Challenges in city logistics and circular value chains for e-waste

Author(s)
Lemiski, David; Ploos van Amstel, Walther

Publication date
2023

Document Version
Final published version

Citation for published version (APA):
Lemiski, D., & Ploos van Amstel, W. (2023). *Challenges in city logistics and circular value chains for e-waste*. Paper presented at 28ste editie Vervoerslogistieke Werkdagen 2023, Mechelen, Belgium. https://vervoerslogistiekewerkdagen.com/deelnemers-en-papers-2023/

CHALLENGES IN CITY LOGISTICS AND CIRCULAR VALUE CHAINS FOR E-WASTE

Dave Lemiski, Amsterdam University of Applied Sciences, the Netherlands
Walther Ploos van Amstel, Amsterdam University of Applied Sciences, the Netherlands

Abstract

Little progress has been made in recent years toward achieving a fully circular economy by 2050. Implementing circular urban supply chains is a major economic transformation that can only work if significant coordination problems between the actors involved are solved. On the one hand, this requires the implementation of efficient urban collection technologies, where process industries collaborate hand-in-hand with manufacturers, urban waste treatment, and city logistics specialists and are supported by digital solutions for visibility and planning. But on the other hand, it also requires implementing regional and urban ecosystems connected by innovative CO2-neutral circular city logistics systems smoothly and sustainably managing the regional flow of resources and data, often at large and with interfaces between industrial processes and private and private and public actors. What are relevant research questions from a city logistics perspective?

1. Backgrounds

Little progress has been made in recent years toward achieving a fully circular economy by 2050 and halving abiotic resource use (abiotic means non-living and is used to refer to the part of habitat or ecosystems that is not living) by 2030. The use of most resources remained the same. Only fossil fuel use decreased, but this decrease was incidental due to the corona-lockdown. Effective circular policies contribute to greater security of supply by recovering strategic raw materials from the existing stock of products and buildings (the urban mine) and keeping them available for future use. This rarely succeeds now. To achieve the Dutch cabinet's goals, more mandatory policy is needed. It is also crucial that products be designed already in the design phase so that high-quality recycling, longer-term use, and less use of new raw materials are possible. The Dutch government's choice of a policy per product group is a step in the right direction. This is the conclusion of the Netherlands Environmental Assessment Agency (PBL, 2023) in the biennial Integral Circular Economy Report (ICER).

A circular economy aims at substantially less and radically more efficient use of raw materials. Product design is key in achieving this: it determines the material choice, lifespan, and reusability. Today, too often, valuable materials still end up in the incinerator, partly due to poor product design. For example, although the Netherlands leads Europe in recycling (78% of waste is recycled), this consists largely of low-grade recycling.

Efficient electronic waste (e-waste) management is one of the strategies to save materials, critical minerals, and precious metals with limited global reserves. The e-waste collection issue has gained attention in recent years due to low collection rates of e-waste. The European Union (EU) has legislated Waste Electrical and Electronic Equipment (WEEE) management since 2002. The WEEE Directive describes two methods for calculating the collection rate in the EU Member States. First, the "WEEE Generated method" is calculated by the mass of WEEE collected divided by the mass of WEEE Generated in the same year. The collection rate increased from 40% in 2014 to 54% in 2021 using this method. The increases are mainly driven by the significant increases in the WEEE collection compared to the WEEE Generation. The second method is the 'EEE POM method,' calculated as the mass of WEEE collected divided by the average amount of EEE POM in the three preceding years. The EEE POM method's collection rate increased from 39% to 50% from 2013 to 2016. From 2016 to 2020, the collection rate dropped to 44%. Despite the significant increases in WEEE collection, the decrease in the collection rate is caused by even more substantial increases in the EEE POM, causing the collection rate to decrease using this method.

The Netherlands scored only 55% using the (certified) WEEE-generation approach and 33% using the EEE POM. One of the obstacles in reaching collection targets is that considerable amounts of WEEE are diverted to other undocumented WEEE flows. Unwanted WEEE flows need to be reduced and steered into the formal WEEE management regime. The exports for reuse and illegal exports are hardly monitored in most countries due to the lack of trade codes for used EEE. Stakeholders estimate 50% of undocumented WEEE flows are incinerated, and non-certified companies handle 50%.

2. Develop a blueprint for a circular urban region

This paper presents a literature review on circular urban supply chains for e-waste and conditions to make collaboration in circular value chains work. Implementing circular urban supply chains for e-waste is a major economic transformation that can only work if significant coordination problems between the actors involved are solved. And, this paper presents relevant research questions from a city logistics perspective. The next step in this research program is mapping the current ecosystem of suppliers, consumer, waste collection, recycling, government, etc…

This paper is a result of the H2020-sponsored research project Circular Foam (https://circular-foam.eu/), in which Amsterdam University of Applied Sciences participates, aims to develop a blueprint for circular urban regions, including the demonstration of a territorial cross-sectorial, large-scale and sustainable systemic solution for the circularity of plastics from diverse applications of rigid polyurethane (PU) foams used as insulation material in refrigerators and construction elements. The project will develop and demonstrate a multifaceted large-scale systemic solution for a circular economy of PU rigid foams present in end-of-life appliances and urban construction waste. In the following years, the research project will develop a blueprint for regional participative governance using an approach involving multiple actors from the public-, private-, academic-, and financial sectors and civil society (by working in living labs). The role of city logistics and collection services is to make these materials accessible for downstream sorting and recycling processes in a sustainable and economically viable way.

3. Challenges in circular urban supply chains

Complex products (like consumer electronics) with many different materials and a relatively high market value, such as printers, need a very different circular design approach than single-use packaging (PBL 2023). A company's power in the value network also has an influence. For example, retailers and SMEs often have limited scope for action, which does not make implementing circular changes easy. Also, a different design requires different collaboration in the chain, for example, supplying (secondary) materials and parts, alternatives, and (return) logistics. In addition, how users deal with circular products in everyday life plays a role. They are responsible for their products' proper use, maintenance, disposal, and return. The product design must therefore be aligned with a circularity strategy that fits the complexity and high value of the product, the relative power of entrepreneurs in the value chain, and the way users interact with the products during and after the use phase. This requires a long-term vision, a lot of knowledge among companies and other organizations, and large-scale knowledge dissemination.

Circular economy business models (CEBMs) are essential levers in the transition to a circular economy. In recent years, a growing body of research has examined the barriers and enablers of these models; however, the available empirical evidence still needs to be improved while sector-specific assessments are lacking (Rizoz et al., 2022). Rizoz et al. (2022) identified barriers and enablers to implementing a variety of CeBMs in the electrical and electronic equipment (EEE) sector. Based on this analysis, they provide several policy insights. Rizoz et al. (2022) adopt a multi-case study approach using 31 cases developed through the CIRC4Life EU-funded project and the snowball sampling method. The key categories evaluated were: policy, finance/economic factors, supply chain, technology, consumer/society, and company organization. This represents the most significant case study sample used to examine circular economy approaches in the EEE sector. Their findings show that despite the various policy instruments in place to boost the transition towards circularity in this sector, there exist gaps that require policy attention. These include a lack of rules for transparency across supply chains, weak enforcement of EU waste legislation rules, limited use of circularity criteria in public tenders, and lack of circular economy standards. Inconsistent requirements stemming from different policy domains can also pose challenges for companies adopting circular economy practices. The suggested actions facilitating circular economy practices include knowledge-sharing platforms and business partnerships, R&D project grants, product labels, financial incentives, and awareness-raising campaigns

From a supply chain perspective, Rizos et al. (2022) see difficulties in gaining access to spare parts and components, a lack of transparency regarding substances in EEE, poor collection of EEE, difficulties in convincing supply chain partners, complex reverse logistics systems, challenges in cooperating with international partners. Dutch RLI (2013) analyzed the impact of a transition towards a circular economy (in general) and the consequences for strategic changes in logistics and the logistics industry executed by the RLI. This report provides insight into the complexity of this issue. RLI acknowledges the importance that it is necessary for all stakeholders involved to move in the same direction. Institutional and economic barriers will therefore have to be taken down. At the same time, consumers, producers, and logistics companies must be encouraged and supported in changing their social and personal behavior. Supply chain barriers are ownership, sharing of costs and benefits, underdeveloped markets for materials and components, lack of collaboration, and lack of transparency and information exchange. Enablers for change could be the establishment of partnerships and collaborations and developing of a network of partners, information-sharing platforms, and improving information transparency across supply chains. Establishing partnerships and alliances was the single most crucial supply chain-related enabler raised by 11 companies (Rizos et al., 2022). For example, in two cases developing a collaboration with manufacturers helped two small companies offering repair and refurbishment services to gain access to original spare parts or software updates. In another case, a recycler could better anticipate demand for certain secondary raw materials through partnerships with manufacturers.

The analysis by Bressanelli et al. (2020) showed that servitized business models and supply chain management actions are widely used levers, while little attention is devoted to circular product design practices. The Internet of Things (IoT), Big Data, and Cloud emerged as powerful enablers of servitized business models. Two main patterns of Circular Economy adoption in the household appliance industry emerged from cases: incremental and radical adoption patterns. Incremental adoption patterns are based on design strategies focused on reducing and recycling, mainly led by manufacturers. More radical adoption patterns are instead focused on disruptive practices based on reuse, remanufacture, servitization, and sharing, where digital 4.0 technologies serve as enablers. Overall, this exploratory research lays the foundation for a more robust and more systemic understanding of the adoption of the circular economy in the household appliance industry.

Pollard et al. (2022) provide an agenda for a circular economy business model and offers many perspectives for the ecosystem design based on case studies in washing machines and the telecom industry. The shift from product manufacturers' linear business model demonstrates a range of opportunities for circular value proposition by applying a CEBM, including product-service offerings, refurbished product sales, take-back systems, and end-of-life product recycling. The findings show that the hierarchical resource loops of the circular economy provide manufacturers with opportunities for value creation and capture, namely through repair, refurbishment, reuse, remanufacturing, and recycling activities. Implementing more resource-efficient CEBM also offers opportunities for manufacturers to reduce the costs associated with inputs to their manufacturing processes and waste management. On a case-by-case basis, several publications about local initiatives and networks (e.g., Lechner et al., 2020) review of e-waste literature by Senna et al. (2022) conclude reverse WEEE supply chain flows must deal with two different issues: how to regulate the recycling and disposal of these electronic wastes avoiding environmental and health hazards (Zhu and Li, 2020), and the design of supply chain processes that can recover materials, critical minerals and precious metals with limited global reserves (Shevchenko et al., 2021).

According to Bressanelet et al. (2020), there is still a significant challenge in achieving the potential environmental, social, and economic gains linked with implementing CE within the WEEE industry. The literature is still generic in the context of manufacturing companies. Some key challenges and gaps are related to a lack of circular economy strategies for enhanced recovery of precious and special resources in WEEE, a lack of a sector-specific approach for circular implementation within the industry, and a lack of a more prescriptive research agenda focused on the. Most of the literature is still focused on discussing sustainability in the WEEE industry. To address these gaps, Bressanelli et al. (2020) aim to systematize the extensive scientific literature that exists about sustainability in the WEEE industry with a circular economy lens regarding what previous research has done in terms of objectives and how they have been achieved, where and how it has mainly geographically focused on, who have been the actors primarily addressed and when the focus was put in terms of life cycle phases, and how circular economy has been implemented in the industry to achieve sustainability. The main goal is to gather and interpret the existing knowledge landscape to devise a research agenda and managerial implications for scholars and practitioners working in the circular economy and WEEE domains.

Shevchenko et al. (2021) searched for solutions in the e-waste collection sphere with close-to-zero transport and infrastructure costs and the minimization of consumers' efforts towards an enhanced e-waste management efficiency and collection rate. Along these lines, they developed a smart reverse system of e-waste from end-of-life electronics holders to local recycling infrastructures based on intelligent information technology tools involving local delivery services to collect e-waste and connect with interactive online maps of users' requests. This system considers the vehicles of local delivery services as potential mobile collection points that collect and deliver e-waste to a local recycling enterprise with a minimum deviation from the planned routes. Besides e-waste transport and infrastructure cost minimization, the proposed smart e-waste reverse system supports the reduction of CO2 through the optimal deployment of e-waste collection vehicles. Shevchenko et al. (2021) also advance a solid rationale for involving local e-waste operators as key stakeholders of the smart e-waste reverse system.

Space must be found for circular activities in land-use planning. The Netherlands has a limited territory (PBL, 2023). Research shows that less primary production through, for example, the sharing of products and machinery can lead to decreasing use of space for industry and logistics. In contrast, recycling will increase demand for locations with a high environmental category and good accessibility. These are preferably easily accessible locations, and for large volumes, multimodal accessibility - by road, rail, and water - is also important. New demands are also arising for logistics, storage, and transshipment of materials and products for reuse, repair, parts, and revision. In addition, spatial planning determines the possibility of the transition. Think of the inability to mix housing and recycling activities that cause a lot of nuisance. Using scenarios, PBL explores the relationships between the circular economy and space in the Netherlands.

It is important to focus firmly on lifetime extension to reduce the environmental impact of electrical appliances such as laptops and phones (PBL, 2023). The current laws and regulations for recycling worked out in the Extended Producer Responsibility (EPR), work against life extension. It is not desirable for the sector responsible for meeting the collection target to focus on life extension, as this would allow fewer volumes to "count" toward collection. The already difficult-to-achieve target would thus only be made more difficult to achieve. Also, products that can be refurbished are bought up by merchants for recycling, as this brings a better price. PBL advises revising the current EPR targets that focus only on offering appliances to recycling facilities into circular targets. This also implies targets on life extension, reuse, and refurbishment and ambitious targets on recovery and high-value reuse of materials in similar products.

4. Collaboration

Industrial symbiosis, in which companies exchange residuals for resource efficiency, is essential to the circular transition. However, many companies are hesitant to implement business models for industrial symbiosis because of the various roles, stakes, opinions, and resulting uncertainties for business continuity (De Lange, 2022).

A circular value chain system (or network) requires collaboration. Companies in the circular value chain indicate that they see collaboration as a solution but do not know how to set it up. Therefore, networking plays a central role: in building trust relationships between stakeholders working together on a shared platform. For value chain collaboration, Barratt (2004) argues that different actors in a value chain do not naturally act together through mutual distrust of stakeholders and their unfamiliarity with collaboration. Barratt distinguishes collaboration into other elements that can be grouped together in strategy, collaboration, and culture (see figure 1).

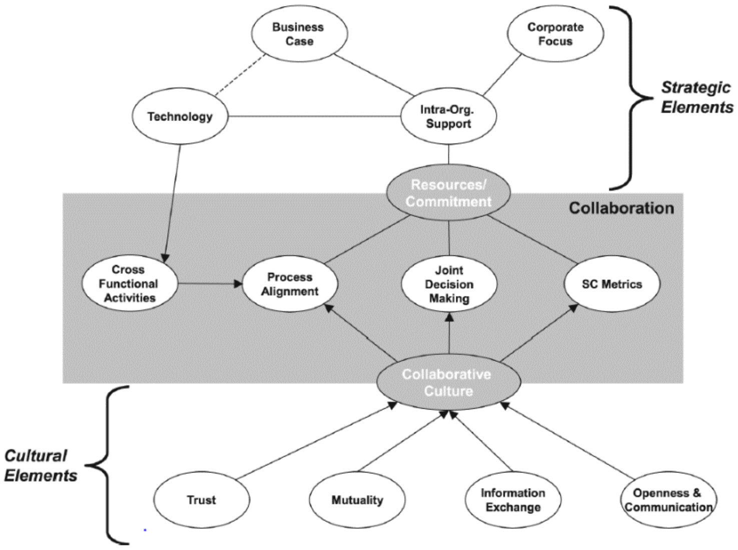

Figure 1: Elements of supply chain collaboration (Barratt, 2004)

- Strategic elements are mainly about a joint business case for the circular value chain: how are financial flows between stakeholders, which resources can be shared, and which technologies are available to do so?
- Collaborative elements are the results of the strategic and cultural elements: structures in which processes and decisions are taken together, and progress is measured. These organizational elements form the basis for a functional design in which the collaborations are described.

- Cultural elements are about the attitude and motivations of the circular value chain partners involved. These elements serve the partners involved at a sufficient level to create a culture that stimulates collaboration.

Martinez-Olvera & Davizon-Castillo (2015) took value creation as a starting point for effective chain collaboration. In line with Barrat (2004), the synchronization of business processes is mentioned as a prerequisite. In addition, setting a common goal and common benefits when moving towards circular value chain collaboration. In doing so, the actions and decisions of these stakeholders can be simultaneously driven to create shared value. Barratt (2004) and Martinez-Olvera & Davizon-Castillo (2015) contribute stakeholder analysis to investigate strategic and organizational relationships between the different stakeholders. E.g., in stakeholders analysis using Agent-Based Modelling (ABM) simulation, common and conflicting interests are identified, and the functioning of a shared resource and service can be tested. This is already applied in the development of waste collection scenarios, such as for the collection of plastic in Singapore (Kerdlap et al., 2020) or for modeling the interactions between stakeholders in the processing of construction and demolition waste in China (Ding et al., 2016). Both studies underline the influence of stakeholder interaction on the results. However, this has not been applied to circular value chains yet. This project will focus on the interaction between stakeholders in the circular value chain.

To map (common) relationships and motivations, the stakeholder model is enriched with mapped dependencies and value propositions of each stakeholder with the business model. In research, this model is applied to test innovative collection models in China (Zuo et al., 2020) and in Santander (Díaz-Díaz et al., 2017). However, these canvases have not been used in published research to analyze further collaborations in a European context or context of appliances and construction waste. A SWOT analysis can help analyze where cultural risks and opportunities lie between stakeholders involved in the collaboration. This has already been applied to public participation in waste collection in Lucknow, India (Srivastava et al., 2005).

Past research on circular value chain systems was not focused on an integrated approach, only on elements of collaboration. As a result, a systemic approach was not followed. This project will take the needed integrated approach to collaboration in circular value chain systems (or networks) from both a practical and scientific perspective, including networked business models looking for (economic) benefits. How can a collaboration framework (e.g. Barratt, 2004) support the required systemic approach.

5. Discussion

A higher value use of secondary materials requires improvements in product design, proper separate collection, opportunities for high-value application, and steering for that. Currently, some parts of the products are designed so that recycling for application as a secondary material is difficult, or it takes a lot of energy to recover some materials. To recover the materials needed for circular supply chains, it is necessary to establish closed-loop supply chains, enabling a circular economy logic. Circular supply chains must be designed to retrieve these values and mitigate the risks. Furthermore, urban collection points must be strategically positioned to make this feasible and, very important, attractive for consumers (with the right incentives), and integrating the concept of smart cities. How can city logistics (cost) modelling support the development of these supply chains? And, what are the planning and control (including ICT-support and control towers) concepts to support operational excellence?

Besides e-waste transport and infrastructure cost minimization, future smart e-waste reverse system supports the reduction of CO2 through the optimal deployment of zero-emission e-waste collection vehicles. New urban waste collection initiatives, and the new roles of stakeholders in collaboration, together form an integrated design for collaboration in the industrial waste sector (or maybe only for collection as a first step). The functional design serves as a blueprint for the distribution and coordination of the different roles of the direct stakeholders in future urban waste collection system in which (common) goals and societal goals serve as motivation. A functional design includes a set of (cross) functional activities, mutual data exchange, logistics nodes (and modeling the network based on cost and resilience), a method of planning and control (and supporting AI-ICT systems for managing the network), and the governance structure as building blocks for collaboration.

For land-use planning the relationships between the circular economy and requirements for space is a ciritical factor in the design of the network.

Collaboration is the result of intentions, opportunities, risks, and mutual relationships of different public and private stakeholders in a new system, which emerge in stakeholder analyses. The question is: how can we use stakeholders analysis using e.g. Agent-Based Modelling (ABM) to identify common and conflicting interests?

Last but not, least. Circular supply chains will 'feed' downstream large recycling and upcycling 'factories' that often require large and predictable volumes for many years. How do we organize for reverse 'sales and operations planning' and the resulting strategic, tactical and operation capacity planning of partners in de circular supply chain to secure resilience in 'feeding' recycling and upcycling?

References

Bressanelli, Gianmarco, Nicola Saccani, Marco Perona, and Irene Baccanelli (2020). "Towards Circular Economy in the Household Appliance Industry: An Overview of Cases" Resources 9, no. 11: 128.

Buren van, Nicole, Marjolein Demmers, Rob Van der Heijden, and Frank Witlox (2016). "Towards a Circular Economy: The Role of Dutch Logistics Industries and Governments" Sustainability 8, no. 7: 647

Díaz-Díaz, R., Muñoz, L., & Pérez-González, D. (2017). The business model evaluation tool for smart cities: Application to SmartSantander use cases. Energies, 10(3), 262.

Ding, Z., Wang, Y., & Zou, P. X. (2016). An agent based environmental impact assessment of building demolition waste management: Conventional versus green management. Journal of Cleaner Production, 133, 1136-1153.

Forti V, Baldé CP, Kuehr R, Bel G (2020) The global E-waste monitor 2020—quantities, flows, and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR)—co-hosted SCYCLE Programme. International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam. Available in: http://ewastemonitor.info/. Searched in: December 2022

Lange, K. P. H. (2022). Simulating industrial symbiosis: understanding and shaping circular business models for viable and robust industrial symbiosis networks through collaborative modelling and simulation.

Lechner, G., Reimann, M (2015), Reprocessing and repairing white and brown goods - the RUSZ case: an independent and non-profit business. Jnl Remanufactur 5

Martínez-Olvera, C., & Davizon-Castillo, Y. A. (2015). Modeling the supply chain management creation of value: A literature review of relevant concept. In Applications of contemporary management approaches in supply chains; InTech.

O'Connell, Maurice W., Stewart W. Hickey, and Colin Fitzpatrick (2013). "Evaluating the sustainability potential of a white goods refurbishment program." Sustainability Science 8, no. 4 (2013): 529-541.

Kerdlap, P. Rabata Purnama, A., Sze Choong Low. J. et. al., Environmental evaluation of distributed versus centralized plastic waste recycling: Integrating life cycle assessment and agent-based modeling, Procedia CIRP, Volume 90, 2020

PBL (2023), De Integrale Circulaire Economie Rapportage (ICER 2023), PBL

Pollard, Jennifer, Mohamed Osmani, Suzana Grubnic, Ana Isabel Díaz, Klaus Grobe, Aybüke Kaba, Özlem Ünlüer, and Rohit Panchal (2022). "Implementing a circular economy business model canvas in the electrical and electronic manufacturing sector: A case study approach." Sustainable Production and Consumption

Rizos, V., Arno Behrens, Van der Gaast, W., et al. "Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers." Sustainability 8, no. 11 (2016): 1212.

Rizos, Vasileios, and Julie Bryhn (2022). "Implementation of circular economy approaches in the electrical and electronic equipment (EEE) sector: Barriers, enablers and policy insights." Journal of Cleaner Production 338 (2022): 130617

Rli (2013). Dutch Logistics 2040: Designed to Last [‘Nederlandse Logistiek 2040: Designed to Last’]; Advies 03; Raad voor de Leefomgeving en Infrastructuur: Den Haag, The Netherlands, 2013.

Shevchenko T, Saidani M, Danko Y et al (2021) Towards a smart E-waste system utilizing supply chain participants and interactive online maps. Recycling 6:1–14.

Senna, P., Marujo, L. G., da Cunha Reis, A., & de Souza Gomes dos Santos, A. (2023). Circular E-Waste Supply Chains’ Critical Challenges: An Introduction and a Literature Review. Conversion of Electronic Waste in to Sustainable Products, 233-250.

Thi L, Doan T, Amer Y, et al (2019) E-Waste reverse supply chain: a review and future perspectives. Appl Sci

Zhiqin Ni, Hing Kai Chan & Zhen Tan (2021) Systematic literature review of reverse logistics for e-waste: overview, analysis, and future research agenda, International Journal of Logistics Research and Applications

Zhu X, Li W (2020) Research on the pricing strategy of "Internet+" recycling platforms in a two-sided network environment. Sustainability 12.

Zuo, L., Wang, C., & Sun, Q. (2020). Sustaining WEEE collection business in China: The case of online to offline (O2O) development strategies. Waste Management, 101, 222-230.