Evaluation of a Sustainable Crowd Logistics Concept for the Last Mile Based on Electric Cargo Bikes

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Abstract During to the recent growth of e-commerce and as the number of shipments is rising last mile services are facing many challenges and hurdles especially in relation to sustainable action. Within the project NaCl measures were tested to address and to positively impact the three dimensions of sustainability on the last mile. Based on the usage of electric cargo bikes and a crowd logistics approach shipments of a regional logistics service provider and beyond of regional stationary retailers were realized during a three-month pilot phase. The project's activities and objects were evaluated regarding positive effects on social and ecological sustainability while including the economic aspects of the transportation system. The aim of the evaluation was to be able to make a fundamental statement regarding the usability of the crowd logistics approach and the sustainable Customer Relationship Management approach and, if necessary, to identify optimization potential and concrete suggestions for improvement. Another objective of the evaluation was to determine the needs of different participants such as retailers and shippers as well as of receivers and deliverers while considering sustainable goals. Various data collection and analysis methods were adopted to evaluate the project objectives in quantitative and qualitative ways. The evaluation audited the approach's ability to have positive impacts on different dimensions of sustainability and showed further possibilities for improvement.

Keywords Sustainability · Electromobility · Last mile · Crowd logistics · SusCRM · Cargo bikes

1 Introduction

The "NaCl—Nachhaltige Crowdlogistik (engl.: 'sustainable crowd logistics')" project pursues the development of an innovative sustainable logistics concept based on electric cargo bikes and a crowd logistics approach. Project participants are the

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Bremerhaven University of Applied Sciences, the industrial manufacturer of cargo bikes Rytle GmbH and the local transport service provider Weser Eilboten GmbH (WEB). In close cooperation, the aim is to design a sustainable logistics system for the last mile. The system consists mainly of electric cargo bikes and a digital infrastructure. The basic objectives of the project are the positive effects on the ecological and social dimensions of sustainability, while considering the economic aspects. Other participants in the project are the crowdworkers, the B2B (Business-To-Business) and B2C (Business-To-Consumers) customers respectively the retailers and recipients.

In order to test the effectiveness of the project-related measures, a three-month pilot phase was planned in a test field close to the city center in Bremerhaven. As part of the piloting, an evaluation of the logistical concept and the project objectives was carried out. The evaluation realized within the framework of a bachelor thesis includes a systematic analysis and evaluation of the project, project-related activities, and the pilot phase, considering the interests of stakeholders. The evaluation is based on an empirical collection of project-related data and information. The results of the evaluation should help to provide information on the achievement of the objectives and to identify weaknesses of the NaCl concept as well as to contribute to the further development and optimization of the concept.

The evaluation procedure first requires the definition of the project-related objectives of the NaCl approach. Subsequently, the evaluation objects of the project are determined. A concept is developed from the underlying objectives and subjects of the evaluation, which includes a selection of appropriate methods for data collection and analysis. After the collection and analysis of the corresponding data, these are interpreted and evaluated. The findings must then be documented and reported to the project partners. Finally, the findings can be used for optimization and as a basis for decision-making.

2 State of Art

2.1 Fundamentals

Sustainability. In the context of sustainability, there has been increasing talk of "sustainable development" since the Brundtland report in 1987. Sustainable development is described there as a process that guarantees that today's generations can meet their needs without limiting the opportunities for future generations to meet theirs. Since then, sustainability has been seen as a three-pillar model that combines the three dimensions of ecology, sociology, and economics, with the core idea often being the equal consideration of the three dimensions, while other approaches go a step further and place ecology above sociology and this in turn above economics [1].

The ecological dimension of sustainability includes efficient and ongoing resource management to ensure that the rate of degradation does not exceed the rate of regeneration of renewable natural resources. At the same time, we must prevent the extraction

of non-renewable resources, or use non-renewable resources only to the extent that equivalent compensation can be created in renewable raw materials. Nature's regulatory and supportive functions must also be preserved, which means that emissions into the environment must be adapted to nature's material absorption capacity [2].

The agenda 21 and the Brundtland report describe social sustainability based on intergenerational and intragenerational justice, i.e., that future generations have the same opportunities as today and that all people living on Earth have the same opportunities [1, 3]. Social sustainability is closely linked to the ecological dimension, since a balance between human needs and the potentials and resources of nature must be sought [4].

According to Heins, social acceptance for sustainable development, social and health protection, social stability and a fair distribution of wealth and equal opportunities are necessary to solve these problems [5]. According to Zimmermann, another crucial level is participation in the form of involvement and co-decision-making of all social classes [4].

The economic dimension of sustainability combines the principles of welfare economics and sustainability. Sustainable development is directly influenced by the way people operate and from the management of natural energy and material resources. Material inputs into the environment that arise in the economic process, such as waste and emissions, illustrate the direct relationship between the ecological and economic dimension [4]. Intelligent management of the economy can reduce entries into nature, and it is necessary to adapt these entries to the absorption capacity of the environment. A look at the distribution problem, which also deals with the possibilities of basic services for all people, shows that the economic dimension is also strongly linked to social sustainability.

Crowd Logistics. Crowd logistics is an approach that is currently increasingly found in specialist literature and is being used in practice to meet the difficulties on the last mile. The term "crowd logistics" can be traced back to the term "crowdsourcing", which was first named by Howe in Wired Magazine [6]. Crowdsourcing, for its part, is a word composition of the words "crowd", which describes a defined mass of people—in the sense of crowd logistics: potential delivery drivers—and "outsourcing", which means the transfer of processes and functions—such as delivery services—to third parties [7]. Crowdsourcing is often described in literature in relation to a digital, internet-based way of working [8, 9].

According to Leimeister and Zogaj, the multitude of existing definitions around the term crowdsourcing underlies the following three elements: the client, the crowd and the process. The client or crowdsourcer and simultaneous initiator starts the process of crowdsourcing by outsourcing internal tasks, e.g. logistical activities such as parcel delivery, to contractors or the crowd. The crowd describes a previously defined or undefined large mass of people or so-called crowdworkers, whereby the size of the crowd depends on parameters of the task to be completed [8, 10].

Blohm et al. state to supplement by a fourth main component regarding internet-based crowdsourcing: the crowdsourcing platform, which is provided internally or through an external intermediary [7]. The platform acts as an interface between the

crowdworkers and the crowdsourcer by providing the tasks that can be accepted by the crowdworkers and then be executed.

Electric Cargo Bikes. Cargo bikes are bicycles designed to transport loads and is basically not a novelty, but new designs and innovations in battery technology have ensured a revival of these means of transport.

As a result, cargo bikes are now found not only as manually driven vehicles, but also as electrically assisted vehicles, referred to as electric cargo bikes or e-cargo bikes. E-cargo bikes make use of the electric drive technology, so that electric cargo bikes can be assigned to the electromobility sector. According to Scheurenbrand et al., electromobility is a highly networked industry and aims to meet mobility needs with the inclusion of sustainable aspects. The vehicles will be equipped with portable energy sources such as batteries and an electric drive [11].

Growing environmental awareness and new developments in modern mobility have led to new perceptions of the benefits of the internal combustion engine. The fact that fossil fuels such as oil are finite and that mobility-related environmental pressures have increased and continue to increase has led to a rethink of the dominant drive. Guidelines on sustainable development and an increasing degree of urbanization promote technological change from the internal combustion engine to electric driving concepts [12].

2.2 Challenges and Opportunities

The Last Mile is currently described as one of the most expensive, less efficient and most polluting sections of the supply chain [13]. Up to 75% [13, 14] of the total logistics costs are attributed to the last part of the supply chain, that can be connected to the high inefficiencies and poor environmental performance due to e.g. high stop densities and low stop factors or the absence of the recipients [15].

An ever-increasing volume of transport and the associated traffic volume [16], especially in inner cities, call for urgent action to relieve society, the economy and, above all, the environment. Consequences of increased traffic include congestion, noise, greenhouse gas and pollutant emissions, as well as safety risks such as accidents. It is therefore not surprising that the last mile has negative effects on the environment and quality of life of people. According to a study by the World Economic Forum, developments on the last mile will lead to increases in CO_2 emissions from delivery traffic of 32 percent and around 21 percent more traffic obstructions until 2030 [17].

Another major problem of urban logistics is the conflict that consumers want a fast and flexible delivery of their goods, especially in online retail, while at the same time low or no delivery costs are required [18]. This discrepancy, together with the difficult to calculate order structure and the atomization of shipment sizes, have a significant impact on the shipping costs of courier, express and parcel service providers (CEP service providers), as well as the heterogeneity of transport packaging

and the handling of goods, which is determined by the type of goods such as products to be cooled [19].

Overcoming the Last Mile presents logistics service providers with many complex environmental and social challenges but offers several opportunities to generate competitive advantages.

Compared to 1990, a 40% reduction in greenhouse gas emissions in Germany should be achieved by 2020. In 2018, the reduction compared to 1990 was 27.5%. According to a recent report by the Federal Environment Agency, with an absolute value of 163 million tons of CO_2 equivalent, 20.2% of greenhouse gas emissions in 2019 were in the transport sector and 254 million tons of CO_2 equivalent accounted for 31.5% in the energy sector [20].

Between 1995 and 2018, CO_2 emissions from road freight transport increased by 22% [21]. Despite improvements in efficiency in transport, there has been little success in reducing greenhouse gas emissions, which can be explained by the increase in traffic volumes and transport services, especially in freight and transit transport [22]. The volume of CEP shipments in Germany has increased by 108% from 1.69 billion in 2000 to 3.52 billion in 2018 and the trend is increasing [16]. A comparison of the trends in the volume of shipments and of goods carried by road transport shows an unequal increase in the two key figures and suggests that a trend towards lighter, but more shipments in terms of quantities has developed. This trend, coupled with emissions developments, poses major challenges and changes in the transport sector. Especially on the last mile, these tendencies are leading to major issues for the CEP sector and solutions must be found to address this situation. At the same time, opportunities arise to distinguish themselves from competition and generate competitive advantages. In connection with the increasing environmental impact, drive technologies based on electromobility are exceedingly popular.

In a study by the Fraunhofer Institute on climate balances of different drive technologies is stated, that electric cars have clearly the best climate balance for both 2019 and forecasted for 2030 [23]. The study used Well-to-Wheel analysis so that the entire impact chain was considered. It can also be observed that cargo bikes are used in the logistics sector with an increasing tendency. A study by the "Ich entlaste Städte (engl.: 'I relieve cities')" initiative shows that companies tend to use cargo bikes as an alternative to delivery vehicles with internal combustion engines on the last mile. The initiative lends cargo bikes to companies for one euro per day for a maximum period of three months. A survey of this activity showed that after the test, one in five users bought a cargo bike or tended to buy one [24]. According to a study of the "Cycle-Logistics "-project, cargo bikes have the potential to replace 50% of all urban transport-related journeys and have a positive impact on air quality and quality of life as well as safety in the city [25].

Sustainability in customer relationship management is understood by the abbreviation SusCRM that is a composition of the word "sustainable" and the abbreviation CRM, that stands for customer relationship management. SusCRM is a novel approach to conveying sustainability in the sense of all three dimensions within companies, in the customer relationship and to third parties. The aim is to increase

participation in sustainable processes and to attract a loyal clientele for a sustainable business model [26].

An idea for shortening delivery routes per shipment and thus saving emissions on the last mile is bundling and can be designed differently. One approach is the bundling of different products and different service providers, as well as pick-ups and deliveries. This can achieve positive environmental impacts through better use of cargo capacity and the reduction of transport routes. Involving local retailers can increase their competitiveness over online retail, making a positive contribution to social sustainability [26].

Modern logistics concepts use approaches to crowd logistics to achieve more flexibility and withstand the increasing cost pressure. Companies such as Uber Freight and Delivery Hero are well-known examples that have already successfully applied this new way of working and have seen great growth. In addition to the advantages of crowd logistics, such as flexibility, efficiency improvements and cost reductions, many problems are also related to these concepts [27].

On the social dimension of sustainability, challenges related to the privacy of crowdworkers can be identified, as they share sensitive data such as their (live) location. Mechanisms must be found to gain the confidence of the crowdworkers at the same time, to create transparency and to maintain privacy through appropriate framework conditions [27].

While crowdworkers are offered a flexible working environment, this approach is associated with risks in terms of working conditions, social security, as well as income and job security [28]. Furthermore, serious changes in the traditional logistics industry can be identified, as numerous startups build logistics concepts based on low-cost structures and on-demand platforms and thus take the market shares of the long-established logistics providers. Crowdworkers are employed when a need arises, creating the potential for efficiency gains for costs and time, but this process also offers the possibility of replacing permanent employees [27].

Advancing digitization and automation in the field of crowd logistics can be supportive, but also disruptive, replacing workers in their working environment [28]. Many novel approaches in the field of the last mile offer opportunities to meet the new challenges. Crowd logistics can help to make better use of transport capacities and to make logistics systems on the last mile more flexible and efficient. Electromobility has the potential to make the supply chain more environmentally friendly. However, the use of these technological instruments must not obscure social sustainability.

3 Project NaCl

The research project NaCl takes up the challenges and opportunities within the last mile and develops a logistical solution system for the problems in delivery logistics on the last mile. The basic idea of the logistics concept described here is the development and piloted application of a novel and sustainable logistics concept for optimizing

the last mile. The aim is to generate positive effects on the three dimensions of sustainability.

The sustainable logistics concept is essentially based on the use of electric cargo bikes, a crowd logistics approach and sustainable customer relationship management (SusCRM). The implementation of electric cargo bikes should above all have positive impacts on environmental sustainability and the regional transport system, as electric cargo bikes are locally emission-free and traffic-friendly. The use of this mode of transport compared to vehicles based on internal combustion engines, which are the current standard in the CEP sector, has further potentials, e.g. for the economic dimension in personnel flexibility, since the driving of electrically driven cargo bikes does not require a driving license. Further elasticity is to be achieved through a crowdsourcing approach, in which a crowdworker pool consisting of students from the Bremerhaven University of Applied Sciences is hired by the local logistics service provider Weser Eilboten GmbH while the delivery is taken over with the help of the cargo bikes of the Rytle GmbH. The aim is to provide crowdworkers with a flexible and voluntary working relationship. The use of crowdworkers is intended to offer potentials for the relief of the traditional delivery staff and not to replace them. Student crowdworkers are to be used at times of peak loads to avoid overtime for regular drivers, to create regular working hours and to reduce work stress.

A bundling of transports in relation to the goods delivered as well as to different contracting entities was carried out to achieve cost reductions, productivity increases and further environmental relief. Empty journeys and incompletely filled boxes should be avoided and collective deliveries of various products and customers should be implemented. The inclusion of pick-up and delivery orders should be dynamic and flexibly plannable into existing tours.

The project uses a SusCRM approach to sensitize recipients and companies, as well as crowdworkers, to the use and participation in sustainable crowd logistics. This approach is implemented through the provision of information on delivery methods and sustainability.

Various project partners are involved in the presented research project. This is on the one hand the Bremerhaven University of Applied Sciences, which is under the management of the project, Rytle GmbH, which provides the digital and technical infrastructure, and Weser Eilboten GmbH, which acts as a transport service provider. Other actors are the crowdworkers, who are under contract with the Weser Eilboten GmbH and handle the operation of the cargo bikes and the delivery, as well as B2C and B2B customers that act as shippers and recipients.

4 Evaluation of the NaCl Pilot Phase

4.1 Evaluation Planning and Design

At the beginning of the evaluation, the evaluator determined the evaluation objectives and objects of the logistics concept with the involvement of the project partners. These objectives have been broken down into a target hierarchy. The objective of positive effects on the sustainability of the last mile was identified as the overall guiding objective. The main objectives were the positive effects on the environmental, social and economic dimensions of sustainability.

Based on the evaluation objects and objectives, the participants and stakeholders of the evaluation were identified. These actors included, on the one hand, the NaCl project partners and, on the other hand, the target groups of the evaluation objects and objectives such as end consumers or recipients, shippers (stationary retail), crowdworkers and the project partners. Criteria and indicators have been defined in relation to the individual evaluation objectives to measure the achievement of the objectives set. The criteria and indicators provided the basis for deciding which data collection methods are used to study the objects of evaluation. Stakeholders and participants acted as data providing of the survey methods, while the cargo bikes telematic systems in conjunction with Rytle's delivery data system acted as data providing of the quantitative data collection.

Table 1 shows the different evaluation objects, their associated objectives and the data collecting and analysis methods that have been applied to them. The data collection methods included different methods of qualitative and quantitative research. Qualitative methods, such as surveys and the focus group were used to determine

Table 1 Evaluation design of the NaCl project

Object	Objective	Data collecting	Data analysis
Crowd logistics	Fair working conditions	Survey	Qualitative content analysis, descriptive statistics
Pickup and delivery	Strengthening of regional Retail	Survey, focus group, counting (delivery data)	Qualitative content analysis, descriptive statistics
Bundling	Reduction of transport ways and stops	Counting, measurement (delivery data)	Descriptive statistics, inductive statistics
E-Cargo-bikes	Reduction of noise and GHG emissions	Measurement (delivery data), literature review	Qualitative content analysis, descriptive statistics, Well-To-Wheel-Analysis
SusCRM	Participation in sustainable logistics	Survey, focus group	Qualitative content analysis, descriptive statistics

subjective assessments of affected and involved stakeholders. Quantitative methods, such as counting and measurement, were used to collect numerical data from the evaluation. After extensive preparation of the collected data, these were examined using various methods of analysis corresponding to the purpose. The data collected from the surveys were evaluated using qualitative content analyses and the application of descriptive statistics. During the counts and measurements, delivery data such as time stamp and parcel number of deliveries as well as process errors in relation to the project's resources were collected. The analysis of the delivery data was carried out by descriptive statistical evaluations. Delivery data were classified into numbers of delivery tours, stops and packages to build a basis for further analysis. As a result, process times and key figures were determined for the assessment of the evaluation objects. This data was used in the further procedure to calculate measures of the achievement of the target. For the determination of e.g. caused emissions or costs during the pilot phase, further analyses were carried out.

4.2 Evaluation Objects and Objectives

The Evaluation objects and linked objectives of the NaCl project are addressing different dimensions of sustainability. Figure 1 shows the allocation of the various objects to the three dimensions.

Electric Cargo Bikes. The use of electric cargo bikes should have a positive impact on the environmental and social dimension of sustainability. In this context the aim was to reduce exhaust and noise emissions and to reduce congestion in the city center. In addition, the goal of practicality in the delivery process is to be achieved in a process-related manner and thus a good working environment for the crowdworkers. These effects were tested by comparing the noise and CO_2-emissions produced using cargo bikes and conventional diesel vehicles. The potential to replace conventional diesel vehicles should be identified. The relief of inner-city traffic should be achieved and investigated through the use of electric cargo bikes.

Crowd Logistics Approach. The crowd logistics approach is linked to the objectives of improving the working conditions of delivery drivers as well as fair and flexible working conditions for the crowdworkers. Positive impacts of the approach are contributed to the economic and social dimension of sustainability. The improvement in the working conditions could not be determined due to a lack of data. Also, the shortness of the pilot phase did not provide a significant assessment. Instead, a potential of the delivery concept was identified to contribute to the relief of delivery drivers. The potential was determined by the limits of the delivery concept, which is characterized by the cargo bikes and the crowdworking approach. For the two cargo bikes used, MovR and Triliner from Rytle GmbH, the limitations were determined via the maximum payload, the load volume, the maximum package sizes that can be stored and the ranges of the cargo bikes. It must be said that a conventional diesel delivery vehicle exceeds all the limits of electric cargo bikes mentioned above. The

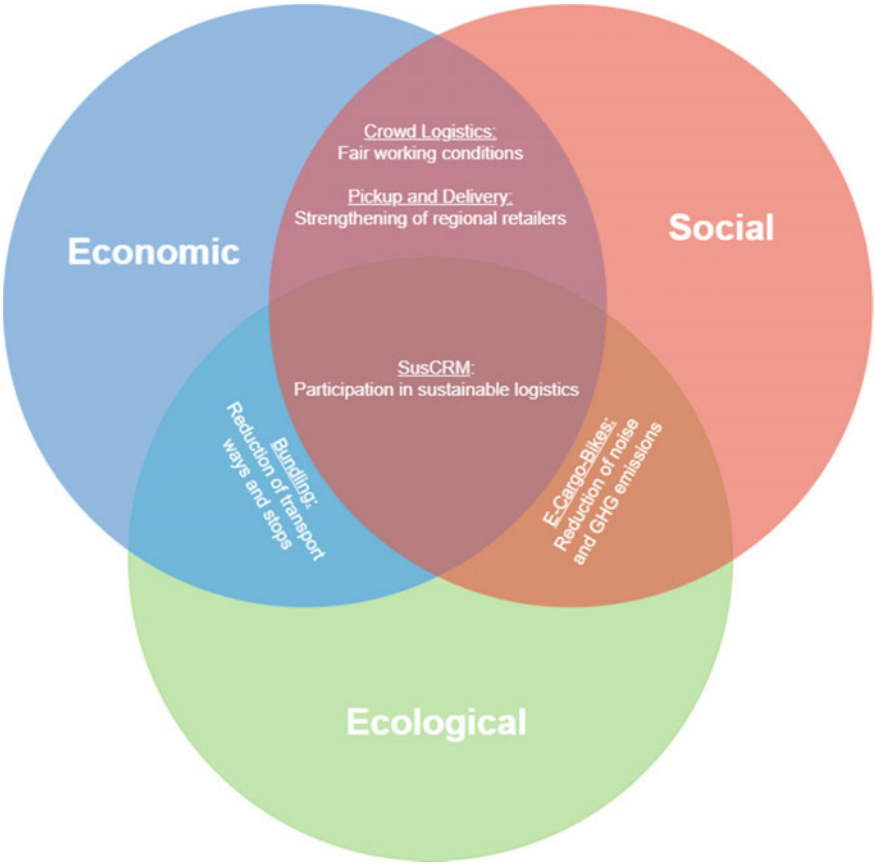

Fig. 1 Evaluation objectives and objects in conclusion under allocation of the dimensions of sustainability

approach studied is primarily geared towards relieving employees during peak times in terms of social sustainability, without replacing them, and is therefore specifically geared towards flexibility. Going further, the potential is limited by the number of available cargo bikes, the size of the crowdworker pool, and the availability of crowdworkers.

SusCRM Approach. The SusCRM was intended to promote participation in the sustainable logistics solution at various levels, such as the B2C customers, the B2B customers, but also of the crowdworkers hired. The SusCRM approach addresses all three dimensions of sustainability.

The study of the SusCRM of the NaCl project has provided insights into the interest and needs of B2B and B2C customers as well as the crowdworker for participation in a sustainable delivery solution for the last mile.

Bundling. The evaluation object bundling addresses the economic and ecological dimension of sustainability and is linked to the objectives of reducing exhaust and noise emissions as well as the relief of inner cities. The process-related goal is the successful bundling of supply orders from different customers.

The bundling of consignments and contracting entities should help to reduce exhaust and noise emissions and ease the burden on inner cities by shortening delivery routes and reducing the number of delivery stops. During the test phase, the bundling measure was not implemented to the planned extent, so it was not possible to assess it according to the criteria and indicators set out in the evaluation design. During the three-month pilot phase, however, bundling was carried out regarding orders from WEB (local logistics service provider) and retailers from the city center.

Pickup and Delivery. Another evaluation object of the project NaCl was the implementation of pickup and deliveries oof the stationary retail. In addition to the logistics partner's deliveries, interested parties from the local retail trade were offered the opportunity to commission pickups and deliveries via a mobile customer app, which were either bundled by the crowdworkers in an existing tour or executed separately. The project NaCl guaranteed same day delivery until 14:00 [29].

4.3 Evaluation Results

Electric Cargo Bikes. The evaluation shows that the use of electric cargo bikes on the last mile has positive effects through CO_2-savings compared to diesel vehicles. With the help of the Well-to- Wheel analysis, the CO_2 emissions generated using the two cargo bikes Triliner and MovR of Rytle GmbH and the diesel-powered delivery vehicles Fiat Doblo and Ducato were determined and subsequently compared. According to the DIN EN 16258 standard [30], a Well-To-Wheel (WTW) analysis is a summary of the Well-To-Tank (WTT) and Tank-To-Wheel (TTW) or indirect and direct emissions. The WTT analysis includes the indirect emissions of the fuel supply from the source or extraction of the raw materials to the vehicle tank or energy storage. The TTW analysis includes all direct emissions from vehicle operation, e.g., from the combustion of diesel fuel. The emission values of the diesel vehicles were 15 to 28 times higher than those of the electric delivery bikes [29]. Furthermore, the emission values determined for the vehicles were used to calculate the emissions for sample tours from the NaCl pilot phase. The tours were carried out with the cargo bikes to determine the level of emissions that would have been generated if the diesel vehicles had been used and the level of emissions that could be saved by using the electric cargo bikes. The determined values show that significant savings in CO_2 emissions can be achieved by using electric cargo bikes. The emission values per kilometer of the electric bikes are significantly lower than the values of the diesel transporters. In addition, apart from one studied tour, the electric bikes required a shorter route to complete the tours. This results from the route planning, which determined the

fastest route for the respective means of transport in each case, whereby the highway was often calculated as a partial route for the transporters [29].

The study of the use of the electric cargo bikes showed that these vehicles are suitable as a means of working the last mile. The evaluation of the cargo bikes by the surveyed crowdworkers, as users of these work tools, is positive. The results of the Well-To-Wheel analysis show a positive CO_2 balance in the operation of the cargo bikes compared to the diesel vans. Already on one kilometer, up to 270 g of the greenhouse gas can be saved [29]. It should be noted that although the determination of CO_2 emissions via a Well-to-Wheel analysis takes a comprehensive look at the emissions caused by the provision and consumption of the drive energies, it does not consider the emissions generated during the production of the vehicles and upstream processes. It is also important to note that a last-mile emissions comparison should always be calculated on a per-package basis to provide a basis for comparison that can be evaluated. At this point, it should be mentioned that the comparison in this paper was made for last mile tours that were carried out with a cargo bike during the pilot phase. A van has much higher loading capacities and can therefore deliver more parcels on one tour, which reduces the emission values per parcel. Nevertheless, the environmental balance in terms of CO_2 emissions per kilometer is clearly in favor of the electric cargo bikes. Positive effects on the ecological dimension of sustainability can thus be identified [29].

The determination of noise emissions is based on a literature search. To determine the specific noise emissions precisely, measurements should have been made which were omitted due to lack of time and resources. In the case of cars, the drive noise up to 25 km/h is the largest source of noise [31]. This corresponds approximately to the average speed at which transporters move in parcel delivery [15]. According to studies, electric vehicles have significantly lower noise volumes in the low speeds range than e.g. diesel vehicles, but this advantage is no longer represented at higher speeds, as the noise source shifts from the drive to the unrolling and wind resistance of the vehicles [32]. Rolling noises of the vehicles depend on the type of vehicle and the vehicle construction, the road surface and the speed, wind noise due to the shape and size of the vehicle and the speed. Here it must be assumed that the cargo bikes cause less noise due to their smaller size and the lower maximum speed of 25 km per hour. Since the cargo bikes and courier vehicles usually operate in a speed range of less than 30 km/h, it is assumed that the noise emissions of the cargo bikes by the electric drive are lower for this area of application.

In a survey of crowdworkers after completion of the test phase, 100% of the respondents stated that they believe the delivery concept can contribute to the relief of inner cities. These answers were justified by the size of the cargo bikes, which is smaller than that of vans, so that they could be better overtaken by other road users and that cargo bikes could use paths that would not be passable by cars. It has also been mentioned that volume and CO_2-emissions would be reduced. The flexibility of the bikes has been mentioned several times. [29]

In addition, advantages such as the possibility to maneuver in narrow streets and pedestrian only zones due to cargo bikes' smaller size, the possibility to park on

sideways and therefor save time and money as well as more safety due to less severe collision in comparison to delivery trucks can be mentioned [33].

Crowd Logistics Approach. During the NaCl pilot phase, one MovR and two Triliners were in use. The worker pool consisted of eight active drivers. There is a further restriction due to the working time limit of the student crowdworkers, who work on a 450€ basis. The maximum working time per month for them is 40 h [29].

In a survey, during the pilot phase, it was investigated on which days of the week and at which times the student crowdworkers are free to work. It was found that the availability of the crowdworkers apart from one day in a period of three hours was always sufficient to manage two tours in parallel. It was also found that for much of the time, competition between drivers can arise when the pool of available drivers exceeds the pool of cargo bikes and thus parallel tours [29].

Availability was further determined by the time that elapsed between order request and order acceptance. Based on the delivery data from the pilot phase, these times were determined as an average of 55 min for the individual packages and 65 min for the tours. The time between order acceptance and parcel pickup was 132 min for the individual parcels and 129 min for the tours [29].

To measure the target of fair and flexible working conditions for the crowdworkers, they were questioned during different times of the pilot phase. More than 80% of the crowdworkers rated the net wage of €11.13 as appropriate for the job. More than 70% of the crowdworkers also described crowdworking as a good side job. The reasons for this were that the activity takes place in the fresh air and is flexible. Nearly 60% of crowdworkers would do the job again. The evaluation of typical crowd logistics characteristics, such as flexibility, self-responsibility, voluntariness, compensation, training, communication, and participation were largely rated positively by the crowdworkers. The goal of providing fair and flexible working conditions for crowdworkers has been achieved [29].

SusCRM Approach. It has been noted that there is a fundamental interest on all sides for sustainable parcel delivery. Most respondents to B2C customers—both those identified as recipients and potential customers—have shown a clear tendency to decide for a sustainable mode of transport when they choose. There has also been a signal of a willingness to pay more for such a form of transport. More than 50% of those who showed this willingness would agree to pay between €1 and €2.50 more per shipment. Overall, support for the relevance of environmental challenges and sustainable action was high among B2C customers. They clearly showed understanding for the importance of environmental issues and improvement measures [29].

The survey of the crowdworkers showed that for a large part of the crowdworkers the motivation for the project participation was from the environmental issue. Overall, the weighting and approval of environmental issues was rather high in the applied surveys [29].

B2B customers have also shown an interest in the sustainable concept. Some of the retailers cited environmental and innovation aspects as well as regionality as the main motivation for participating in the project. They also considered the importance of

changes in purchasing behavior to reduce the burden on the environment. During the acquisition, a great deal of interest and enthusiasm of the dealers for the sustainable orientation of the project could be noted [29].

Bundling. The analysis of the delivery data showed that out of the total of tours carried out for regional retailers in a quota of 50% successful bundling could be applied. The remaining orders of retailers were handled in separate tours. Moreover, it could be stated that savings in delivery routes were achieved with every bundled delivery tour. For this scenario, it was assumed that the orders would be divided into individual tours for each client. In order to determine the bundling effect, the kilometers driven by the individual tours were then subtracted from the kilometers driven by the bundled tour [29].

The reduction in delivery stops could not be compared due to non-existent data from the WEB regarding stops per tour and packages per stop. Bundling, which leads to the reduction of delivery stops, requires that orders from different customers (logistics service provider and retail) are delivered in one tour to the same customer or customers who live in the same house or proximity. This fact could not be measured within the evaluation. The probability of this situation occurred during the pilot phase is extremely low, as it requires a large volume of deliveries. To reduce delivery stops by bundling, a check of delivery addresses must be carried out when orders are created in order to determine that the addresses of existing orders and new orders match. In the case of same-day deliveries, the merging of the same delivery addresses into a tour is made even more difficult since the order acceptance and execution by the crowdworker takes place at short notice and here the probability of a match between two delivery addresses with the accepting crowdworker is low. The bundling of the same delivery addresses therefore requires a large delivery volume and the involvement of many customers for short-term implementation. Also, a corresponding order may only be sent to the crowdworker whose existing tour contains the same delivery address, in order to avoid another driver accepting the tour. Long-term planning of delivery orders makes it easier to bundle the same delivery addresses, but this minimizes the likelihood of same day deliveries [29].

Pickup and delivery. For the retail trade, pick-ups of goods and deliveries to customers were to be realized, also in the form of same day deliveries. The aim is to strengthen brick-and-mortar retail. The verification of the targets was verified by comparing the requested pickups and the deliveries made. Same day deliveries were measured by the variance of order date and delivery date [29].

In principle, the goal of the realization of pickups and deliveries for the retail trade was achieved and the promise of delivery on the same day could be complied with when ordering by 14:00. Provided that failed delivery attempts due to absence of the recipients were not considered, the same-day delivery could be fulfilled in any case during the pilot phase. Pickup and delivery, however, requires process design to be as simple as possible to keep the implementation effort down for the participating dealers and thus to promote participation. It turned out that the integration into a trading platform with corresponding functions for marketing, billing, etc. as well as an automation of the underlying logistics processes has a high potential for a more

successful marketing of the delivery offers as well as the participation of the dealers. [29]

5 Conclusion and Future Outlook

In summary, it can be stated that the crowd logistics approach presented, and the logistics system used, which is based on electric cargo bikes, address all three dimensions of sustainability. Potentials for improvement could be observed on the ecological as well as on the social level. A compatibility of these potentials with the economy of the logistics concept can be assumed but requires further adjustments of the system by adapting to a mode of operation based on electric cargo bikes.

The reduction of emissions in comparison to traditional delivery vehicles is achieved by using light electric vehicles such as electric cargo bikes and micro depots, while from an economic point of view this combination can be more economical than conventional delivery methods [34]. As stated, it is possible to map almost the entire city logistics with such a system. The area of use of the electric cargo bikes plays a decisive role for the economic efficiency of the logistics concept and should be optimized in disposition and route planning.

Significantly more efficient and environmentally friendly logistics can be achieved by bundling transports, in terms of the products delivered and the logistics service providers commissioning them. Furthermore, delivery and pick up are bundled in one tour. The implementation of the idea of a singular regional logistics service provider achieves maximum bundling effects since optimization can be achieved across the entire flow of goods.

The logistics concept drives the strengthening of regional retail through regional logistics service providers. It offers a possibility of same day delivery for stationary retail. Regional retail can be reinforced against the e-commerce companies and gains competitiveness by combining the advantages of stationary retail such as proximity to customers and the advantages of e-commerce such as convenience of “shopping on the couch”. Combined with a regional e-commerce platform and a SusCRM approach, retail can potentially regain significant market share. Regional added value can be promoted in a targeted manner and transport distances can be shortened enormously. In the context of a regional retail platform the creation of a critical mass of participants from stationary retail and end consumers is of great importance. The research project "R3 - Resilient, Regional, Retail in der Metropolregion Nordwest" of the Bremerhaven University of Applied Sciences addresses this challenge. It has started in June 2021.

By addressing the social dimension within SusCRM, crowdworkers, end consumers and shippers can be motivated to participate in a sustainable supply chain e.g., by using a more sustainable delivery method and supporting a fair labor organization.

Potential goals of improving the working conditions of permanent employees through flexibly deployable crowdworkers can be achieved. This reduces fluctuation as well as associated costs and establishes long-term employment relationships with the regional logistics service provider. Efficiency gains associated with this and bundling, may enable higher wage levels and can help put an end to the current, sometimes precarious, employment relationships in the industry. For a successful implementation of a crowd logistics approach the limitations of the applied system must be considered.

Through the promotion of political restructuring processes, such an approach should be supported e.g., this includes instruments such as taxes on emissions, infrastructure realignments such as more bike lanes and less road space, the establishment of car restricted zones in inner cities as well as the provision of space in inner-city areas for micro-hubs, cargo bikes, and charging stations.

Many aspects can be identified and further developed based on the concept evaluated, that has the potential to make a major contribution to a more sustainable economy and society while relieving the burdens on environment and climate.

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