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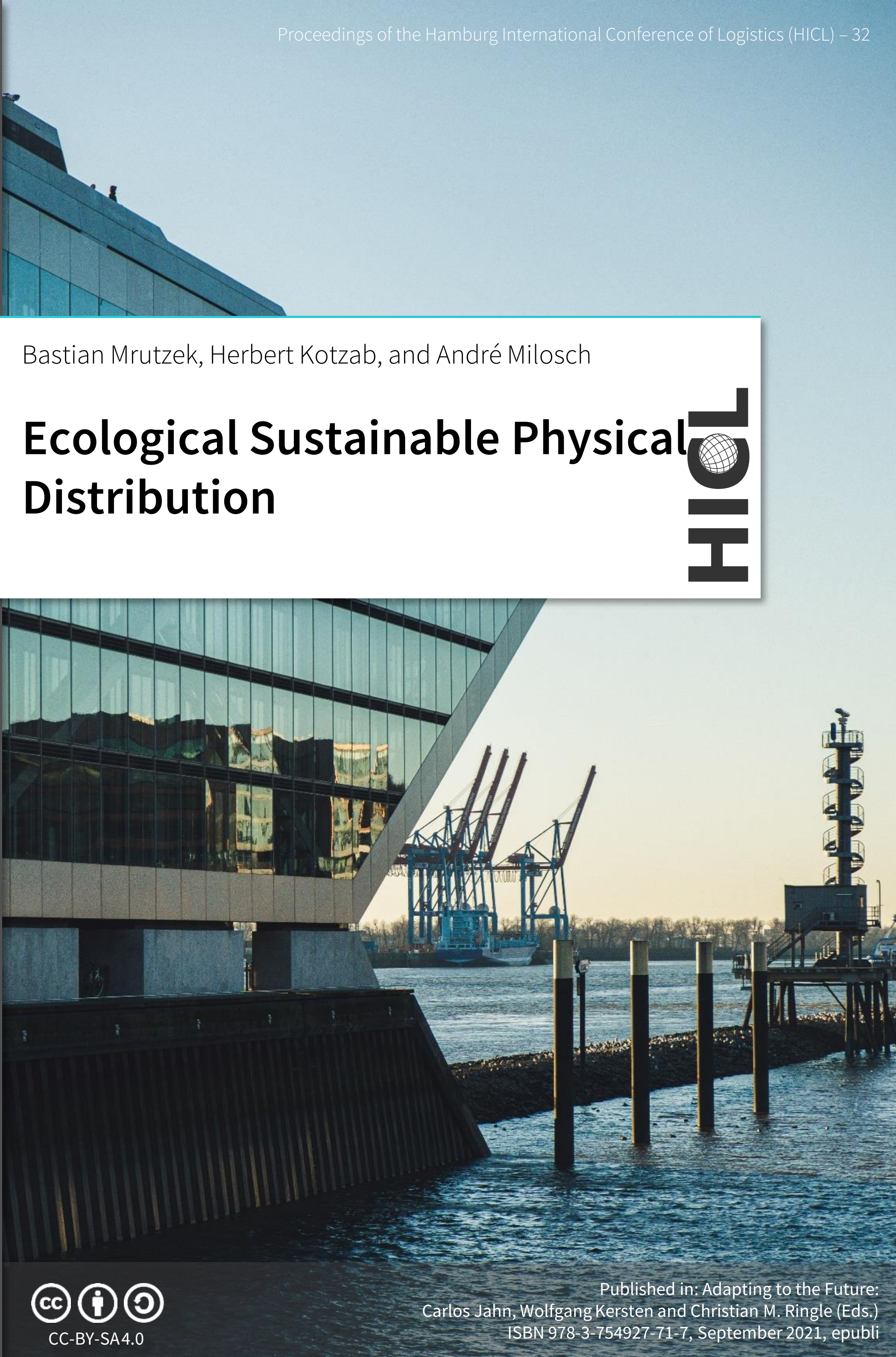

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Ecological Sustainable Physical Distribution

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Ecological Sustainable Physical Distribution

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Purpose: *Increasing online retailing leads to increased transportation processes on individual levels, which is impacting the environment negatively. Consequently, logistics needs ecological sustainable concepts to reduce its anthropogenic emissions, especially in physical distribution. The paper identifies such solutions, which avoid, shift and reduce such emissions and hence improve the environmental impact of logistics.*

Methodology: *For this study, the paper examines 28 relevant papers out of a sample of 219 contributions, with a content-based qualitative literature analysis by applying the methodology suggested by Fink (2010).*

Findings: *Following the fundamental notions of green logistics as proposed by Wittenbrink (2015), the paper identifies various sustainable concepts, which were condensed into a framework of ecological sustainable physical distribution. The overall goals refer to the protection of the atmosphere, decreasing dependence on fossil fuels and conservation of biodiversity. Drivers of such a concept of ecological sustainable physical distribution include horizontal cooperation to avoid, the use of resource-saving transportation means to shift, fleet management and utilisation of alternative fuels to reduce emissions.*

Originality: *This work applies generic strategies for dealing with emissions to the field of physical distribution and presents a first conceptual frame of reference that can be used to implement ecological sustainable notions to the field of physical distribution.*

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1 Introduction

Increasing online retailing and growing numbers of individual deliveries of goods lead to increased transportation processes and this is negatively impacting the environment (Crainic, Ricciardi and Storchi, 2004; de Mello Bandeira et al., 2019). A representative survey by DS Smith found out that the covid-19 pandemic and the restrictions imposed are further catalysts for online product purchases (Röhrle, 2020), which will lead to even more home deliveries. This final stretch to the end consumer – also known as the so-called last mile (Brabänder, 2020) – requires many individual transport routes, which not only cause high transport costs, but also impact the environment negatively (Liu, Wang and Susilo, 2019).

The transportation function is hereby taken over by courier, express and parcel (CEP) service providers (Brabänder, 2020), who use mostly diesel-powered vehicles (Destatis, 2020; Kords, 2020) and this fossil non-regenerative fuel releases the greenhouse gas carbon dioxide (CO2) when burned and consequently impacts negatively to the climate change (Brickwedde, 2010; Merker and Teichmann, 2018; Pompl, 2019). In Germany, the transport sector accounted for 19 % of the emissions caused in 2018 (BMU, 2019a) and the share of emissions caused by diesel trucks was 73 % (BMU, 2016).

The use of fuels from renewable energies is seen as an opportunity. Currently, it accounts for the smallest share in the transport sector in 2019 with 5.6 % of the total energy required. This shows that physical distribution has a lot of potentials to make a contribution to achieving climate targets and sustainability. In order to realise long-term climate improvements, sustainable changes in economic processes must also be made after the covid-19 crisis (Barbier and Burgess, 2020; D'Adamo and Rosa, 2020).

Thus, this paper focuses on the logistics sector and the need for ecological sustainable concepts, especially in the area of physical distribution. We seek to examine the following question by the means of qualitative literature: To what extent can concepts in physical distribution improve the use of natural resources with regard to ecological sustainability?

The remainder of the paper is the following: the conceptual frame of reference will be introduced in the next section, which is our basis for synthesising the literature. Afterwards, the methodological approach for gathering and analysing the literature will be explained and the subsequent section will present the results of our literature analysis in detail. The paper concludes with a discussion and reference to the research question as well as an outlook for the future.

2 Conceptual Frame of Reference

2.1 Defining Physical Distribution

Outbound logistics or physical distribution is that part of logistics that deals with the delivery of final products to ultimate customers (Gudehus and Kotzab, 2012). Due to the developments in e-commerce, the return of products may also be an important addition to physical distribution (Koether, 2014). Conventionally, e.g. in the fast-moving consumer goods industry, the structure of a distribution system includes multiple echelons between manufacturers and retail stores, where distribution centres are located and serve either as break-bulk and/or consolidation points (Pfohl, 2018).

Since e-commerce gains more importance, distribution systems are expanding and include the last mile, which is the delivery of orders to the homes of the ultimate customers (= end-users) (Koether, 2014). Contrary to traditional distribution systems, where heavy goods vehicles are used for transportation, the last mile logistics is served by courier and express service providers who use smaller vehicles (BIEK, 2020).

Another important development within physical distribution relates to the increasing urbanisation for which specific city logistics solutions are developed (Rodrigue, Notteboom and Shaw, 2013). The overall goal of city logistics is the reduction of inner-city traffic (Wolpert, 2013).

2.2 Defining Sustainability for Physical Distribution

The major ecological targets are the protection of the atmosphere, decreasing the dependence on fossil fuels and preserving biodiversity. According to Hardtke and Prehn (2001), sustainability is defined in this paper as meeting the needs of present generations without depriving future generations of a way to meet their own needs on an equal basis. Furthermore, the concept of sustainability is typically divided into the three sub-areas of ecological, social and economic sustainability (Elkington, 2013). For the purpose of this paper, we focus solely on ecological sustainability and follow the notions of Hauff (2019, p.110), who defines it as "the preservation or improvement of ecological systems or the ecological capital stock". This is also due within the field of physical distribution, where concepts are needed that improve the use of natural resources there.

Natural resources can be split into regenerative and non-regenerative natural resources. Non-regenerative natural resources refer to raw materials that are not recoverable. These are also known as fossil fuels and are, for example, petroleum, ores, coal and minerals (Wacker and Blank, 2016). As non-renewable raw materials are finite, they must be replaced by alternatives to ensure the security of supply (Brickwedde, 2010). Renewable energy sources such as sun, wind, hydropower or geothermal energy are considered alternative energies. According to the current state of technology, they are regenerative or almost inexhaustible (Bundesregierung, 2021).

2.3 The Concept of Green Logistics

Piecyk et al. (2015) understand green logistics as the inclusion of environmental effects when it comes to the execution of logistics processes. In our paper, we follow the notions of Wittenbrink (2015) who sees reduction, avoidance and shift as the main principles of green logistics, which aims at lowering emissions and a reduced use of natural resources (see Figure 1).

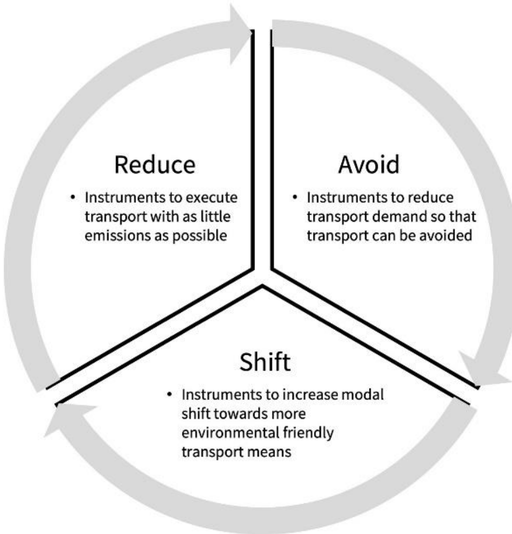

Figure 1: Conceptual Frame of Reference for Ecological Sustainable Physical Distribution (adapted from Wittenbrink, (2015))

In the next step, we apply this framework to the field of sustainable physical distribution and aim to identify specific measures within different aspects of our framework.

3 Methodology

We employ a qualitative literature analysis in seven steps as suggested by Fink (2010), which are extensively described in subsequent Figure 2.

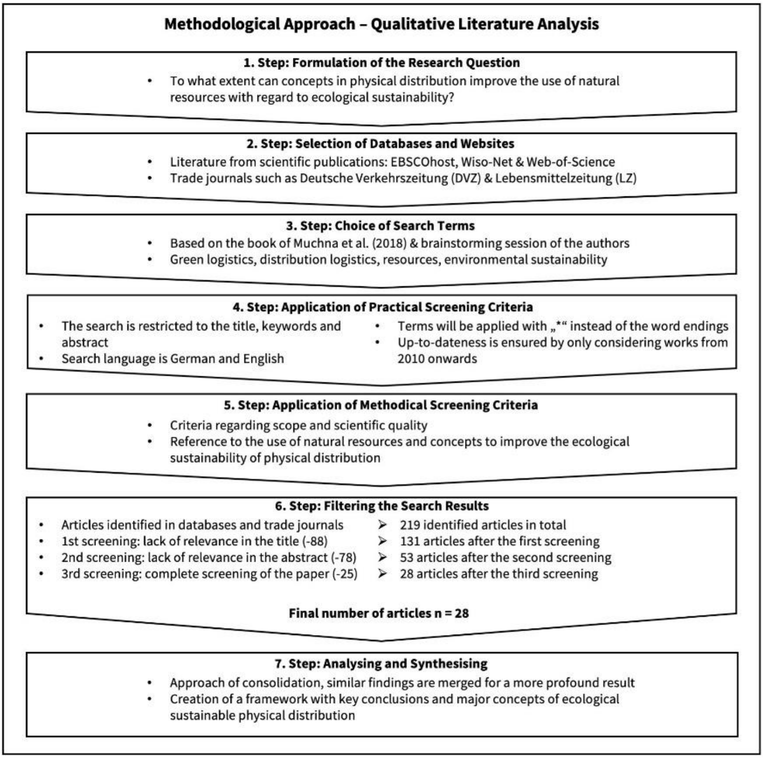

Figure 2: Qualitative Literature Analysis Following the Seven Steps of Fink (2010)

Next, we specify the framework of Figure 1 with the key conclusions from our analysis.

4 Findings

4.1 Avoidance

Avoidance turns out to be the most effective way to conserve natural resources and thus evade emissions. Adequate avoidance strategies were found in the area of horizontal cooperation, which refers to concerted entrepreneurial practices between companies that operate at the same market level (European Union, 2001) intending to save transport routes with the help of various mechanisms.

One mechanism that supports this concept relates to shared resources. These are resources that are made available to cooperating competitors across companies for joint use (Becker and Stern, 2016). If companies do not use the same system, online platforms allow providers to announce their freeloading capacities, schedules and means of transport for upcoming tours and to join forces with other companies (Schneider, 2020). In the area of road freight transport, additional free capacities can be made available by the use of which is made possible via so-called groupage systems, in which transport capacities are shared and bundled through the consolidation of orders from cooperation partners (Kopfer, Schönberger and Bloos, 2010).

The advantages of this type of cooperation are fewer transport routes as the utilisation of capacities is maximised. A reduced number of journeys also reduce wear and tear on the vehicles, lower emissions and less congestion and accidents due to the lower utilisation of the road network. By using the same IT, some express service providers can work 24 hours a day and offer collection and delivery at any time, which means that orders can be processed in a much shorter time (Cremer, 2020).

However, cooperation also has disadvantages. A survey by Cruijssen et al. (2007) showed that there are reasons why cooperation rarely takes place in reality. On the one hand, when contracting out, companies face uncertain planning where the quality of the execution is not known because the cooperation partners have different quality requirements. On the other hand, the selection of partners is a challenge for small and medium-sized enterprises, as the analysis of potential partners is often time-consuming and cost-intensive. The specific distribution of profits also presents itself as an additional problem, as does a lack of trust regarding the provision of sensitive information (Reimann, 2020).

4.2 Shift

In order to effectively conserve resources, the shift primarily requires the use of less environmentally damaging means of transport (Wittenbrink, 2015). Trucks are the most frequently used means of transport for the distribution of goods (BMU, 2016; Kords, 2020). Consequently, shift strategies refer to replacing truck transport with other resource-saving means of transport.

One way is the use of cargo bikes, which release no emissions and consume few to no resources. Rudolph and Gruber (2017) show that cargo bikes have cost advantages over a small delivery vehicle. The purchase, as well as the annual costs for maintenance, taxes, insurance, are low. Other advantages refer to the avoidance of traffic jams via bicycle lanes and the independence from environmental zones. In urban delivery areas within a radius of 5 kilometres, journey times with cargo bikes are the same or in some cases shorter in relation to motorised vehicles. Furthermore, cargo bikes are silent transport means and bike riders do not need a driving licence (Schneller, 2020). Disadvantages refer to lost time advantages, if distances are long. Reorganising logistics hubs would be a costly factor, with high complexity and low profitability (Rudolph and Gruber, 2017). Due to their size, their capacities are also limited, which can lead to the driver having to return to the depot several times and thus losing his time advantage within the city.

In addition, rail freight transport offers a modal shift opportunity. In Germany, 90 % of rail freight transport is electric and is considered climate-friendly due to recuperation (BMVI, 2017; DB AG, 2020). Nevertheless, rail freight transport has a load factor of 57.3 % and could contribute to the ecological sustainability of the logistics sector through a higher load factor as well as an expansion of rail freight transport (Knörr, 2019).

A decisive advantage of rail freight transport, in addition to the resource-saving drive, is the good plannability and reliability. As freight trains are often operated at night and can be easily integrated into the timetable of passenger rail transport, rail freight transport, in contrast to road freight transport, is considered to be less susceptible to disruptions.

Besides, the land consumption of rail as a mode of transport is smaller in terms of area than that of the trunk road network concerning transport performance (Logistikbranche.net, 2020). However, rising warehousing costs are also fuelling the trend towards ever smaller consignment sizes, as a result of which general cargo and express goods are mainly shipped by truck (Wittenbrink, 2015). Bretzke (2014) also describes the transport of goods by rail, for distances of less than 300 kilometres, as slower and more costly than by truck, which is why this transport option is considered unprofitable in these conditions.

Another shift option is inland waterway transport, where an inland freight ship with a loading capacity of 3000 tonnes can replace up to 150 trucks (BMVI, 2019). Particularly heavy and bulky goods can be transported suitably via waterways (BDB, 2020). The share of inland navigation in overall German freight transport was 6.7 % in 2018 and offers a lot of untapped potentials (Keller, 2020). A possible concept for better use of inland navigation is presented by the research project "DeConTrans - Innovative Concepts for Decentralised Container Transport by Waterway", which aims to make the West German canal network usable for regional supply with goods for daily needs (Granzow, 2020). The project envisages the use of small environmentally friendly ship units, the so-called regio-carriers, which can reach secondary routes and canals as well as smaller terminals and transhipment points. The Regio-carriers consist of electrically driven barges that can be coupled and, due to their low height, fit under all bridges without lifting them. Former coal jetties are reactivated and converted into micro depots, from where the goods are distributed over the last mile. However, there are also disadvantages or obstacles in inland waterway transport. On the one hand, the dependencies on environmental influences and, on the other, the cost-intensive expansion and the impairment of nature (Koether, 2014).

4.3 Reduction

After avoidance and shifting, reduction is the last measure to enable resource-efficient distribution logistics. Reduction in physical distribution is primarily aimed at emissions and reduced consumption of natural resources. Since there is a correlation between fuel consumption and CO2 emissions, approaches to reduce fuel consumption are of particular interest (Wittenbrink, 2015). Thus, we focus on fleet management and alternative fuels.

Fleet management serves to optimise logistics processes within the existing vehicle fleet and to monitor and control the flow of goods (Ubeda, Arcelus and Faulin, 2011). This includes all activities that contribute to making the delivery of goods more efficient. This includes telematic systems which, due to digital developments, have hardware and software that optimise logistical processes. The term telematics is a combination of the terms telecommunications and information technology, which refers to the collection, processing, transmission and exchange of transport-related data and information (Bäumler, 2019; Hamidi, Lajqi and Hamidi, 2016; Melheritz, 2013). The data obtained is real-time data for route and route planning or traffic situations, so that unnecessary transports are avoided and thus less fuel is consumed (Eikona AG, 2020; Günthner, 2012). Furthermore, platooning, in which several networked trucks drive close to each other in a convoy, can optimise traffic flow, reduce energy consumption and thus ensure more ecological sustainable physical distribution (BMVI, 2020; eCoMove, 2020). Safety-relevant information, such as a collision warning or the warning of an approaching rescue vehicle, can cause congestion of the radio channel and thus unreliable information transmission during high traffic volumes. Another disadvantage of telematic systems is the high costs for the acquisition and the generation change or the overhaul of the hardware and software of the systems. Also, there are costs for staff training, which is necessary to sensitise employees to new technologies (Waßmann, 2017).

Even non-digital measures can lead to fuel and thus resource savings. Up to one-third of a truck's fuel consumption is related to air resistance. Many manufacturers offer aerodynamic packages which, at a price of about €2,500 to €4,500, result in fuel savings of about 5 %. At a price of 1.15 €/l diesel, this corresponds to pay back after 19 months. In addition, this corresponds to a reduction of over 5,000 kg CO2 per year per vehicle (Wittenbrink, 2013). Limiting the maximum speed from 90 Km/h to 80 km/h can also lead to a diesel saving of about 12 % with a small additional expenditure of time (Wittenbrink, 2014).

The use of alternative fuels for fossil fuels to reduce emissions represents one of the greatest aspects of environmental protection. In the following, the electric drive, hydrogen and biodiesel are presented as alternative fuels.

An electric drive can be installed in a vehicle in two ways. On the one hand, a vehicle can be operated purely electrically via a battery, on the other hand as a hybrid, in which the battery is combined with an internal combustion engine. On average, the installed lithium-ion battery has an energy output of about 140 watt-hours (Wh) per kilogramme (Henne, 2020). The electric delivery vehicle StreetScooter (model: Work L), which is used by Deutsche Post, has a battery capacity of 40-kilowatt hours (kWh) with a range of around 187 km (StreetScooter, 2020). The consumption and thus the costs for the fuel can be derived from this. With consumption of 21.39 kWh per 100 km, at an electricity price of 29.88 cents/kWh, electricity costs amount to 6.39 €/100 km (BMWi, 2020). Comparing the fuel consumption of a diesel-powered Ford Transit (model: 2.0 TDCI Ford EcoBlue 136 kW) with a similar load volume, this is 6.8 litres of diesel, which at an average diesel price in 2019 of around €1.27, results in fuel costs of €8.64/100 km (Ford, 2020; Hohmann, 2020).

Hybrid vehicles can also save about 20 % fuel, depending on the model (Wittenbrink, 2014). UPS reduced road fleet fuel consumption by up to 28.9 % through hybrid vehicles (Dey, LaGuardia and Srinivasan, 2011). In addition to saving energy costs during operation, electrically powered vehicles are quieter, causing fewer emissions such as noise (Dudenhöffer, 2013). But an electric drive also has disadvantages. For one thing, the charging time of the batteries is currently much longer than with refuelling, and for another, the life expectancy of lithium-ion batteries is given as 10 years on average (Henne, 2020; van Basshuysen, 2010).

In addition, the energy output of liquid fuel is 100 times higher, which is why purely electrically powered vehicles have a significantly shorter range than diesel-powered vehicles (Stegmaier, 2019). Another point of criticism is the emissions balance of the production of the batteries and the provision of electricity under the current conditions. According to the Federal Environment Agency, a compact-class passenger car as a purely electric vehicle causes 134 g of CO2 per vehicle kilometre over its entire service life, taking into account production, driving, maintenance, energy supply and disposal - in contrast, a diesel vehicle causes 159 g of CO2 per vehicle kilometre (BMU, 2019b).

Splitting water into oxygen and hydrogen using electricity produces alternative fuel hydrogen. When hydrogen is used as a propulsion system, it is filled into the vehicle's tank in liquid form and converted into kinetic energy via a combustion engine. Water is sufficiently available as a raw material for the production of hydrogen and is added back to the water cycle as a by-product of combustion (Iwan, Kijewska and Kijewski, 2014). Thus, there are no direct emissions from the use of hydrogen and only an electricity source is needed to convert water into hydrogen. Also, Germany has the best network of hydrogen filling stations in the world and produces green hydrogen in Schleswig-Holstein, among other places, which means that it does not have to be imported, resulting in less dependence and lower acquisition costs (Johanning, 2020; Landwehr, 2020). However, keeping hydrogen in liquid form requires cooling of -253°C, otherwise, the hydrogen heats up and returns to its gaseous state and is also highly explosive in combination with air (Iwan, Kijewska and Kijewski, 2014). Furthermore, the market price for a kilogram of hydrogen is €9.50, which is higher than the projected marketable price of €5.00, and the acquisition costs for hydrogen vehicles are currently three times higher than for a diesel-powered model (Johanning, 2020; Neeland, 2020).

An additional way to reduce emissions is to use biodiesel, which is produced from hydrogenated vegetable oils (Koch, 2012). The raw material used is oil obtained from soy or rapeseed (Figueroa et al., 2014). After multiple filtering and the addition of methanol, biodiesel is obtained, which is used as fuel in a mixture with fossil diesel (DBFZ, 2010). Production, processing and use have a 60 % lower carbon footprint than fossil fuels (Koch, 2012). Furthermore, biodiesel has good ignition properties and the high oxygen content prevents soot formation and minimises residues in the engine (VDB, 2020). However, the cultivation of soy and rapeseed has a negative impact on soil and groundwater due to the use of fertilisers and pesticides. Furthermore, the combustion of biodiesel produces higher nitrogen emissions than conventional diesel (Fraunhofer IVI, 2020).

4.4 Synthesis of Results and Discussion

The final illustration (Figure 3) shows the complete conceptual framework of ecological sustainable physical distribution. It includes the condensed and synthesised results of our analysis and includes the ecologically sustainable principles as outlined in Figure 1.

We expand it further by instruments and outcomes for an ecological sustainable physical distribution.

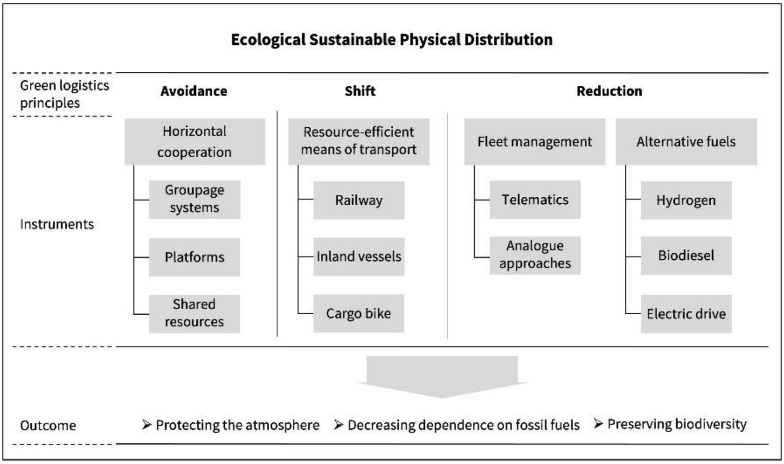

Figure 3: Ecological Sustainable Physical Distribution

Under optimal conditions, such as similar route planning, the same quality standards and a basis of trust, cooperation approaches are promising solutions as all participating companies can benefit from fewer emissions. However, many companies are not willing to work due to fierce competition. Thus, horizontal cooperation makes sense if all participants have equal rights and are willing to negotiate with each other at fair prices.

Resource-saving transport means should also be a sensible substitute for diesel-powered vehicles, so that, for example, the main leg of good shipments can be transported by inland waterway or rail, depending on the shipping point and destination. The pre-carriage and onward carriage, for example from the hub to the end consumer, involves smaller units of cargo and can be carried out over the last mile with the help of cargo bikes. If the use of trucks is unavoidable, investments in fleet modernisation can lead to ecological increases. An exact calculation of the amortisation of the measures is necessary to determine the individual improvements for the respective fleet. All companies should undertake small measures, such as the dismantling of air horns, which require no investment, as the improvement in aerodynamics leads to immediate fuel savings. Other investments in analogue and digital measures, can also lead to higher profitability and may not only make sense from an environmental point of view.

In regard to the research question, systems that have already been tested, such as telematics or the use of alternative fuels promise immediate improvements for the ecologically sustainable use of natural resources. As it stands today, electric propulsion is the most attractive ecological sustainable physical distribution option of alternative fuels, as the acquisition costs are lower than comparable hydrogen vehicles available on the market so far.

Equally attractive is the concept of the cargo bike, which can be used very variably and flexibly for last-mile deliveries and thus drive the reduction of diesel-powered trucks on the cost- and energy-intensive last section of physical distribution.

5 Conclusion and Research Outlook

This paper identified generic green logistics strategies for dealing with emissions to the field of physical distribution and presents a first conceptual framework for ecological sustainable physical distribution. In particular, the avoidance, shift and reduction of the use of diesel trucks in physical distribution as the largest emitter of carbon dioxide, has not yet been placed in this theoretical frame of reference, which can be used to implement ecological sustainable notions to the field of physical distribution.

It should be noted that this work has focused on concepts to improve environmental sustainability in the area of trucks used in physical distribution. In today's globalised world, aeroplanes and container ships are also used in large numbers for worldwide distribution. This area has not been dealt with in this work and thus represents ways to expand the conceptual model.

For this purpose, suitable concepts can be found and supplemented in other research fields. Furthermore, the authors focus exclusively on ecological sustainability. Aspects of economic and social sustainability are not primarily addressed and represent a future scope of research that can be investigated as a complement to this work.

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