VDI Zentrum Ressourceneffizienz

On behalf of:

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

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VDI ZRE Publications: Brief analysis no. 27

Resource efficiency in trade and logistics

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This brief analysis was developed on behalf of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection.

The brief analyses of VDI ZRE provide an overview of current developments in the field of resource efficiency in research and industrial practice. They each contain a compilation of relevant research results, new technologies and processes as well as best-practice examples. The brief analyses thus provide an introduction to selected areas of resource efficiency for a broad audience with business, research and administration background.

Editorial:

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AC	Alternating Current
AR	Augmented Reality
DIM	Demand Inventory Management
BIS	Business Intelligence System
DC	Direct Current
DCM	Demand Capacity Management
GLA	German Logistics Association
CACC	Cooperative Adaptive Cruise Control
CCU	Carbon Capture and Utilisation
CLFT	Connected Lightweight Future Truck
CSL	Council for Sustainable Logistics
CO_2	Carbon dioxide
$CO_{2\text{-eq}}$	Carbon dioxide equivalents
GAC	German Aerospace Center
RE	Renewable Energies
EnSO	Energy Saving Ordinance
ERP	Enterprise Resource Planning
Fraunhofer IML	Fraunhofer Institute for Material Flow and Logistics
TCS	Trade, Commerce, Services
ICT	Information and Communication technology
IoT	Internet of Things
CEP	Courier Express Package Service Provider

AI	Artificial Intelligence
kW	Kilowatt
kWp	Kilowatt peak (maximum power)
LCV	Long Combination Vehicle
LNG	Liquid Natural Gas
M2M	Machine to Machine
NFC	Near Field Communication
OEM	Original Equipment Manufacturer
PP	Polypropylene
PV	Photovoltaics
RFID	Radio Frequency Identification
SCM	Supply Chain Management
TWh	Terawatt hours
FEA	Federal Environmental Agency
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
AGE	Association of German Engineers
VDI ZRE	VDI Zentrum Ressourceneffizienz GmbH
GEA	German Engineering Association (Verband Deutscher Maschinen- und Anlagenbau e. V.)
VR	Virtual Reality
WMS	Warehouse Management System

1 INTRODUCTION

Logistical processes are of elementary importance in the economy in all branches and industries, whether for storage and goods distribution within the company (intralogistics) or for the exchange of goods with other companies or end customers (transport logistics and supply chain management). The retail and logistics sectors are among the highest-turnover industries in Germany and are therefore of enormous importance to the German economy. Overall, retail and logistics generated sales of approximately 2.35 trillion euros in Germany in 2017 (cf. 2.1).

Both the retail and logistics sectors consume large quantities of natural resources, especially raw materials and energy. The transport of goods plays a significant role in this, but so do other factors such as the construction and operation of retail and logistics properties, the storage and conveyor technology available there, and the production and use of a wide variety of packaging and loading aids.

The aim of this brief analysis is to provide companies in the retail and logistics sectors with suggestions for resource-efficient business process design. The strategies, measures and practical examples presented here are also intended to help tap additional potential in terms of resource efficiency.

According to VDI Guideline 4800 (Sheet 1) [1], resource efficiency refers to the ratio of a specific benefit or result to the resource input required to achieve it. Resource efficiency can be increased both by saving materials and by reducing energy requirements.

The scope of this analysis includes the supply chain elements shown in Figure 1. It includes logistical processes of manufacturing companies as well as wholesale and retail. In addition, the necessary transport processes as well as the real estate associated with the retail and logistics sector will be examined for resource efficiency potential. Overarching strategies and measures such as automation and digitisation complement the consideration of the two areas. Upstream processes such as raw material extraction and downstream processes after delivery to the customer are not considered. In order to be

[1] Cf. VDI 4800 sheet 1: 2016-02.

able to comprehensively assess measures with regard to resource efficiency, the effects on the entire life cycle of the modified product system play a decisive role.[2]

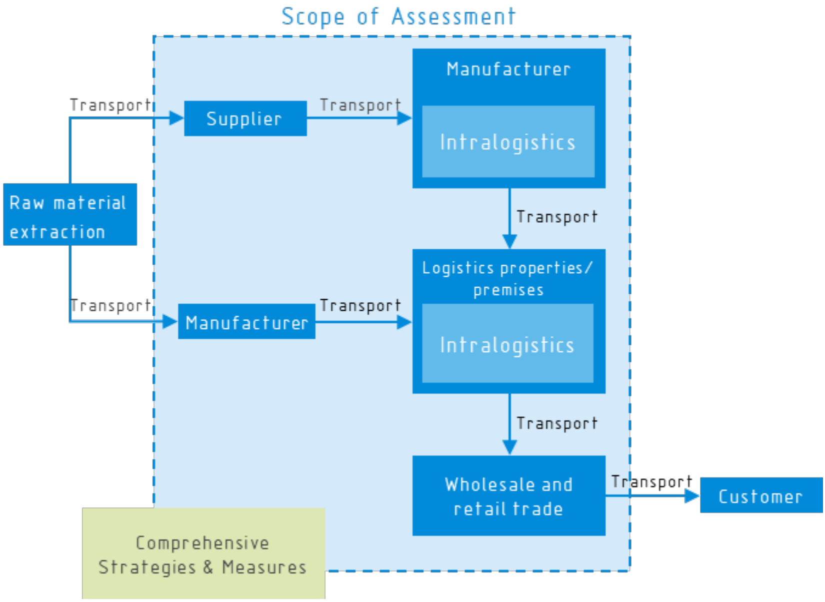

Figure 1: Framework of the brief analysis

The introductory chapter first provides an overview of the economic importance of trade and logistics in Germany (chapter 2.1). Current trends and anticipated developments are then highlighted in order to be able to assess which topics will become more relevant in the future for the scope of investigation considered here (chapter 2.2). So-called green logistics plays a crucial role in this process and is therefore dealt with in a separate chapter (chapter 2.3).

Chapters 3, 4 and 5 deal with the core of the brief analysis. Here, a selection of concrete resource efficiency measures for retail and logistics are highlighted and their potential discussed. Concrete examples from practice (high-

[2] Further information: VDI 4800 sheet 1: 2016-02.

lighted in blue) are intended to show successful approaches and provide impetus for your own paths. The main part is divided into three sections: intralogistics/warehousing (chapter 3), transportation (chapter 4) and packaging (chapter 5). The focus is always on aspects where there is still considerable potential for increasing resource efficiency.

Automation and digitisation have become indispensable in today's industry and also find their place in this brief analysis. In addition, cooperation between companies, adjustments to the vehicle fleet and efficient route planning can help to conserve resources; these are presented along with other topics.

2 TRADE AND LOGISTICS

The following section provides an overview of the economic significance of trade and logistics and highlights important developments and trends. Finally, the topic of green logistics, which has now become an established term and will become increasingly important, will be discussed.

2.1 Classification of trade and logistics

Trade is generally understood as the exchange of goods and services. Which companies are involved is initially irrelevant. If companies purchase goods from other market participants that they do not usually process themselves and sell them on to third parties, this is referred to as trading.[3] In the present brief analysis, the term “trade” is to be understood predominantly as the economic sectors of retail and wholesale trade.

Logistics is defined by the German Logistics Association (BVL) as follows: “Logistics is the holistic planning, management, coordination, execution and control of all internal and cross-company flows of information and goods. Supply chain management (SCM), the intelligent planning and control of value chains, are used synonymously.”[4]

Economic importance of trade

In terms of sales, retail in Germany is one of the largest sectors of the economy (in 2017) with approximately 2.09 trillion euros. At the same time, around 6.4 million people are employed in the German retail sector.[5] The total turnover of the German trade already shows the enormous importance for the German economy. For comparison: The construction sector generated sales of around 260 billion euros in 2017, employing around 2.3 million people.[6]

Depending on how tasks are distributed between producers, wholesalers, and retailers, five different supply chain types can be identified in the retail

[3] Cf. Schneider, W. (2019).
[4] German Logistics Association (2019).
[5] Cf. Federal Statistical Office (2020).
[6] Cf. Federal Statistical Office (2019).

industry (see Figure 2). Since the large retail groups in particular are increasingly ordering directly from the producer, the multi-stage structure is being used less and less. As a result of increasing Internet trade, direct sales are gaining strongly in importance. In food retailing, the extent of direct selling is somewhat lower than in other sectors. Sales via so-called flagship stores are also steadily increasing. This is the name given to sales outlets operated directly by the manufacturer. Established online retailers are also already opening such stores, some as self-service stores in major cities. Vertical integration involves the distribution of private brands produced for the retail companies.[7]

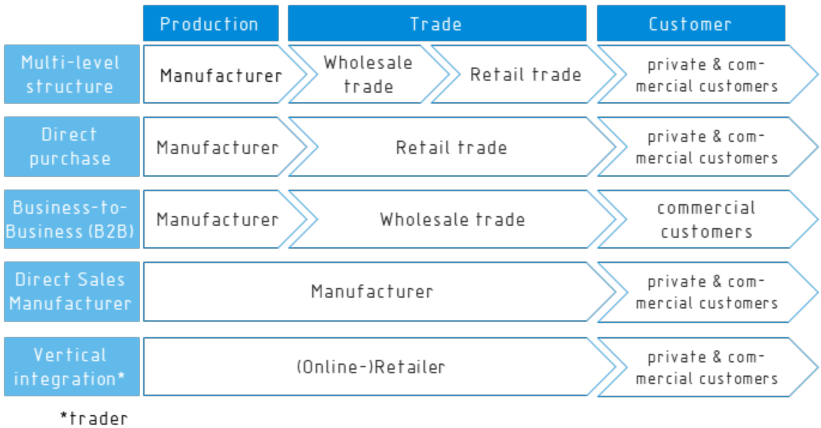

Figure 2: Supply chain types in retail[8].

Logistics, which is also referred to as trade logistics, is of particular importance in the retail sector. This can be divided primarily into the areas of procurement logistics, warehouse logistics, distribution logistics and store logistics. The different areas of activity result in particular from the diversity of trading companies and their desired flows of goods. Value-added steps such as quality control, assembly or just-in-time delivery can also be part of the task of logistics companies. In retail, cross-sectional supply chain man-

[7] Cf. Seeck, S.; Groß, W.; Bötel, M. and Herrmannsdörfer, M. (2014), p. 10.
[8] Based on Seeck, S.; Groß, W.; Bötel, M. and Herrmannsdörfer, M. (2014), p. 9.

agement with end-to-end supply chains and collaborative planning, forecasting and replenishment (CPFR) is becoming increasingly important – not least due to increasing digitisation and the associated information logistics. The wide range of possible goods poses special challenges for logistics (e.g. bulky goods, frozen goods, etc.). Logistics must continue to ensure that it functions reliably even in a constantly changing environment with many variables and that it maintains the shortest possible delivery times. A functioning logistics industry is of indispensable value to the trade.[9]

The enormous relevance of trade logistics becomes clear when looking at costs. In 2011, the total costs for German trade logistics amounted to an estimated 64 billion euros, or around 30% of the total logistics costs of 223 billion euros in Germany. Logistics in the automotive industry accounted for only 11% of total costs in the same year.[10]

In the strategic orientation of retail companies, however, greater importance is often attached to other areas such as purchasing or sales. In this context, logistics can assume a business-critical function if comprehensive supply chain management is operated within the company. The closest possible cooperation between logistics and other areas such as purchasing [11]and sales is then of particular advantage to the company.[12]

Economic importance of logistics

With over three million employees and annual sales of approximately 279 billion euros, the logistics sector was the third largest economic sector in Germany in 2019. Only the automotive industry and the retail sector have even higher sales. In 2017, transport and storage as well as the management of goods and information flows in logistics generated total sales of approximately 267 billion euros. The value of the entire European logistics market was put at 1,050 billion euros in 2017. Germany accounted for around a quarter of this. Figure 3 shows the temporal development of recent years regarding the turnover in logistics in Germany. There, it can be clearly seen

[9] Cf. Seeck, S.; Groß, W.; Bötel, M. and Herrmannsdörfer, M. (2014), p. 5.
[10] Cf. Seeck, S.; Groß, W.; Bötel, M. and Herrmannsdörfer, M. (2014), p. 16.
[11] Cf. Seeck, S.; Groß, W.; Bötel, M. and Herrmannsdörfer, M. (2014).
[12] Cf. Seeck, S.; Groß, W.; Bötel, M. and Herrmannsdörfer, M. (2014), p. 16.

that both values were subject to steady growth in the period from 2015 to 2019.[13]

But not all processes that take place in logistics are immediately recognisable as such. In addition to the transport of goods, this also includes the planning, control and implementation of intralogistics services, i.e. processes within the company. Slightly more than half of the logistics processes take place in this area. The majority of the approximately 60,000 companies that provide logistics services in Germany are classified as small and medium-sized enterprises (SMEs). Due to the high number of employees and the importance of the supply function alone, logistics is a driving force for Germany as an economic factor. In addition, highly efficient logistics ensure that German companies can continue to produce profitably at home. Moreover, logistics enables goods to be exported effectively and efficiently, thus driving a flourishing foreign trade.[15]

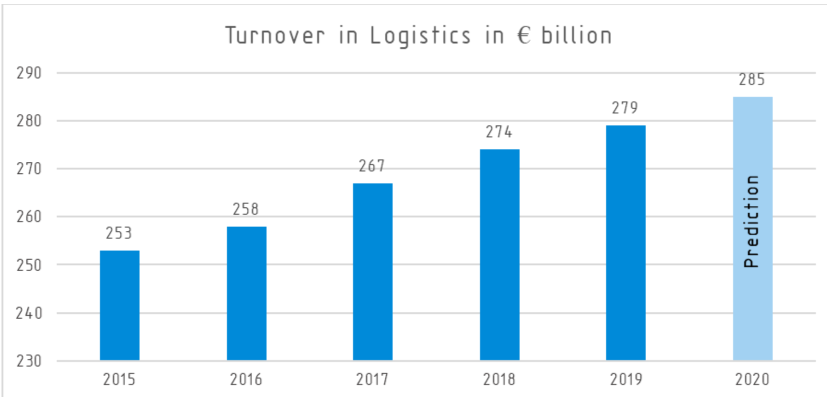

Figure 3: Revenue development in logistics in Germany (as of January 2020)[14]

[13] Cf. German Logistics Association (2020).
[14] Cf. German Logistics Association (2020).
[15] Cf. German Logistics Association (2020).

2.2 Developments and trends of trade and logistics

New requirements create need for action

External factors can have a significant impact on the development of retail and retail logistics. Currently, digitisation with the accompanying fast-growing online trade and the increased use of the mobile Internet is seen as the main challenge for retail and logistics. Added to this is demographic change, with changes in terms of customer demand and possible staff shortages.[16]

For the year 2021, the sales volume in German online retail is estimated at around 80 billion euros.[18] This would represent a fourfold increase over 2010 (cf. Figure 4). The sales volume for electronic products alone is then expected to reach 23 billion euros. Online retailing has thus recorded higher growth rates than all other sectors. In order to meet the demand for products in demand, logistics in its role as a service provider is becoming more important than ever.[19]

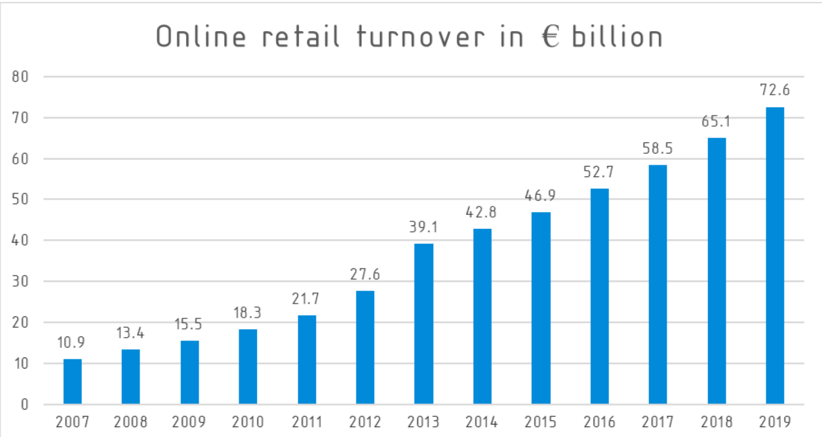

Figure 4: Annual sales volume in online retailing in Germany[17]

[16] Cf. KPMG AG Wirtschaftsprüfungsgesellschaft (2016), p. 13 et seqq.
[17] Based on Rabe, L. (2020).
[18] Cf. KOMSA Kommunikation Sachsen AG (2018), o. 5.
[19] Cf. KOMSA Kommunikation Sachsen AG (2018), o. 5.

New concepts are urgently needed to meet changing requirements. This is also true in view of rising consumer demands and increasing pressure from rising costs. Not to be neglected is the desire for sustainability, which is finding its way more and more into retail and logistics. To meet future challenges, it is critical to make adaptive changes early on and seize available opportunities through innovative capabilities.[20]

Logistics experts already emphasised the relevance of the trend toward green logistics as a component of sustainable corporate management in a 2014 study.[21] The interviews with the experts clearly showed that the economic feasibility of the measures is rated as a decisive success criterion for sustainable logistics and resource conservation. In a study from 2013, it was already possible to show measures that are of ecological and at the same time economic benefit for logistics.[22] However, measures are also described that, while very beneficial ecologically, are associated with significant additional costs for companies. Rising logistics costs, primarily due to external factors, and the resulting cost pressure were described by experts as a trend.[23] Respondents also underscored the increasing problems posed by demographic change.

In 2017, a study[24] identified 15 trends that will influence the logistics market in the future. Accordingly, cost pressure, individualisation and the complexity of logistics processes will increase in particular. The call for transparency in the value chain as well as for stronger networking of trade and logistics processes is also shown as a current development. The methodologically identical study was already conducted in 2012. When comparing the results from 2012 and 2017, it is clear that the trend toward sustainability has gained considerable relevance. An outstanding role is attributed to the digitisation of business processes.[25]

[20] Cf. Seeck, S.; Groß, W.; Bötel, M. and Herrmannsdörfer, M. (2014), p. 5.
[21] Cf. Seeck, S.; Groß, W.; Bötel, M. and Herrmannsdörfer, M. (2014), p. 33 et seq.
[22] Cf. Gross, W.; Zesch, F.; Gelau, T.; Hayden, C.; Bötel, M. and Brock, M. (2013).
[23] Cf. Seeck, S.; Groß, W.; Bötel, M. and Herrmannsdörfer, M. (2014), p. 33 et seq.
[24] Cf. Kersten, W.; Seiter, M.; See, B. von; Hackius, N. and Maurer, T. (2017), p. 8.
[25] Cf. Kersten, W.; Seiter, M.; See, B. von; Hackius, N. and Maurer, T. (2017), p. 8.

Digitisation in logistics

In the field of logistics and supply chain management, enterprise resource planning (ERP) systems and warehouse management systems (WMS) are currently the most widespread. Currently, they are also considered to be of the highest importance in the field of management systems.[26]

In the coming years, predictive analytics, mobile access to data, and supply chain monitoring using sensors will play an increasing role. The mentioned concepts and techniques can be optimally combined and complement each other. Predictive analysis in particular offers a high potential for saving resources in practice through process optimisation (for example, through intelligent, cross-company transport cooperation) (see also chapter 4.3). New technologies are currently being developed that have the potential to significantly change logistics and supply chain management as they become technologically mature. These include, in particular, drones, augmented reality and blockchain.[27]

2.3 Green Logistics

The aim of so-called green logistics is to enable logistics companies to act sustainably by realising both economic and ecological efficiency measures. By aligning and adapting corporate processes accordingly, environmentally sound and resource-efficient logistics processes are to be created.[28]

As defined by Deckert & Fröhlich (2014), Green Logistics refers to “the alignment of logistics functions with the goals of environmental sustainability. The goals here are resource conservation, i.e. improved resource efficiency, and environmental sustainability, i.e. reduced impact of emissions.” The functions of logistics are divided by the authors into storage, transport and packaging.[29]

The topic of environmentally friendly logistics services is attracting increasing attention from business and the public. In the logistics sector, this area

[26] Cf. Kersten, W.; Seiter, M.; See, B. von; Hackius, N. and Maurer, T. (2017), p. 8.
[27] Cf. Kersten, W.; Seiter, M.; See, B. von; Hackius, N. and Maurer, T. (2017), p. 8.
[28] Cf. Schmidt S. (2019), p. 227 et seqq.
[29] Cf. Deckert, C. and Fröhlich, C. (2014), p. 14.

is seen as one of the most important future challenges. A planned, environmentally friendly orientation of logistics services also eliminates the need to purchase CO_2 certificates, thus reducing costs. Aiming to implement the principles of green logistics, open-mindedness and a willingness to cooperate are essential prerequisites. Stakeholders from all stages of the value chain should work together on this, from raw material extraction to recycling. In addition to large companies, SMEs are also particularly challenged, as they account for a large share of value creation in Germany. To make the German logistics industry environmentally friendly and sustainable, a broad awareness of the issue is essential. The willingness to bear the effort and possible costs of measures is ultimately crucial for a successful implementation.[30]

Possible starting points are offered by sustainable transport, warehouse and packaging management. In the area of transport management, the number of transports, transport volumes and transport damage can be reduced to make logistics more environmentally friendly. Sustainable warehouse management offers opportunities for environmentally friendly storage and reduction of warehouse space. Sustainable packaging management measures can save packaging materials and increase recycling shares. Further possibilities for individual areas of green logistics are shown in Figure 5.[31]

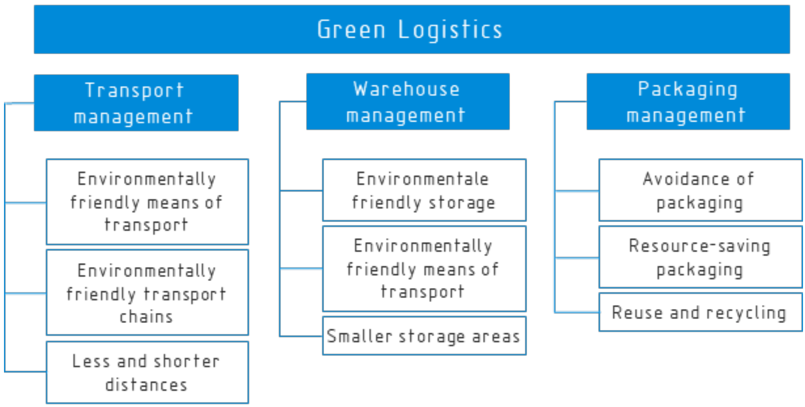

Figure 5: Framework conditions of green logistics[32]

[30] Cf. Schmidt S. (2019), p. 227 et seqq.
[31] Cf. Deckert, C. and Fröhlich, C. (2014), p. 13.
[32] Based on Deckert, C. and Fröhlich, C. (2014), p. 15.

The following section (chapter 3) presents the potential for increasing resource efficiency in logistics and retail.

Measures already in practice as well as trends and visions for the future are highlighted. Practical examples (in blue boxes) give impulses for the implementation of own measures and show already existing possibilities.

3 RESOURCE EFFICIENCY IN INTRALOGISTICS AND WAREHOUSING

According to the VDMA definition, intralogistics is "the organisation, control, implementation and optimisation of the internal flow of materials, the flow of information and the handling of goods in industry, commerce and public institutions"[33]. The essential elements of modern warehousing are the planning and design of intralogistics processes, the selection of conveyor, storage, handling and sensor technology, ensuring a proper flow of information, and the optimal control of system components.[34]

3.1 Efficient conveyor technology

Conveyor systems are used in various areas of logistics. These include, for example, systems for storing, picking, sorting and distributing goods, as well as conveyor systems in packaging technology and handling processes.[35]

The choice of the conveyor drive of equipment is of particular importance. Approx. 67% of industrial electricity in Germany is consumed by electric drives.[36] The use of energy-efficient motors not only requires less electricity and thus protects the environment. Costs can also be reduced, since in addition to maintenance costs, energy costs during the operating period play a major role in life cycle costs. Acquisition costs are less of an issue.[35]

The efficiency of conveyor technology can be improved by (among others):

(a) Use of high-efficiency electric motors (for certain applications)

(b) Minimisation of friction losses within the conveyor system

(c) Use of synchronous drives, spur bevel gearboxes and frequency converters

(d) Adjustment of conveying speed and reduction of peak power of the plant

[33] Cf. German Engineering Association (Verband Deutscher Maschinen- und Anlagenbau e.V.) (2020).
[34] Cf. Thomas, S. (2013).
[35] Cf. Osnabrück University of Applied Sciences (2011), p. 32.
[36] Cf. Bavarian State Ministry for the Environment and Health (2010), p. 3.

Other measures, which will not be discussed in detail below, include lightweight construction in materials handling technology (especially for stacker cranes), recuperation of energy and feeding it back into the grid (if operationally possible) or intermediate storage in supercaps, DC link coupling of drives (recuperation of one drive is used for the energy requirements of another drive, e. g. lifting and trolley drive in the case of storage and retrieval equipment). e.g. lift and trolley drive in stacker crane), intelligent control of drives to exploit recuperation through DC link coupling, and the use of energy-efficient storage strategies taking into account isoenergetic storage compartments.[37, 38, 39, 40]

In Figure 6 typical efficiencies or coefficients of friction of components of a belt conveyor are shown. Based on the range of values, it can be seen in which components an increase in efficiency can be realised most effectively. The performance characteristics of the existing plants in the company can also serve as benchmarks for classifying the existing energy efficiency and identify any potential for improvement.

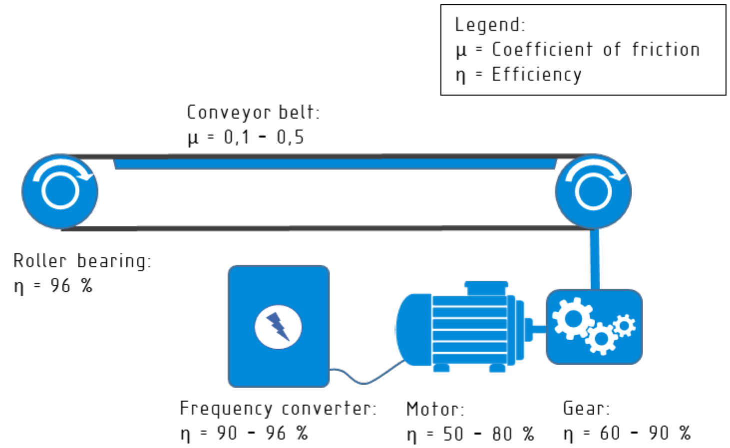

Figure 6: Typical efficiency characteristics of belt conveyor systems[41]

[37] Zadek, H. (16 April 2020).
[38] Cf. Schulz, R.; Monecke, J. and Zadek, H. (2012a).
[39] Cf. Schulz, R.; Monecke, J. and Zadek, H. (2012b).
[40] Cf. Siegel, A.; Turek, K.; Schmidt, T.; Schulz, R. and Zadek, H. (2013).
[41] Adapted from: Forbo Siegling GmbH (2019), p. 5.

(a) Use of high-efficiency electric motors

Electric motors are divided into DC and AC motors with regard to the supply voltage. The latter can be further divided into synchronous and asynchronous three-phase motors. In industry, low-voltage three-phase induction motors are the most common.[42]

In 2010, the IEC 60034-31:2010 standard was published and updated in 2014. Since then, electric motors in the power range from 0.12kW to 1000kW have been differentiated by the IEC 60034-30-1:2014 standard into efficiency classes IE1, IE2, IE3 and IE4, with the latter class having the highest efficiency. In the next update of the standard, the inclusion of a further efficiency class (IE5) is planned.[43]

The requirements for electric motors with regard to energy efficiency have been regulated in the ErP Implementing Regulation No. 640/2011/EC since 2011. Accordingly, since the beginning of 2015, asynchronous motors in the power class up to 5.5kW may only be used with efficiency class IE2 or higher. In the power class above 7.5kW, only motors with IE3 or better are still permitted. However, if these electric motors are equipped with speed control (e. g. by means of a frequency converter), the efficiency requirements from class IE2 are sufficient. The second part of this standard (IEC 60034-30-2) is currently being developed and is intended to regulate the efficiency requirements for electric motors supplied with variable voltage and frequency (for example, synchronous motors).[44]

In Table 1 some rated efficiency limits of electric motors depending on rated power are given as examples. The values there apply to a 4-pole machine. IEC 60034-2-1 specifies that the rated efficiency and efficiency classes refer to operation at an ambient temperature of 25 °C.[45]

[42] Cf. TU Berlin and TU Hamburg-Harburg (2014).
[43] Cf. elektro.net (2018).
[44] Cf. elektro.net (2018).
[45] Cf. elektro.net (2018).

Table 1: Comparison of selected limit values of 4-pole electric motors[46]

	Nominal efficiency limits in %			
Rated power in kW	IE1	IE2	IE3	IE4
0.55	70.0	77.1	80.8	83.9
1.10	75.0	81.4	84.1	87.2
3.00	81.5	85.5	87.7	90.4
30.00	90.7	92.3	93.6	94.9
200.00	94.0	95.1	96.0	96.7

The efficiency class of an electric motor can usually be found on the nameplate. The product documentation must also include further information on the efficiency of the motors.

If the (continuous) operation of materials-handling equipment, e. g. roller conveyors, is as constant as possible, the use of a few larger electric motors with a high rated power is usually more efficient than that of many smaller motors, since the larger motors usually have higher efficiencies.[47]

In conveyor technology with many start/stop movements and high acceleration values, energy-efficient drives are sometimes even worse in terms of energy than older energy classes, since (in contrast to continuous operation) they do not operate at their performance optimum.[48]

(b) Minimisation of friction losses within the conveyor system

Internal frictional forces in conveyor systems play a role in deflections, belt removal, and other components where friction occurs to a significant degree. By reducing the frictional resistance of components in a conveyor system, the electric motors require less power to reach the transport destination, which increases the energy efficiency of the system. In addition, the wear of the individual components is lower. This leads to an extension of the service life of the components and thus also to an extended service life of the conveyor systems. Since fewer components need to be replaced throughout the life cycle of the equipment, material efficiency is increased. Furthermore,

[46] Based on elektro.net (2018).
[47] Cf. Osnabrück University of Applied Sciences (2011), p. 32.
[48] Zadek, H. (16 April 2020).

maintenance and repair intervals are extended, which additionally saves costs.[49]

Special low friction conveyor[50]

An innovative conveyor belt from a German company offers energy savings of up to 50% on the overall system thanks to particularly low friction between the underside of the belt and the sliding table. The special coating of the barrel side fabric ensures that a sliding layer is created which is comparable in its effect to the permanent use of a dry lubricant. The reduced coefficient of friction on the running side reduces the required drive power in relation to a fixed conveying length.

(c) Use of synchronous drives, spur bevel gearboxes and frequency converters

Use of synchronous drives

Compared to asynchronous motors, synchronous motors usually have a higher electrical efficiency. Some manufacturers assume a 20% reduction in energy requirements. Although the investment costs are usually higher than those of asynchronous machines, the higher energy efficiency and lower maintenance requirements can quickly amortise the increased acquisition costs for synchronous motors. At the moment, synchronous motors are still used quite rarely for conveyor technology. If electricity prices continue to rise, this drive technology will become increasingly profitable.[51]

Use of helical bevel gear units

If lower or higher speeds are required than the synchronous motors can deliver, gearboxes are used. When the speed is reduced, the torque can thus be increased at the same time. However, gearboxes are subject to energetic transmission losses. Mechanical energy is converted into heat in the process. The losses are mainly due to friction, gearing and sealing between the motor

[49] Cf. Osnabrück University of Applied Sciences (2011), p. 33.
[50] Cf. Forbo Siegling GmbH (2019).
[51] Cf. Osnabrück University of Applied Sciences (2011), p. 33 et seqq.

and the gearbox. In general, the gearbox variants spur gear, bevel gear, helical bevel gear and worm gear are available. At around 95%, helical-bevel gear units have the highest efficiency. The least efficient, on the other hand, are the worm gear units with efficiencies between 50% and 90%.[52]

Use of frequency converters or inverters

In conveyor systems, cyclic acceleration and braking are often required instead of continuous motion. Energy losses can be significantly reduced if the electric drive motors are coupled with frequency converters. The converters ensure that only the energy actually required at the moment is made available to the motors. The speed and torque are controlled with virtually no loss. If no frequency control is applied, the motor must run at a higher rated power to ensure the power for the required starting torque. The frequency converter can increase the efficiency of the motor so that a lower rated power is required. Energy converters also offer the possibility of converting braking energy into electricity and feeding it back into the grid. Speed control not only ensures lower energy requirements, but also results in reduced component wear, which reduces maintenance costs. In addition, noise pollution is minimised. Frequency inverters can bring about efficiency improvements especially when the operating loads are speed-dependent. However, a certain minimum annual operating time should be ensured. If plants run at full load most of the time, frequency converters make little sense. In such a case, a highly efficient electric motor can be much more cost-effective than using frequency converters. If the conveyor systems are subject to high utilisation, the payback periods for frequency converters are nevertheless usually quite short. In some cases, they can be as short as a few months.[53] For highly utilised storage and retrieval machines, frequency converters are mostly worthwhile, as there are strong fluctuations in the operating loads and braking here.[54]

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[52] Cf. Osnabrück University of Applied Sciences (2011), p. 33 et seqq.
[53] Cf. Osnabrück University of Applied Sciences (2011), p. 33 et seqq.
[54] Zadek, H. (16 April 2020).

(d) Adjustment of conveying speed and reduction of peak power of the plant

To ensure efficient and resource-saving operation, it is advisable to base the required rated power of the motors on the existing power requirements of the plant. Often the annual peak load is used to determine the required power and an estimate is made for the development of this value for future years. It may be possible to reduce the peak day load by judiciously restructuring the energy-intensive processes so that a lower rated power is required for the motors from the outset. When the power demand fluctuates less, the plants can run at reduced speed and the highest power required can be lowered. These measures usually entail higher investment and control costs, but also lead to lower energy costs and extend the service life of the equipment.[55]

Intelligent DC link coupling of drives and energy-efficient bearing and operating strategies can save up to 50% of the energy that would otherwise be required, despite slightly reduced conveying speeds – without serious loss of throughput.[56, 57, 58]

3.2 Automation & digitisation in intralogistics

The Internet of Things in intralogistics

Large amounts of data are continuously generated in the course of intralogistic work processes. This applies in particular to the areas of incoming and outgoing goods, storage and retrieval, order picking, and returns management. Intralogistics processes can be executed much more efficiently if software systems such as ERP (Enterprise Resource Planning), WMS (Warehouse Management Systems) or databases are used and coupled with the intralogistics systems (materials handling equipment such as high-bay warehouses, pocket sorters, automated small parts warehouses). Decisive for the logistics industry are above all so-called execution systems, which flexibly schedule and control the operative processes. From production, these are

[55] Cf. Osnabrück University of Applied Sciences (2011), p. 34.
[56] Cf. Schulz, R.; Monecke, J. and Zadek, H. (2012a).
[57] Cf. Schulz, R.; Monecke, J. and Zadek, H. (2012b).
[58] Cf. Siegel, A.; Turek, K.; Schmidt, T.; Schulz, R. and Zadek, H. (2013).

known as Manufacturing Execution Systems (MES). In logistics, this is usually referred to as the logistics control centre (internal) or the supply chain execution system (external) coupled with supply chain event management. The latter is used for targeted controlling of the supply chains with an early warning system.[59]

In the age of digitisation, material flow analysis and optimisation are becoming increasingly important. The possibilities offered by digitisation have increased enormously, not least due to the further development and falling prices of sensor technology, while at the same time reducing the effort required for data acquisition.[60] The Internet of Things (IoT) represents an opportunity to address this challenge. With the help of the IoT, data and material flows can be made visible and easily understood. As a result of the improved process understanding, optimisation potentials in process handling can be identified and measures for process and machine optimisation can be better implemented. In intralogistics, products, components, machines, people and means of transport can be networked with each other, thereby making processes efficient and minimising disruptions. The networking of system components in the overall system is also increasingly leading to autonomous, decentralised subsystems that organise and control themselves independently. Lower defect rates result in fewer rejects, which leads to less material waste and thus to the conservation of natural resources. Despite increasing trends toward automation, human labour is still indispensable in some areas of retail and logistics. Picking tasks, for example, have so far been difficult for robots to perform because they still have problems with the different packaging sizes and textures when gripping and handling goods.[61]

Warehouse operation with the help of augmented reality

With the help of augmented reality (AR), a large amount of helpful information is superimposed on the user's field of vision or display on data glasses. For example, the glasses show the user the optimal route to the desired item or provide information on the quantity, size and weight of thenext pick required during picking. Subsequently, the removal of the goods can be

[59] Zadek, H. (16 April 2020).
[60] Zadek, H. (16 April 2020).
[61] Cf. Thomas, S. (2019).

reported to the managing management system (ERP or WMS) by voice input or via a mobile data device (smartphone or similar). The goods picked during picking or their storage compartments can also be scanned directly with the AR glasses and the associated data transmitted to the WMS. The picking process can thus be made more efficient. Unnecessary distances are avoided, and the error rate is reduced. In addition, all necessary and helpful data for process improvement are recorded in the higher-level system.[62]

Driverless transport guidance systems and transport robots

By using automated guided vehicles (AGVs), transport damage can be minimised and personnel costs can be saved. If the frequency of transport damage decreases, the work is ultimately more resource-efficient, as material losses are reduced. Furthermore, driving and waiting times are reduced thanks to the constant exchange of data and the route-optimised control of the autonomous transport units by the transport control system. A continuous and rapid flow of materials is ensured, which benefits any upstream production. Transport robots are now available for all intralogistics tasks, whether for transporting small containers or moving pallets with loads weighing several tons.[63] Challenges in this area exist in the further development of automated transport systems toward autonomous systems that autonomously recognise demands, avoid obstacles and determine the best route through the factory themselves according to the current traffic situation.[64]

Efficient information management

Both demand inventory management (BBM) and demand capacity management (BKM) can help compare and forecast inventory levels with the goods needed or demanded for a certain period of time. This can avoid costly special orders or rush deliveries due to bottlenecks, or even production stoppages. If transport routes can be avoided and means of transport better utilised, fuel and energy requirements are reduced. It also saves time and money. Downtimes in production are also associated with high costs and additional energy

[62] Cf. Thomas, S. (2019).
[63] Cf. Thomas, S. (2019).
[64] Zadek, H. (16 April 2020).

consumption. Downtimes can be kept to a minimum through just-in-time deliveries and rapid transport processing. Efficient information management and transparent logistics processes further enable the reduction of time and energy expenditure as well as error-prone deliveries.[65]

However, the situation where order books are filled several months in advance is becoming increasingly rare. Flexibility is required to manage inventories or stocks according to demand. This requires fast information transfer from the point-of-sale not only to the OEM, but at the same time to its main suppliers and a fast supply chain from the suppliers to the OEM. The better and faster these processes work, the less stock (range of coverage) needs to be held in warehouses.[66]

New usage possibilities and applications

Wearable electronics

Wearable electronics will play a role in logistics processes in the future. Logistics companies can thus design processes more efficiently. For example, RFID wristbands speed up picking by automatically scanning the goods and giving an acoustic signal in the event of incorrect picking.[67] This avoids incorrect deliveries and unnecessary transports, thus indirectly conserving resources. Devices already familiar from the private sector (e. g. smartphones) can be used to digitally capture and process data from logistics processes (e. g. scanning QR codes).[68]

Predictive maintenance and servicing

Digitisation also offers great potential for improvement in the maintenance of intralogistics machines and systems (e. g. conveyor systems). For example, sensors can be used to measure and evaluate the current degree of utilisation, the wear of machine parts or temperature values. With the help of individualised application software within a cloud, the data can be managed and prepared in an application-friendly manner. In this way, forecasts for expected failures, faults or overloads can be made in good time on the basis

[65] Cf. VDI Zentrum Ressourceneffizienz GmbH (2019c).
[66] Zadek, H. (16 April 2020).
[67] Cf. Richter, K.
[68] Cf. Schenk, M. and Behrendt, F. (2014), p. 25 et seq.

of the development of the measured values and these can be prevented. Spare parts can thus be ordered at an early stage. The replacement of the plant components is then carried out during a scheduled downtime without any loss of necessary capacity. It also reduces serious process errors that lead to material damage. At the same time, the digitisation of machines and plants offers an economic advantage, as maintenance costs are reduced. Maintenance measures only need to be carried out when they are really necessary, as the condition of the plant components can be accurately assessed in the optimum case.[69]

Digital twin

"Digital twins are digital representations of things from the real world. They describe both physical objects and non-physical things e. g. services by making all relevant information and services available through a unified interface." This is the definition according to Kuhn (2017). A digital twin can be created in some cases even before a real-world equivalent exists. Algorithms help to model the real image optimally. Simulation models are used, for example, to test or represent functional or physical properties of a digital twin.[70]

There are numerous possible applications for digital twins in logistics at every point in the value chain. For example, IoT sensors can be used to monitor the location of containers, and they can be checked for damage or contamination at the same time. The collected data, supported by machine learning, is processed by the digital twin of the container network. The additional data subsequently allows the efficiency of container deployment to be increased.[71]

Furthermore, digital twins even make it possible to optimise complete logistics networks, e. g. warehouses. This involves creating a 3D model of the site or facility and populating it with as-built and operational data. The system can then reflect the condition of machines and the availability of products, make predictions about future inventory levels, and even make decisions

[69] Cf. Schenk, M. and Behrendt, F. (2014), p. 25 et seq.
[70] Cf. Kuhn, T. (2017).
[71] Cf. Pieringer, M. (2019).

about deliveries on its own. The principle is equally applicable to any size of logistics centres and networks.[72]

Digital twins can also be used to predict and understand the behaviour and suitability of new materials in packaging or entire packaging systems. For example, temperature, vibration and impact loads can be modelled. A digital twin of an existing product can be used as a data source to describe its geometry. However, the data can also be generated by 3D scanners and computer vision technologies. Product and packaging data could combine to help companies increase packaging and transportation efficiency, whether through automated packaging selection or an optimised container packaging strategy.[73]

A digital twin of warehouses can be continuously fed with data during ongoing warehouse operations, which originate from different automation technologies. These include drone-based inventory counting systems, driverless transport systems, systems for picking goods by people, and automated storage and retrieval equipment. With the help of digital twins, it will be possible to further improve the performance of these automation technologies. The use of sensor data, simulation and monitoring technologies helps to reduce energy consumption without having to reduce throughput.[74]

A digital twin can also help reduce material waste in warehouse operations by collecting and analysing comprehensive data on the movement of inventory, equipment and personnel. Overcrowded, overly busy warehouse floors, low productivity, staff picking errors, and much more can be identified and avoided in the future through smart replanning.

Before changes are made in the real world, a simulation using digital twins can enable responsible managers to test and evaluate the potential impact of process or plant changes.[75]

[72] Cf. Pieringer, M. (2019).
[73] Cf. Dohrmann, K.; Gesing, B. and Ward, J. (2019), p. 22.
[74] Cf. Dohrmann, K.; Gesing, B. and Ward, J. (2019), p. 23.
[75] Cf. Dohrmann, K.; Gesing, B. and Ward, J. (2019), p. 25.

Data collection and networking of system components

In the future, decentralised networking and direct networking of process participants in value chains will play a greater role. Identification and sensor systems make it possible to collect machine and plant data and use it to promote processes. Individual components of the value chain can communicate with each other completely autonomously. Examples include machine-to-machine (M2M), vehicle-to-vehicle (V2V), and vehicle-to-infrastructure (V2I) communication channels. Technologies such as RFID (radio frequency identification) and NFC (near field communication), barcodes and visual identification can be used to collect information about the current and future status of machines, means of transport, plants and inventories. Wireless communication systems based on WLAN, radio, LTE and the like allow a variety of possible networking structures. The plants and processes involved are controlled in real time, either centrally or decentrally. Decentralised networking and control have certain advantages in view of the increasing amount of information. By exploiting swarm intelligence and cloud computing, the best situational decisions can be made for process control. Resources are thus used at the right time, in the right place and in the right quantity, thus minimising waste. Thanks to the possibility of decentralised networking, value-added processes can be implemented efficiently and with little control effort even for very small batch sizes.

For Industry 4.0, with the accompanying individualisation, this is a significant advantage that promotes development.[76]

Warehouse Management Systems

Warehouse management usually refers to the management, control and optimisation of storage and distribution systems. Warehouse management generally includes quantity and storage location management, material handling equipment control and scheduling. A Warehouse Management System (WMS) also includes these functions, but goes beyond them. Thus, a WMS also includes comprehensive methods and measures for monitoring system states as well as a wealth of operational and optimisation strategies. A WMS should take over the control and optimisation of internal warehouse systems.

[76] Cf. Schenk, M. and Behrendt, F. (2014), p. 26.

VDI Guideline 3601 provides detailed information on what a WMS must be able to do in order to be designated as such.[77]

Saving resources through intelligent merchandise management[78, 79]

At the Blechwarenfabrik Limburg, a warehouse management system (WMS) manages the inventories in the automated high-bay warehouses. The system knows at any time which goods are on which load carrier. As a result, there are no more undefined warehouses and unnecessary stocks in the factory. In this way, space is used more efficiently. In addition, the WMS controls the movement of materials in the warehouse using driverless transport systems. This results in less transport damage previously caused by manual handling. Thanks to these measures, Blechwarenfabrik Limburg saves around 100t of tinplate every year.

The WMS is additionally linked to the business intelligence (BI) system.

It is used to control when the stored goods are moved. This is done depending on the availability of electricity from the company's own photovoltaic system. The flow of goods in the high-bay warehouse is thus coordinated by the WMS with the solar power supply. This increases the share of solar own power consumption.

Together with further digitisation and energy optimisation measures, the company saves around € 500,000 euros in material and energy costs annually. In addition, the measures reduce the company's annual greenhouse gas emissions by more than 2,600 metric tons of CO_2-equivalents.

3.3 Resource-efficient retail and logistics buildings

In 2013, the area occupied by logistics real estate in Germany was estimated at around 330 million m^2. The area is not expected to have changed significantly by 2020. With a total building area of approx. 24,800 million m^2, this

[77] Cf. Fraunhofer Institute for Material Flow and Logistics IML (2020).
[78] Cf. Unternehmermagazin 3/4 2019, p. 62.
[79] Cf. VDI Zentrum Ressourceneffizienz GmbH (2019a).

results in a percentage share of logistics buildings in the total building area in Germany of approx. 1.3%.[80]

From the energy consumption of logistics properties in Germany, direct conclusions can be drawn about the amount of greenhouse gas emissions from these buildings. According to an estimate by the Fraunhofer Institute for Systems and Innovation Research (ISI), the final energy consumption of German logistics properties totaled approximately 21.4TWh in 2013.[81] Wholesale properties accounted for about 15.2 TWh, buildings for freight forwarding and storage for about 5.0TWh, and cold storage for the remaining 1.2TWh. Of the total final energy consumption of the GHD sector (commerce, trade, services), logistics properties accounted for approximately 5.5% in 2013.[82]

Based on the previously mentioned data, the average final energy demand of German logistics properties is calculated to be around 65kWh/m^2. The comparative value of the currently valid Energy Saving Ordinance (EnEV)[83] for the corresponding building category is 30 to 35 kWh/m^2. However, only the consumption of building services equipment is taken into account, leaving out materials handling systems, information and communication technology systems (ICT systems), and the like.[84]

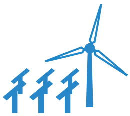
Logistics real estate accounts for a non-negligible share of greenhouse gas emissions in the GHD sector, as the above figures prove. Measures to increase resource efficiency in the logistics real estate sector can thus make an important contribution to climate and environmental protection in general.

[80] Cf. Rüdiger, D. (2019), p. 10.
[81] Cf. Fraunhofer ISI (2015).
[82] Cf. Rüdiger, D. (2019), p. 24.
[83] Cf. Federal Government of the Federal Republic of Germany (21 November 2013).
[84] Cf. Rüdiger, D. (2019), p. 24.

Measures to increase the resource efficiency of buildings

The measures shown in Table 2 are critical to realising buildings toward zero emissions. Three categories are essential here: Reducing resource consumption, substituting fossil fuels with renewable energy sources, and offsetting greenhouse gas emissions.[85, 86]

Table 2: Measures toward zero-emission buildings[87].

Measures in the direction of zero-emission buildings		
Resource efficiency	Regenerative energy sources	Compensation measures
		
• reduce energy and material requirements • optimised building envelope • efficient plant technology • water management • recyclability of the building fabric • minimize waste	• replace fossil fuels with renewable energy sources • photovoltaics (PV), combined heat and power (CHP), wind power, geothermal energy, heat pumps, biomass, • combined heat and power (CHP), purchase of green electricity • “Electricity-only building” • heat accumulator • local and district heating networks	• voluntary emission certificates • Avoidance of emissions, e. g construction of wind farms, • or binding of climate gases, e. g. through reforestation • “Verified Emission Reductions” (VER) • Avoid “indulgence trade”

The following example of the Elobau logistics centre in Leutkirch (Germany) clearly shows how the realisation of a resource-saving logistics property can succeed.

Logistics centre as a plus-energy building[88]

In 2015, the company Elobau inaugurated an ecologically exemplary logistics centre in the Allgäu region of Baden-Württemberg. The energy-plus building, made primarily of the sustainable material wood, provides the

[85] Further information at:
https://www.ressource-deutschland.de/themen/bauwesen/nullemmissionsgebaeude/
https://www.ressource-deutschland.de/instrumente/prozessketten/produktionsinfrastruktur/
[86] More information: Zadek, H. (2011).
[87] VDI Zentrum Ressourceneffizienz GmbH (2019b).
[88] Cf. Transsolar Energietechnik GmbH (2020).

company with more energy than it needs inside thanks to the building-integrated photovoltaic (PV) system. PV modules on the roof provide solar energy in the form of electricity with an area of 1,400m^2.

Thanks to the all-wood construction, the so-called grey energy integrated in the building is reduced to a minimum. This refers to the amount of energy used for the entire life cycle of the material, i.e. from raw material extraction through transport and sale to disposal.

When goods are delivered by truck or delivery van, the loading and unloading area of the building is thermally separated from the outside area. Thermal energy losses are enormously reduced by this measure. By means of building simulation, the insulation systems as well as the heating and cooling systems were designed to the optimum during the planning of the building. A ventilation system could be dispensed with for the logistics centre. Instead, time-controlled night ventilation in combination with intelligent positioning of windows and skylights ensures the necessary air exchange.

Furthermore, very little energy is required for lighting, as the use of daylight has been optimised. Glazing in the shed roof of the hall and tracking louvres for shading help to perfectly control natural light. The little required LED artificial light is adjusted to the light supply during the course of the day via an automatic control system.

The logistics hall is heated with the help of radiant ceiling panels, the offices with convectors. A biogas boiler, which is supplied with biogas from food waste via the plant network, provides the necessary thermal energy. The building's heat supply is therefore designed to be extremely primary energy efficient. Compared to the specifications of the latest EnEV, the building requires only about 10% of the energy of the reference building.

When comparing all consumptions (including user electricity) with the energy gains of the PV system (225kW$_p$), the energy surplus is 2.6 times the demand. The logistics centre is therefore not an energy consumer, but an energy supplier – a true energy-plus building.

4 RESOURCE EFFICIENCY IN TRANSPORTATION

4.1 Opportunities for resource-efficient transport

At the top of the list of measures to realise resource-efficient transportation should be the avoidance and reduction of transportation and the reduction of the harmfulness of transportation. The latter refers to the degree of environmental impact caused by transportation.[89]

Complete avoidance of transportation is only feasible in very few cases. In the retail and logistics sector, this measure is therefore of little significance.

The transport effort can be reduced mainly by increasing the transport utilisation. Empty runs should be avoided as much as possible. The utilisation of the transport volume of the individual transport units can be increased by optimally combining material flows through freight bundling. Measures that can be implemented include reducing the number of carriers, forming paired transports (utilisation of carrier vehicles on the outward and return routes) or so-called milk runs (sequential delivery and receipt of goods similar to milk deliveries in the USA to private households). Modifications to delivery vehicles (see chapter 4.2.3) are also conceivable efficiency improvement measures that have already been put into practice by some companies.[90]

A reduction in transport pollution can be realised primarily through measures on the vehicle fleet and the use of environmentally friendly means of transport. Particular importance is attached to alternative fuels and new types of drive technologies. In the truck sector, further training for drivers and the use of driver assistance systems are possible measures to increase efficiency. The measures result in fuel savings and reduce the environmental impact of individual transport journeys.[91]

[89] Cf. VDI Zentrum Ressourceneffizienz GmbH (2019c).
[90] Cf. VDI Zentrum Ressourceneffizienz GmbH (2019c).
[91] Cf. VDI Zentrum Ressourceneffizienz GmbH (2019c).

4.2 Measures on the vehicle fleet

Appropriate measures on the vehicle fleet of logistics and retail companies can save resources and costs. Alternative drive technologies, the use of renewably generated fuel and other measures such as aerodynamically optimised trucks are possible starting points.

4.2.1 Alternative drive technologies and vehicles

There is much to suggest that alternative drive technologies for motor vehicles will play a more significant role. Stricter legal regulations to reduce emissions, dwindling reserves of fossil fuels, but also technological advancements are driving the use of new vehicle drives in the retail and logistics sectors. For example, through the "White Paper on Transport"[92] the European Union has set itself the goal of making logistics in cities completely CO_2-neutral from 2030.

Replacement technologies for the classic combustion engine are on the advance. Electric drives currently dominate research and development as well as practical applications. Batteries are often used to supply energy to the electric motors. However, vehicles with fuel cells are also already in successful use, for example transport vehicles for intralogistics such as forklifts.[93] Further ecologically advantageous alternatives are offered by gas engines, e. g. when using natural gas, biogas or so-called wind gas. The latter refers to hydrogen gas produced with the help of electricity from wind power.[94]

In the following, some alternative drive technologies are briefly described and their potential is highlighted.

Fuel cell drive systems

In fuel cells, hydrogen is usually brought into contact with oxygen and electrical energy is generated from the chemical reaction. In conjunction with an electric drive, this can create a means of transport that can be regarded as emission-free in operation. How high the actual overall environmental impacts or reductions are must be investigated on a case-by-case basis. The

[92] Cf. Schenk, M. and Behrendt, F. (2014), p. 25.
[93] Cf. Linde Material Handling (2016).
[94] Cf. Greenpeace Energy eG (no date).

entire life cycle of the respective transport system is decisive. Among other things, life cycle assessments can provide information on this. Tests have shown that a fuel cell drive for commercial vehicles is so far only really practical in conjunction with a conventional combustion engine. The additional weight required for fuel cell technology and the short range of around 250km are currently still standing in the way of the breakthrough of this drive variant. In addition, the infrastructure for refueling with hydrogen has been inadequate to date.[95] Currently (early 2020), there are 87 hydrogen refueling stations in Germany. By 2021, this figure should already be 130.[96]

Hybrid drive systems

Hybrid drives can offer a good alternative to the classic diesel engine. This uses an electric motor in conjunction with a conventional combustion engine. The electric motor provides high torque for starting, while the combustion engine is used at higher speeds. Especially for smaller distribution trucks with constant starting and braking, hybrid drives potentially enable efficiency improvements.[97]

Electric drive systems

Purely electric drives are also already available for goods transport; both in the field of intralogistics and in off-site transportation. For the time being, the most common area of application is inner-city distribution traffic. According to the United Nations, the world population is expected to reach approximately 9.7 billion people by 2050, of which about 70% will live in cities.[98] Freight transport in cities will therefore increase. At the same time, the demands on the environmental friendliness of transport are growing, both through legal regulations and consumer demands. It is therefore important for the transport and logistics industry to respond appropriately to these developments.[99] The efficiency of modern electric motors is visibly higher than

[95] Cf. Lohre, D.; Bernecker, T. and Gotthardt, R. (2011), p. 31 et seq.
[96] Cf. Oel, S. (2020).
[97] Cf. Lohre, D.; Bernecker, T. and Gotthardt, R. (2011), p. 32.
[98] Cf. https://population.un.org/wpp/
[99] Cf. Gaul, M. (2018).

that of internal combustion engines, making them much more efficient and offering high potential energy savings.[100]

Electric trucks for inner city logistics[101]

As part of the Austrian Council for Sustainable Logistics (CNL), an electrically powered transport vehicle is currently being tested for everyday use in inner-city logistics. A total of nine companies from the retail and logistics sectors are involved in the test of the MAN eTruck, which is equipped with refrigerated boxes, beverage bodies and swap bodies. In addition, a tractor-trailer combination is also being tested. The truck manufacturer intends to use the experience gained from the project to develop further electrically powered trucks.

Not only does the truck's drive work purely electrically. Power steering, air compressor and air conditioning are also supplied with power from the batteries. The charging of the batteries usually takes place during the night. However, it can also be charged intermediately, e. g. during a driver's rest break or loading and unloading of the cargo area. Opportunity charging increases the ability to plan truck routes and operations.

Another example of an all-electric truck is the Mercedes-Benz eTruck. This van is also designed to provide food and daily necessities. The truck, with a maximum gross vehicle weight of 26t, is based on a conventional three-axle distribution truck. Instead of a conventional drivetrain, the eTruck has electric motors to drive the rear axle directly next to the wheel hubs. The motors receive the electrical energy from several modules of lithium-ion batteries, with the help of which a range of up to 200km can be realised. For an average day's use in distribution operations, this is usually perfectly adequate. The truck is scheduled to go into large-scale production from 2021.

[100] Cf. Business Metropole Ruhr GmbH (2019), p. 49.
[101] Cf. Gaul, M. (2018).

Many companies are already willing to act in an environmentally friendly manner. In numerous online stores, customers can already opt for climate-neutral shipping. To be able to ensure this service, logistics partners are increasingly equipping their fleets with emission-neutral vans. Alternative drive technologies are being tested and the most efficient delivery models identified.

Companies like UPS and Hermes already carry all-electric vehicles in their transport fleets. As part of their sustainability strategy, logistics companies are also considering different delivery models. For example, microdeposits are combined with the use of cargo bicycles as a delivery concept.[102]

One of the latest developments on the market is sustainable parcel delivery by electrically powered drones. To what extent this concept has a future remains to be seen. However, initial trials in real operations have already begun. This is shown by the example of the SEAT plant in Martorell, Spain.

Delivery of vehicle parts by drone[103]

A production facility for automotive parts in Martorell, Spain, has been supplied with steering wheels and airbags by drones since July 2019. The flying vans connect the Sesé logistics centre in Abrera, 2km away, with the automotive plant in Martorell. It takes them only 15 minutes to deliver the vehicle parts, while transporting them by truck takes about 90 minutes. The drones are powered purely electrically and charged by electricity generated exclusively from renewable sources. Thus, using the airway in this way not only saves valuable time. At the same time, CO_2 emissions are also lower compared with road transport, and important resources such as crude oil are conserved.

For safety reasons, the drone flights are controlled by the Spanish Aviation Safety Agency (AESA). In the current test phase, only a few flights are operated per day. The project already shows that the use of drones holds great potential for delivering goods more resource-efficiently and can also increase competitiveness.

[102] Cf. Thomas, S. (2018).
[103] Cf. Endres, M. (2019).

Natural gas drive systems

Progress is also being made with natural gas-powered transport vehicles in terms of resource efficiency, as the following examples show.

Efficiency improvements in natural gas-powered trucks [104]

Two series of a truck manufacturer already published in 2017 show a 7% improvement in fuel efficiency and a reduction in vehicle weight of at least 100kg compared with the respective predecessor model. This can increase the payload and additionally increase efficiency. The decisive factor in the development of the new truck was to reduce engine speed while increasing maximum torque, which is available at just 900rpm. The new vehicle models were named "International Truck of the Year 2018" thanks to their efficiency in road transport.

Efficient gas engine for commercial vehicles [105]

In November 2017, a truck engine manufacturer unveiled the Euro 6 OC13 gas engine, a world first in the field of gas-powered commercial vehicles. The engine can be used for long-distance traffic as well as for construction site vehicles. The achievable output of 410hp makes the 13-litre gas engine competitive with diesel engines of the same size. Fuelled by liquefied natural gas (LNG), a 40-ton semitrailer truck achieves a range of up to 1,100km. The variant with twin tanks even manages 1,600km. In the process, CO_2 emissions are reduced by between 15 and 90% compared with those of the manufacturer's conventional diesel in-line six-cylinder engine.

According to experts, conventional diesel drives will continue to dominate the market in transport logistics for the foreseeable future. Nevertheless, al-

[104] Cf. Gaul, M. (2018).
[105] Cf. Gaul, M. (2018).

ternative drive concepts are becoming increasingly widespread and are revealing new opportunities for greater resource efficiency in the transportation sector.[106]

4.2.2 Use of regenerative fuels

For road transport, alternative fuels (e. g. power fuels) can make a major contribution to achieving the German government's climate protection targets. By 2030, CO_2 emissions from the transport sector are to be reduced by 40 to 42% compared with 1990 levels. In recent years, heavy-duty road traffic in Germany has risen sharply and now accounts for around 25% of traffic-related climate-damaging emissions.[107] Measured against 2010, traffic is assumed to increase by about 38% by 2030. A significant increase in transport performance [tkm/a]] is to be expected, especially in road and rail transport.[108]

For heavy-duty road transport, no significant efficiency improvements in conventional drive technology are expected in the near future. A switch to climate-friendly fuels is therefore crucial. Freight transport by road is characterised by long transport distances and tight time windows. Fuels for this sector should therefore have high energy densities to ensure rapid refueling and the necessary ranges. Environmentally friendly manufactured fuels such as Power Fuels are ideally suited for this application.[109] In theory, electromobility is currently the most energy-efficient form of propulsion, but it cannot be assumed that this technology will be used significantly in long-distance trucking in the near future, as sufficient technical solutions are not yet available. The infrastructure for charging batteries with electricity or refuelling fuel cells with hydrogen is also far from being available to a sufficient extent. Power Fuels as so-called CCU fuels (Carbon Capture and Utilisation), on the other hand, can be offered in already existing filling stations.[110]

[106] Cf. Gaul, M. (2018).

[107] Cf. Wilms, S.; Lerm, V.; Schäfer-Stradowsky, S.; Sandén, J.; Jahnke, P. and Taubert, G. (2018), p. 9 et seqq.

[108] Cf. Federal Ministry of Transport and Digital Infrastructure (2019).

[109] Cf. Wilms, S.; Lerm, V.; Schäfer-Stradowsky, S.; Sandén, J.; Jahnke, P. and Taubert, G. (2018), p. 9 et seqq.

[110] Cf. RWE (2019).

Power Fuels for Heavy Duty Road Transport

In the production of so-called power fuels, electricity from renewable energy sources (RES-E) is used to produce low-emission synthetic fuels. Power-to-X technologies are used to obtain elemental hydrogen by electrolysis of water. Ideally, only renewable electricity is used to operate the electrolysis. There are several options for the further use of hydrogen. It can be used directly as a fuel (in fuel cells or other hydrogen engines) or as a basis for producing other power fuels. In the process, other gases such as CO_2 or nitrogen are added and further processed in various processes to produce fuels such as diesel or methanol. In contrast to hydrogen, usable supply structures (e. g. service stations) already exist for most of the processed power fuels, which represents a major advantage. In the production of alternative fuels using CO_2, the otherwise climate-damaging gas can be taken either from biogas and industrial plants or directly from the outside air. In this way, a closed loop without creating harmful climate impacts could be established. Procedures to operate this method economically are currently still being researched.[111]

Table 3 shows the main advantages and disadvantages of using the alternative fuels hydrogen, synthetic methane, and synthetic diesel.

Table 3: Advantages and disadvantages of selected power fuels[112].

Hydrogen	Synthetic methane	Synthetic diesel
Advantages	Advantages	Advantages
• no CO_2 and local pollutant emissions • fuel cell with high efficiency	• no CO_2 and local pollutant emissions • use of existing vehicles and infrastructure possible (for CNG)	• use of existing engines and infrastructure possible • can successively replace fossil diesel through blending
Disadvantages	Disadvantages	Disadvantages
• supply and service station infrastructure barely developed	• for liquefied natural gas (LNG)) No refuelling station network available yet	• no significant efficiency improvements of the motors to be expected

[111] Cf. Wilms, S.; Lerm, V.; Schäfer-Stradowsky, S.; Sandén, J.; Jahnke, P. and Taubert, G. (2018), p. 9 et seqq.

[112] Based on Wilms, S.; Lerm, V.; Schäfer-Stradowsky, S.; Sandén, J.; Jahnke, P. and Taubert, G. (2018), p. 11.

4.2.3 Modifications to delivery vehicles

The resource efficiency of transportation processes can also be increased through modifications to delivery vehicles. Opportunities arise, for example, with multi-temperature concepts, aerodynamic improvements or lightweight vehicle construction.

Multitemperature concepts for trucks

By dividing the transport loading areas on trucks into different temperature ranges, products with different temperature requirements (frozen goods, chilled goods, etc.) can be delivered within one transport operation. This has the advantage that trips can be saved, so that fleet-related trip kilometres are reduced. This in turn leads to reduced fuel consumption and lower wear rates of vehicle components (tires, engine, transmission, etc.), so that ultimately less material is consumed. This conserves resources and increases cost-effectiveness.

Multi-temperature concept for truck cargo space[113]

With the help of the multi-temperature logistics system introduced at Lekkerland, sustainable bundling effects are achieved in the logistics processes. Before the measure was implemented, customers were supplied with several different trucks for different product ranges. To make the delivery process more efficient, the Group had special multi-compartment vehicles developed that are equipped with flexibly adjustable temperature zones: an unrefrigerated area (above 7 °C), an area for fresh products (0–7 °C) and a frozen area (below -18 °C). Up to eleven laterally and longitudinally movable walls are used in the truck transport area, which enable the respective transport volumes to be adjusted as required. Finally, in 2012, the switch from multi-stop to one-stop delivery with assortments of different temperature requirements took place. The tours for a total of 61,400 customers were also rescheduled.

The conversion saves a total of 260,000 stops and 3.4 million kilometres driven and greenhouse gas emissions of around 2,000t $CO_{2\text{-eq}}$ per year.

[113] Cf. Lekkerland Deutschland GmbH & Co. KG (2013).

The delivery quantity could also be increased. In relation to the delivery quantity, the mileage reduction is approx. 10%.

In addition to the conversion to multi-compartment vehicles, the trucks are equipped with telematics tools for real-time communication. Sensors in the refrigerated areas of the cargo hold continuously measure the temperature. The data is sent from the truck to a central server at regular intervals via a mobile network. If unwanted temperature deviations occur, the server triggers an alarm to the office and the driver's communication devices. In addition, the process is automatically documented in a log. With the help of the alarm system, a temperature drop can be reacted to at an early stage. Any necessary countermeasures can be initiated in good time. This means that less delivered goods have to be disposed of. That saves resources.

Aerodynamically optimised trucks

Another measure to increase the resource efficiency of delivery vehicles is to improve the aerodynamic vehicle properties. According to the DLR (German Aerospace Center), aerodynamic resistance accounts for more than 20% of the total energy losses of a truck.[114]

With an average annual mileage of 100,000km and a total weight of 40t, a truck-trailer combination requires about 30,000l of diesel per year and emits greenhouse gases amounting to about 786kg of CO_2-equivalents ($CO_{2\text{-eq}}$). The so-called teardrop trailer in the following example shows that a flow-optimised vehicle design can lead to significant fuel savings not only in cars but also in trucks.[115]

Low drag trailers[116]

According to the manufacturer, the teardrop trailer inspired by tears leads to fuel savings of up to 15% compared to conventional road trains thanks to its aerodynamically improved shape. Due to the roof edge sloping backwards, the trailer offers less air resistance than its cuboid counterpart. In

[114] Cf. Öngüner, E. (2019).
[115] Cf. Mayer, H. W. (2019).
[116] Cf. Mayer, H. W. (2019).

England, more than 1,100 such teardrop trailers are already in use at the logistics company DHL. The German company Active Cars GmbH has also been using a single-axle 18-ton teardrop trailer with a usable volume of 88m^3 since 2019 to transport Airbus components between Hamburg and Toulouse. In contrast to the manufacturer, however, Active Cars promises slightly lower fuel savings of 6 to 10%. The difference in expectations is mainly due to the fact that the maximum permitted height of lorries in England is 4.90m, while in continental Europe it is restricted to 4.00m. With the lower maximum height of the trailer, the lowering of the roof and side lines has a less beneficial effect on aerodynamics. In addition, the loading volume is more restricted, since the height of the trailer end can be a maximum of 3.22m. Based on initial practical experience, average fuel savings of around 5% can be achieved in continental Europe. An ordinary truck, as described above, would thus consume approx. 1,500l less diesel per year and avoid 39.3kg $CO_{2\text{-eq}}$ in greenhouse gas emissions.

Figure 7: Aerodynamically improved trailer (© DHL Freight GmbH)

In addition to the fluidic optimisation of the trailer or semitrailer, projects already exist for the aerodynamically optimised design of entire trucks, as the following example shows.

Aerodynamically optimised semitrailer[117]

The project partners succeeded in optimising the aerodynamic vehicle design even further with the so-called Aero Liner, a prototype of a thoroughly

[117] Cf. Mayer, H. W. (2019).

optimised truck tractor presented for the first time at the IAA 2012.[118] Both tractor and trailer are designed down to the last detail to minimise air resistance. According to the manufacturer, this should result in fuel and CO_2 savings of up to 25%.

The load volume corresponds to that of a conventional truck-trailer combination. However, at 20.40m, the Aero Liner is significantly longer than the EU currently allows under Directive 96/53/EC. According to this, a semi-trailer truck may not exceed a length of 16.50m. Trailers are limited to a maximum length of 12m, and carriages may not be longer than 18.75m.[119] So, for the time being (at least in Europe), the Aero Liner remains a prototype without road approval.

Figure 8: Prototype of the aerodynamically optimised Aero Liner semitrailer tractor (© MAN Truck & Bus SE)

In Germany, it is possible to apply for a permanent exemption (three or six years) so that vehicles with an overall length of up to 22m can also obtain a road permit. In addition, approved long trucks are allowed to move on a selected portion of the road network in Germany (positive network).[120]

[118] see also: https://www.youtube.com/watch?v=dSuDb-49rM4 und https://www.youtube.com/watch?v=a8Kw1ZPe4Ho

[119] Cf. Council of the European Union (25 July 1996).

[120] Zadek, H. (16 April 2020).

Much easier to implement are the retrofittable air control elements presented in the following two examples.

Air deflectors at truck rear and sides

The example of a manufacturer from the USA shows how the aerodynamic drag of trucks can be improved retroactively. With the “Opti Flow Tail System”, the air flow at the rear of the truck is directed advantageously. For this purpose, four foldable plastic elements are attached to the wing doors of the trailer.

Figure 9: Air-guide flaps at the rear of a vehicle [121].

Air-guide elements called Opti Flow Side Wings continue to provide airflow retardation due to their special shape. Air resistance is reduced because the dynamic pressure at the axles and wheels decreases. The manufacturer claims that fuel consumption is reduced by up to 7% overall with the help of the two systems.

[121] Image source: https://www.wabco-auto.com/apac/News-Events/Media-Center#/media/1/11

“Trucksack” improves aerodynamics and saves fuel [122]

Another example from this area is the development called Trucksack by the company Trailer Dynamics GmbH from Aachen. This is a system for reducing the aerodynamic drag of vehicles. An air-filled bag at the rear of the vehicle improves the aerodynamic shape of vehicles with an angular rear end. The shape was developed based on biological models. Under test conditions, the use of the “Trucksack” leads to fuel savings of up to 22%. From a speed of 65km/h, the system is automatically extended. When falling below this speed, the system sucks itself empty again and lies flat against the tail. When loading the vehicle, the truck bag can simply be pulled up onto the roof or, in another variant, folded to the side together with the rear door. The bag is inflated and deflated with the help of an active pitot nozzle and venturi nozzle or a deflator. The airstream alone is necessary for this. The weight of the entire system is less than 100kg.

Figure 10: “Trucksack” at the rear of a truck (© Alpha Team GmbH)

[122] Cf. Trailer Dynamics GmbH (2020).

Lightweight construction for more efficient commercial vehicles

While a lower vehicle mass in the case of passenger cars usually results directly in lower fuel or electricity consumption, the situation is somewhat different in the case of trucks. If the vehicle mass of a commercial vehicle is reduced, it can usually be assumed that the mass saved is compensated for in the form of cargo in the load compartment. This also leads to an increase in resource efficiency. The additional transport weight reduces the specific fuel consumption of the transported goods, i.e. the energy required per kg of payload, while the total weight remains the same. In terms of a company's entire delivery fleet, fewer trips would thus be necessary, since more would be transported per trip. Alternatively, the same amount of freight can be delivered with fewer vehicles, allowing the vehicle fleet to be reduced. This saves further material and energy resources that would otherwise be needed to manufacture the vehicles. Such a measure can also be very profitable from an economic point of view. According to Heimann et al. (2019), the payback period of an investment in weight-saving commercial vehicles is mostly relatively short. Of course, this can vary greatly from case to case and must be determined individually. In addition, reducing the size of the fleet required may provide a response to the prevailing driver shortage.[123]

Connected Lightweight Future Truck[124]

In a project called Connected Lightweight Future Truck (CLFT), it was possible to develop a lightweight chassis concept for a heavy-duty 4×2 long-haul truck that saves a total of 110kg of vehicle weight. This was achieved by intelligently redesigning the chassis systems and components. The rear and front axles, including steering, are combined with the adapted damping system to form a new type of lightweight truck chassis. According to the manufacturer, the concept could already be implemented in series production.

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[123] Cf. Heimann, J.; Müller, I.; Neu, A. and Stieglitz, A. (2019).

[124] Cf. Heimann, J.; Müller, I.; Neu, A. and Stieglitz, A. (2019).

4.3 Efficient route planning and fleet management

Transportation cooperation

If the transport volume of logistics service providers increases, better route planning and higher utilisation of truck loading areas can improve transport efficiency in general. Due to increased efficiency, harmful emissions are in turn reduced.

Transport cooperation in practice[125]

As part of a study, two independent automotive suppliers entered into a transportation cooperation to optimise their supply structures. The logistics centres and networks of the two companies were merged and centrally coordinated. Transport-related emissions were reduced by 27% through increased utilisation of daily deliveries from the logistics centre to the production site. In addition, the total cost of transportation decreased by 7%. Average transport capacity utilisation in the individual networks was previously only 33%. As a result of the cooperation, the utilisation rate was increased to 49%. This was achieved thanks to the increased number of possible routes and the selection of the nearest logistics centre in each case. In this way, the transport kilometres travelled were reduced by 54%. The location of the transshipment centres remained unchanged in the cooperation, only the transport frequency and routes were adjusted.

Further efficiencies would be achievable by redistributing or relocating transportation centres. However, this would require even closer cooperation between the individual suppliers.[126]

Intermodal transports and use of long trucks

Intermodal transportation is the use of several different transportation media for the delivery of a good from the point of delivery to the destination. Land, water and air routes can all be considered. On land, a distinction can also be made between road and rail transport. A long truck or EuroCombi (also LCV,

[125] Cf. Gross, W.; Zesch, F.; Gelau, T.; Hayden, C.; Bötel, M. and Brock, M. (2013), p. 28.
[126] Cf. Wimmer, T. und Grotemeier, C. (2018).

Long Combination Vehicle) is an extra-long combination of truck motor vehicle or tractor unit and several semitrailers and/or trailers.[127] The maximum permissible overall length of a long truck is 25.25m with a maximum permissible gross weight of 44t in the pre- and on-carriage in combined transport.[128]

Intermodal transports

A study by Gross et al. (2013) compared the effects of using intermodal transport networks and long trucks compared to transport with conventional trucks for the European region.[129] It was found that in both cases the emission of harmful emissions could be reduced. The baseline scenario refers to transport exclusively in standard truck trailers. In the underlying study, transportation costs for intermodal increased by 76% compared to the baseline scenario. In terms of harmful emissions, intermodal transport only performed better than conventional truck transport on very long transport routes and only if the distance between the logistics centre and the transfer station was not too great. The prerequisite is always that the transport volume is sufficiently large to ensure efficiency through high utilisation of the transport media. The study identified a total greenhouse gas savings potential of approximately 39% for a switch to intermodal transport.[130]

Use of long trucks

Since the possible total weight and volume of transported goods is higher for long trucks than for conventional trucks, fewer deliveries are needed overall to transport the same quantity. In the previously mentioned study, the use of long trucks resulted in a cost savings of about 25% and an emissions reduction (in $CO_{2\text{-eq}}$) of almost 17% compared to the baseline scenario.[131]

From an environmental point of view, intermodal transport is clearly preferable, but since the overall costs for this variant rise sharply, transport by

[127] Cf. Gross, W.; Zesch, F.; Gelau, T.; Hayden, C.; Bötel, M. and Brock, M. (2013), p. 44.
[128] Cf. Verband der Automobilindustrie e.V. (2019).
[129] Cf. Gross, W.; Zesch, F.; Gelau, T.; Hayden, C.; Bötel, M. and Brock, M. (2013), p. 44.
[130] Cf. Gross, W.; Zesch, F.; Gelau, T.; Hayden, C.; Bötel, M. and Brock, M. (2013), p. 44.
[131] Cf. Gross, W.; Zesch, F.; Gelau, T.; Hayden, C.; Bötel, M. and Brock, M. (2013), p. 44.

long truck seems more practicable and realistic. The latter has not only ecological but also economic advantages for the transport companies.

The costs of intermodal transport increase in particular due to the additional handling services required between pre-carriage and main carriage as well as the main carriage and on-carriage. These costs could be offset with increasing automation in handling processes and transport on the main run, as not inconsiderable personnel costs would then be eliminated. A prerequisite for this, however, is an end-to-end modernisation of the transport infrastructure.[132]

Reduction in the frequency of deliveries

Reducing deliveries from four to two days per week saved up to 23% of costs and 25% of CO_2 emissions in an example scenario. The lower number of deliveries per week leads to shorter handling and travel times overall, which greatly reduces costs especially in a country with high labour costs like Germany. The average utilisation of truck loading areas also increased from 43 to 55% in the example. This shows that, in principle, there is great potential for savings by reducing the frequency of deliveries. This potential could be further exploited by adding flexibility to delivery windows (see also below *Expansion of delivery windows*). The total transport distance travelled was reduced by a quarter in the example studied. In addition, since waiting time and loading and unloading time are reduced overall, delivery efficiency increases. However, successful implementation of this measure also requires consideration of the respective options of involved parties. For example, implementation is only possible if there is also sufficient shelf or storage space available in the supplied warehouses. Furthermore, the additional personnel and time required for loading and unloading the individual deliveries must be taken into account, since a higher volume of goods is incurred per delivery day.[133]

[132] Zadek, H. (16 April 2020).

[133] Cf. Gross, W.; Zesch, F.; Gelau, T.; Hayden, C.; Bötel, M. and Brock, M. (2013), p. 58.

Extension of the delivery time window

If delivery windows are extended, more customers can be supplied with one round trip. This leads to a reduction in the transport distance travelled by up to 15%, while the utilisation of the vehicles increases. In exemplary model calculations, Gross et al. (2013) assume a possible reduction in emissions of up to 16% with a simultaneous reduction in delivery costs of 5 to 11%. In the model calculation, just extending the delivery window by 30 minutes resulted in 6% fewer emissions with a 5% reduction in delivery costs.[134]

In this case, the cost reduction can be passed on to the customer in the form of lower delivery prices. Some flexibility in supply chain design and a willingness to cooperate and share data can then provide both economic and environmental benefits for the parties involved.

For the planning of transport processes, the delivery deadlines and delivery time windows (for example, of retail companies) are an important condition. In order to meet the deadlines, the transport vehicles are often not fully loaded. This results in underutilisation of available transport capacity and additional distances required, which not only lead to increased transport costs but also to unnecessary environmental pollution. For the companies supplied, however, an expansion and/or flexibilisation of delivery windows places greater demands on the number of personnel needed at the same time for what may only be a short period of time. Furthermore, the spatial capacities of the delivery zone and the warehouse as well as the traffic situation entail possible bottlenecks for the implementation. When planning to extend delivery windows, these aspects should also be taken into account.[135]

Relief for inner-city delivery traffic

Customers have increasingly high expectations regarding the timeliness of delivery and the ability to deliver their orders to their desired location and

[134] Cf. Gross, W.; Zesch, F.; Gelau, T.; Hayden, C.; Bötel, M. and Brock, M. (2013), p. 60.
[135] Cf. Gross, W.; Zesch, F.; Gelau, T.; Hayden, C.; Bötel, M. and Brock, M. (2013), p. 60.

time. In order to meet the changing requirements, the urban logistics infrastructure in particular must become denser and more decentralised than it has been to date.[136]

A project to restructure inner-city delivery traffic in Stuttgart shows possible approaches and potential savings.

Pilot project on inner-city delivery traffic in Stuttgart[137]

In 2016, the city of Stuttgart and Fraunhofer IAO launched a joint project on this topic called "logSPAZE". This is an innovative logistics concept that includes deliveries on foot (with handcarts) and by cargo bike. The ordered packages are delivered directly to the city centre from two nearby depots. The special feature here is that the depots consist of normal truck trailers. These are driven daily from the distribution centre outside the city to the vicinity of the pedestrian zone and made accessible to the parcel carriers via a mobile staircase. The empty trailers are later returned to the distribution centre, where they are reloaded with packages during the night shift. Compared to the previous method, this method allows the parcel delivery company to eliminate 80% of the trucks that previously travelled in the downtown area. The service level has remained constant. The few trucks that continue to operate deliver the large packages that cannot be transported on foot or by cargo bike.

The problem is that different CEP service providers (courier express parcel service providers) travel to the same districts and neighbourhoods every day – often just a few minutes later. Solutions that bundle delivery across service providers and have just one delivery person deliver all the parcels in a neighbourhood or district are more effective. This reduces emissions and puts significantly less strain on the infrastructure. How such an approach can succeed is being investigated at the Institute of Logistics and Material Flow Engineering at the University of Magdeburg since 2019 in a research and pilot

[136] Cf. Kässer, M.; Müller, T.; Kley, F.; Wee, D.; Hannemann, D.; Diedrich, D.; Rothkopf, M.; Neuhaus, F.; Küchler, S.; Hausmann, L.; Wojciak, J.; Höflinger, N. and Raiber, S. (2016), p. 29 et seq.

[137] Cf. Kässer, M.; Müller, T.; Kley, F.; Wee, D.; Hannemann, D.; Diedrich, D.; Rothkopf, M.; Neuhaus, F.; Küchler, S.; Hausmann, L.; Wojciak, J.; Höflinger, N. and Raiber, S. (2016), p. 29 et seq.

project called “Parcel-KV-MD2: Sustainable parcel service through combined transport on the last mile with micro depots in Magdeburg.”[138]

4.4 Digitisation in transportation

Digitisation at a glance

Digitisation is now mentioned in many forms in numerous media. Nevertheless, no accepted definition is available yet. However, cyber-physical systems are a good way of describing what digitisation is ultimately all about. Cyber-physical systems network the physical world with the virtual-digital world. With the help of microelectronics in real objects (e. g. vehicles, containers, products and packaging), these can be clearly identified and data collected by means of sensors. The data can be automatically exchanged and processed with other objects (networking of cyber-physical systems). From the collected data sets, Big Data analytics methods can be used to generate knowledge that would probably remain hidden without this technology. Cloud and mobile computing ensure that the data needed can be accessed anytime, anywhere. For processes, the strategies and measures of digitisation offer the opportunity for increased transparency, flexibility and efficiency.[139]

Digitised transport logistics

The optimised control of inter-company transports with the help of cyber-physical systems is also referred to as Transport Logistics 4.0. During loading and unloading as well as during the commissioning of the transport process, data is collected, analysed and a digital image is created from it. Subsequently, measures for cross-company efficiency enhancement can be derived from this. Information from IT systems, cameras and sensors provide additional support. Transport logistics 4.0 aims at efficient, decentrally controlled and flexible transport handling.[140]

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[138] Zadek, H. (16 April 2020).

[139] Cf. Pflaum, A.; Schwemmer, M.; Gundelfinger, C. and Naumann, V., p. 6 et seq.

[140] Cf. Pflaum, A.; Schwemmer, M.; Gundelfinger, C. and Naumann, V., p. 9.

Optimised routing alone can save an average of 5% fuel. With the help of a system called “idle alert”, a logistics company succeeded in locating available trucks more quickly and adjusting the routes of all vehicles accordingly, saving about 75 l of fuel per truck per month.[141]

Transport Logistics 4.0 continues to serve to improve general cargo cooperation between logistics service providers. Usually, small and medium-sized, regionally operating forwarding companies work together and provide their customers with a national or international supply of goods. Here, transport planning is carried out on a cross-company basis. By comparing orders and available freight capacities of all cooperating parties, possibly even including forecasts, ideal transport compositions can be planned. Thanks to the possibilities of digitisation, rapid transfer of data provides the necessary information to all parties involved, for example via a cloud. A decision support system selects the ideal option for transport handling in near real time using appropriate algorithms. The resulting optimised control of transport networks leads to a reduction in empty runs and lower costs for all parties involved.[142]

Approximately every fourth truck transport in Germany is an empty run. On average, the transport capacity utilisation of trucks in this country is only between 50 and 70%. If the digital transport logistics systems already available on the market (sensors, software, data transmission technologies) were used, capacity utilisation could already be between 80 and 95% today, which would mean that significantly fewer trucks would be needed to transport goods and resources would be saved.[143]

Capacity increase of transport modes

Telematics and novel navigation solutions such as vehicle-to-vehicle communication (V2V) and vehicle-to-infrastructure communication (V2I) provide the technical starting point for online planning and control of logistics processes. These are accelerated as a result. Decentralised and autonomous traffic management using telematics will become more important in the future.

[141] Cf. Schiller, T.; Maier, M. and Büchle, M. (2017), p. 14.
[142] Cf. Pflaum, A.; Schwemmer, M.; Gundelfinger, C. and Naumann, V., p. 28 et seq.
[143] Cf. Kramer, S. (2015).

Measures to ensure the smooth flow of traffic can be supported by extensive, location-accurate, real-time data. Dynamic pricing, selective overtaking bans and individual speed limits, among other things, are helpful in this regard. These measures will increase the capacity of roads as a mode of transport. Telematics, V2V and V2I technologies also offer great potential in the field of rail transport. Here, smaller train distances can be realised than with the currently common block section control, which can increase the utilisation of the rail mode of transport. This is particularly beneficial to the environment, as rail transport (especially in electric mode) has a lower environmental impact than truck transport.[144]

Truck Platooning

The digital collection and processing of real-time truck data (exact location, distance to the next vehicle, etc.) with the help of various technologies (radar, cameras, GPS) as well as the individual data exchange between the individual vehicles via V2V communication allow the networking of several trucks for so-called truck platooning.[145] In this process, several trucks drive completely autonomously at a very close distance (less than 1 sec.) and are connected to form a truck convoy that acts together. All the controlling functions of the individual trucks (except those of the lead vehicle) are handled by the driver assistance system called CACC (Cooperative Adaptive Cruise Control). Once the system is activated, the driver has only a control function. All following vehicles react according to the behaviour of the lead vehicle. When it brakes, accelerates or changes lanes, the rest of the trucks in the convoy automatically do the same. Should another vehicle want to merge, the distance is automatically increased until it leaves the convoy again. The vehicles behind the lead truck in particular benefit from reduced air resistance due to the close distance, thereby reducing their fuel consumption.[146] A 2013 study of experiments suggests fuel savings of up to 22% for vehicles within the convoy. Due to the reduced air pressure and turbulence at the rear, even the lead vehicle is said to be able to save up to 10% fuel.[147] From a purely

[144] Cf. Schenk, M. and Behrendt, F. (2014), p. 27 et seq.
[145] Cf. https://www.youtube.com/watch?v=I-xMdybBzUY
[146] Cf. Stehbeck, F. (2018).
[147] Cf. Tsugawa, S. (2013).

technical point of view, platooning is already possible today. However, Europe-wide regulations still need to be created and a multi-vendor system developed. Once these challenges have been overcome, platooning has the potential to make freight transport a great deal more environmentally friendly.

Autonomous scheduling

Automated transport planning makes a decisive contribution toward self-organised and intelligent logistics. The following example illustrates how autonomous dispatching can succeed in practice.

Autonomous dispatching by means of software in real time[148, 149]

As part of a research project, a company from Hamburg has launched software that helps generate optimal route plans without manual intervention. The transport vehicles used send their exact locations to the control centre by means of telematics. There, an evolutionary algorithm calculates the ideal route in real time, based on the comparison of current traffic and order data. If there is a threat of non-compliance with delivery deadlines or statutory rest periods, the software automatically reschedules. The driver is informed about the changes via mobile devices. The system not only helps reduce delays, but also shortens the overall distances travelled. This positively affects the flow of traffic on the roads, saves fuel, and reduces the amount of CO_2 emissions.

4.5 Efficient logistics in business parks

Cross-company synergies

In commercial and industrial areas, it is possible to generate synergies through networking and cooperation between local companies, thereby increasing resource efficiency overall. In the area of logistics, for example, transport cooperation can be created and thus deliveries of any kind can be bundled. E. g. purchasing pools can reduce the amount of transportation to the business park. If delivery times are coordinated, the transport capacity utilisation of individual trucks can be increased so that fewer trucks are

[148] Cf. Walter, M. (2018).
[149] Cf. Hamacher, M. (2018).

needed overall. Furthermore, joint waste management concepts are possible, which minimise transport kilometers for waste disposal and save waste. One company's waste may even serve as a secondary raw material for another company in the industrial park. However, this can only be found out and implemented through inter-company cooperation.[150]

For the most part, the biggest obstacle is the need for communication between the individual businesses in a business park. Networking opportunities are often not utilised due to lack of time and staff capacity.[151]

Network management

Aiming to identify cooperation opportunities, to initiate and manage cooperation, network managers are of great benefit. They organise joint meetings and coordinate inter-company communication. Through network managers, joint energy and material purchases, the use of a joint vehicle fleet, waste bundling and recycling of raw and residual materials can also be managed.[152]

Resource-efficient management of the industrial park

To increase the resource efficiency of an entire business park, the following measures can serve as starting points:[153, 154]

- Establishment of a community of interest,
- Development of cooperative ventures in decision-making areas typical of the commercial area (joint purchasing, waste disposal, joint use of the rail connection),
- Development of operational synergies as well as horizontal or vertical networks, e. g. companies of the same or different production stages of a product,

[150] Cf. Sauerborn, K.; Schlump, C. and Keller, A. (2013), p. 33 et seqq.
[151] Cf. Sauerborn, K.; Schlump, C. and Keller, A. (2013), p. 33 et seqq.
[152] Cf. Sauerborn, K.; Schlump, C. and Keller, A. (2013), p. 33 et seqq.
[153] Cf. Freudenau, H.; Hennings, G.; Rinke, B.; Siebert, S. and Ziegler-Hennings, C. (2014), p. 40.
[154] Cf. Folz, A. and Lauerburg, K. (2010), p. 122 et seqq.

- joint use of the fleet, storage facilities and logistics.

Optimised traffic control

The goal of optimised traffic control is to reduce the volume of traffic and the environmental impact caused by traffic. This refers to traffic within the business park as well as passenger and delivery traffic to and from the individual companies. Possible measures for optimisation are[155, 156]:

- direct connection of the industrial park to the highway (traffic reduction),
- Combination of delivery and removal in the area (traffic reduction),
- Reduction of traffic areas,
- Use of the railroad connection,
- Design of operating hours for public transport connection,
- Order of stationary traffic (shared parking, multi-storey parking garages),
- Connection to bike path links,
- Reducing fuel use and switching to alternative fuels.

The project of the Motzener Straße business network[157] described below vividly illustrates how bundling transports through business cooperation could help reduce environmental pollution.

Project: Bundling of general cargo transports of the Unternehmensnetzwerk Motzener Straße e.V. (Berlin)

The Motzener Straße business network is an initiative of companies in the industrial area of the same name that has been in existence since 2005.

[155] Cf. Freudenau, H.; Hennings, G.; Rinke, B.; Siebert, S. and Ziegler-Hennings, C. (2014), p. 41.
[156] Cf. Bondzio, L.; Silius, A. and Scheit, M. (2010).
[157] At the time of publication, the project is still nearing feasibility analysis, which is expected to be completed in August 2020.

On average, around 800 trucks currently pass through the commercial and industrial area each day, of which around 50% are destination and source traffic. The high traffic load sometimes leads to spatial bottlenecks and conflicts with residents. Bulky goods, general cargo and parcels are delivered to Berlin by freight forwarders and fleet operators from the freight transport centre (GVZ) in Großbeeren. At present, general cargo deliveries for the Motzener Straße companies are generally still made individually to the respective recipient. There is no bundling of traffic and logistical processes. Underutilised truck transport volumes are therefore the order of the day. This leads to wasted resources and unnecessarily high traffic on the roads. The substance of the feeder roads is also subjected to increased stress as a result, since more trucks are on the road than is actually necessary. The company network is now aiming to significantly reduce the flow of supplies and goods in the project area. To this end, it is being considered to have a service provider receive and collect general cargo consignments for various recipients on Motzener Straße at a central warehouse in the GVZ Großbeeren and then have them delivered in bundles. This would improve the transport capacity utilisation of trucks. Delivery could also be made by low-emission vehicles (for example, with electric motors). Recipient requests such as specific delivery times and restrictions (e. g. required lifting platforms and ramps) should also be taken into account.

Cross-company use of facilities

If parking lots and buildings, canteens, sports and leisure facilities are shared, this reduces costs on the one hand and ensures more efficient use through higher utilisation on the other. Another key benefit of sharing is the reduction of land sealing. This can be achieved, for example, through central truck parking areas with service facilities (supply and wash rooms for truck drivers) and ramp management, as well as through shared parking and fleet management.[158]

[158] Cf. Northern Black Forest Chamber of Industry and Commerce (2015), p. 12.

Measures for resource-efficient delivery and passenger traffic

To implement environmentally friendly and progressive delivery and passenger transport in industrial and commercial areas, the following measures can be helpful[159]:

- Central location of parking spaces for trucks and integration with company ramp management as much as possible. This will reduce the amount of space needed in the street space as well as on the company's premises.

- Costly service facilities can be operated jointly (e. g. e-vehicle charging facilities, truck driver service, supply and wash rooms for truck drivers).

- Proximity to public transportation makes it easier for employees to reach their workplace in an environmentally friendly manner and increases the pool of potential workers due to a larger catchment area.

- With the help of car sharing and intelligent fleet management, the space required for parking spaces is reduced and operating costs are saved.

- Situationally adapted mobility and logistics concepts (ramp management, closed-loop systems for packaging and transport) can lead to further resource conservation.

Transportation cooperation

In transport logistics in particular, major savings in terms of both costs and energy and materials can be achieved through cooperation. The aim of cooperation is to fully utilise the loading capacities of logistics service providers and to reduce transport routes and the number of loading operations.[160]

The example of a transport cooperation between two large food manufacturers in Germany shows that cooperation can make transport logistics more

[159] Cf. Chamber of Industry and Commerce Northern Black Forest (2015), p. 18 et seqq.
[160] Cf. LPV GmbH (2011).

efficient, cost-effective and environmentally friendly. The example can be directly applied to the cooperation of companies within industrial parks.

Transport cooperation reduces costs and CO_2 emissions[161]

Back in 2010, a food manufacturer launched a cooperation offensive called "Agenda 2017" to promote more cooperation in the logistics sector of the consumer goods industry. In the case of cooperation with a direct competitor, joint warehousing and delivery were realised with the help of an external logistics service provider. Storage and transport costs have been reduced by 20% thanks to the cooperation. In addition, common delivery days were agreed and ordering systems were standardised, reducing the number of necessary ramp contacts by 4,000 contacts per year and transport kilometers by 720,000km per year. This not only saves fuel, but also CO_2 emissions. Moreover, since the logistics provider already had trucks with hybrid drives, CO_2 emissions were reduced even further.

The decisive prerequisite for a functioning cooperation in the field of transport logistics is trust among the partners involved as well as an agreement with regard to the required quality standards. For the beginning, a cooperation should be limited to a maximum of four partner companies in order not to unnecessarily increase the complexity. Similar customer structures, products and sales volumes continue to be advantageous. One barrier to realising collaborations is the need to share sensitive information such as customer data, costs, quantities and prices. An external logistics consultant can be useful in removing this obstacle. This person can uncover the commonalities, identify all the crucial information, process it confidentially and highlight cooperation potentials with the available data.[162]

[161] Cf. LPV GmbH (2011).
[162] Cf. LPV GmbH (2011).

5 RESOURCE EFFICIENCY IN THE PACKAGING INDUSTRY

Decisive for sustainable, environmentally friendly packaging management are, above all, the efficient use of materials in packaging production or use, as well as environmentally sound waste disposal. Transport and outer packaging in particular are within the sphere of influence of logistics. The Packaging Act (VerpackG) of 2019 regulates the take-back obligation for transport and outer packaging. Until then, the Packaging Ordinance applied, which has now been replaced by the Packaging Act. In retail, product, service and shipping packaging must also continue to be optimised.[163] For an environmentally sound packaging management – according to the Closed Substance Cycle Waste Management Act – a ranking for measures can be defined (decreasing in importance):[164]

(1) Avoidance of packaging,

(2) Reduction of packaging quantity and harmfulness,

(3) Reuse through reusable systems,

(4) Recycling of packaging materials.

Reusable transport packaging vs single-use systems

In reusable logistics, reusable transport packaging (for example, foldable plastic containers) is used to transport goods, and is frequently applied by means of return logistics. In disposable logistics, transport packaging is used only once and then disposed of.

Before deciding on the most suitable transport concept in each case, the ecological advantages and disadvantages of the two variants should also be taken into account. A study by Gross et al. (2013) on the subject, which relates to transport by truck, describes that for short transport distances and very heavy goods, the environmental balance of reusable transport boxes is advantageous, provided they are foldable. In this scenario, a switch to disposable packaging would be neither ecologically nor economically beneficial.

[163] Definitions in: Seyring, N. and Kaeding-Koppers, A. (2019), p. 5.
[164] Cf. Deckert, C. and Fröhlich, C. (2014), p. 16.

By folding empty boxes, less volume is required for return transport, thus increasing the utilisation of the truck.[165]

Before a decision is made on the appropriate transport packaging, a detailed analysis should be carried out with regard to the environmental impact. The properties and the entire life cycle of the packaging should be taken into account. The expected service life of reusable packaging also has a decisive effect on the environmental impact caused. If other environmental impacts are taken into account in addition to the global warming potential, such as land consumption, soil acidification or ozone depletion, an ecological assessment of packaging options can be made on a much more informed basis. However, an ecological analysis and assessment do not usually have general validity but must be prepared on a case-by-case basis. A standardised procedure for assessing the potential environmental impact of a product system over its entire life cycle is described in the DIN EN ISO 14040 and 14044 standards. VDI Guideline 4800[166] is particularly helpful in evaluating resource consumption.

Efficient packaging design

In Figure 11, the average utilisation of long-haul truck transports in Europe in 2004 can be seen. Accordingly, in many cases the transporters were not used efficiently. In 2015, domestic truck transports again showed an average utilisation rate of only 50 to 70%.[167]

[165] Cf. Gross, W.; Zesch, F.; Gelau, T.; Hayden, C.; Bötel, M. and Brock, M. (2013), p. 49.
[166] See VDI 4800 Sheet 1: 2016-02.
[167] Cf. Kramer, S. (2015).

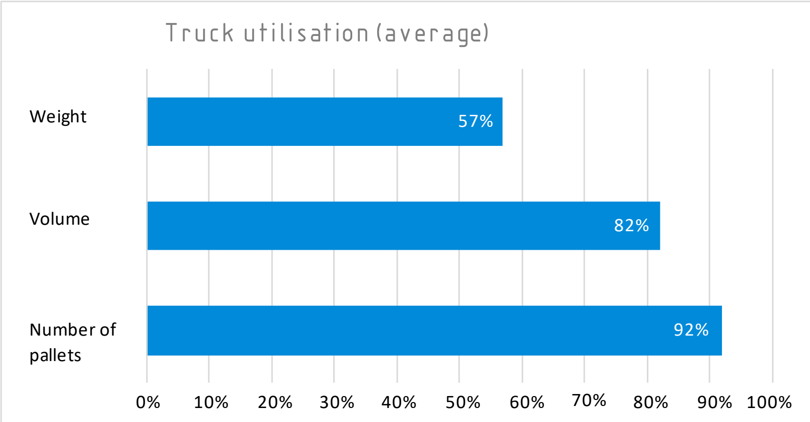

Figure 11: Long haul truck utilisation [168]

The limiting factors in truck loading are primarily the quantity of transport pallets and the loading volume. In terms of transported weight, the vehicles could generally be utilised to an even greater extent.

Optimised packaging design improves the shape of the transported goods and thus increases the possible packing density in the truck. This also increases the load weight and improves the utilisation of the loading area. One example of how this can be implemented in practice is the resource-saving packaging of tea lights.

Resource saving tealight candle packaging [169]

One furniture company succeeded in reducing product-related transport emissions per cubic metre of transported goods by 12.4% in the period from 2006 to 2009. This is mainly thanks to the optimised packaging design. In the process, the packages were designed to be as small and densely arranged as possible for optimal loading onto standard pallets.

The example of tealight packaging makes this particularly clear:

[168] Based on Lumsden, K. (2004).
[169] Cf. Schönberger, H.; Galvez Martos, J. and Styles, D. (2013), p. 256.

To spot inefficient product packaging, the company launched a competition among employees called the Air Hunting Competition. Among other things, the packaging of tea lights was identified as inefficient, with 100 candles each packed loosely in a bag.

Instead of the loose packaging method, the tea lights were stacked in five layers of 4×5 each. As a result, the packaging volume was reduced by 30%. Each pallet can now be loaded with 360 packs instead of 250. For international shipments of the tea lights, only 42,000 pallets per year are needed instead of the 60,000 pallets previously required. In addition, the tea lights consume less shelf space thanks to the new packaging. Handling costs have also decreased.

A fully loaded 40-foot container with pallets of 360 packages of tea lights each would weigh 22 tons, exceeding the maximum allowable shipping weight. To get around this problem, the company has decided to ship the tea lights along with specifically lighter products such as pillows and mattresses. This is supported by a bundled and intelligently coordinated supply network[170].

Optimised packaging design increases the packing density in transport containers. This improves efficiency in the area of logistics with an accompanying reduction in transport operations and the environmental impact of logistics activities. In the example of tea lights, only a slight change in product packaging led to a 30% reduction in the required transport volume.

A film by VDI ZRE entitled "Less is more – packaging machines that save packaging material" shows, among other things, how a company succeeded in saving 75% material and 95% energy in the repackaging of beverage bottles by improving the packaging design and process compared to the previous procedure.[171]

[170] More information: Schönberger, H.; Galvez Martos, J. and Styles, D. (2013), p. 270.

[171] Cf. https://www.youtube.com/watch?time_continue=1&v=oeKrTFyrnvE&feature=emb_logo

Further examples of good practice are provided by a discount store:

Save packaging material in retail[172]

With the same content, the packaging of cashew nuts was reduced by 20%. Since more goods can now be transported on a pallet at the same time, not only is plastic saved, but also CO_2. In addition, the discounter was able to increase recyclability by using a mono-PP composite instead of metallisation in the new packaging.

Furthermore, the film thickness of plastic packaging for toast was reduced by 25%, saving approximately 50 tons of plastic per year.

When picking fruits and vegetables, a cord is wrapped around the transport boxes instead of packaging film (stretch film) to hold them together. This saves 85% of the previous film consumption. This corresponds to an annual saving of around 428,000kg of plastic.

Various indicators can be used to quantify improvements in packaging design and the environmental impact avoided as a result. For example, improved packing density can be measured in:

- kg of CO_2-equivalents saved per tkm (ton kilometres) or
- kg CO_2-equivalents saved per tonne of transported goods delivered.

It is quite conceivable that a modified packaging design that allows for lower packing density could generate increased environmental impacts in other areas, for example, if the material of the packaging is changed. To predict and, if necessary, avoid this effect, a life cycle analysis[173] or a comparable assessment of the environmental impact of the new packaging can be helpful.

[172] Cf. Lidl Germany (2018), p. 5.

[173] For more information, visit: https://www.ressource-deutschland.de/instrumente/leitfaden-ressourceneffizienz/analyse/detailanalyse-lebensweg/

Biological based packaging

Environmentally friendly packaging should consume as few resources as possible in its production, be easy to recycle and be ecologically recyclable after its period of use. Nature provides a perfect example of such packaging in the form of the banana peel. But paper and cardboard are also produced from renewable raw materials and are easy to recycle and reuse. Relatively new is packaging made from bio-based plastics, which are largely manufactured from renewable raw materials and usually consume only small amounts of resources in production. In addition, many biobased plastics are biodegradable in short periods of time.[174] However, it should be noted that the packaging is compostable in the required time period. If this is too long, the materials block the decomposition process in conventional composting plants and often have to be sorted out at great expense.

In an Internet database on biobased packaging materials, created by Büro Lebensmittelkunde & Qualität, Dr Alexander Beck, the materials can be classified in terms of their environmental compatibility on the basis of sustainability assessment factors. The user of the database, which is available free of charge, can check the various plastics for their technical suitability and compare them with each other. The database is available on the website of the Association of Organic Food Producers. (AöL).[175]

Less and better recyclable packaging

In recent years, the volume of transport in the mail order business has risen sharply, and with it the consumption of packaging within the industry. The amount of paper packaging used in distance selling has increased more than sixfold from 1996 to 2017. Shipping packaging increases packaging volume primarily for the following three reasons: They are used in addition to the primary packaging, the weight of the shipping packaging is higher than that of the retail packaging, or the additional environmental impact is not offset by the elimination of carrier bags.[176]

[174] Cf. Agency for Renewable Resources e. V.
[175] Cf. Association Agency for Renewable Resources
[176] Cf. Federal Environment Agency (2019).

Packaging can be classified into different categories. Listed below are the individual categories and possible measures to increase resource efficiency and recyclability.[177]

Product packaging

- using as few different materials as possible (ideally mono-material packaging),
- the individual material layers should be easy to separate (both for the customer in waste separation and for the companies in waste treatment),
- packaging should be able to be emptied completely so that no unnecessary waste is generated and waste contamination is kept to a minimum,
- make plastic packaging as light-coloured as possible; black or very dark plastics are difficult to sort in automatic waste sorting due to the optical processes,
- reduce printing on packaging to a minimum and avoid metallic printing,
- adhesives and inks used should be water-soluble and not heat-resistant, if possible, so that they can be separated more easily,
- if possible, avoid labels, otherwise make them from the same material as that of the packaging itself and make them as small as possible,
- using water-soluble labels that can also be easily detached from the rest of the packaging.

[177] Cf. Seyring, N. and Kaeding-Koppers, A. (2019), p. 7.

Service packaging

- avoid packaging or use reusable systems,
- optimally adapt packaging material and size to the product and requirements,
- using mono-material packaging without labels,
- reusing of service packaging (also for other purposes).

Transport and shipping packaging

- keep the amount of filling material as low as possible,
- using environmentally friendly filling materials (for example, recycled paper, wood- or straw-based material, compostable material made from wheat starch),
- here, too, use cardboard boxes and the like made of mono-material without unnecessarily large labels, if possible.

6 CONCLUSION

The retail and logistics sectors are among the highest-turnover industries in Germany and continue to show growth trends.[178] Both the retail and logistics sectors consume large amounts of natural resources, especially raw materials and energy. By adopting suitable strategies and measures, companies can counteract this and act more resource-efficiently. This brief analysis shows possible approaches to this. It also uses real-world examples to illustrate that resource-efficient actions are, for the most part, not only environmentally friendly, but often economically beneficial as well.

There is high potential for savings in the area of intralogistics and warehousing, for example through the optimisation of conveyor systems. Approx. 67% of industrial electricity consumption in Germany is caused by electric drives.[179] Plant and process optimisation therefore offers enormous potential for reducing electricity requirements and operating costs.

Digitisation also provides numerous opportunities to increase resource efficiency. With the help of digitisation and energy optimisation measures, the company described above saves around 500,000 euros in material and energy costs annually. In addition, the measures reduce annual greenhouse gas emissions by more than 2,600 metric tons of CO_2-equivalents (cf. p. 33).

Logistics properties account for a non-negligible share of greenhouse gas emissions in the GHD sector. Measures to increase building efficiency can make an important contribution to environmental protection. For example, one company managed to construct a logistics centre as a plus-energy building, generating more energy in a regenerative way than is needed for the building (cf. p. 36 et seqq.).

Furthermore, there is great potential for increasing efficiency in the area of transportation. The use of renewable fuels, alternative drives and further modifications to delivery vehicles are among many other possible starting points. For example, a logistics company managed to avoid 260,000 stops

[178] Cf. German Logistics Association (2020).

[179] Cf. Bavarian State Ministry for the Environment and Health (2010), p. 3.

and 3.4 million kilometres of travel each year with the help of a multi-temperature concept for truck holds (see p. 46 et seqq.). With the aid of adaptive air control elements to improve the aerodynamic profile, fuel savings of up to 22% can be achieved (cf. p. 47 et seqq.)

Resource consumption and costs can also be reduced through efficient route planning and fleet management. Thanks to the increased number of possible routes and the selection of the nearest logistics centre in each case, transport cooperation between two independent automotive suppliers succeeded in reducing the transport kilometres travelled by 54%. Digitisation technologies also have great future potential in this area and are already available today for many applications (cf. p. 58 et seqq.).

For both retailers and logistics companies, there are also numerous opportunities to save packaging material, both for product packaging and for service and transport packaging. For the transport of tea lights, for example, the packaging volume could be reduced by 30% by adapting the packaging design (cf. p. 68 et seqq.).

The brief analysis shows that there are numerous opportunities to save materials and costs in retail and logistics. Digitisation and automation technologies are on the rise. Companies, especially SMEs, can use these and other technological innovations as well as various efficiency measures to tap and profit from resource efficiency potential.

7 DOCUMENTATION OF THE EXPERT TALK

7.1 Programme of the Expert Talk "Resource Efficiency in Trade and Logistics"

Berlin, 29 September 2020

Moderation:	Dr. Christof Oberender, VDI Centre for Resource Efficiency
Top 1	Presentation of Selected Aspects of Brief Analysis No. 27: "Resource Efficiency in Retail and Logistics", Tim Kestner, VDI Centre for Resource Efficiency
Top 2	Packaging – protection and waste at the same time, Jessika Kunsleben, Efficiency Agency NRW
Top 3	Discussion on the subject area
Top 4	Transport packaging in the digital world of logistics: Potentials for resource efficiency?!, Dr Volker Lange, Fraunhofer Institute for Material Flow and Logistics (IML)
Top 5	Digitisation in trade and logistics – How digital business models save resources and offer economic opportunities, Florian Lange, Bitkom e.V.
Top 6	Discussion on the subject area

7.2 Documentation of the Expert Talk

The expert talk was held on 29th September 2020 by the VDI Centre for Resource Efficiency (VDI ZRE) on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Participants from the German Federal Ministry for the Environment, business, politics and science discussed the opportunities and challenges for trade and logistics that arise when implementing resource efficiency measures. The event focused on resource-saving packaging and the resource efficiency potential of digitisation.

7.3 Selected Aspects of Brief Analysis No. 27

At the beginning, Mr Kestner from the VDI Centre for Resource Efficiency presented a summary of the essential principles of resource efficiency. To this end, he first discussed natural resources (raw materials, energy resources, water, air, land and soil, ecosystem services) and explained what is meant by them. Subsequently, resource efficiency was defined according to VDI 4800 sheet 1 [180] as the benefit of a product or service compared to the effort required for it. Furthermore, strategies and measures were presented on how companies can increase their resource efficiency. In this context, product development, the production process and the production environment play a key role. The latter also includes transportation as well as warehousing and packaging of products. These topics were of particular importance for the technical discussion. The presentation of a linear product life cycle compared to the ideal case of closed-loop recycling concluded the basic section.

In the following, the participants were given an overview of the topics of the brief analysis "Resource Efficiency in Retail and Logistics". The introduction (chapter 1) is followed in chapter 2 by an overview and classification of trade and logistics in the economic context. Furthermore, current developments and trends are highlighted before "Green Logistics" is discussed in more detail. Chapter 3 presents essential topics of resource efficiency in intralogistics and warehousing. These include efficient materials handling technology, automation and digitisation, and resource-efficient retail and logistics buildings. Chapter 4 identifies numerous measures for increasing resource efficiency in the transportation sector. Finally, chapter 5 provides an overview of possible measures in the field of packaging. A conclusion summarises the key points of the brief analysis.

In the "Overview of trade and logistics" section of Mr Kestner's presentation, the annual sales and number of employees in the German trade sector were compared with the construction sector to show the great economic importance of trade in Germany. In 2017, this sector generated annual sales of approximately 2.09 trillion euros with a total of approximately 6.4 million

[180] VDI 4800 Sheet 1: 2016-02.

employees. The role of retail within logistics was also illustrated by figures. In Germany, retail logistics accounts for around 30% of total logistics costs. The biggest current trends in logistics emerge from a study with a survey of experts by the German Logistics Association (BVL). Accordingly, an increase in cost pressure, the individualisation of transports and products, and the complexity of logistics processes can be observed.

Green logistics, as defined by Deckert and Fröhlich[181], refers to "the alignment of logistics functions with the goals of environmental sustainability. The goals here are resource conservation, i.e. improved resource efficiency, and environmental sustainability, i.e. reduced impact of emissions."

An excellent example of the digitisation of intralogistics is provided by Blechwarenfabrik Limburg. A warehouse management system (WMS) controls the inventories in the automated high-bay warehouses there. At any time, the system has information about which goods are on which load carrier. As a result, there are no more undefined warehouses and unnecessary stocks in the factory. This also makes more efficient use of space. In addition, the WMS controls the movement of materials in the warehouse using driverless transport systems. This results in less transport damage previously caused by manual handling. Thanks to these measures, Blechwarenfabrik Limburg saves around 100t of tinplate every year.

In another practical example, the logistics centres and networks of two companies were merged and are now coordinated centrally. This reduced transport kilometres by 54% and transport-related emissions by 27%. This was only possible thanks to the increased number of available routes and the selection of the nearest logistics centre in each case.

With regard to packaging, it was emphasised that transport utilisation is still too low, also due to insufficiently optimised packaging in German road transport. At an average of 82%, volumetric capacity utilisation is significantly higher than weight-based capacity utilisation, which averages only 57%.[182] Although the above data dates back to 2004, other sources also show

[181] Deckert, C. and Fröhlich, C. (2014).
[182] Lumsden, K. (2004).

that this situation has not changed much, such as an article in the Tagesspiegel from 2015 entitled “A quarter of all trucks drive around empty.”[183]

Furthermore, the so-called air-hunting competition of a furniture manufacturer was presented. To identify inefficient product packaging, the company launched a competition among employees. Among other things, the packaging of tea lights was identified as inefficient, with 100 candles each packed loosely in a bag. Instead of the loose packaging method, the tea lights were stacked in layers. As a result, the packaging volume was reduced by 30%.

It was also emphasised in the presentation that a trade-off between reusable or single-use systems should always be made on an individual basis, depending on the specific case. General statements on the benefits are hardly possible here. Life cycle assessments and comparable methods, on the other hand, provide a good basis for decision-making.

Many bio-based plastics are biodegradable in relatively short periods of time. A plastic is considered to be biodegradable if it decomposes within twelve weeks. However, it should be noted that the packaging is compostable in the required period of time. Most composting facilities operate with a decomposition time of six weeks. Therefore, bioplastics often block the decomposition process in conventional composting plants and have to be sorted out at great expense.

Finally, possibilities at the vehicle fleet were presented. Aerodynamic improvement of delivery vehicles, for example, can reduce fuel consumption by up to 25%. Options range from aerodynamically shaped trailers and fold-out air deflectors to completely flow-optimised semitrailers.

In the conclusion, it is shown in summary that companies from the retail and logistics sectors can act more resource-efficiently through suitable strategies and measures. Examples also show that digitisation and automation technologies are on the rise and that resource efficiency can also become an economic advantage.

[183] Kramer, S. (2015).

7.4 Packaging – protection and waste at the same time

Packaging plays an important role in terms of resource efficiency, as it protects products and thus preserves resources on the one hand. On the other hand, natural resources are also needed to produce the packaging material. Mrs Jessika Kunsleben from the Effizienz-Agentur NRW presented this dichotomy in her keynote speech and showed possible approaches for improving packaging, but also their limitations.

Sustainable innovations in packaging can efficiently reduce the use of resources. This is the case, for example, when packaging can be collected and recycled at the end of its life cycle. This requires an appropriate design of the packaging, since it is already decided in the development phase how the product will behave in the further course of its life. Mrs Kunsleben emphasised that approximately 80% of a product's environmental impact and cost are determined by design. Thinking in terms of life cycles is therefore a crucial key to resource efficiency.

In the linear value chain model, there is a value build-up from raw material extraction to the use phase. This is followed by an exclusive loss of value. In the circular economy model, this is different. The model for this is nature, which generally knows no waste. In the Circular Economy, a distinction is made between biosphere and technosphere. Products and services are part of an extensive value network. Currently, about 43% of the total costs of a manufacturing industry are material costs.[184] Only about 11% of recyclable materials are returned to production.[185]

Eco-design is a design approach for environmentally friendly products, services and business models. The goals of the eco-design methodology are to minimise the environmental impact along the value chain and to increase resource efficiency. Principles that should be followed are durability, repairability, material efficiency, energy efficiency, low problematic materials, use of alternative raw materials and recyclability.

[184] VDI Centre for Resource Efficiency GmbH (2015).
[185] Eurostat (2020).

Furthermore, Mrs Kunsleben addressed the Packaging Act, which came into force at the beginning of 2019. The aim of this law is to promote a resource-saving cycle of packaging. The law states that the person who commercially circulates packaging that accumulates as waste at the end user is also responsible for its disposal. Dual systems take care of the proper disposal of packaging (yellow and blue garbage cans, bottle banks) as well as sorting and recycling. The Packaging Act provides the legal framework for companies subject to licensing. In the next few years, the federal government will examine whether recycling quotas should be raised further. Ecologically advantageous (easily recyclable) packaging should cost less to license in the future.

The “10Rs” of the Circular Economy show potential for resource efficiency in the packaging industry. In descending order of importance, the following principles should be followed: Refuse, Reduce, Resell/Re-use, Repair, Refurbish, Remanufacture, Repurpose, Recycle Materials, Recover (energy), Remine.

However, there are also limits to resource efficiency in the area of packaging. One aspect of this is the limited separability of material composites. If different packaging materials are too interconnected, recycling may no longer be possible. Other limitations include the limited availability of environmentally friendly materials, hygiene regulations, and economic and aesthetic considerations.

A good example of how resource efficiency can be achieved in the packaging industry is provided by DY-Pack GmbH. The company produces paper bags for demanding applications. Resource efficiency measures can save around 30t of glue, around 89t of paper and cardboard, and around 143t of CO_2-equivalents per year in the company.

Bioplastics represent a possible alternative to conventional plastics. However, the disposal and the degradation behaviour in nature or in industrial plants are discussed very controversially. There is a conflict between biodegradability and environmental littering. The transformation of plastic by microorganisms leads to biodegradation. When oxygen is added, the plastics are converted into carbon dioxide, water, mineral salts, and biomass; when no oxygen is added, they are converted into carbon dioxide, methane, mineral salts, and biomass. Bioplastics are considered compostable if complete degradation takes place in a comparatively short time. The Closed Substance Cycle Waste Management Act provides for the avoidance, re-use or recycling (material, raw material) of plastics. The biodegradation of plastics is only beneficial if the property of biodegradability results in an additional benefit, e. g. if it could positively influence the decomposition process of biological waste.

The abandonment of product packaging, such as in "unpackaging stores," also raises controversy. The applicable hygiene regulations must be met, which is why such a concept is not suitable for every product. Furthermore, the shelf life of food must be indicated. Last but not least, aspects of economic efficiency also play a role.

Along the value chain of products, there are numerous conflicts of interest on the part of the various players. These arise primarily between packaging manufacturers, politicians, retailers and consumers in a wide variety of forms. Skilful cooperation is of particular importance here to advance resource efficiency in the packaging sector.

7.5 Discussion – Part 1

With regard to the Packaging Act, it was emphasised that the quantities of plastic waste returned to the Dual System have increased, although less than generally hoped. The fact that the Packaging Act for the first time contains a catalogue showing which packaging must be licensed in the dual system before it can be placed on the market was also described as progress. Also, he said, packaging in the dual system has already become cheaper and packaging design in general has improved in recent years, as there are clear criteria for environmentally friendly and efficient packaging design. However, material composites are considered problematic. The packaging material is sometimes not recognised correctly by the consumer and sorted incorrectly. In addition, material composites are difficult to recycle because the individual materials can often no longer be separated by type, or at least this is not possible in an economically viable manner. The demand was put forward to financially favor ecologically advantageous packaging in licensing in order to thereby create incentives. The evaluation or classification of the ecological advantage could be done by means of life cycle assessment or CO_2 balance.

The question was asked what the current recycling rates for packaging materials refer to: These result from the mass ratio of the (plastic) material delivered to the recycling plants versus the material that can be recycled from it. The recycling rate thus shows how well the (technical) recovery within the recycling plants is proceeding and how much foreign material is entering the respective value streams.

In response to the question about existing approaches to cargo space capacity planning, reference was made to the following presentation by Dr Volker Lange, as well as with regard to the question about digitisation measures to improve transport utilisation.

Furthermore, the question of the additional financial cost of ecologically sustainable packaging came up. It was pointed out that this could hardly be generalised and can vary greatly from individual to individual. For example, there is already easily soluble adhesive for material composites. However, the economic aspects of this were not known in the discussion group.

Furthermore, the question was discussed whether metal packaging with good recyclability but certain other disadvantages would be a conceivable alternative to plastic packaging, for example in the food sector. According to experts, plastic packaging is indispensable in this area in particular, however, as it has many advantages (also compared to metal packaging), which were not explained in detail. Recycled plastic is also often problematic, he said, as it often shows poorer properties than primary material and is often more expensive.

When asked if there were any special methods for ecological packaging development besides eco-design, it was answered that innovative business models can serve as a possible approach. One example given was the use of cardboard packaging, which is foldable and can be returned to the sender at the sender's expense. Eco-design was also highlighted as an already very good approach. The “triple-layer business canvas” was also mentioned as a suitable method to find further solutions. This method is used to create sustainability-oriented business models. It adds two levels to the original Business Model Canvas: an environmental level based on a life cycle perspective and a social level based on a stakeholder perspective.

Furthermore, the role of wholesalers and retailers with regard to the more environmentally friendly use of packaging was discussed. In this context, the citizens' dialogue of the new German resource efficiency programme “ProgRess III” was mentioned, in which packaging played an extraordinary role. This issue is apparently already perceived by the population as a very urgent and important environmental issue. A pilot project from Hamburg was presented below. In this process, products ordered online are delivered in reusable plastic bags, known as “re-packs”, which can then be folded and returned by the customer.[186] To do this, the customer simply has to drop the bag into the nearest mailbox. Postage will be paid by the supplier. It was noted that, in general, response rates were a critical issue of such systems. In addition, there are usually flat-rate prices for packaging systems between retailers and logistics companies, so there is little incentive to improve the systems because it is not financially worthwhile. Both sanction and subsidy measures are being demanded by citizens in order to design and use packaging in a more resource-efficient manner, the group of participants said.

The question of why the cost pressure is not passed on to the customer was answered by an expert from the business community. According to the study, there are currently only a few truly ecologically oriented e-commerce retailers, and there are also too many different packaging systems, so that it would be very time-consuming and expensive to convert these systems completely. The players involved would first have to make major investments here, which they are generally not prepared to do without further ado.

7.6 Transport packaging in the digital world of logistics: Potential for resource efficiency?!

In his keynote speech, Dr Volker Lange from the Fraunhofer Institute for Material Flow and Logistics (IML) gave an overview of transport packaging in the “Digital World”. This means that in the future, packaging will not only serve as a load carrier, but also as an information carrier.

[186] More info on the project at: https://www.originalrepack.com/?lang=de

At the beginning of his presentation, Dr Lange introduced the social and technological change as well as current developments in the field of transport packaging and digitisation. These include topics such as globalisation, individualisation, demographic change, sustainability, social media, urbanisation, and climate change, but also automation, robotics, smartphones, sensor technology, 3D printing, drones, augmented reality (AR) and virtual reality (VR), autonomy, Big Data and artificial intelligence (AI), and the fourth industrial revolution.

Digitisation is a key driver with exponential growth rates. Digital devices such as smartphones, tablets and others are used to identify goods and as a means of communication. Mobile devices enable the merging of the physical and virtual worlds. Social media contribute to networking in new dimensions with high influence. Big Data and AI technologies enable the processing of enormous data streams and machine learning.

In addition, digitisation is having a strong influence on retail, services and the consumer. Thanks to “mobile commerce”, there is often only one click on the (mobile) electronic device between need and satisfaction. In addition to individualisation, the personalisation of products is also playing an increasingly important role here. The so-called hybrid customer, who switches between the online and offline worlds, is changing logistical structures. Since packaging depends on the retail format, there are large differences in packaging depending on the distribution channel. In e-commerce, the trading units are significantly smaller than in retail or wholesale. In addition, customers increasingly prefer to have their deliveries delivered individually by dropping them off in parcel stores, parcel boxes, at their workplace or similar.

Innovations in the packaging sector can be divided into three areas: “physical”, “interactive” and “digital”. Physical innovations include improved quality assurance and testing, production technologies such as 3D printing, and alternative packaging materials. The “interactive” area includes smart devices, assistance systems such as AR & VR, as well as intelligent labels and smart displays. Digital innovations can be found in the area of Big Data and AI, cloud services, platform economy, IoT technologies (Internet of Things) and sensor technology.

The highest priority for the ecological improvement of packaging is the avoidance of unnecessary packaging material. Above all, the avoidance and reduction of over-packaging and over-stocking, air in the packaging and during transport, damage, shrinkage on the packaging and a packaging material mix with costly recycling processes are crucial.

One challenge lies in the heterogeneity of packaging as a result of increasing individuality. An enormous variety of packaging, a lack of modularisation and a lack of compatibility lead to high logistical expenses overall. Standardisation through modular coordination offers a lot of potential here for increasing resource efficiency.

Dr Lange further emphasised that the decision in favour of a single-use or reusable packaging system must always be made anew and in relation to the individual case. A general evaluation of the advantageousness is not possible. There are good arguments for both packaging systems. Logistical parameters such as delivery distance play a decisive role here.

Another challenge concerns volume utilisation in the transport vehicle. Low volume utilisation of the packaged goods, the packaging and the loading unit results in a "triple" type of waste: low volume utilisation of the packaged goods in relation to the packaging, of the packaging in relation to the loading unit and of the loading unit in relation to the loading space. Efforts should always be made to avoid storing and transporting “air” and instead make the best use of existing volumes.

Dr Lange presented smart packaging using the EURO pallet as an example. Functions that an intelligently equipped transport pallet fulfils are uniqueness of assignment, localisability, identification, status recognition, communication with corresponding electronic devices and data networking among each other. In this context, the speaker presented a Fraunhofer IML project on the 2D code pallet. Such a code allows the pallets to be serialised and thus digitally recorded, both individually and in batches. In addition, defect reports can be made very easily. Using IoT and sensors on the pallets, data on location, temperature, vibration, humidity and the like can be collected and processed. A project for AI-based empty pallet counting was also presented by the speaker. The Fraunhofer Institute has developed a smartphone app specifically for this purpose, which automatically records and counts the pallets using the attached codes.

In summary, the potential for increasing resource efficiency in the area of transport packaging was highlighted. These include, above all, the clear assignment of load carriers and transported goods, the avoidance of inefficiencies in the logistics process, the reduction of inventories, optimised empties management, the creation of transparency through near-real-time tracking and tracing, the clear assignment of responsibilities, and the detection of quality losses and shrinkage.

7.7 Digitisation in Retail and Logistics – How digital business models save resources and offer economic opportunities

In his keynote speech, Mr Florian Lange from the German Association for Information Technology, Telecommunications and New Media (Bitkom e.V.) presented the two topic complexes “Digital Resource Efficiency in Logistics” and “Digital Resource Efficiency in Retail” and went into selected aspects.

At the beginning, Mr Lange presented basic ideas on digital resource efficiency and briefly explained to them. He emphasised that digitisation measures in companies usually have an economic and not an ecological background. Resource efficiency is often a result, but not an intention, of digital transformation processes.

Opportunities for digitisation are available along the entire value chain and in all areas of logistics. Digitisation measures can lead to dematerialisation, i.e. less material is needed to provide the same service. As a result, digitisation can contribute to the decarbonisation of logistics and trade. However, the ecological effect of digitisation measures is not automatically positive and should be examined on a case-by-case basis to ensure an ecological benefit.

According to Bitkom, only 15% of logistics companies agree that one of the biggest benefits of digitisation in logistics is the reduction of environmental impact. So there is still a lot of groundwork to be done here so that companies become more environmentally oriented, recognise the environmental benefits of digitisation, and take advantage of them.

For the above-mentioned topics, Mr Lange presented selected aspects and addressed possible technologies, the sustainable influence (impact) and possible use cases.

The first of the three Digital Resource Efficiency in Logistics topics presented is the Digital Supply Chain. This involves the complete digitisation of the entire supply chain with seamless information sharing and real-time information. The holistic view of supply chains is of particular importance here. Ideally, the digital supply chain enables paperless handling of logistics processes along the entire value chain and leads to a reduction in transport and travel distances. Increased transparency along the supply chain can uncover inefficiencies. Possible use cases are currently being investigated and tested in an experiment on the digital supply chain conducted by the Bitkom working group “E-Logistics and Digital Supply Chain”.

Relieving road congestion can ultimately lead to resource efficiency if it means that repair and maintenance work is less frequent and roads can be smaller in size from the outset. Intelligent concepts for last-mile delivery, i.e. delivery to the end customer, can provide support here. While intelligent route planning and new mobility concepts such as delivery by electric trucks or e-bikes are already in use, concepts for delivery with the help of drones and transport robots are still in the development and testing phase. Other benefits of efficient last mile delivery include a reduction in idle time and travel distances, as well as a reduction in emissions. Current projects in this area include DPDHL's Greenplan and Cityscooter and Amazon Drone Delivery.

Blockchain solutions can also help increase resource efficiency. A blockchain with dashboards and international interfaces can provide insights into deep dimensions of one's supply chain with the help of tracking and tracing. In addition, human rights and environmental standard violations can be tracked and thus the Due Diligence Act can be better complied with. Overall, blockchain technologies enable greater transparency of the supply chain and thus also the uncovering of efficiency potentials. A current practical example is IBM's Food Trust project.

On the topic of digital resource efficiency in retail, Mr Lange first presented the general concept of smart stores. These are designed to enable reduced energy requirements, extended building and product life cycles, and store comparison for sustainability optimisation. This is achieved through the extensive use of sensor technology including the use of IoT technologies and smart lighting and system controls such as cooling, heating and ventilation devices.

The use of artificial intelligence (AI) can also increase resource efficiency in retail. AI-powered returns management and Big Data technologies enable the reduction of over-ordering and over-production, as well as the optimisation of the company's own supply chain.

Furthermore, the use of 3D printing technologies in retail can contribute to resource efficiency in the development of prototypes – whether in the area of packaging or directly in product development. New, environmentally friendly production materials can be used in the 3D printing process. In addition, plastics can be optimally recycled if certain design rules are observed, thereby creating a closed material cycle.

Finally, the speaker emphasised that there is not one logistics and likewise not one retail trade per se. Rather, there are multiple facets with varying degrees of digitisation. Furthermore, Mr Lange summarised that digitisation and sustainability should always be thought of together. However, modern technologies also require large amounts of energy. The key to sustainable digitisation is therefore environmentally friendly (regenerative) energy concepts. Digital sustainability concepts are generally more economical than conventional business models and, if planned and applied appropriately, can help increase resource efficiency and thus protect the environment.

7.8 Discussion – Part 2

The question of which digitisation technologies are already being used in retail and logistics and to what extent was discussed To this end, it was presented that AI technologies are already established in the market and lead to cost savings. Blockchain technologies, on the other hand, are generally still too cost-intensive and have not yet been widely deployed by companies. Furthermore, it was stated that there is currently little concrete data on the use of the technologies mentioned. However, the transformation process has not yet taken place, above all “in the minds”. Accordingly, a psychological obstacle had to be overcome before a real breakthrough could be expected. Other countries are already ahead of Germany in this area, while there is still a great deal of scepticism in this country. It is important to learn how to deal with new technologies and to have the courage to innovate. Digitisation as a general trend is unstoppable, he said. The panellists agreed on this. At the moment, we are in a transitional period toward a comprehensive Industry 4.0.

There was also discussion on which areas there are still obstacles that hinder the digitisation trend. One important aspect, he said, is the workforce of companies and their strong heterogeneity in terms of affinity for digital technologies. It is very important to fully involve the company's workforce in digitisation measures right from the start and also to encourage employees to contribute ideas and innovations themselves. Ultimately, it is the corporate culture that determines the successful planning and implementation of measures to increase resource efficiency. This is especially true with regard to digital technologies. One inhibiting factor is still the fear of surveillance by the workforce. Increasing data collection would also provide more opportunities for misuse of this data. It is therefore important to handle collected data in a trustworthy manner and in compliance with the law.

The question was raised whether AR systems and the like can contribute to resource efficiency in retail and logistics. It is relevant that the technologies are accepted by the people who use them and that the management level is open to their use and implementation in the company. Technologies such as AR glasses, for example in order picking, could significantly restrict employees' degrees of freedom. It is also important to show them the positive aspects, i.e. the benefits of the technologies.

Blockchain technologies could be used to increase data security and traceability of processes. Projects such as IBM's "Food Trust" and others like it are already demonstrating that the use of blockchain in retail and logistics is possible and makes sense.

It was also noted that there are major deficits in the area of uniform data standards. In order to facilitate the cross-company and international exchange of digital data, such a data standard is indispensable. The EURO transport pallet offers a good example of successful standardisation in the logistics sector. By the end of 2021, according to one panellist, if possible, every new EURO pallet should have a unique QR code. In this way, the transport pallet can be digitised and tracked.

The question of whether transportation cooperatives were already widely used in practice was answered in the negative by the panel. Rather, he said, it is difficult to set up transportation cooperatives because companies are primarily interested in optimising themselves. In addition, there is a great deal of scepticism regarding the data integrity of any cooperation partners.

The potential and limitations of using 3D printing were also discussed. The COVID-19 pandemic has led to massive supply chain restrictions in some cases. In response, 3D printing processes have been used to produce spare parts in the automotive sector, for example. The use of this technology has probably made a strong leap as a result and will also be used more frequently from now on. This is especially true for small components and low volumes, as the performance of 3D printers is still severely limited compared to conventional production processes.

Another topic of discussion was packaging. It was emphasised that it is important to think through the entire supply chain from the very beginning, i.e. from product development onwards, in order to achieve the highest possible resource efficiency. For example, he said, there is a furniture retailer whose goods produced in China and India are already packaged there in the factory in the same way as they would be delivered directly to the end customer. This could save unnecessary packaging material.

The question arose as to what was needed to increase resource efficiency in the packaging sector. The response was that numerous research projects were already underway in this area, but that many solutions were still lacking.

The panel was also asked whether rail transport could be made even more resource-efficient and how it could be used more. The response was that rail transport in Germany had originally been designed primarily for passenger transport. In addition, there was a lack of flexibility, as very rigid structures prevailed. Another barrier to greater use, he said, is the low average speed of rail transport of only about 6km/h compared to about 50km/h for road transport.

7.9 Summary

In the first keynote speech of the event, selected topics of the brief analysis No. 27 “Resource efficiency in trade and logistics” were presented. The presentation focused on measures in packaging and digitisation technologies as well as on the topics of the expert discussion.

The second lecture presented the dichotomy of packaging, on the one hand having to ensure a protective function and on the other hand not contributing to the waste of resources. Appropriate measures to reduce packaging materials and harmful environmental impacts were presented. Opportunities were highlighted, but limits were also pointed out.

In the discussion that followed, some relevant issues of the current packaging problem were addressed. The Dual System and recycling quotas were addressed, but alternative packaging materials and the role of wholesalers and retailers in increasing resource efficiency were also discussed.

In the subsequent keynote speech on the topic of transport packaging and digitisation, the speaker outlined various aspects of the digitisation currently taking place and highlighted how digitisation technologies can be used to make transports and transport packaging more resource-efficient.

The fourth and final presentation was dedicated to the topic of digitisation in retail and logistics and illustrated how digital business models save resources and offer economic opportunities. In this context, the speaker presented resource-related aspects of the digital supply chain, last mile delivery and also blockchain technologies. Other topics included smart stores, artificial intelligence and 3D printing.

The final discussion was held mainly in relation to digitisation technologies and their resource efficiency potential. For example, the question was discussed which digitisation technologies are already being used in retail and logistics and to what extent. In addition, it was discussed in which areas there are still obstacles that hinder the digitisation trends. There were also exchanges on data standards, transport cooperation and data security. Despite the focus on digitisation, the topic of packaging found its way back into this panel and good practice examples from retailers and logistics providers were highlighted. Finally, the potential of German rail transport compared to road transport was discussed.

In summary, it can be seen from the presentations and discussions that many measures to increase resource efficiency in the area of trade and logistics are already being applied in practice. However, there is still great potential for improvement, particularly with regard to digitisation technologies and the further improvement of packaging systems. Numerous research projects and practical projects are underway on these topics. This also shows the relevance that is attributed to these topics by politics and business. However, the successful use of promising, innovative and resource-saving technologies and measures depends not least on how economically they can be implemented in practice and whether companies have the necessary will to do so.

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