling evidence provided here and with inference from previous research that focused on the broader supply chain it seems that emissions for some consumer trips, particularly private car trips, could be greater than all emissions for upstream distribution and retail activities irrespective of the sales channel. Further work is underway to examine this issue in greater detail. Clearly however, it is always better to maximise the number of purchases at any one time. Rather than going to the shops for one or two items, products should be bought as part of larger shopping trips when many items are purchased at the same time, thereby spreading the emissions for the trip among many different items.

Equally, in an effort to minimise emissions it should be noted that average bus travel emits considerably less CO_2 than a car journey over the same distance, assuming average bus patronage. Importantly, when a shopper travels by bus at busy times and makes several purchases, the emissions per item are lower than when a home delivery van delivers just one item to a consumer's home. Consequently, the use of public transport needs to be promoted wherever practical, especially for shorter trips. Until now it has been difficult to switch car users to bus travel (DfT, 2008). It is possible that if some motorists were made aware of the environmental savings that such a modal switch on shopping trips would yield, they might be persuaded to travel by bus. For longer shopping trips, home delivery by van is almost always the most efficient method of acquiring non-food goods, assuming successful first-time delivery and the goods are kept by the customer i.e. no returns (this holds true even when the relatively high rates of online parcel returns are factored into the calculations as long as the unwanted returns are collected by the parcel carrier.

Given increasing concern for climate change, it is important that shoppers are made aware of the CO_2 consequences of their chosen shopping behaviour. With a little planning and thought on both the part of consumers and carriers / retailers, emissions related to the transport element of any shopping activity could be minimised through a few simple actions. Carriers should aim to maximise drop densities (something that is likely to happen anyway as a consequence of the growth of online retail sales), avoid dedicated collection trips when picking-up returned items and where possible use low emissions vehicles, e.g. electric vehicles. The use of reception boxes at people's homes and separate collection points (possibly at shops passed as part of a daily routine journey) would eliminate failed deliveries, the consolidation of orders to a particular address in a single delivery would cut vehicle-kms and wider adoption of variable delivery pricing would promote off-peak / out-of-hours deliveries, allowing delivery vans to run more of their mileage at fuel-efficient speeds. While acknowledging their social benefits, from an environmental point of view the use of couriers, using their private cars for local delivery, should be discouraged unless deliveries are combined with other car-based trips. Likewise, conventional shoppers need to combine their shopping trips with other activities, and ideally buy as many of the items as possible on a single shopping trip.

The relative carbon intensity of the different forms of retail distribution depends on their particular circumstances. Neither has an absolute environmental advantage. Some forms of conventional shopping behaviour emit less CO_2

than some home delivery operations. On average, however, in the case of non-food purchases, the home delivery operation is likely to generate less CO_2. This environmental advantage can be reinforced in various ways if online retailers and their carriers alter some of their current operating practices.

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