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Review

The Environmental Impact of Transport Activities for Online and In-Store Shopping: A Systematic Literature Review to Identify Relevant Factors for Quantitative Assessments

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Abstract: In the scientific literature, there are numerous studies with different approaches and focuses on assessing the environmental impact of online shopping and shopping in the traditional retail channel. The aim of this work is to analyse scientific studies that quantitatively assess the environmental impact of transport activities in both channels and to extract the factors used for this assessment. A literature search was conducted for the period 2006 to October 2020, with 90 studies shortlisted, of which 15 studies were identified as relevant in a screening process. The analysis showed that a different number of factors is included in the selected studies. Logistics-related and behavioural factors are mostly of similar importance. Third-order effects, such as rebound or complementary effects, are rarely considered. Furthermore, it becomes clear that the results also depend on differences in study design and external factors. This work illustrates the complexity of quantitatively assessing the environmental impact of online and in-store shopping. Caution is advised when deriving recommendations for action from general statements about the environmental friendliness of a distribution channel. The 15 factors found, together with the classification method used, form a solid basis for building new models.

Keywords: online shopping; transportation; environmental impact; systematic literature review

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1. Introduction

Electronic commerce has become increasingly popular in recent years and has experienced an additional boost from the COVID-19 pandemic. In 2020, worldwide online sales increased by 27.6% to 4.280 trillion US dollar, while total global retail sales declined by 3%. The share of global online sales in total retail sales thus corresponds to approximately 18%. For the US, the increase in online sales from 2019 to 2020 was as high as 44%, with e-commerce sales accounting for 21.3% of total retail sales in 2020 [1,2]. E-commerce cannot be assigned to a specific research area; studies on this topic are anchored in various fields. There are studies that focus primarily on the barriers and drivers of online shopping at the level of consumer behaviour [3,4]. However, they usually do not link this to the impact on the number of trips or the level of resulting emissions. In addition, there are qualitative studies that take a closer look at the mobility effects associated with online retailing [5–9]. Changes due to e-commerce at the infrastructural level [10] or in the transport of goods [11–13] are also examined in more detail. The studies listed represent only a small selection. This shows the relevance of this topic in scientific research.

Retail trade is closely linked to the need to overcome distances. The conditions created by the existence of space require time-consuming and costly transport of products from A to B. When shopping online, the delivery is usually carried out by service providers; in traditional shopping, consumers take care of the last mile themselves. All these activities cause traffic, which is a major source of greenhouse gas (GHG) emissions. In 2019, the transport sector was responsible for approximately 30% of total EU-28 GHG emissions. Compared to 1990, GHG emissions from the transport sector were 33% higher in 2019 [14]. The extent of environmental pollution caused by transport depends on a number of factors. In order to take measures to reduce the environmental impact, it is first necessary to understand the factors that contribute to the level of pollution.

Many scientific articles also deal with the environmental impact of online shopping or compare the effects of the online and the offline channel. In doing so, they focus on different influencing factors. Pålsson et al. [15] analysed 44 papers on the energy efficiency of the two distribution channels. They also collected data on quantitative cases and analysed the importance of five energy factors: packaging, product waste and return, freight transport, passenger transport and buildings. For passenger transport, they stress the importance of transport distance for the modal split and thus also for energy consumption. Mangiaracina et al. [16] selected 56 papers for their literature review that focus on the environmental impact of transport activities resulting of online shopping. The papers were then assigned to the following main topics, which emerged from the contents of the selected articles: transportation planning and management, warehousing, packaging, and distribution network design. For transport planning and management, the following factors were considered relevant for the level of the environmental impact: failed deliveries and return deliveries, separate deliveries of products in the online channel by ordering from different websites or by storing them in different warehouses and trip chaining. Changes in the distribution network design can influence the extent of the environmental impact due to the changes resulting from e-commerce in the areas of shopping basket size, shopping frequency and failed deliveries.

In order to better understand the different impact levels of influencing factors, the classification of Fichter [17] is helpful. He divided the impact of online shopping on the environment into three classes. First-order effects relate to the prerequisites for the functionality of the information and communication technology infrastructure and its use, which includes production, energy use and waste. These effects are not considered in this paper as this work focuses on transportation activities and closely related areas. Second-order effects on the environment arise as markets and processes change, including changes in the field of logistics. Factors such as packaging, transport distance, return rate, distance to shops, trip chaining and mode of transport play a particularly influential role [6,7]. In this work, second-order effects are divided into two classes for clarity. Those effects that result from changes in logistical processes or can be assigned to the logistical process are referred to as second-order logistical effects (SOLE). Those effects that result from the activities or decisions of consumers are called second-order behavioural effects (SOBE). Third-order effects (TOE) include rebound effects and refer to the effects of behavioural changes that result from the use of online shopping. One example of these effects are complementary effects, where the consumer makes a trip to the shop despite buying online in order to test the product beforehand or to pick it up as part of click and collect. Net effects also play an important role in this context [17,18].

Quantitative analyses are needed to assess the extent of the environmental impact. These also play an important role in the discussion on policy measures to promote one of the two channels. However, despite the extensive literature on the effects, comprehensive quantitative studies seem to be scarce so far. Mangiaracina et al. [16] noted in their literature review that there are very few articles providing quantitative assessments. "In fact, the majority of the papers analysed simply provide a qualitative assessment of the impact, which is very often simply a comparison between the two different ways (e.g., online vs. offline) of conducting the same activities" [16] (p. 584).

As the factors influencing the environmental impact of online shopping are numerous, the question arises as to which of them were included in quantitative studies conducted so far. The selection of factors influences the conclusiveness of the quantitative results and limits the comparability of studies due to differences in the factors included. To our knowledge, there is no work dedicated to this topic, as the focus is mostly on the results of other studies and not on how they are conducted. Therefore, we try to answer the following research question: Which factors are included in quantitative studies calculating the environmental impact of transport activities of online shopping and in-store shopping? To answer this question, a systematic literature search was conducted. Databases were searched for scientific articles that provide a quantitative assessment of the environmental impact of the transport processes in both channels. Subsequently, the selected papers were analysed with regard to the factors included and other relevant aspects, such as the focus of the observation. In a final step, the extracted results were condensed and prepared for a clear presentation.

By answering the research question, this paper aims to help clarify the current state of quantitative research and thus highlight the need for further research. Especially for the construction of quantitative models, the identified factors can be a solid basis. This work also provides a kind of framework to be able to place the results from other research projects into a holistic picture.

The remainder of this paper is organized as follows: Section 2 explains the methodology of this work and Section 3 presents the results. For this purpose, Section 3.1 introduces the selected studies and Section 3.2 describes the product group considered and the way in which the environmental impact is measured. Section 3.3 deals with the considered transport section in the selected papers and Section 3.4 finally presents the factors that are used to measure the environmental impact. Section 4 is dedicated to the discussion of the results, whereby the individual Sections 4.1–4.4 deal separately with second-order effects, third-order effects, study design and external conditions. Finally, conclusions are drawn in Section 5.

2. Review Methodology

In order to identify relevant studies, a systematic literature review was conducted following the checklist of Preferred Reporting Items for Systematic Reviews and Meta-Analysis [19], which can be used as a basis for documenting the procedure for systematic reviews. We supplemented the database search with the snowball approach, similar to the method described by Pålsson et al. [15]. The following Figure 1 gives an overview of the procedure for literature search and selection.

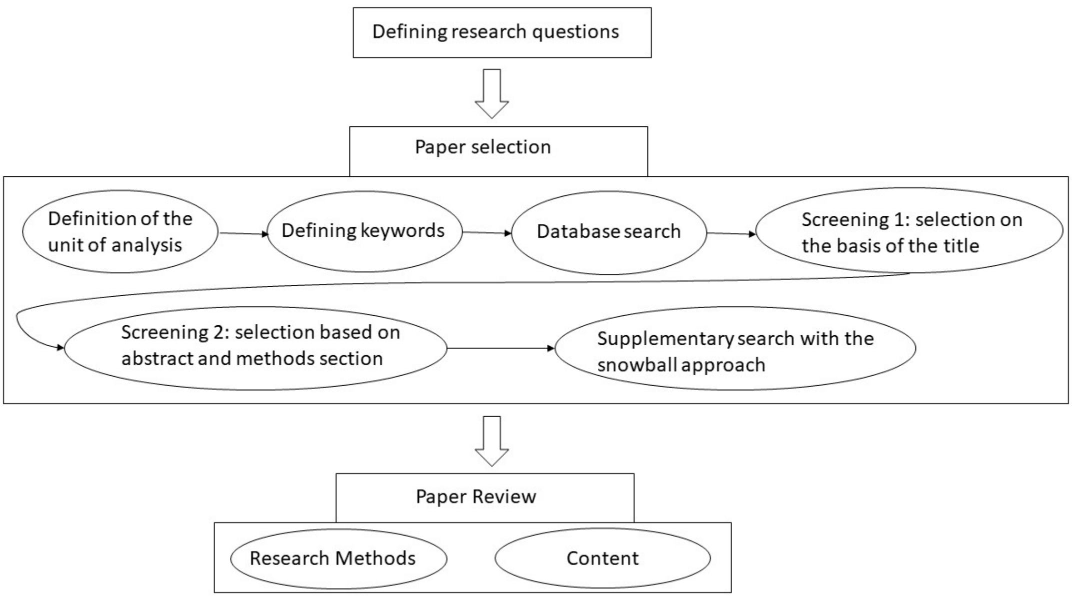

Figure 1. Schematic overview of the method.

As a selection criterion, it was specified that the studies must have been published within the last 15 years, i.e., in the period from 2006 to October 2020 in a peer-reviewed scientific journal. Conference papers and grey literature were not considered. In terms of content, the work must focus on a quantitative assessment of the environmental impact of transport activities resulting from online and in-store shopping. Studies in which transport activities are only one part of the analysis were also included if the calculations were shown separately. Content exclusion criteria were purely qualitative studies, studies that did not quantitatively assess environmental impacts, studies that did not consider transport processes and studies that only considered one distribution channel. The databases Science Direct and Scopus served as sources of information. The search was carried out using different combinations of the following search terms: e-commerce, online shopping, in-store shopping, brick and mortar shopping, transport, last-mile, mobility, behaviour, CO_2-emissions, GHG, emissions and environmental impact. The search terms were also linked with Boolean operators, for example: (emissions OR environmental impact) AND (brick and mortar OR in-store shopping) AND (e-commerce OR online shopping) AND transport.

The first screening was based on the title to filter out potentially relevant articles. For example, papers dealing with the motives for consumer behaviour or other specific aspects of online shopping could be excluded at this stage. Approximately 90 articles were shortlisted. In the second round of screening, the selection was narrowed down further. The abstract served as the basis, although the information in the methods chapter or the results were also consulted if the abstract did not provide decisive information. This made it possible to find out whether the statements made were based on calculations or other findings. The database search was extended by the snowball approach, which describes the screening of references of key papers. The same screening process was used as in the database search. The selection process leads to a total of 15 studies that are considered relevant for this work and thus included in the further analysis process. For each paper, data were collected on the following topics: Regional reference, method, transport section, product category, the way environmental impacts are measured and the factors used for the calculations. The most important sections for data extraction were the methodological chapters of the selected studies.

3. Literature Review

This chapter presents the results of the literature review. First, the selected studies are presented in terms of their content focus, the methods used and the assessment made, followed by a description of the product groups considered and the measurement of environmental impact. Then, the focus is placed on the transport section under consideration. The last subchapter deals with the factors that were included in the calculations of the environmental impact.

3.1. Introducing the Selected Studies

Table 1 is intended to provide an overview of the included studies and lists some of their key points for this purpose. The studies were clustered according to the method used and then sorted alphabetically. The order is also maintained for the following tables in order to be able to recognise any patterns that can be attributed to the method used. The column "Regional reference" allows a better classification of the studies with regard to the data used and the country-specific environment in which the study was conducted. The column "Statements" reflects the central message of the selected studies regarding the environmental friendliness of in-store and online shopping.

Table 1. Key parameters of the selected studies.

Authors	Focus of the Work	Regional Reference	Statements
Case Study (with data from a specific company)			
Buldeo Rai et al. [20]	Analysis of the most common omnichannel behaviour pattern and their influence on consumers' travel behaviour and retailers' transport activities and the resulting transport-related CO_2-emissions. Pre-purchase activities were also included through path-to-purchase profiles.	Belgium Offline channel: 70 stores in the north of Belgium, online channel: free next-day delivery to any address in Belgium	The least environmental impact is caused by consumers who order online
Wiese et al. [21]	Comparison of the transport-related CO_2 emissions of the online and offline channel (based on supply, delivery, shipping, orders and travel data)	Germany Offline channel: Store 1 in the centre of a large city is supplied six times a week with 3000 parcels each, Store 2: outside the centre of another city is supplied five times a week with 2200 parcels each, online channel: 40 000 orders in four weeks	Online shopping tends to cause fewer emissions, but the result is influenced by the variability of various factors
Data analysis and calculations			
Smidfelt Rosqvist and Winslott Hiselius [22]	The focus is on the potential CO_2 reduction in passenger transport due to increasing online shopping and changes in population size. They also include trips for other purposes than shopping in their model in order to be able to map rebound effects.	Sweden Data for total Sweden from one-day travel survey diaries (for all trips), data from reports and national statistics	An increase in online shopping leads to a reduction in CO_2-emissions
Weltevreden and Rotem-Mindali [23]	The focus is on the effects of business-to-consumer and consumer-to-consumer commerce on freight travel and personal trips by calculating the net mobility effects	The Netherlands Data from an online survey with a nationwide sample of 3000 e-shoppers on in-store and online shopping behaviour, interviews with a logistics company	Online shopping leads to a reduction in the total distance travelled, as the reduction in the total distance of consumer trips is greater than the total distance of additional freight transport. However, the extent of the actual environmental impact is highly dependent on the level of several variables.
Life Cycle Assessment			
Borggren et al. [24]	Analysing the environmental impact of online and in-store shopping of paper books and defining key factors influencing the extent of these impact	Sweden Data from interviews and supplementary data from the internet for the selected bookshop, interview with a logistics company	Online shopping has a lower global warming potential
Sivaraman et al. [25]	The authors assess and compare the impact of the traditional retail channel and e-commerce on DVD rental.	USA Study from the perspective of a fictional customer living in the city of Ann Abor, Michigan	Online shopping generates less CO_2-emissions and consumes less energy

Table 1. *Cont.*

Authors	Focus of the Work	Regional Reference	Statements
van Loon et al. [26]	Identification of all relevant factors that determine the environmental impact of online and in-store shopping	United Kingdom Data from the literature and a national survey	Travel behaviour of consumers, the choice of the fulfilment method, basket size, packaging and energy efficiency of buildings are the main factors influencing the extent of the environmental impact
Mathematical model			
Brown and Guiffrida [27]	Comparison of carbon emissions of online and conventional shopping, including trip chaining for different initial situations	USA Data for mathematical calculations from a survey in the Midwest USA with a focus on suburban Ohio and Pennsylvania	CO_2-emissions can be saved through online shopping
Carling et al. [28]	Development of a calculation method to measure the CO_2-emissions of in-store and online retailing	Sweden Data from Dalecarlia region in Sweden with 277,000 customers, seven brick-and-mortar stores and 71 delivery points	CO_2-emissions can be reduced by online shopping
Edwards et al. [29]	Calculation of CO_2-emissions that occur on the last mile and consumer shopping trips	United Kingdom Data from UK government statistics and primary data from one of UK's largest home delivery companies	Online shopping generates less CO_2 if the in-store shopping basket contains less than 24 items
Seebauer et al. [30]	Quantification of greenhouse gas emissions for different shopping situations (four in-store situations, one online situation) and analysis of the effects of market trends and different policy scenarios (e.g., facilitating online shopping)	Austria Study area is the agglomeration of Graz with an urban core, suburban surroundings and a rural district, data from a household survey with 690 interviews	Policies that facilitate online shopping have no impact on the level of emissions compared to the baseline scenario (status quo)
Zhao et al. [31]	Development of a model to compare the CO_2 emissions of e-commerce and traditional retail in cities	China Shenzhen with 14.8 million inhabitants, online channel: 9 distribution centres, 957 delivery points, offline channel: 129 shopping centres, 98 commercial streets, 2727 supermarkets, the share of online shopping is 47%	Online shopping generates less CO_2-emissions
Simulation (also includes calculations)			
Jaller and Pahwa [32]	Estimation of vehicle miles and environmental emissions in Dallas and San Francisco using disaggregated individual shopping behaviour from an econometric behavioural model	USA Data on shopping behaviour from the American Time Use Survey, estimation of the environmental impact for Dallas and San Francisco	The number of vehicle miles tends to be lower due to online shopping but depends on the shopping basket in the two channels and the degree of consolidation

Table 1. *Cont.*

Authors	Focus of the Work	Regional Reference	Statements
Shahmohammadi et al. [33]	Quantification of greenhouse gas emissions for different retail channels resulting from freight transport, analysis of the variability in consumer purchasing behaviour, comparison of the results of this work with the results of other countries and estimation of the impact of electric cargo bicycles on the last mile	United Kingdom Data from industry sources, national statistics and literature	Replacing an in-store purchase with an online order with fulfilment through shop delivery can reduce the environmental footprint. In contrast, buying from pure players in online shopping usually creates higher emissions.
Xu et al. [34]	Comparison of the effects of e-commerce and traditional retailing on energy and the environment from a bottom-up perspective, using behavioural decision rules and historical data for the US book market in an agent-based model	USA Data on the US bookselling market from 1998 to 2005	Online shopping produces fewer emissions and uses less energy when an online purchase replaces an in-store purchase

3.2. Product Group and Measurement of the Environmental Impact

The selected studies also differ with regard to the product group examined and the way the environmental impact is measured. This is addressed in Table 2 below. Especially in a more detailed analysis, the distinction between different product groups can be important. For example, the return rate for online clothing purchases is usually much higher than for books or food. Wiese et al. [21] use a return rate of 35% for clothing. Edwards et al. [29] work with a return rate of 25% for non-grocery items and cite a rate of 6–10% for stationary retail. The transport conditions can also change if, for example, food is delivered refrigerated.

Table 2 shows that most studies refer to a specific product group. Moreover, groceries seem to play a specific role in the selected studies because there is a collective term that distinguishes them from non-groceries products. The most commonly used way to measure environmental effects was to measure CO_2-emissions or GHG emissions. Twelve of the selected studies used one of the two measurement types. When looking at the methodological clusters, it is noticeable that the studies in the groups "Case study" and "Mathematical models" tend to refer to concrete products or do not provide any information at all, while the studies in the groups "Data analysis and calculations" and "Simulation" tend to take a more abstract view with collective terms.

Table 2. Product group and type of measuring the environmental impact in the selected studies.

Authors	Product Groups								Type of Measurement of the Environmental Impact					
	Apparel/Footwear	**Books/DVDs**	**Electronics**	**Non-grocery (as a Collective Term)**	**FMCG**	**Grocery/Daily Goods**	**Not specified**	**Intangible Goods (e.g., Tickets, Financial Products)**	**GHG or CO_2e**	**CO_2**	**Energy**	**External Costs**	**General Environmental Impact (Different Units)**	**Net Mobility**
Count	4	4	3	3	2	3	2	1	6	6	2	2	1	1
Buldeo Rai et al. [20] [1]	x											x		
Wiese et al. [21] [1]	x									x				
Smidfelt Rosqvist and Winslott Hiselius [22] [2]				x						x				
Weltevreden and Rotem-Mindali [23] [2]				x		x		x						x
Borggren et al. [24] [3]		x											x	
Sivaraman et al. [25] [3]		x							x		x	x		
van Loon et al. [26] [3]					x				x					
Brown and Guiffrida [27] [4]							x			x				
Carling et al. [28] [4]			x							x				
Edwards et al. [29] [4]	x	x	x							x				
Seebauer et al. [30] [4]	x		x			x			x					
Zhao et al. [31] [4]							x			x				
Jaller and Pahwa [32] [5]				x		x			x					
Shahmohammadi et al. [33] [5]					x				x					
Xu et al. [34] [5]		x							x		x			

[1] Case Study, [2] Data analysis and calculations, [3] Life Cycle Assessment, [4] Mathematical model, [5] Simulation.

3.3. Transport Section

The analysis of the transport sections considered enables further specification of the selected studies. Table 3 below shows the starting point and intermediate points of the route a product takes before reaching the customer. For each study, the number of sections considered is also given. This does not indicate the number of points, but the number of sections between the points. In almost all cases, only freight deliveries are considered for online shopping. An exception is the study from Smidfelt Rosqvist and Winslott Hiselius [22], which only considers consumer trips. For in-store shopping transport activities, the section from the shop to the customer is included in the total number of sections, but is not listed separately as it is considered in the same way in all studies. The consumers themselves carry out the last mile transport.

Table 3. Transport section considered in the selected studies.

Authors	Considered Transport Section			
	In-Store Shopping–Freight Transport	**No. of Sections ***	**Online Shopping–Freight Transport and Last Mile Delivery**	**No. of Sections**
Buldeo Rai et al. [20] [1]	From the distribution centre to the store	2	From the distribution centre to logistics partners' distribution centre to the local distribution centre to the customer (collection point/home)	3
Wiese et al. [21] [1]	From the central warehouse to the store	2	From the central warehouse to the outbound depot (close to the central warehouse) to the inbound depot (close to customer's destination) to the customer	3
Smidfelt Rosqvist and Winslott Hiselius [22] [2]	-	1	From the pick-up point to the customer (no freight transport included)	1
Weltevreden and Rotem-Mindali [23] [2]	-	1	From the store to the customer	1
Borggren et al. [24] [3]	From the printing office to the central warehouse to the bookshop	3	From the printing office to the central warehouse to the internet bookshop warehouse to the pick-up point	3
Sivaraman et al. [25] [3]	From the production site to the distribution centre to the store	3	From the production site to the warehouse to another warehouse to the customer	3
van Loon et al. [26] [3]	Click and collect/conventional retailing: From the manufacturer to the retail distribution centre to the store	3	Pure players: From the manufacturer to the manufacturer's warehouse to the e-fulfilment centre to the cross-dock location to the customer per van or from the manufacturer to the manufacturer's warehouse to the e-fulfilment centre to the parcel network distribution centre to the customer or from the manufacturer to the manufacturer's warehouse and directly to the parcel network distribution centre and then to the customer, Bricks & Clicks: From the manufacturer to the manufacturer's warehouse to the retail distribution centre to the store to the customer per van delivery	4/4/3/4
Brown and Guiffrida [27] [4]	-	1	From the central depot to the customer	1
Carling et al. [28] [4]	From the entry point of the studied region to the store	2	From the entry point of the studied region to the customer	1

Table 3. *Cont.*

Authors	Considered Transport Section			
	In-Store Shopping–Freight Transport	No. of Sections *	Online Shopping–Freight Transport and Last Mile Delivery	No. of Sections
Edwards et al. [29] [4]	-	1	From the local depot to the customer	1
Seebauer et al. [30] [4]	From the national/regional distribution centre to the store	2	From the national/regional distribution centre to the customer	1
Zhao et al. [31] [4]	From the toll station to the warehouse to the retailer	3	From the toll station to the distribution centre to the delivery points to the customer	3
Jaller and Pahwa [32] [5]	-	1	Via a delivery tour to the customer	1
Shahmohammadi et al. [33] [5]	From the factory to the manufacturer's warehouse to the distribution centre to the retail shop	4	Pure Players: From the factory to the manufacturer's warehouse to the distribution centre to the parcel distribution centre to the customer Bricks & Clicks: From the factory to the manufacturer's warehouse to the distribution centre to the retail shop to the customer	4/4
Xu et al. [34] [5]	-	1	Transportation to the customer via local delivery trips	1

* Also including the section from store to customer (last mile consumer transport). [1] Case Study, [2] Data analysis and calculations, [3] Life Cycle Assessment, [4] Mathematical model, [5] Simulation.

Table 3 illustrates that the considered transport section varies considerably between the studies. The reason is usually the main leg, whether and how it is included. On the one hand, this is due to the different research questions and focal points of the studies. On the other hand, there are also different assumptions about the importance of the individual transport sections for the environmental impact. In terms of methodological clusters, it can be seen that the studies in the "case study" and "life cycle assessment" groups have most consistently considered a relatively high number of sections.

In the following section, additional information that relate to the transport sector is provided for some studies in order to do justice to the different perspectives. Buldeo Rai et al. [20] calculated the distances of the shopping trips using postcodes and Google Maps, resulting in a median of 18.5 km for the total trip distance. When trip chaining is included, the distance is reduced to 8.2 km. To create the logistics trip, they used a transport model and included data on vehicle fleet, volume per destination and distribution centre locations. They argue that efficient transport is related to the size of the logistics company. Wiese et al. [21] considered the transport section from the central warehouse, as they assume that the first part is the same in both channels. For the offline channel, they consider two stores, the first with a supply route of 437 km and the second with a supply route of 10.7 km. The consumer distances to the shops are on average 18.6 km and 16.1 km each way. For the online channel, the outbound process is 13 km, the line-haul averages 388.8 km, or 1.3 km per parcel, and the inbound process is 200 km per tour and includes 150 parcels. Weltevreden and Rotem-Mindali [23] made a distinction between different delivery options as they involve different circumstances: In the case of delivery at the workplace, there are no failure deliveries. The difference in the case of delivery to the letterbox or to the front door is that in the first case conventional postal services can also deliver. The e-commerce category includes not only everyday products, but also tickets and financial products, which are often delivered digitally, as well as C2C purchases, which are often picked up at a private address. In the study of Sivaraman et al. [25] a consumer trip to rent a DVD has a total distance of 8 km and the last mile tour in online shopping is 210 km. The distance from the distribution centre to the local store corresponds to a length of 1825 km, whereas the distance from the main distribution centre to the regional warehouse in online shopping is 3800 km. van Loon et al. [26] analysed the transport section from the factory to the consumer. The manufacturer transport was carried out with a 28 t gross-weight truck over a distance of 500 km. The brick-and-click delivery tour comprises 22 drops on a distance of 50 km, and the home delivery tour includes 120 drops in 80 km. The trips of the consumers result in distances of 19.95 km to the carrier depot as a round trip and 12.5 km to a local shop for the collection of items. Brown and Guiffrida [27] build their mathematical formulation of last mile and passenger trips on a circular demand region with a single depot in the centre of the circle. They use the solution algorithm for the Travelling Salesman problem by changing the number of trucks and customers. For the average vehicle speed, they used data from Google Maps. The average distance of a customer to the nearest Walmart was 6.7 miles but varied depending on population density (3.7–24.4 miles). Carling et al. [28] calculated the shortest distance between the entry point to the region and the final node with the Dijkstra algorithm. The average distance from the consumers' home to a brick-and-mortar retailer is 48.54 km and the average distance to an online delivery point is 6.7 km. The distance from the entry point to the region to a brick-and-mortar shop is equivalent to 47.15 km and from the entry point to the online delivery point is 122.75 km. They conclude that the stores could be better located, reducing the average distance for the consumer from 48.5 km to 28.8 km. The freight transport calculation was based on the use of a Scania truck loaded 60% with 600 products. The calculations of Edwards et al. [29] are based on a 60 miles delivery round with 150 drops. For a city centre tour, they used a distance of 25 miles with 110 drops. The average distance for non-food shopping is 6.4 miles for car trips and 4.4 miles for bus trips each way. Seebauer et al. [30] do not only distinguish between online and offline channel, but also consider purchases in neighbourhood shops, town centres, discount stores, shopping malls and online sales separately in their calculations. They show that not only different distances result for consumers to buy different types of products, but also that different shopping situations result in different distances and give a distance of 6–25 km as a two-way distance (without chaining trips) for the analysed region. Shopping for clothes and electronics tends to involve longer trips than shopping for groceries. They also point out that the retail structure can influence the results. Austria has a higher share of small supermarkets (65%) than other European countries (28% on average in the EU). A similar situation can be found, e.g., in Germany, and the UK is an example of an opposite structure. Zhao et al. [31] assume that the production process and the transport routes to Shenzhen are the same for both channels and only diverge at the Shenzhen motorway toll stations. From this point on, the shortest routes are used for freight transport. The calculated delivery distances in online shopping are eight times longer than in conventional retail. In conventional retail, the distance of customer trips is 25.8 km and is the main source of CO_2 emissions. Jaller and Pahwa [32] estimated distributions for the number of shopping trips per person, and for each shopping trip, the trip length was estimated based on the number of stops in a tour. The average distance for an in-store purchase is 11.25 miles. An online retail purchase results in 1.4 miles if a tour with an average of 35 deliveries is used as the basis. E-commerce reduced vehicle kilometres travelled by 7%, resulting in an 87% reduction if everyone would shop online. Shahmohammadi et al. [33] used 157 km as the geometric mean for primary transport by truck and 163 km for secondary transport. Last mile distance contributes strongly to the variability of GHG footprints (32% of variance for brick and mortar, 15% for brick and clicks and 34% for pure players). The number of parcels delivered per tour accounts for 15% of the variance in the GHG footprint of pure players. Xu et al. [34] found that increasing the e-commerce share of the total book market can reduce the average transport distances from 4.65 km to 3.62 km. Self-collection from a nearby shop goes hand in hand with lower prices and can avoid additional transport distances. However, it is less convenient for the consumer than direct delivery and also limited by the lock-in effect. This means that the consumer's initial choice and social network choice is a cognitive barrier to switching to other options.

3.4. Factors Used to Measure the Environmental Impact

Table 4 below lists the various factors used to measure the environmental impact of the online or offline channel. The table only shows whether a factor is included in the calculations or not. The scope—i.e., whether the factor is included in the calculations as a single value or more comprehensively—is not considered in the table. Very basic factors, such as the number of tours and the length of tours, are not mentioned separately as they are a prerequisite for any calculations. Factors that are not directly or indirectly related to transport processes are also excluded. In particular, life cycle analyses often take a broader perspective and include the energy consumption of shops or of consumers when ordering online, as well as the emissions or energy consumption for the production of the products.

Table 4. Factors included in the selected studies.

Authors	**Count**	**Basket Size SOBE**	**Change in Consumption TOE**	**Delivery Time Window SOLE**	**Failure Deliveries SOLE**	**Mobility Effects in General TOE**	**Modal Split SOBE**	**Interactions between the Channels TOE**	**Packaging SOLE**	**Population Density**	**Population Size**	**Return Rate SOBE**	**Shopping Frequency SOBE**	**Showrooming SOBE**	**Trip Chaining SOBE**	**Trips for Other Purposes TOE**	**Unsold Products SOLE**
Count	69	6	1	2	5	4	11	2	6	7	2	6	3	3	9	1	1
Buldeo Rai et al. [20] [1]	5				x	x	x					x			x		
Wiese et al. [21] [1]	6	x					x			x		x		x	x		
Smidfelt Rosqvist and Winslott Hiselius [22] [2]	6					x	x			x	x		x			x	
Weltevreden and Rotem-Mindali [23] [2]	5				x	x	x			x					x		
Borggren et al. [24] [3]	3								x						x		x
Sivaraman et al. [25] [3]	3						x		x						x		
van Loon et al. [26] [3]	9	x		x	x	x	x		x			x	x		x		
Brown and Guiffrida [27] [4]	2									x					x		
Carling et al. [28] [4]	2						x							x			
Edwards et al. [29] [4]	6	x			x		x					x		x	x		
Seebauer et al. [30] [4]	8		x				x	x	x	x		x	x		x		
Zhao et al. [31] [4]	5	x					x		x	x		x					
Jaller and Pahwa [32] [5]	3	x		x							x						
Shahmohammadi et al. [33] [5]	5	x			x		x		x	x							
Xu et al. [34] [5]	1							x									

SOLE—second-order logistical effects, SOBE—second-order behavioural effects, TOE—third-order effects, [1] Case Study, [2] Data analysis and calculations, [3] Life Cycle Assessment, [4] Mathematical model, [5] Simulation.

Those factors whose meaning is not clear from the name or where there may be confusion about why and to what extend the factor is included are briefly explained below:

- Basket size and shopping frequency: These factors were marked as included if they were considered for at least one channel.
- The population size influences the number of potential consumers and thus the demand in a region.

- Mobility effects refer to the impact of online shopping on freight transport and personal trips. They include substitution and complementary effects. Substitution effects describe a situation in which one activity is completely replaced by another. This is the case, for example, when an online purchase replaces a trip to the shop in conventional retail [8]. Studies that assume, solely for reasons of simplicity, that an online purchase is replaced by a purchase in a retail shop are not assigned to this category. Complementary effects occur when the opportunity to shop online leads to behaviour that results in additional activity in the complementary channel. This is the case, for example, when purchases in the offline channel can be attributed to the online advertising of products. Trips to pick up goods ordered in the online channel to avoid delivery costs are also part of the complementary effects [8,35,36].
- Population density refers to spatial conditions and structures and influences the length of supply routes, the length of consumers' routes to the shop and the modal split. Wiese et al. [21] took this into account, for example, by calculating break-even points at which emissions become greater for one channel than the other.
- Showrooming describes a consumer behaviour in which consumers take extra trips to examine products they want to buy online.
- Unsold products: this factor was included because it has a kind of hybrid status. It is not exclusively related to transport but is influenced by the distribution structure. In conventional retailing, each shop also forms a kind of decentralised warehouse, whereas in e-fulfilment centres the products are concentrated in one place [15]. Therefore, Borggren et al. [24] assume that in conventional retailing more products have to be produced for one item sold. This not only renders the emissions and energy consumption from production pointless but can also set additional transport processes in motion.

The factors extracted from the selected studies were also assigned to the categories second-order effects (SOLE and SOBE) and TOE. The factors shopping frequency and basket size were assigned to the SOBE, as these factors were used in the studies exclusively to account for differences between channels or shopper groups or to calculate a break-even quantity. Rebound effects or mobility effects were not considered in this context. Two factors were intentionally not assigned: population density and population size. This is because the effects are not those that result from or are influenced by online shopping, but rather external circumstances that are independent of online shopping. However, these factors can have a major impact on the extent of the environmental impact and are therefore included in the results.

The number of factors considered in the selected studies varies greatly. On average 4.6 factors per study are included in the calculations, the median has a value of 5. The factors were also not used to the same extent by the studies. Forty percent of the factors are only included in a maximum of two studies. The most popular factor "modal split" was included in 73.3% of all selected studies, while the second popular factor "trip chaining" was included in 60% of cases. This result reflects the situation that in some studies only partial aspects were deliberately considered. In some cases, the factor was not considered relevant, in others this may be due to insufficient data. The number and use of factors do not seem to follow any particular pattern in the methodological clusters. In the following paragraphs, the individual factors are described in more detail in order to illustrate how they have been included in the studies.

3.4.1. Basket Size

Wiese et al. [21] used a basket size of 1.72 products in their calculations. van Loon et al. [26] changes the basket size depending on the type of delivery. For van delivery, they assume an average of 55 items per drop, for in-store shopping a basket size of 30 items and, for home parcel delivery, 1.4–2 items per drop. They concluded that the shopping basket size is a significant factor. When 2–22 items are ordered, van delivery from local shops have the lowest emissions. For larger baskets, delivery by van from central warehouses are more environmentally friendly. Edwards et al. [29] included a basket size of 1.4 items for books/DVDs/CDs and 2.5 items for other non-food goods (e.g., clothes, household items) in their calculations. They see the size of the shopping basket as a critical factor for the level of CO_2 emissions. Since the emissions from a car trip to a shop is 24 times greater than the CO_2 emissions from a single home delivery, the basket size when shopping in-store needs to be at least 24 items to be more environmentally friendly. If 2.5 items are delivered per trip, customers driving to the store will have to buy 59 non-food items (calculation excluding returns and failed deliveries). Zhao et al. [31] used a basket size of 1.97 packages per one trip to the store. Jaller and Pahwa [32] used a basket size of 1.1 for online purchases and a basket size of 2.73 for in-store purchases. They concluded that the higher the basket size for in-store purchases compared to online purchases, the more consolidation is required for delivery. Shahmohammadi et al. [33] used a basket size of 1–5 items per delivery for pure players, which means that basket size contributes to 28% of variance in GHG emissions for them.

3.4.2. Change in Consumption

Seebauer et al. [30] assumed in their study that consumer spending would grow by 1.5% per year.

3.4.3. Delivery Window

van Loon et al. [26] included delivery windows in their study by taking into account a low rate of delivery failures in the models where transport is done by vans because a delivery time is agreed with the customers in advance. Jaller and Pahwa [32] concluded in their study that the vehicle miles travelled per delivery stop increase when the number of deliveries per tour is reduced (e.g., when the delivery has to be made within two hours or on the same day). This results in all measured environmental parameters for online shopping perform poorly when a tour includes less than four deliveries. When more than 92 deliveries are consolidated for a tour, e-commerce performs better than in-store shopping in all measured environmental aspects.

3.4.4. Failure Deliveries

Buldeo Rai et al. [20] used a delivery failure rate of 0.3% in their calculations, which resulted from the sample considered. Weltevreden and Rotem-Mindali [23] included in their calculations that 1.12 freight trips are required to successfully deliver an online order. van Loon et al. [26] assumed that 40% of all deliveries are failed deliveries, of which 90% are redelivered and 10% have to be picked up at a local Collection-and-Delivery Point. Edwards et al. [29] included three ratios in their calculations: 25%, 12% and 2% of failed deliveries. Shahmohammadi et al. [33] only allow one failed delivery in their model. For this they used a probability of failed deliveries for Pure Players of 14%, of which 50% are redelivered and 50% are delivered to a pick-up point from which consumers have to collect the delivery. The variability in the number of failed deliveries accounts for 13% of the variance in Pure Players' GHG footprint.

3.4.5. Mobility Effects in General

Buldeo Rai et al. [20] created different consumer profiles in their study to account for different combinations of pre-purchase and receiving activities. They distinguish between purchasing, testing, receiving and returning trips and conclude that external costs are eight times higher for showroomers than for online-only shoppers and twice as high as for traditional-only shoppers. Smidfelt Rosqvist and Winslott Hiselius [22] found that regular online shoppers generate 45% less CO_2 for purchases than people who rarely or never shop online. Weltevreden and Rotem-Mindali [23] surveyed substitution effects by asking whether the customer would have bought a certain item in the shop if it could not be bought online. From this, they calculated the shopping trip that was saved due to online shopping. If the customer would not have bought, this indicates that it is impulse buying or that the item is only available online. They concluded that 73% of all online orders would have been bought in-store and 32% would have saved a car trip. In total, 7% of online orders would have been made by phone or email instead and 19% of products would not have been purchased. They also point out that, in addition to the complementary effects, more freight transport kilometres often have to be covered as customers shop at more distant retailers. van Loon et al. [26] addressed mobility effects in their second scenario. To this end, they include the shopping trips that remain despite online retailing in the environmental impact of online retailing by including 75% or 90% (depending on the retail channel) of the consumer trip to a physical shop in the emissions of online retailing.

3.4.6. Modal Split

Buldeo Rai et al. [20] carried out their calculations with a share of 81% of total trips as car trips. Wiese et al. [21] have included in their calculations a car trip share of 50% for the first shop and 55% for the second shop. Smidfelt Rosqvist and Winslott Hiselius [22] also collected in their survey information on the modal split and included car and bus journeys in the calculations of CO_2 emissions. Weltevreden and Rotem-Mindali [23] concluded that 53% of the net number of shopping trips reduced by e-commerce would be car trips, the other shopping trips would be environmentally friendly. In terms of distance, 72% of the net reduced kilometres would have been travelled by car. Sivaraman et al. [25] showed a decreasing life-cycle energy consumption result for different transport modes. van Loon et al. [26] mentioned that they use data for the UK, which limits geographical transferability. In the Netherlands, for example, there is a higher proportion of consumers who walk or cycle to the stores. Carling et al. [28] concluded that if every consumer within a 2 km radius walked to pick up the product, the emissions savings for online retail would increase by 2% to 86% compared to in-store shopping. Edwards et al. [29] found in their study that 72% of all shopping trips are made by bus or car. Seebauer et al. [30] concluded that a different modal split can be found depending on the shopping situation and the product group under consideration. Zhao et al. [31] carried out their calculation with a share of 76.3% of car trips. Jaller and Pahwa [32] assume in their calculations that all trips are made by car. However, the actual percentages are 79% for San Francisco and 94% for Dallas. Shahmohammadi et al. [33] concluded that the difference in modal split leads to a variance of 14% of the results for in-store shopping. When comparing their results with those of other countries, they use different modal shares.

3.4.7. Interactions between the Channels

Seebauer et al. [30] calculated in their third scenario that stimulating online sales to a 30% market share would have the largest impact on shopping mall purchases of electronics products, but would only reduce overall carbon emissions growth by 1% to 32% compared to the baseline scenario. A decreasing market share of shopping malls would increase the price of products by 4.4% and favour online sales of clothing and electronics. This would increase the share of online sales to 38%. Xu et al. [34] concluded in their studies that while high growth rates in e-commerce sales lead to a higher market share more quickly, the market shares of the two channels settle into the same equilibrium regardless of the growth rate. If all consumers have internet access, e-commerce will have a market share of 37% of the sales volume of the book market.

3.4.8. Packaging

Borggren et al. [24] included additional packaging for products in online retail in their calculations. Sivaraman et al. [25] noted differences in the online and offline channels, as in the former case a single plastic DVD case is replaced by a plastic case with the company logo at the distribution centre and in the latter case the plastic case is replaced by a paper sleeve package at the regional warehouse. van Loon et al. [26] included three types of packaging in their calculation: cardboard packaging and filling material for parcel delivery and plastic bags in van delivery. They concluded that cardboard packaging accounts for a significant share of GHG emissions. Seebauer et al. [30] included the use of corrugated cardboard as packaging material in their calculation for products in the online channel. Zhao et al. [31] covered corrugated cardboard and plastic bags in their study. They reach the conclusion that packaging is the main CO_2 emitter in e-commerce, but point out that some of it could be reused by consumers, which would reduce emissions. Shahmohammadi et al. [33] included the environmental impact of the packaging used by Pure Player in their study. They considered corrugated board and Kraft paper as well as paper waste treatment after opening the packaging.

3.4.9. Population Density

Wiese et al. [21] included population density to account for differences in infrastructure availability. For this purpose, they calculated the break-even point at which the CO_2 emissions are greater when shopping in-store than when shopping online, and came to a result of 14 km. Smidfelt Rosqvist and Winslott Hiselius [22] incorporated differences in population density into their study by finding that car trips are twice as long for consumers who never or rarely shop online. This is due to geographical differences, as online shoppers tend to live more centrally. As the difference is not so great for grocery shopping and for activities other than shopping, they concluded that non-food shopping is more affected by localisation than other activities. Weltevreden and Rotem-Mindali [23] concluded that people in less urbanised areas have poor accessibility to shops and, therefore, have to travel more kilometres for in-store shopping. Therefore, the saving of car trips through e-commerce could be greater in rural areas. Brown and Guiffrida [27] created a Manhattan and a Euclidean distance metric for the different distances to the shops and showed the dependence of the average distance to the depot and the delivery radius on population density. Seebauer et al. [30] found that travel length appears to depend on the local settlement structure and the available road network. The results between urban, suburban and rural regions differ by 25%. Zhao et al. [31] analysed the results in terms of population density within the city, with lower emissions produced in easily accessible parts. Shahmohammadi et al. [33] included data from regions with different population densities in their calculations in order to take into account different initial situations for freight transport.

3.4.10. Population Size

In their calculations of CO_2 emissions for the year 2030, Smidfelt Rosqvist and Winslott Hiselius [22] not only include an increasing proportion of online shoppers but also take into account changes in the size of the population.

Jaller and Pahwa [32] concluded that differences in demographics manifest themselves in different shopping behaviour. In their study, the externalities in Dallas are only 2.3 times larger than in San Francisco, even though the population in Dallas is three times larger than in San Francisco.

3.4.11. Return Rate

Buldeo Rai et al. [20] included a 20% return rate for online shopping in their calculations. Wiese et al. [21] use a return rate of 6–10% for in-store shopping and 35% for online shopping. When the return rate is included in the break-even calculation, which calculates the distance at which in-store shopping causes more emissions than online shopping, the break-even point increases from 14 km to 19 km. van Loon et al. [26] took into account a return rate of 3.5% of all cases. Edwards et al. [29] use a return rate of 25% and 40% for clothing in their calculations. Depending on how the return delivery is made, there can be different impacts on the environment. If the returned items are collected as part of the usual delivery round, the environmental impact is lower than if they are collected separately. In addition, the customer can return items at a physical shop or return them by standard postal service. Seebauer et al. [30] included a return rate of 30% in their calculations. Zhao et al. [31] used a 6% return rate for both channels and resulted, that returns are responsible for 19.6% of total transport emissions. CO_2 emissions for returns in conventional retail are twice as high as in online retail.

3.4.12. Shopping Frequency

Smidfelt Rosqvist and Winslott Hiselius [22] distinguished between people who shop online frequently, regularly or seldom or never. Seebauer et al. [30] collected data on the frequency of purchases in their household survey and include this factor in the calculations of emissions for different product groups.

3.4.13. Showrooming

Wiese et al. [21] calculated the break-even point at which in-store purchases cause more emissions. If they include channel-switching consumer behaviour and assume that 50% of consumers seek information in-store before buying online, the break-even point shifts from 14 to 27 km. Carling et al. [28] included the mobility effects in a scenario calculation. If 71% of consumers would make a trip to test the product, the environmental benefits of online shopping would be offset. However, they point out that only 6% of Swedes indicated that they would do so for the consumer electronics. Edwards et al. [29] included browsing trips in their calculations with the following values: 10% for all shopping trips, 20% for clothes and 33.3% for furniture.

3.4.14. Trip Chaining

Buldeo Rai et al. [20] included trip chaining in their calculations by dividing the total trip distance by the number of activities performed in the trip. Since, on average, 66.7% of the trips are chained, the distances are reduced, sometimes considerably. Median distances drop from 15 km to 5.7 km for researching trips, from 14.4 km to 7.9 km for testing trips, from 18.5 km to 8.2 km for purchasing trips and from 10.1 km to 6 km for receiving trips. Wiese et al. [21] only considered trips in their study where respondents had indicated that shopping was the main purpose of the trip. Weltevreden and Rotem-Mindali [23] assumed that 61% of all substituted in-store purchases are part of another trip. Brown and Guiffrida [27] concluded that 42% of the respondents would have refrained from making the trip to the other location if home delivery had been offered. In total, 5% of respondents did not combine shopping with other activities and 53% would have made the trip to the other stops anyway. Edwards et al. [29] considered trip chaining as a consolidation of consumer shopping trips that is an important factor in reducing emissions from in-store purchasing. Seebauer et al. [30] used a share of 30% of trips in urban areas and 20% in rural areas as trip chains in their calculations.

3.4.15. Tips for Other Purposes

Smidfelt Rosqvist and Winslott Hiselius [22] found no rebound effect from online shopping, as frequent online shoppers have a 45% CO_2 reduction for shopping trips and a 24% reduction for travel for any purpose (does not include calculation of emissions from logistical activities). Frequent online shoppers tend to have more sustainable travel behaviour.

3.4.16. Unsold Products

Borggren et al. [24] took into account that, due to the differences in the distribution systems, more books cannot be sold and have to be returned in brick-and-mortar shops compared to online shopping. They used 0.05% returns for books bought online and 14% returns for books bought in-store for their calculations.

3.4.17. Classification of the Factors

The factors included can also be analysed one level higher in terms of their classification. Table 5 below gives an overview of how often a factor of each category was used. The

SOLE and the TOE category include four factors each, the SOBE category has six factors and the category of external parameters has two factors.

Table 5. Number of factors per category.

	SOLE	SOBE	TOE	Other
Buldeo Rai et al. [20] [1]	1	3	1	0
Wiese et al. [21] [1]	0	5	0	1
Smidfelt Rosqvist and Winslott Hiselius [22] [2]	0	2	2	2
Weltevreden and Rotem-Mindali [23] [2]	1	2	1	1
Borggren et al. [24] [3]	2	1	0	0
Sivaraman et al. [25] [3]	1	2	0	0
van Loon et al. [26] [3]	3	5	1	0
Brown and Guiffrida [27] [4]	0	1	0	1
Carling et al. [28] [4]	0	2	0	0
Edwards et al. [29] [4]	1	4	0	0
Seebauer et al. [30] [4]	1	4	2	1
Zhao et al. [31] [4]	1	3	0	1
Jaller and Pahwa [32] [5]	1	1	0	1
Shahmohammadi et al. [33] [5]	2	2	0	1
Xu et al. [34] [5]	0	0	0	1
Total	14	37	7	10

SOLE—second-order logistical effects, SOBE—second-order behavioural effects, TOE—third-order effects, [1] Case Study, [2] Data analysis and calculations, [3] Life Cycle Assessment, [4] Mathematical model, [5] Simulation.

A look at the second-order effects factors shows that both logistics-related (one factor is used on average 3.5 times) and behavioural factors (one factor is used on average 6.16 times) are regularly included. The external parameters were also frequently included in the studies, on average 5 times per factor. In contrast, the factors of the category TOE are only included in a few studies (one factor is used on average 1.75 times for TOE).

4. Discussion

In this study, 15 factors were extracted from 15 selected works. It can be seen that, with an average of 4.6 factors a rather small number of factors were included per study. Even if the research questions can justify the selection of factors, it should be considered that only partial aspects are represented by a few factors. This is particularly important if policy implications are to be derived from these results. Most of the extracted factors were used in the study by van Loon et al. [26]. This is also in line with their aim to be the first to make a quantitative assessment from a holistic perspective. In the course of this work, an attempt was made to synthesise the approaches and results of the selected studies. In order to provide an overview, the information collected was partially abstracted for presentation in the tables. To account for the different study settings, more detailed information was also provided in the running text.

4.1. Study Design

When looking at the methodological clusters, it becomes clear that there are only weak indications of the actual design of the studies based on the method alone. Although the studies have a similar objective, the reasons for the actual design seem to lie more in detailed aspects of content.

The results of the quantitative assessment of the environmental impact of online and in-store shopping depend not only on the factors included, but also on the focus of the studies. Particularly through studies that look at several product groups, it becomes clear that the significance of some factors and their concrete values can strongly depend on the product group studied. The differences are most obvious in relation to groceries, since non-grocery is used as a separate collective term.

The consideration of the different transport sections can be attributed to the different perspectives from which the environmental impact is examined. On the one hand, this has to do with the method chosen, as, e.g., life cycle assessments naturally take a wider perspective. On the other hand, differences may occur depending on the question raised and the assessment of the importance of the individual sections. In addition, even within a channel, the methods of fulfilment can be designed differently. The different values for the distances in the selected studies may be due to differences in population density and considered product group. The different retail structures (e.g., share of large supermarkets) as well as the localisation of the shops can also influence overall emissions. The entire transport route is rarely considered in the selected studies, as the divergence of transport routes is often seen starting at the central warehouse. A more detailed consideration of the entire routes could provide new insights into third-order effects (e.g., products are sourced from more distant locations).

4.2. Second-Order Effects

The extracted factors show that relevant influencing factors are not restricted to a single subject area. It is not only the way in which logistical processes take place that influences the extent of environmental pollution, but also the behaviour of the actors who trigger processes. This is also underlined by the classification of second-order effects in the areas of logistics and behaviour. As can be seen in the course of this work, both aspects were considered in many of selected studies when quantifying the environmental impact. Five studies did not use a factor that could be assigned to the logistics domain and only in one study no factor was used that could be assigned to the behavioural domain. The less frequent use of logistics factors can also be attributed to the circumstance that all studies already contain an important transport-related component through the calculation of trips and distances. The additional factors address the different design of certain aspects. However, the regular use of the factors reflects that the way the transport processes are carried out influences the level of emissions.

In the area of behavioural factors, the size of the shopping basket plays an important role. It differs depending on the product group (e.g., FMCG versus books) and the distribution channel considered. Lower emissions from higher basket sizes in in-store shopping can be offset by increased consolidation in the delivery of goods ordered online. Sensitivity analyses in particular show that large differences in purchasing behaviour between the two channels can have a decisive influence on environmental friendliness. Better data on actual behaviour could provide further insights. In most studies, the modal split was included. This allows to take into account that the saving of emission-free trips has no environmental benefit. Compared to online retail, where delivery is almost always motorised, the share of emission-free shopping trips can play an important role in the environmental friendliness of in-store shopping. The proportion of car trips varies greatly between studies and is often seen as a relevant difference when comparing situations in different countries. This factor seems to be closely related to the available infrastructure, which may differ not only between countries but also within a country. Due to a lower density of shops in more rural areas, consumers are more dependent on car use because of the longer distances. Conversely, it must be considered that trip chaining could mitigate this effect. The values for trip chaining differ in the selected studies. On the one hand, this could be due to the differences between the countries, on the other hand, recoding such effects is difficult, which could also be the reason for the often-poor data situation. However, due to the close connection with the modal split, this factor seems to have relevance for the estimation of environmental emissions, as it can mitigate the impact of a high share of car trips to the shop, if the trips would be made anyway regardless of the purchase. A close connection with third-order effects can also be seen if, for example, the entire route that also includes other stops would be completely omitted if the product could also be purchased online.

The frequency of shopping also influences the level of emissions. However, only a few of the selected studies deal with this explicitly. This may be because this factor is indirectly considered when the total volume and the basket size are known, or it does not play a role when comparing emissions for a specific product. In connection with the basket size, the frequency could provide information about a change in purchasing behaviour in the sense of third-order effects (purchases are divided between the channels, etc.). The return rate differs not only between products and channels, but also how the return transport is carried out (as part of an additional tour, as part of the existing delivery tour or by the consumer himself). In addition, emissions also occur when unsold products are returned from the shops to the central warehouse or unsold products are returned to the manufacturer or need to be disposed of. This was hardly included in the selected studies. Online shopping is characterised by the fact that delivery can fail if no one receives the package. The values for this proportion diverge in the studies considered. This could be due to different circumstances in the countries (e.g., use of parcel boxes, deliveries to work), but also to the different product groups considered and the associated delivery options (digital delivery, delivery to the letterbox, etc.). Failed deliveries can be reduced by specifying a specific delivery window. However, delivery windows can also lead to lower consolidation, especially when used in the context of fast delivery. This can mitigate the higher delivery efficiency of online shopping.

The perspective adopted in this study can also be extended. For example, by considering factors that cause consumer behaviour. In this way, dynamic development can be taken into account, in which the interactions between the two channels can be included in addition to the development of the emission level. Xu et al. [34], for instance, consider customers as part of social networks and use the factors convenience and price for the cognitive choice of the distribution channel. Consumers' choice of channel depends on the satisfaction of their needs. This is composed of individual satisfaction with the factors of price and convenience and social satisfaction, which depends on the market share and leadership power of neighbouring friends. They also include the uncertainty of the market environment. A deeper understanding of interrelationships of this kind can help to better assess the effects of changing initial situations.

4.3. Third-Order Effects

Third-order effects have seldom been considered in quantitative studies so far. The explanation often lies in the lack of data. Complementary effects influence the level of emissions from purchasing activities. Even if the purchase is made online, this can result in trips to test, pick up or return the product. At the same time, in-store shopping is not always completely replaced by online shopping. This influences the total emissions generated by shopping. This could be because only part of the shopping is done online or because in-store shopping can also satisfy others needs than online shopping. Showrooming was explicitly included as a mobility effect in some studies. This was mostly done with a percentage share of online purchases and in the context of break-even analyses. Differences of opinion in research on whether substitutive or complementary effects predominate could also contribute to the circumstance that these effects have seldom been included in the selected studies. Weltevreden [8] found in his literature analysis seven papers that found evidence of pure substitution, two that argued for neutrality and one that identified solely complementary effects. For twelve papers he found more than one of the mentioned effects. Rotem-Mindali and Weltevreden [36] hold the view, that recent literature turns toward complementary effects. They concluded that the different results in scientific literature are caused by the various aims of the studies, different assumptions and differences in the used methodology. In context of substitutive and complementary effects, Weltevreden and Rotem-Mindali [23] also point out that it is not only the type of impact that is relevant, but also an assessment of the extent. This shows that individual sub-sectors, which determine the extent of the environmental impact, can also be very complex in themselves. Closely related to mobility effects are also changes in consumption, for example if products were not bought at all if they were not offered online. Increased consumption through online shopping can also influence the development of total emissions. Online retail has the potential to increase consumption, for example because a large number of products are offered and the convenient shopping process can tempt people to make impulse purchases. In this context, changing basket sizes and shopping frequencies can have a major impact on transport activities and the change in total emission. Interactions between the two channels that are not due to mobility effects were hardly integrated in the selected studies. However, it can be seen that the existing in-store structure (different shop types such as shopping malls, department stores, etc.) and their development can strongly influence the e-commerce share. The question of market equilibrium between the two channels brings to the fore a dynamic approach that also incorporates reasons for consumer behaviour. In addition to comparing the two channels, relationships between the factors are also informative for mapping possible developments over several years. These examples of third-order effects illustrate that the overall picture must not be ignored when interpreting the results and drawing conclusions regarding the environmental impact of online and in-store shopping. Further research into third-order effects and the creation of better data are, therefore, important tasks for the future.

4.4. External Conditions

External factors also influence the degree of the environmental impact. Urban and rural regions differ in terms of population density and available infrastructure. In rural areas, the distances between customers, but also between shops and customers, tend to be greater. This means that the question of whether online shopping is more environmentally friendly than traditional retail can lead to different results even within the same country. Population density was often considered in the selected studies by comparing the environmental impact for different densely populated regions. Differences could be caused not only by different distances, but also by different behaviour due to other circumstances (e.g., available infrastructure). The transferability of the results to other countries is limited, as some factors can be assumed to differ between countries. For example, spatial circumstances can lead to differences in average distances and logistical networks, and cultural characteristics can be reflected differently in consumption patterns. Retail structures may also vary between countries. This would also be in line with Mangiaracina et al. [16], as they point out that the environmental impact is highly dependent on actual conditions. They conclude that there can be no generally applicable models, but that they must always be adapted to the prevailing situation. Emissions from freight transport can also be influenced by different population densities. Population size, conversely, was rarely taken into account. A change in this variable influences the total emissions. The population size of cities does not necessarily always lead to the same relative share of emissions, as the demographic structure also plays an important role in consumer behaviour.

Shopping behaviour can also change considerably as a result of changing external conditions. An example of this is the closure of many brick-and-mortar shops in the wake of the lockdown during the COVID-19 pandemic. This led to a shift in shopping to the online channel, which was also reflected in the increase in parcel volumes [37–39]. The time after the pandemic will show whether these behavioural changes are profound and thus permanent or whether the turn to online shopping is mainly due to a lack of alternatives at the time of the lockdown.

5. Conclusions

This study shows that a variety of factors is used in the scientific literature to assess the extent of the environmental impact of online and in-store shopping. Different product groups and delivery types can influence the values of the factors. This is already considered in some studies dealing with these differences. The environmental effects occur at different levels and can be classified as second- and third-order effects. In the area of second-order effects, logistics-related and behavioural factors were used to a similar extent, with the factors modal split and trip chaining in particular being frequently included. Third-order effects have seldom been considered so far. Additional trips as a share of existing trips in the context of showrooming were considered in some studies, but more complex interactions were hardly included. Studies that also incorporate the effects of channel development (e.g., by changing the circumstances of in-store shopping or considering the attractiveness of channels as market share increases) are rare and thus represent a future field of research, as these effects have the potential to significantly influence the overall level of the environmental impact. Different study designs and external conditions also influence the results of quantitative studies and make it difficult to compare and transfer the results to other countries. Regional factors, such as population density and the structure of the retail trade, can have an impact not only on transport distances but also on other factors such as the modal split. Studies comparing data collected with the same method from different regions would be helpful to better assess the extent of regional differences. This work can help to facilitate the interpretation of the results of quantitative studies in the context of the overall picture. Furthermore, the identified factors can form a solid basis for the building of new models. Dynamic models, in particular, could provide interesting insights into interrelationships and possible future developments. An in-depth analysis of the third-order effects will also be important in order to quantitatively assess these effects in an appropriate way.

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