Procedia
Environmental Science, Engineering and Management
http://www.procedia-esem.eu

Procedia Environmental Science, Engineering and Management **9** (2022) (4) 851-860

25th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 8th-11th November 2022, Rimini, Italy

INTELLIGENT WASTE INFRA MANAGEMENT AS A PART OF CORPORATE CARBON RESPONSIBILITY*

Johanna Alakerttula[1], Mikko Ahokas[2], Outi Laatikainen[3],**

[1]Tampere University, Unit of Industrial Engineering and Management, Korkeakoulunkatu 7, 33720 Tampere, Finland
[2]Macon, Teknologiantie 18, 90590 Oulu, Finland
[3]KAMK University of Applied Sciences, Ketunpolku 1, 87101 Kajaani, Finland

Abstract

The waste sector is in transition. More efforts are being made to improve the separate collection of waste directly from households and to promote recycling, but on the other hand, waste companies are under heavy pressure to keep waste management costs moderate to the customers and limit the environmental impacts of waste management. Carbon neutrality has become a competitive and reputational factor and an essential aspect of corporate responsibility, and therefore companies are setting ambitious targets to become carbon neutral in the future. Still, in the waste management sector, monitoring or mitigating the carbon footprint of waste transportation is not a common practice. Yet, optimizing logistic operations by intelligent monitoring can provide remarkable possibilities to reduce emissions and save fuel consumption and waste management costs. This case study analyzes the implementation of carbon neutrality as a part of CSR in a regional waste transport company. The waste bin level measurement results from one household company are utilized to demonstrate the effects of digital monitoring. The results summarize active measures that companies can take to reduce waste transport emissions and costs. Companies can switch to lower-emission vehicles, optimize logistics, add multi-compartment vehicles, and develop marketing and reporting. In this case, digitalization has been used to renew the operational business model and to provide new innovative data-based waste management. Intelligent remote monitoring in waste container infra has changed logistics planning and a digital marketplace has made the climate and economic benefits of databased waste collection visible to the customers. This research concludes that digitalization will change waste management and that carbon neutrality will likely become a differentiator for waste sector organizations, allowing them to gain competitive and reputational advantage.

Keywords: carbon emissions, CSR, digitalization, waste logistics

---

* Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: johanna.alakerttula@tuni.fi

1. Introduction

Municipal Solid Waste (MSW) management plays a crucial role in modern society when building sustainable, environmentally safe, and livable cities (Villalba Ferreira et al., 2022; World Bank, 2020). MSW accounts for 10 % of the total waste generated in the European Union, but it has high political status due to its close link to consumers, complex composition, and increased generation (European Commission, 2022 a; Eurostat, 2021; Ma and Hipel, 2016). In most EU countries, the trend of MSW generation has been upward from 2005 to 2020, but the management of the wastes hasn't been developed at the same pace, and the recycling rate of MSW is still under 50 % (Eurostat, 2021). The European Commission has responded to this with the Waste Framework Directive and set ambitious waste collection and recycling targets for municipal solid waste and specific waste streams, which EU countries need to achieve between 2020-2035 (European Commission, 2022 a).

The sustainable MSW management system consists of mixed and sorted household and garden waste collection, transport and treatment such as recycling of wastes (Jouhara et al., 2017; Li et al., 2021). Traditionally MSW systems have been developed to protect public health and the environment, cut carbon emissions, and respond to resource scarcity (Marshall and Farahbakhsh, 2013; World Bank, 2022). Significantly increasing concern about climate change has encouraged municipalities and organizations to mitigate their greenhouse gas emissions in many sectors (Villalba Ferreira et al., 2022). In fact, the waste treatment sector has been aware of its environmental impacts for a long time (Guzdek et al., 2020), and in MSW treatment, greenhouse gas emissions have decreased by 42 % from 1995 to 2017. The reason is that municipal waste disposal in landfill sites has reduced to a minimum, and landfill gas recovery has increased (Eurostat, 2020). On the contrary, carbon emissions from the heavy-duty vehicles have increased by 25% during 1990-2020 in the EU (EEA, 2020), and transport sector is already responsible for a quarter of the EU's greenhouse gas emissions (European Commission, 2022 b).

It is expected that changes in EU waste legislation will significantly impact waste sorting, separate collection, recycling and logistics of different wastes, such as packaging waste and textiles (European Commission, 2022 a; Óskarsson et al., 2022). In Finland, municipalities are obligated to collect separately different materials, such as packaging waste and biowaste, directly from households (Ministry of the Environment, 2022). This will increase transport performance, waste management costs, and carbon emissions if nothing changes. Therefore, empirical knowledge on how waste transport companies are responding to the urgent need to reduce carbon footprint is needed. This study aims to expand our understanding of technical, social, and economic dimensions of waste logistic companies' climate strategies. Our study is strongly linked to the corporate social responsibility (CSR) policy, where companies take voluntary acts to develop their economic, social, and environmental sustainability and respond to global crises such as climate change (Kadyan, 2016; Le, 2022; Singh and Misra 2021).

2. Materials and methods

This study's main objective is to analyze how carbon neutrality is implemented as a part of CSR in the waste transport sector. The case study method was chosen to explore the studied issue in real-life settings. The first case selected for this research is a waste transport company from Oulu, the Northern part of Finland, which has been a forerunner in climate-neutral transport solutions. The second case is a housing company in the capital region of Finland, whose municipal waste collection has been monitored for two months in July-August 2022.

The study is based on primary interviews, numerical data, and secondary sources (Table 1). Data was gathered during 2021-2022.

To reach the research goal, the study follows a qualitative and quantitative research design. A qualitative method was used to interview the waste transport company, the municipality, and the start-up company and collect data by observing and reading relevant publications. The interview data were transcribed and qualitatively examined with content analysis to provide a picture of the respondents' views and ideas about the research topic. The quantitative research method was used to collect and analyze the numerical data from the housing company.

The results obtained from the interviews were combined with numerical data to get a complete picture of how carbon-neutral targets can be implemented in the waste transport sector and what kind of direct and indirect impacts are found at the company and customer levels.

Table 1. Data type and source

Data type and source	***Description of the data source***
Interviews (semi-structured) with key actors, duration 1h per interview	- CEO and owner, Waste transport company Haurun Jäteauto (10/2021, 01/2022) - Transport manager and owner, Waste transport company Haurun Jäteauto (11/2021, 01/2022) - Foreman, Waste transport company Haurun Jäteauto (11/2021) - CEO and owner, start-up company Wastebook developing Jaete sensors (11/2021)
A group interview (semi-structured), duration 2h	Service manager and Office Secretary / both owners of the Waste transport company Haurun Jäteauto (11/2021)
A general interview with other experts, duration 1 h	The municipality representative responsible of municipal waste management (01/2022)
Observation	Coordinating ISO 9001, ISO 14001 and ISO 45001 management systems to the Waste transport company Haurun Jäteauto (10/2021 -> 02/2022)
Minutes, reports	Waste management company responsibility reports (4 different companies) Waste companies' websites (4 different company sites) Ministry of the Environment publications (2)
Numerical data	A housing company (103 residents) in the capital region of Finland, Southern Finland. Numerical data of the surface level of mixed waste, plastic packaging waste, glass, metal, cardboard, paper and biowaste containers were measured in July-August 2022

3. Case studies

In this study, two cases were studied: Waste transport company actions towards carbon neutral waste logistics and numerical waste collection data from one housing company. Haurun Jäteauto is a local waste transport company in Oulu, the Northern part of Finland. Its service includes comprehensive waste collection from residential, commercial, industrial, and municipal customers and sewer maintenance services. The company is very committed to safe and responsible waste management, and the core of its strategy is to develop and provide carbon-free waste solutions for its customers. Reducing the carbon footprint of waste transport is a strategic goal of Haurun Jäteauto. Therefore, the company has been innovating and

investing in carbon-free vehicles, routing, and waste collection since 2018. In the last two years, Haurun Jäteauto has developed smart waste management services with Wastebook company by equipping waste bins and deep collection containers with surface measurement sensors that measure filling levels from 0 % to 100 %. This enables timely emptying of waste bins. Customers are also offered a Smart Waste Bin mobile application with which they can send a call to empty the waste bin.

The housing company, with 103 residents and 30 apartments, started using sensors to measure the waste bins' surface in July 2022. The reason was to find out the current fill level of a waste bin upon collection and to optimize the emptying of the waste bins. The housing company was chosen for this research to provide numerical data using the sensors. The sensors used to measure the filling level of waste bins are powered by IoT (Internet of Things). This is a network that connects devices and systems through the internet (Fig 1).

Fig. 1. Data from measuring the degree of filling of the mixed waste deep collection container in the housing company (Original picture from Wastebook Oy company).

The waste bins of the housing company were equipped with a smart sensor that measures their fill levels and temperature. Smart sensors collect data on waste generation patterns and send it to the cloud. When the waste bin is full, the waste management company's ERP or route optimization system receives the order to collect the waste bin through an API and transmits the data to the driver. Data collected by smart sensors is ultimately translated into concrete and actionable insights like waste statistics and carbon footprint calculations for the customer.

4. Results and discussion

Measuring the degree of waste bin surface indicates that waste bins can be emptied unnecessarily since not all the waste bins fill at the same rate as others. Based on the sensor data from July-August 2022, four out of seven mixed waste bin emptying were in vain since the degree of the waste bin filling was just 29-43 % (Fig 2). This means that the amount of waste from the first and second emptying would have fitted to the bin, if only the third emptying had been done. This same applies to the 5th and 7th emptying of the bin. If emptying of the waste bins were optimized, it would mean savings in waste costs – in this case, savings in waste management fees would be almost 60 % in two months.

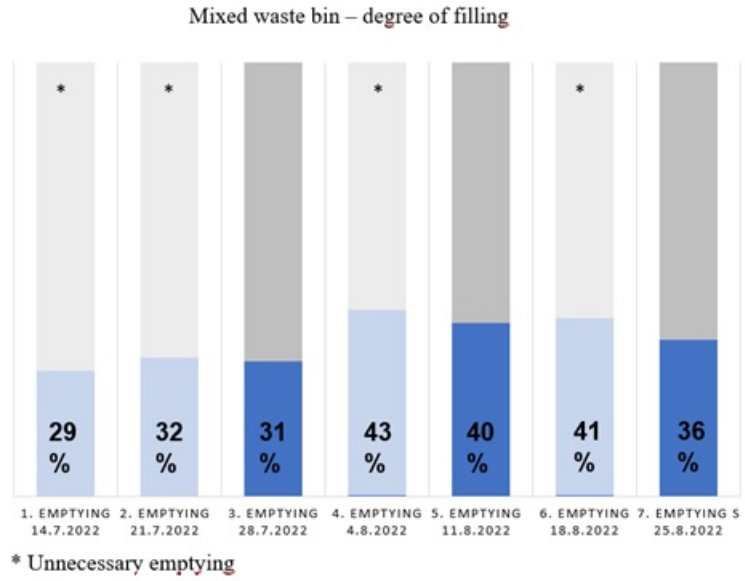

Fig. 2. Data from measuring the degree of filling of the housing company's mixed waste deep collection container.

Our study identifies the spectrum of company strategies enabling the shift towards carbon-neutral waste logistics (Table 2). Changing to green energy is influenced by current fuel prices and the availability of alternative fuels like biogas. Carbon emissions can be reduced by replacing fossil vehicles with lower emission vehicles, and multicompartment vehicles allow for collecting different sorts of wastes simultaneously. Transport optimization can be achieved by digitalization and sensor technology and by using waste bins that can be emptied more scarcely (like an aerated biowaste bin). Online store streamlines customers' choice of waste management services and makes innovative waste management's economic and environmental benefits, e.g., using sensors to measure waste surface levels, visible. Carbon neutral strategies and reporting of the carbon emission reduction achievements present a significant opportunity for companies to become forerunners and gain reputational and economic benefits. In the bigger picture, cooperation between different companies is needed to develop climate-neutral solutions.

Table 2. Different carbon neutrality strategies and their impacts on waste companies and customers

Strategies	*Waste companies*	*Customers*
Green energy	**Green energy for transport:** Using advanced biofuels, electricity, hydrogen and renewable synthetic fuels in waste transport vehicles cut downs carbon emissions.	**Green energy co-transition:** Utilizing biogas filling stations that have been opened in the areas of the municipal waste management companies
Low carbon emissions	**Zero-emission and multi-compartment vehicles:** Procuring low-emission vehicles over original fossil fuel vehicles. Using multi-compartment vehicles in waste collection when the transportation of different wastes (with one vehicle) is profitable for environmental reasons.	**Positive environmental impacts:** Cutting down the waste transport emissions and noise, in the case of electric vehicles.
Optimization of transport	**Efficiency of the transport system:** Saving working hours and fuels by designing the transport routes according to the degree of filling level of waste containers. Piloting new need-based innovations to measure waste container surface and innovating and testing new containers that can be emptied less often.	**Lower waste management costs**: Cutting down the waste management costs since the waste container is emptied only when it is full.
Green marketing	**Electronic marketplace:** Developing an e-marketplace that makes it easier to market intelligent low-emission transport solutions to the customers and compare them to the original ones.	**Value creation:** The e-marketplace is bringing the carbon footprint of separate waste collection and transportation visible to the customers when they are making purchase decisions. This can encourage separate collection of different wastes compared to sole mixed waste collection.
Sustainability strategies and data	**Carbon emission reduction targets and strategies:** Including carbon neutrality into company strategies and making the companies' carbon footprint issues more transparent to the employees and stakeholders. Providing information of companies' carbon footprint in the sustainable reports or including them into the environment management systems**.**	**Digital applications:** Mobile application is allowing customers to follow their waste accumulation in real time and calling for the emptying of the waste container when needed. Waste data and carbon footprint calculations of the waste management can be provided easily for the customer in weekly or monthly periods.

5. Conclusions

This paper summarizes the recommendations on how the waste transport sector can promote a carbon-free future through concrete actions and strategies while ensuring that the impact of the transitioning process for the customers is also taken into account. Results indicate that waste transport companies can take up to five strategies to promote carbon neutrality and implement them separately or together.

The study also reveals that the benefits of developing carbon neutrality are not limited only to positive environmental impacts. Still, the social and economic dimensions of carbon neutrality strategies are often under-represented even though decreased traffic load, savings in fuel and waste management fees, creation of innovations and jobs, and an emission-free environment can be apparent results of climate neutrality.

Acknowledgements

This paper was elaborated with the support of a grant of the funding programme KareliaCBC, project REMAC-Renewing Sludge Management practices in Karelia and Kainuu, number Ka11000.

References

EEA, (2020), Carbon dioxide emissions from Europe's heavy-duty vehicles, On line at: https://www.eea.europa.eu/themes/transport/heavy-duty-vehicles

European Commission (2022a), Waste Framework Directive, https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

European Commission, (2022b), Transport emissions, On line at: https://ec.europa.eu/clima/eu-action/transport-emissions_en

Eurostat, (2020), Greenhouse gas emissions from waste, On line at: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200123-1

Eurostat, (2021), Municipal waste statistics, On line at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Municipal_waste_statistics#Municipal_waste_generation

Guzdek S., Malinowski M., Religa A., Liszka D., Petryk A., (2020), Economic and ecological assessment of transport of various types of waste, *Journal of Ecological Engineering*, **21**, 19–26.

Jouhara H., Czajczyńska D., Ghazal H., Krzyżyńska R., Anguilano L., Reynolds A.J., Spencer N., (2017), Municipal waste management systems for domestic use, *Energy*, **139**, 485-506.

Kadyan J.S., (2016), Impact of companies Act 2013 on the functioning of Corporate Social Responsibility (CSR) in India, *Primax International Journal of Commerce and Management Research*, **4**, 2321-3604.

Le T., (2022), How do corporate social responsibility and green innovation transform corporate green strategy into sustainable firm performance?, *Journal of Cleaner Production*, **362**, 132228, https://doi.org/10.1016/j.jclepro.2022.132228.

Li Z., Huang T., Lee J-Y., Wang T-H, Wang S., Jia X., Chen C.-L., Zhang D., (2022), Crisp and fuzzy optimization models for sustainable municipal solid waste management, *Journal of Cleaner Production*, **370**, 133536, https://doi.org/10.1016/j.jclepro.2022.133536.

Ma J., Hipel K., (2016), Exploring social dimensions of municipal solid waste management around the globe - A systematic literature review, *Waste Management*, **56**, 3-12.

Marshall R., Farahbakhsh K., (2013), Systems approaches to integrated solid waste management in developing countries, *Waste Management*, **33**, 988-1003.

Ministry of the Environment, (2022), Waste legislation, On line at: https://ym.fi/en/waste-legislation

Óskarsson G., Agnarsson S.,avíðsdóttir, B. (2022). Waste management in Iceland: Challenges and costs related to achieving the EU municipal solid waste targets, *Waste Management*, **151**, 131-141.

Singh K., Madhvendra M., (2021), The evolving path of CSR: toward business and society relationship, *Journal of Economic and Administrative Sciences*, **38**, 304-332.

Villalba Ferreira M., Geske Dijkstra G., Scholten P., Sucozhañay D., (2022), The effectiveness of inter-municipal cooperation for integrated sustainable waste management: A case study in Ecuador, *Waste Management*, **150**, 208-217.

World Bank, (2020), Management of Municipal Solid Waste: Approaches and Practices within the World Bank. Management of Municipal Solid Waste: Approaches and Practices within the World Bank | GPSC (thegpsc.org), On line at: https://www.thegpsc.org/sites/gpsc/files/wm_brief_d.pdf

World Bank, (2022), Solid Waste Management, On line at> https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management