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Assessing circularity in terms of environmental impacts and supply chain

A case study of reusable food container service in Indonesia

Master's thesis in Industrial Ecology

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Cover:
A picture of reusable container by Allas Circular Packaging, taken from @allas.id Instagram account which was posted on August 7th, 2021.

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ABSTRACT

In the battle against plastic waste, reusable packaging is hailed as the adversary to the rising dependence on single-use packaging. However, reuse system is mostly suffered from impacts from considerable weight of the reusable packaging compared to single-use and higher energy requirements for reverse and redistribution logistics, as well as water heating for cleaning purposes. This study investigates the environmental impacts contributed by both single-use and reusable packaging in the context of online food delivery using Life Cycle Assessment (LCA) and qualitative analysis under a framework of Closed-loop Supply Chain, using a real business case in Jakarta, called Allas Circular Packaging, where the company provides product-service system (PSS) of reusable containers to restaurants for food deliveries. The LCA results were used to quantify necessary break-even point for reusable packaging to fully offset the impacts of the single-use. Allas, restaurant, and logistics service provider are the respondents for the qualitative research to define the challenges arising from the implementation of the supply chain. The results showed that one-time usage of reusable silicone packaging system yields two to six times higher environmental impacts than the single-use, particularly caused by the use of silicone material and motorcycles for transportation as depicted in global warming, human non-carcinogenic toxicity, and terrestrial ecotoxicity impact categories, and the water used for washing in water stress index (WSI). It requires four to six uses at minimum to offset the first three impact categories, while WSI prevents any break-even point. In addition, the challenges in the supply chain lie in the obscurity in the value chain, inefficient packaging return mechanism, lack of communication with each actor, including customers, and different mindsets on the selection of sustainable packaging. Considering the break-even point and its feasibility, the reuse system should be well supported by proper measures and policies to be widely used in online food delivery businesses.

Keywords: reusable packaging, silicone food container, reuse LCA, online food delivery, closed-loop supply chain, environmental break-even point

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We hope you readers find our thesis report insightful and interesting, just like how we enjoyed all the process in doing it! Thank you.

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ABBREVIATIONS

ADP_e	Abiotic depletion potential for elements
ADP_f	Abiotic depletion potential of fossil resources
BEP	Break-even point
CLSC	Closed-loop supply chain
EoL	End of life
EPS	Extended polystyrene
GPS	Global positioning system
GWP	Global warming potential
HDPE	High-density polyethylene
HTPnc	Human non-carcinogenic toxicity
LCA	Life Cycle Assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
MAETP	Marine aquatic ecotoxicity potential
MSME	Micro, small, and medium enterprise
NGO	Non-governmental organizations
ODP	Ozone depletion potential
PED	Primary energy demand
POCP	Photochemical oxidants creation potential
PP	Polypropylene
PSS	Product-service system
RFID	Radio-frequency identification
TETP	Terrestrial ecotoxicity potential
WSI	Water stress index

INTRODUCTION

Plastic pollution has been identified worldwide in the ocean, freshwater systems, land, and atmosphere (Ford et al., 2021). Plastics also contribute to climate change throughout their life cycle, from extraction, production, to end-of-life (EoL) phases (Zheng & Suh, 2019). The EoL phase does not only contribute to global warming but also affects the marine and terrestrial environment if mismanaged. The evidence has shown that marine plastic debris threatens marine species through ingestion and entanglement, increasing physical damage to corals, facilitating the distribution of invasive species (Gall & Thompson, 2015), and disrupting biogeochemical cycles (Ford et al., 2021).

Given the above findings, plastic production conversely has been proliferating among the other packaging material due to its lightweight and durable characteristics. On a global scale, plastic production reached 8,300 Mt from a period of 1950 to 2015 (Geyer et al., 2017). Packaging accounts for large portions of the plastic output, approximately 46% of which is single-use packaging (Geyer et al., 2017). The majority of plastics produced were mismanaged, which could accumulate in landfills or potentially leak into aquatic and terrestrial environments (Geyer et al., 2017; Lau et al., 2020). Projection exhibits the world will cumulatively discard 12,000 Mt of plastic waste to the environment by the end of 2050 (Geyer et al., 2017).

To put into context, Indonesia was classified as the second-largest emitter of plastic marine debris in 2015 (Jambeck et al., 2015) and the 9th top country to generate mismanaged plastic waste (MPW) (Lebreton & Andrady, 2019). Despite the claim, plastic waste generation in the country are still increasing by 5% every year and is expected to reach 8.7 million ton in 2025, with one-third of which entering the water bodies (NPAP, 2020).

One of the culprits causing a significant rise in plastic waste generation in Indonesia is the growing demand for online food delivery services, especially in metro cities, such as Jakarta, Bandung, Surabaya, and Medan (Deloitte, 2020). The industry development prompts Indonesia to become the top Southeast Asian country with the most considerable estimated Gross Merchandise Value (GMV)[1] in 2020, followed by Thailand and Singapore (Bhushan, 2021). There are two prominent online food delivery service providers in Indonesia: Grab and Gojek, that swiftly became start-up giants by digitalizing the market of thousands of micro, small, and medium enterprise (MSME) merchants (Jayani, 2021), one of which contributes to an increase of cloud kitchen space (Bhushan, 2021).

The food delivery sector has been recorded as one of the most resilient pockets of growth amidst COVID-19 pandemic (Deloitte, 2020). The city-wide lockdowns resulted in a surge of online delivery orders up to 10 uses in a month (Nurhati, 2020). This incident also saw a sharp increase in the number of users of online food delivery services in Indonesia from 13.6 million in 2019 reaching 19.1 million in just a year (Statista, 2021). The rivalry of both tech start-ups spurred the dynamic competition in metro- and big cities in Indonesia with a total population of 240 million (Sawatzky, 2021), which drive the ever-increasing number of uses due to promotional deals and cheap delivery fee on top of a variety of merchants and cuisines (Rauf, 2021).

The phenomenon has exacerbated the consumption of single-use plastics derived from food and beverage packaging. For instance, Camps-Posino et al. (2021) listed components of a food delivery

[1] Gross Merchandise Value is a total monetary value of sold merchandise through a consumer-to-consumer online marketplace.

packaging consisting of various plastic products, including HDPE (high-density polyethylene) single-use plastic bags, straw, dumpling container base, spoon, sauces pots, dumpling container top, and packaging for sauces from polypropylene (PP), and bamboo chopsticks. The inevitable behavior changes eventually led to a surge in household plastic waste, with single-use packaging making up most of the shares (Tobing & Setiawan, 2021). In response to this phenomenon, both Indonesian online transport services started fewer plastic initiatives through #GoGreener by Gojek (Gojek, n.d.) and Returnable Container by Grab in 2021 (Grab Indonesia, 2020). A similar reuse business model was initiated by Grab to reduce food plastic packaging; however, the idea did not align with the recommendation of keeping hygiene as the top priority considering the pandemic situation (S. Pristine, personal communication, 24 January 2022).

Although this system shows promises of high potential in reducing the amount of waste and resource use, academic papers rarely touch on the reuse system of food containers, specifically in Southeast Asian countries. Business models using reuse strategies can increase the value of the products through product-service system (PSS), i.e., the creation of non-material aspects, such as technological improvements, intellectual property, product image and brand names, and aesthetic design in comparison to customer-owned packaging (Mont, 2002). PSS is a set of products and services with varying ratios to fulfill the consumers' needs, and decouple the environmental impacts of material and energy uses through the shift in ownership structure and attitude from sales to service (Mont, 2002). PSS to work effectively requires a closed-loop supply chain where logistic and rental services are important to return product back to the market for reuse.

Further research on reuse scheme is necessary given food delivery services entail incremental transport and additional processes, becoming the trade-offs of the system. Eventually, it may contribute to higher energy consumption leading to more significant environmental impacts. Therefore, this study uses a quantitative method of Life Cycle Assessment (LCA) to assess the environmental effects of reusable food containers and to indicate the potential parts within the supply chain that require significant improvement.

This study aims to answer the following research questions:

RQ 1. What are the environmental impacts of one portion of meal in a single-use packaging using online delivery services in Jakarta, Indonesia?

RQ 2. What are the environmental impacts, and which processes contribute to the highest impacts of providing one portion of meal in a single online delivery service using reuse scheme in Jakarta, Indonesia?

RQ 3. What is the least number of uses to offset the environmental impacts of reusable food containers against the single-use option?

RQ 4. What are the identified hotspots of the reuse scheme within the closed-loop supply chain (CLSC) framework?

As for the study limitations, the authors could only attain limited primary data for LCA modeling, thus primarily relying on Ecoinvent background processes with adjustments to reflect on local context, which could be improved with more geographical and technological representative data. For example, the emissions for motorcycle use for food delivery has been adjusted to the Indonesian setting, and electricity use for food container production in China is also modified. The cut-off criteria include indirect energy use in the warehouse, the use of credits in the recycling, production of the cutleries, secondary packaging (e.g., plastic bags), and other complementary products within the food delivery packaging (e.g., tissue, utensil wrapper, and sauce), and leaving out food preparation and food waste to not overcomplicate the system boundaries. Several assumptions were made, one of which is the estimation of transport distance on upstream processes and various customer locations.

The qualitative study similarly lacks the necessary depth as the authors were unable to gather insights from customers and managed to only set interviews with one respondent from a restaurant aside from Allas and a delivery service provider. Due to time and budget constraints, the only primary data collection is the water consumption measurement using manual equipment, which may prompt potential human error. The lack of previous studies in online food delivery, and specifically in Southeast Asian countries where the prominent online food delivery services use motorcycles, have made performing this research more challenging to provide a thorough comparative assessment.

BACKGROUND

As the foundation of this thesis, existing literatures within the scope of this study is elaborated in this section, which is divided into three parts: growth of reuse system, LCA on reuse, and the perspective on the CLSC.

2.1 The Rise of Reuse System

The birth of circularity in industrial processes was generated from growing concerns over environmental impacts and raw material supplies. This notion was first introduced in a 1972 report called Limits to Growth. However, the concept had been actualized in business context in Industrial Ecology field through recycling and industrial symbiosis by Frosch (1992), who coined that "The idea of an industrial ecology is based upon a straight-forward analogy with natural ecological systems. In nature an ecological system operates through a web of connections in which organisms live and consume each other and each other's waste.".

Thus, in the light of current trends in material price and abundance, and growing consumption patterns, circular economy is promoted to be the new economy that is able to decouple economic gains from material input. Ellen MacArthur Foundation (2013) convey that circular economy embodies a shift toward function service model through retaining ownership of manufacturers' products and acting as service providers. The prerequisites of this model are business model and product design that facilitates durability, modularity, and disassembly.

Ellen MacArthur Foundation (2013) illustrate the circular economy model in biological and technical nutrient cycles from end-use circling back to the value chain. The butterfly diagram of circular economy is in line with three types of 'loops' developed by Bocken et al. (2016): narrowing the loop, meaning reducing material flows in the products; slowing the loop, implying that prolonging the lifespan of the products; and closing the loop, which is connecting the flow of products from the hands of consumers to production for recovery . Although the efficiency in narrowing the circle is fairly questioned due to its adoption of conventional business model design, slowing and closing the loop is clearly displayed through the cascaded use of the products, components, or materials between biological and technical nutrient cycles and the circles back to the production line.

In the context of packaging, reuse is one of many options already tried and performed in retail. Ellen MacArthur Foundation (2013) argue that the benefits entailed by adopting reusable packaging include improved user experience, user insights, brand loyalty, personalization, and of course, contribution to positive environmental performance. Coelho et al. (2020) add numerous opportunities across the value chain and barriers hindering the growth of the reusable packaging business, particularly hygiene issues in light of COVID-19 pandemic (Zero Waste Europe & Reloop, 2020). Companies must be able to ensure and communicate with their customers to retain their trust, especially those offering refill services, e.g., refillable by the bulk dispenser and refillable parent packaging (Coelho et al., 2020). This circular business model is not susceptible to overall positive environmental impacts as several hotspots across the supply chain are identified as elaborated in the Section 2.3.

2.2 Reuse Life Cycle Assessment (LCA)

The rising concerns of single-use packaging consumption have brought attention to reusable packaging as a more sustainable option in reducing material and energy use, as well as decreasing production emissions (Coelho et al., 2020). Instead of disposed directly after use, reusable packaging could reduce the workload on waste management services by redirecting material back to the market after conditioning process. Nevertheless, it has potential negative impacts associated with higher amount of material for product manufacturing, recurring washing process, and intensified transport due to reverse logistics (Coelho et al., 2020; Garrido & Alvarez del Castillo, 2007). Impacts could vary between the difference of life cycle processes, type of packaging, choices of impact categories, and calculation assumptions.

LCA has been used to quantify environmental impacts of various single-use packaging and its alternatives to understand which material performs better for the environment. In particular, LCA method is also adapted to compare environmental impacts of single-use and reusable products (UNEP, 2020) because of the aforementioned reasons. In general, reusable packaging contributes to lower environmental impacts than single-use packaging after multiple number of uses (Coelho et al., 2020).

To ensure a fair comparison between products, earlier publications used functional units that represent the functionality of both single-use and reusable packaging, such as the number of coffee cups used for one year (Almeida et al., 2018) or 360 uses of food container (Institute for Sustainable Futures, 2018). Furthermore, multiple studies applied 'break-even point' or 'transition point' (Gallego-Schmid et al., 2019) to calculate a point where reusables start to perform better than the single-use product in 'number of uses' unit. The environmental break-even point (BEP) allows researchers to use a simpler functional unit with similar function as single-use packaging (i.e., providing 200 ml of coffee), instead of assuming how many times the packaging will be used throughout its life cycle (Cottafava et al., 2021). By understanding the minimum number of uses should be applied for reusable packaging, environmental benefits could be improved significantly.

According to Gallego-Schmid et al. (2019), food container made of thin-wall PP requires one to nine uses to have lower impact than single-use aluminum and extended polystyrene (EPS) packaging in all 12 impact categories examined, except for abiotic depletion potential for elements (ADP_e), which is aligned with the results obtained by Institute for Sustainable Futures (2018). Additionally, the more durable PP container, *Tupperware,* performed better compared to aluminum container after one to 18 uses, and 18 to 37 uses against EPS containers. The study highlighted that material-wise, EPS generates the lowest impacts of all, although the main concern is the effects on marine organisms due to low degradability and littering problems which could not yet be captured by the LCA method (Gallego-Schmid et al., 2019). Furthermore, glass food container was also analyzed and resulted in 12% to 64% worse than the plastic *Tupperware* container, with the main difference on the material production impacts (Gallego-Schmid et al., 2018). Glass containers should perform 1.3 to 3.5 times additional number of uses than plastic *Tupperware* container in order to offset the environmental impacts (Gallego-Schmid et al., 2018). Similarly, the finding was consistent even with the inclusion of reverse logistics, due to the heavier weight of glass container which requires more carrying capacity during transport (Cottafava et al., 2021).

Contribution analysis of single-use containers with different materials shows that significant impacts were generated from raw material extraction, production, and end-of-life phases (Gallego-Schmid et al., 2019). Raw material extraction contributes the most to abiotic depletion potential of fossil resources (ADP_f), photochemical oxidants creation potential (POCP), and primary energy demand (PED) categories, even more for Alumunium container due to electricity consumption in refineries. Whereas production had substantial impacts on abiotic depletion potential of elements (ADP_e), marine aquatic ecotoxicity potential (MAETP), and terrestrial ecotoxicity potential (TETP). Finally, EoL phase caused major impacts associated with landfill treatment.

Use phase impacts of reusable products were claimed to be highly significant among the other life cycle impacts (Almeida et al., 2018; Camps-Posino et al., 2021; Martin et al., 2018). In the case of plastic container, use phase impacts account for 40% of the entire life cycle impacts, followed by PP granulates production (>15%), food container manufacturing, and lastly, transportation and EoL phase (Gallego-Schmid et al., 2018). The high share is a consequence to the energy consumption in water heating of hand-washing process or electricity use of dishwasher (Gallego-Schmid et al., 2018; Martin et al., 2018). Cottafava et al (2021) complemented the results by developing different washing scenarios, which shows the least environmental impacts are generated from the industrial central washing facility, on-site dishwasher, and handwashing, respectively. On the other hand, handwashing option is considered the best when using room-temperature water (Changwichan & Gheewala, 2020; Martin et al., 2018). The frequent waste management method for analysis are landfill, recycling, and incineration. Overall, improvements on plastic containers recycling rates would lead to reduction of fossil fuels, primary energy, eutrophication potential, photochemical ozone creation potential, and global warming potential impacts (Camps-Posino et al., 2021; Gallego-Schmid et al., 2019).

In respect of transportation, earlier studies mainly include forward transportation from raw material site to production factory, distribution to the food outlet, and collection to the waste management facility (Foteinis, 2020; Gallego-Schmid et al., 2018, 2019; Martin et al., 2018; Garrido & Alvarez del Castillo, 2007). The modeling choice reflects on the personal use of reusable container at home instead of delivery service, which results in less pronounced impacts of transportation between 7% to 20% of the cradle-to-grave impacts. Conversely, literature that examine reverse transport in reuse systems vary in the transport modes, such as electric motorbike in China and light commercial vehicle in Europe (Camps-Posino et al., 2021; Cottafava et al., 2021). These studies generate different findings, wherein the former only contributes up to 6% and the latter emphasizes that transport distance during use phase has a notable effect. As an example concerning climate change, the study suggests maintaining the distance in City/Metropolitan areas shorter than 30-50 km to keep the impacts of reusable plastic cups lower than the single-use cups (Cottafava et al., 2021). Considering the results above, the local context of washing method, technology choices, and transportation modes are considerable factors of LCA results.

Comparative LCA publications are still developing to enrich the detail of embodied impacts of reusable packaging as a valuable input for policy-making and behavior change strategies. Consequently, the crucial aspects of comparative LCA are functionality equivalence, assumptions regarding transportation and reuse scenarios, impact categories indicators, and consistent modeling choices (UNEP, 2020).

2.3 Closed-loop Supply Chain on Reusable Packaging

Industries have placed emphasis on remanufacturing since 1990s, but the research on that was severely lacking (Guide & Van Wassenhove, 2009). Companies adopting circular business models have reported numerous benefits from tapping the aftermarket, which comprise additional revenue streams, strengthened customer loyalty, and improved product innovation (Baines et al., 2017). EMF (2019) reiterates and adds identified advantages, including customization according to needs and users, and better visibility along the supply chain using RFID (Radio-frequency identification) tags and GPS (Global Positioning System). Nevertheless, major barriers are reportedly found in the supply chain, regulations, and markets (Govindan & Hasanagic, 2018), hence improving closed-loop supply chain in practicality is necessary to enable the scale-up of the circular economy initiative.

Increasing pressures from customers and NGOs as well as regulatory changes on the global production and consumption systems have driven brand-owning companies to adopt systemic change across their supply chain toward sustainability. In particular, closed-loop supply chain (CLSC) is defined as "the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time." (Guide & Van Wassenhove, 2009). Technically, the focal points of value retainment of products after use include product returns management, value-added operations, and market development (Guide & Van Wassenhove, 2009), a setting which apart from conventional linear supply chain management. Necessary improvements in reverse logistics, inventory management, and operations, e.g. inspection, remanufacturing, refurbishing, and information and knowledge flows are recommended as these are the most common existing issues in implementing CLSC (Gatenholm et al., 2021).

As shown in **Figure 1**, according to Guide & Van Wassenhove (2009), the first activity of the CLSC is product returns that can be categorized as commercial, end-of-use, and end-of-life returns. These categories of returns influence the decisions of recovery strategies, particularly through repair, remanufacturing/ refurbishing, and recycling, respectively to the categories. The returned products from customers back to the retail/warehouse, commonly defined as reverse logistics, are then inspected, tested, and reprocessed according to its condition to be restored to its original setting. Afterward, the reprocessed products are redistributed to the secondhand market, where in this case, reusable packaging serves the same market as new ones (McKerrow, 1996b).

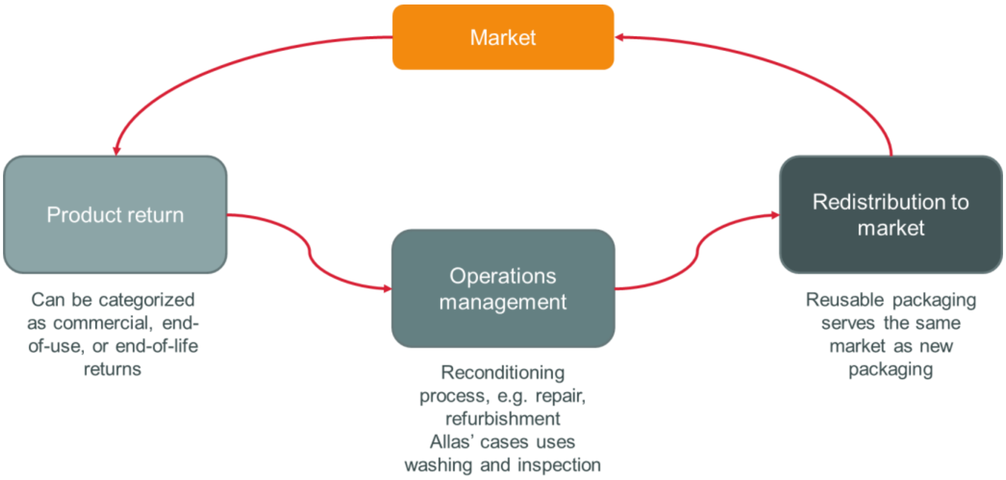


Figure 1 Closed-loop supply chain framework (redrawn from (Guide & Van Wassenhove, 2009))

In addition to the post-consumer side, systemic change similarly needs to occur in the upstream processes. Sustainability must be integrated in the product design (e.g., material selection, modular options, recyclability), leaner supply chain by reducing and reusing the by-products from manufacturing line and in-use, product life extension against obsolescence, and recovery processes at end-of-life (Linton et al., 2007). In practical examples, focal companies, or the brand owners with closest proximity to customers, set up initiatives with and develop their suppliers to implement life cycle management to supply "sustainable products" using criteria that goes beyond the final products (Seuring & Müller, 2008). The trade-off of supply chain management for sustainable products is a closer relationship with the suppliers and buyer power shift to gain visibility and clearer information flows (Seuring & Müller, 2008), which are in line with the requirement of CLSC with the reverse logistics partners (Guide et al., 2003).

Carrasco-gallego et al. (2009) distinguished the features of CLSC of reusable packaging into the following.

1. New and reused packaging serve the same markets
2. Simple reconditioning operations before entering back to the market and the activity does not entail cost as high as acquiring the new one
3. High rate of packaging return
4. Considerable number of units circulating in the system
5. Difficulties in balancing supply (return) and demand

The design of supply chain for reusable packaging may be similar across all packaging types (primary, secondary, tertiary), but there is merely a handful of research on reusable primary packaging. It is too great of a risk from sacrificing food products to reduce packaging waste given the high share of contribution to global warming and the losses across the food supply chain (Barlow & Morgan, 2013). However, in comparison to secondary and tertiary packaging, design standardization is uncommon in the packaging with direct contact to the product owing to marketing reason, which is a challenge for the operations management.

The operations management of reusable packaging partly concerns the actors who would perform take-back of packaging in end-of-use, inspection, inventory management, purchasing policies, and performance measurement (Mahmoudi & Parviziomran, 2020). In addition, the companies must consider convenience while designing the return scheme as it depends on the service touchpoints, i.e. the location where customers receive the service (Long et al., 2020). The rest of the operations are subject to the focal organization bearing the responsibility. Therefore, the supply network configurations are shaped according to the roles and responsibilities specified with the main organization. In the instance of Carrasco-gallego et al. (2009), two network models were identified; first, the star system requires all packaging to be returned to the same facility, while the multi-depot system allows packaging to be reconditioned by several other actors that are capable of performing the operations. Meanwhile, Kroon and Vrijens (1995) classified the actors performing the operations and the focal company into four main categories:

- transfer system (sender of the products owns and thus is responsible for all the operations),
- book system (central agency owns the packaging, but is notified by the sender of all the packaging movement using debit-credit system),
- deposit system (the central agency is responsible for all the operations funded by the sender plus the deposit to finance losses or theft of the packaging),
- and systems without return logistics (sender rents from the central agency but is responsible for all of the operations of the packaging).

Mahmoudi and Parviziomran (2020) have identified salient activities within logistics system and operations management of reusable packaging, including ownership and the responsibility of managing the packaging, tracking method, and performance of keeping the quality of the products. The authors argue that the considerations are also applicable to primary packaging, which are iterated by Long et al. (2020) and McKerrow (1996). Ownership of the reusable packaging determines the logistics network design and the responsibility of managing, cleaning, controlling, and storing the packaging; the reusable packaging can belong to the manufacturer, customers (Long et al., 2020), logistics company (e.g. Grab (2020)), or a third-party service provider (Kroon & Vrijens, 1995; McKerrow, 1996b). The focal organization is responsible for keeping the incentives aligned and perform respective tasks across the supply chain as to maintain the reusability of the packaging (Mahmoudi & Parviziomran, 2020). Poor management and exercise of the authority of the packaging owner will lead to unauthorized use or misuse by another actor and inefficient logistics system (McKerrow, 1996b).

Furthermore, the logistics network is designed according to the service touchpoints that Long et al. (2020) categorized into four main locations: at home, at the store, at public area within a close (office), or in an open environment (station, coffee shop). The necessity of partnering with a logistics company is dependent upon the service touchpoint above, as refilling products in public areas is usually performed by the customers directly, for instance. In that case, the return scheme occurs in the same place and at the same time as the direct sales. Meanwhile, the opposite is found in businesses providing delivery of refill products, which requires management of forward and reverse logistics to ensure the return of the packaging. The planning of service touchpoints is shaped by several criteria, including customer profile (office employees, commuters, or people staying at home), value proposition, and operations (Long et al., 2020).

As shown above by Kroon & Vrijens (1995), the identified entities and their dynamic relationship shape the operations of reverse logistics. In the case of reusable packaging using online food delivery services, key actors are restaurants, food delivery services, customers, and third-party organizations (Janairo, 2021; Long et al., 2020). Particularly, the packaging owner, which can belong to any entity above, determines the communication and financial flows within the CLSC. Furthermore, Janairo (2021) argues that each stakeholder has its own contribution to the success of reuse scheme of food packaging using online food delivery services, even emphasizing the potential benefits if online food delivery services take up the mantle as the packaging owner, as they connect with both the merchant restaurants and their customers. For example, Grab Indonesia (2022) provides their customers an option to not be provided the cutleries to cut down single-use plastics. Although restaurants and customers may have their own preferences to maximize their marginal benefits, detailed research on the existing activities of each actor within the CLSC is necessary to grasp better understanding on this matter.

Reuse scheme of food packaging has a considerable potential to offset the environmental footprints and reduce resource demand. However, the trade-offs lie in a more complex supply chain, e.g., more energy for transportation, reverse logistics, and additional operations, which require further scrutiny, especially in the case of primary packaging and online food delivery service, in which the academic literature is scarce. Moreover, there lacks an absolute guarantee that reusable packaging offers lower environmental impacts. Hence, these are assessed quantitatively using Life Cycle Assessment, and qualitatively using CLSC framework in the following Chapter 6 Results and Discussion.

METHODOLOGY

This research is based on the case study of a reusable packaging service for online food delivery, namely Allas Circular Packaging, or Allas in short, in Jakarta, Indonesia. The overall research methodology has been formulated to achieve the aim of the study, as presented in **Figure 2**. To solve the first through third research questions, a quantitative analysis of LCA will be applied. Furthermore, a qualitative analysis with CLSC framework is expected to answer the last research question.

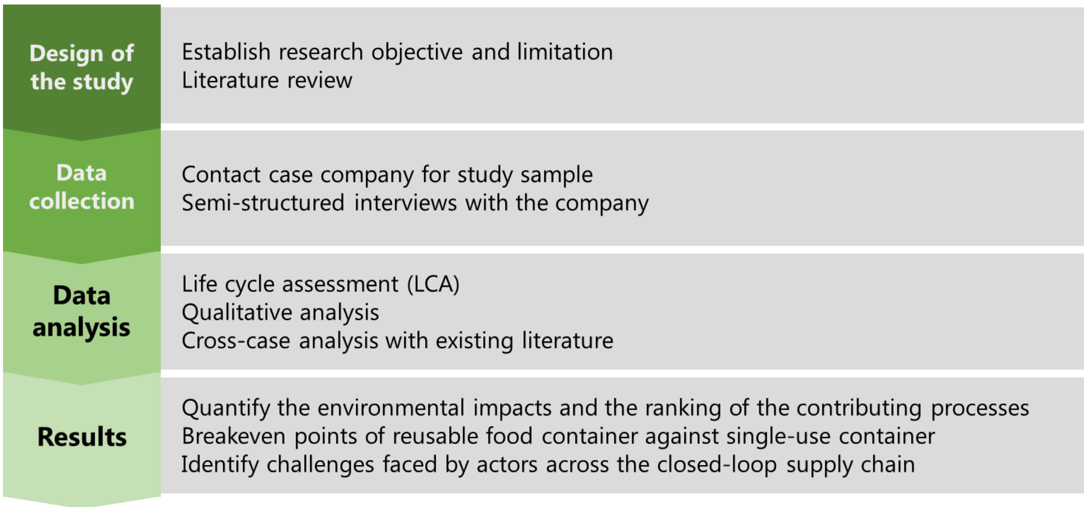


Figure 2 Research methodology flowchart

3.1 Literature Review

A literature review is useful to examine the validity of the research topic and initial hypothesis with the earlier studies. Starting with clear and feasible research questions, it helps structure the literature review by finding relevant research articles, data, and methodology for analysis (Jesson et al., 2011). Once the draft of research questions is formulated, further collection of information using specified keywords is necessary to reassess and secure the final research question. This study conducted a literature review for the background chapter with a 'traditional review' method, specifically the 'state-of-art' review based on Jesson et al. (2011). The method aims to understand and summarize the current state of knowledge and gaps on a specific topic, which has less established methodology than a systematic review but could be supported by search description and selection rationale of the chosen literature. This type of review is also called 'narrative review', where the reviewer analyzes the literature in an informal procedure, searching and reading through snowballing approach (Fan et al., 2022). The review process partly referenced from Xiao & Watson (2019), involves the following steps.

1. Searching the literature

   In the beginning, the authors performed an iterative literature search using the keywords of 'reusable container', 'refillable container', 'product-service system', 'reverse logistics', 'online food delivery', 'reuse life cycle assessment', 'food container life cycle assessment', 'single-use and reusable product comparative life cycle assessment', and 'environmental impacts break-even points' as a search description, mostly on Google Scholar and Chalmers Library databases. Several studies were found through backward search, where authors identified relevant papers cited by the articles, usually listed in the list of references at the end of the article.

2. Screening

   The authors then decided to include which of the compiled literature through the screening process. In order to answer the research questions, hereby the following selection rationale of inclusion was previously defined:

   - since the majority of the existing literature in CLSC field discuss about remanufacturing and refurbishing, which is not part of the scope, only research with a specific focus on reusable/refillable/returnable containers is further assessed and analyzed
   - on the LCA topic, only research using Life Cycle Assessment method with midpoint impacts are included. Comparative studies between single-use and reusable containers are prioritized, then complemented with comparative assessment of different materials for food containers. However, studies discussing bio-material container is omitted due to the irrelevancy to the product systems under this study, which are polypropylene and silicone.
   - studies published in peer-reviewed academic journals and grey literature (e.g., a report from governments or NGO)
   - studies written in English

3. Data analysis

   Screened literature was then highlighted and coded to gather insightful information that is relevant to the research. Simple codes are used, which are 'general information', 'reuse LCA', and 'CLSC in reusable packaging' since the work was performed by more than one author. Both qualitative and quantitative studies were analyzed separately; the former was by sorting findings into categories, while the latter used relevant LCA data and findings to observe similarities and differences between studies. Relevant data extracted from LCA studies were the functional units, comparison method, type of databases, choice of impact categories, and impact assessment results.

4. Reporting

   All relevant findings were reported in the Background and Methodology section of this report, to provide adequate information on the topic and serve as the basis to conduct the study.

3.2 Data Collection

In the first stage of the research, objectives were determined, and limitations and cut-off criteria were identified to set up system boundaries. Subsequently, literature review was performed to build substantial background section and to develop an interview list for the respondents, including the company, restaurants, and online courier service provider. The respondents include the following.

1. Allas Circular Packaging

   Interviews with Allas were carried out 3 times to gather information on their business operations. First introductory interview was held on 28 January 2022 without structured questions but more explanation on Allas' business model and was followed up with second interview held on 8 March 2022 using semi-structured interviews. Both interviews were conducted virtually. Then, authors managed to pay a visit to their operation office in Jakarta, Indonesia on 23 March 2022 and collected quantitative data of their washing operation and inventory management.

2. Restaurant

   The interview questions for the restaurant mostly concerned drop-off mechanism, storage design, and frequent reporting and communication with Allas. The respondent from restaurant group is Feel Good Food, whose physical outlet was founded in 2021.

3. Online delivery service

   Allas' logistic partner for returning the packaging to Allas' cleaning hub is called Westbike, which was established in 2020 using bicycles to provide last-mile delivery service. The interview with Westbike was held on 5 April 2022. Their communication on taking orders from Allas and the pick-up and delivery route are the main topic for the interview guide.

Semi-structured interviews were deemed appropriate to gather as much valuable insight as possible from the company. The interview list guide was developed from the conceptual framework based on the literature review, which included questions regarding actors, main responsibilities, and challenges of logistics and operations. The interview data was assessed by connecting it with other sources of data (i.e., literature review and secondary data). Finally, the result was displayed according to the developed codes utilized in the analysis step. The interview questions are presented in the Appendix B.

3.3 Life Cycle Assessment (LCA)

Environmental impacts of single-use and reusable containers were quantified by LCA method in accordance with ISO 14040/14044 standards. The basic definition of LCA in ISO 14040 presented as "LCA studies the environmental aspects and potential impacts throughout a product's life (i.e., cradle-to-grave) from raw material acquisition through production, use and disposal" (ISO, 1997). The product's life stages are referred to "product life cycle", which comprises unit processes as the smallest unit, that receive inflows and convert it to generates outflows. The combination of unit processes forms a "product system" that is connected with the upstream processes, such as a product system of PET bottle containing production, distribution, and end of life processes (Acero et al., 2016). Life cycle impact assessment is applied on a product system level, delivering a specific function of a product. The output of LCA studies could used for product development, marketing purposes, or strategic planning on a product level to a global level.

LCA method allows a holistic environmental analysis on the reuse system of food containers using online food delivery services, in response to the first three research questions. This approach avoids problem-shifting, where usually a problem is solved in one process only to shift the problem to another process within the life cycle of a product (Guinée, 2004). Problem-shifting can also occur between impact categories, i.e., reducing one impact category while increasing another at the same time. As LCA studies evaluate products according to its function (Guinée, 2004), the method is ideal for comparative analysis between single-use and reusable products, due to the multiple usage nature of reusable product that can deliver more functionality than a single-use product. The environmental impacts assessment results of reusable and single-use product systems were used as the inputs of BEP analysis, indicating a point where the reusable product system impacts offset the single-use product system. The calculation method of BEP was derived from Cottafava et al. (2021), noting the advantage in using a more simplified functional unit for comparing single-use and reusable product systems. In that sense, the impact assessment in this study is not an independent study but serves as an initial step for BEP estimation, in order to emphasize the environmental benefits of reuse scheme.

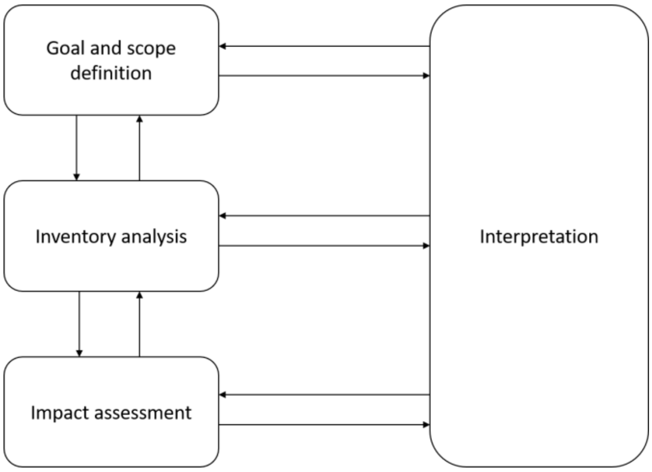


Figure 3 LCA Framework

The established assessment procedure by ISO consists of goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA), and interpretation, with iterative fashion as presented in **Figure 3** (ISO, 2006). In goal and scope definition, fundamental concept of the study was described, comprising the purpose and intended application of the study, system definition and boundaries, functional unit, type of impact assessment, and methods of interpretation. Afterward, the input and output flows for a product life cycle were measured and compiled in life cycle inventory. These flows made up of material, energy, auxiliary material, waste, emissions, or services. Next, mandatory elements of LCIA phase composed of selection of impact categories, classification of LCI results in correlation to impact categories, and calculation using characterization factors to obtain category indicator results according to the impact category (e.g., kg CO_2eq for global warming potential impact). The results were then examined based on the goal and scope of the study in order to define conclusions, recommendations, and limitations in the final stage, interpretation of LCA results (Klöpffer and Grahl, 2014).

Goal and scope, as well as the LCI of this study can be read further in Chapter 5 LCA Procedure.

3.4 Environmental Break-even Point (BEP)

Environmental BEP method was derived from Cottafava et al (2021), who propose a way to quantify the break-event point by decoupling product efficiency (from production and EoL phases) and use phase efficiency. The results of environmental performance of single-use and reusable containers were compared not only based on the differences in life cycle processes (with and without loop), but also in terms of impacts in production and EoL phases.

The 'loop' in the reusable product system involves at-customer washing, return transportation, at-Allas washing, and redistribution to restaurants, illustrated as a part of **Figure 10**. As defined in Chapter 2: Background, the result of BEP quantification is the "minimum number of uses where reusables start to perform better than the single-use product system". In this study, the reusable container was assessed using two scenarios: (1) without loop, or the baseline, for differentiating the production and EoL impacts from those of the use phase, and (2) with loop, for the use phase as the presentation of actual condition in our case study. The variables of the calculation are defined below:

1. The impact of life cycle phases: A = production, B = use, and C = EoL
2. Single-use or reusable product system impact: X = single-use, and Y = reusable
3. Scenario of washing (only applicable for reusable product): 0 = no washing, and 1 = handwashing

For example, A_X means the impact of production phase for single-use container. The subscript '0' for the use phase represents reusable container without the loop as baseline for calculation. Using these variables, the denotation of total environmental impacts considering only the baseline scenario for single-use is X, and for reusable product without loop (subscript 0) is Y_0. In the baseline scenario, the use phase impact was considered to be zero for the purpose of equal comparison between reusable and single-use, which is not complemented with additional processes of washing and reverse transport. The total impacts of each product system for the baseline scenario are as follow.

Environmental impacts of single-use product

$$X = A_X + B_X + C_X \tag{1}$$

Environmental impacts of reusable product

$$Y_0 = A_Y + B_{Y_0} + C_Y \tag{2}$$

Following are three Key Performance Indices (KPIs) for reusable product system established from above variables.

1. Product efficiency

$$\eta_p = \frac{Y_0}{X} \tag{3}$$

, where η_p is the number of single-use food container needed to balance out the impacts of production and EoL phases for reusable food container. The larger amount of η_p, the more inefficient reusable product becomes in terms of production and EoL phases. For example, reusable product tends to be more durable, requiring considerable amount of material to produce, which lead to higher environmental impacts, that is represented by $\eta_p > 1$.

2. Use phase efficiency

$$ŋ_{u1} = \frac{B_{Y1}}{X} \tag{4}$$

, where $ŋ_{u1}$ indicates the efficiency of use phase impacts of reusable container (B_{Y1}) compared to the total life cycle impacts of single-use container (X). The use phase impact for dishwashing scenario is denoted as B_{Y1}. If $ŋ_{u1} > 1$, the use phase impacts for handwashing scenario are higher than the total impacts of single-use, hence implying an inefficient use phase process.

3. Environmental BEP

$$n_1 = \frac{Y_0}{X - B_{Y1}} \tag{5}$$

, where n_1 represents the minimum number of reuses needed to gain environmental benefit for reusable container in relative to the single-use container. If $X > B_{Y1}$ or $ŋ_1 > 0$, then the impacts of reusable product system will offset those of the single-use container usage after reaching the BEP.

3.5 Sensitivity Analysis

Sensitivity analysis is a procedure to estimate the influence of parameters to the outcome based on the selected methods or data (Björklund, 2002). This study used scenario analysis and one-way sensitivity analysis method to test the robustness of the model. Scenario analysis projects the results from running different scenarios in order to understand the effects of multiple parameters change according to the scenarios. In addition, one-way sensitivity analysis requires altering a single input parameter value with the rest of parameters remain constant to see the degree of output change by percentage.

In total, three sensitivity analysis were conducted: (1) scenario analysis for return scheme method, (2) one-way sensitivity analysis for transport distance from restaurant to Allas, and (3) one-way sensitivity analysis on usage cycle. The first analysis used three scenarios of reusable container return scheme as follows.

1. Pick-up (baseline): food container is picked up with bicycles from customers to Allas' cleaning hub
2. Drop-off to Allas: food container is taken by customers to Allas' cleaning hub with motorcycles
3. Drop-off to restaurants: food container is taken to the restaurants by customers with motorcycles and then delivered to Allas' with bicycles

Parameter changes in the second sensitivity analysis for the transport distance is shown in **Table 1**. Additionally, the third analysis for usage cycle was defined based on Allas' plan to reach minimum cycle usage of 50 uses (Allas, personal interview, January 8, 2022).

Table 1 Parameter od transport distance scenario

Scenario	Values	Description
Baseline	4.4 km	The average distance between Allas and restaurants
Within regency (min)	10 km	Within the Regency of South Jakarta (or part of central Jakarta)
Within regency (max)	15 km	
Inter-regency (min)	20 km	To West, East, part of Central, and North Jakarta
Inter-regency (max)	25 km	
Inter-city	30 km	To Serpong, Tangerang, Bekasi

3.6 Closed-loop Supply Chain

In addition to quantitative analysis using LCA, a qualitative research approach was chosen to identify the challenges present in the food packaging reuse scheme using online food delivery services. The analysis process required both deductive and inductive methods to generate meaningful insights from the responses and to answer our research questions. Initially, theoretical framework as a primary guide for this thesis was determined and used for building hypotheses. This method is more common in natural science field to elaborate one's lived experiences in their own words (Brinkman, 2013). The findings from qualitative research were then analyzed against the theories to form a deduction, which is useful to refine existing or even discard preexisting theories after being confronted with empirical realities (Brinkman, 2013).

Afterward, the authors developed codes from both a predetermined list and in-vivo codes according to the respondents' own answers, which were assigned to every line of the responses, often called line-by-line coding through inductive analysis. Inductive approach allows the findings to emerge from raw data and to be summarized without being dependent on structured methodologies (Thomas, 2006). The combined use of both deductive and inductive methods helped link the emergent results with existing research and develop meaningful implications. The practices are elaborated below based on Miles et al. (2014) and Bingham and Witkowsky (2022).

1. Code and theme development and attribution

   Before plunging into the data, major categories and attributable codes were pre-determined, which were derived from Guide & Van Wassenhove (2009). The categories are the three main activities of CLSC, i.e., product returns (e.g., logistics), operations, and redistribution to market, and were put into a matrix. The matrix, as shown in **Table 2**, was developed with processing codes placed across the x-axis and respondents across the y-axis to indicate their roles within the CLSC.

Table 2 Preliminary codes of the qualitative analysis

Actors	Logistics design	Operations	Redistribution
Allas	Product recovery Tracking Pick-up or drop-off mechanism Transport mode	Dashboard/database Inspection method Washing method Communication with restaurant	Transport mode Scheduling Purchasing strategy Inventory management
Restaurants	Drop-off mechanism Challenges in packaging return	Administration and reporting Communication with Allas	Restock Storage place
Online transport services	Opportunities in reverse logistics Challenges in reverse logistics Transport mode		Return lead time Scheduling Transport mode

2. Data organization into relevant themes

   All responses were then organized into three themes listed in the matrix. For example, a response concerning drop-off mechanism was assigned to 'Product Recovery' topic, while restocking was to 'Redistribution'. This process was undergone using Microsoft Word and required color highlighting to indicate which response matches which theme.

3. Line-by-line coding

   Following the previous deductive cycle, the authors assigned every line of responses into predetermined codes and add several in-vivo codes that were representative of certain findings. Throughout the analysis, memos were frequently added in to connect findings with the theory or evidence in the literature.

4. Second iteration of coding

   The iterative process was necessary to ensure the consistency of the analysis. Each coded response was moved to a spreadsheet with a table of themes and respective codes. This process required the authors to take a second look at the codes and the answers before putting it into the matrix, which was displayed in a Microsoft Excel file for better visibility before the next step.

5. Linking theory to the findings

   Combination of deductive and inductive coding helped converging the findings that were supported by the existing literature discussed in the Background chapter. All important findings reported in Chapter 6, Results and Discussion, are the ones echoed in the literatures and newly emerged from the interviews.

3.7 Research Ethics

Aside from the research aim, the means taken to produce this thesis are within the boundaries of following ethical principles.

1. Minimizing the risk of harm
   Both quantitative and qualitative research methods were applied with minimal exposure risks to the interviewees, i.e., an environment with low contributions to distress and disadvantage (all participants had access to and are familiar with the internet for video calls).

2. Obtaining informed consent
   All interviews started with gaining consent from the interviewees for collecting data and authors specifically asked whether the data was permitted to be used for our modeling and analysis as well as published to the public.
3. Protecting anonymity and confidentiality
   Information that was declared confidential was left out completely in this report and a Non-Disclosure Agreement with Allas Circular Packaging was established.
4. Avoiding deceptive practices
   The true purpose of the research was informed to all of the interviewees during the interviews and the report will be given for their reference inventory.

The introduction of Allas and information regarding their network as the result of the interviews was elaborated in following Chapter 4 Case Company.

CASE COMPANY

Founded in 2004 in the Netherlands, Enviu strives to actualize an economy that serves people and planet. In doing so, they have built a team of venture builders to deliver the impact-driven entrepreneurship spread across 6 countries, namely Indonesia, India, Kenya, Rwanda, Ghana, Chile, and the Netherlands. The non-profit organization develops multifaceted business ideas from ground zero as well as partnering with existing start-ups to scale up the impacts.

Enviu in Indonesia has their pivotal program, called Zero Waste Living Lab, in the spirit of being the enabler of sustainable consumption paradigm. Directly tackling the source of second world's marine polluter, Zero Waste Living Lab Indonesia incubates six zero-waste business models that work around reducing single-use plastic uses in end-consumer stage. One of which is Allas, our case study in further analyzing the feasibility of food packaging reuse business model using online food delivery service.

Allas was established in July 2021 as the follow-up to the off-the-shelves CupKita, the reusable beverage cups. Looking at the current trend, the citizens in megacity, such as Jakarta, have more and more relied upon e-commerce to meet daily necessities, leading to the rise in food delivery. For that reason, Allas partners up with eleven like-minded merchant restaurants in hopes for bringing forth the sustainable alternative. Interested customers can register to become a member through their webpage and then select one of three available packages with different price points: First-timer, Eco, and Friendly. Then, the customers are ready to order food through online delivery apps, e.g., Gojek and Grab, and insert their user ID in the delivery notes section. The restaurants proceed with packing the order in Allas packaging and have them delivered through the customer's doorstep. Within 14 days the packaging must be returned to Allas to be reused again. Until now, Allas has provided 440 containers in circulation and recorded more than 100 users since they first started.

While packaging reuse system is already performed by catering services in a small scale, Allas is proud to be the first reusable packaging service provider in Indonesia under a regulatory sandbox[2] that protects start-ups in delivering service to their customers. Going forward, Allas hopes to expand the number of partner restaurants as well as their customers to bring the sustainable solution to a larger scale. Improving the business may require a scientific perspective as elaborated in this study. Ensuing a series of interviews with Allas, the return scheme and information flows can be mapped out as follows.

1. Return distribution network
   Considering the ownership status, Allas, as a third-party organization for restaurants, is responsible for managing, cleaning, and maintenance of their packaging. They may not provide the logistic service, but they are in charge of ensuring the movement of all of their packaging, balancing the supply and demand, and designing the collection mechanism back to use phase. Therefore, Allas offers two types of return mechanism in the interest of customers' convenience as displayed in **Figure 4**.

[2] A regulatory sandbox is a regulatory approach that allows live and time-bound testing of innovations and business models under a regulators' oversight according to UNSGSA.

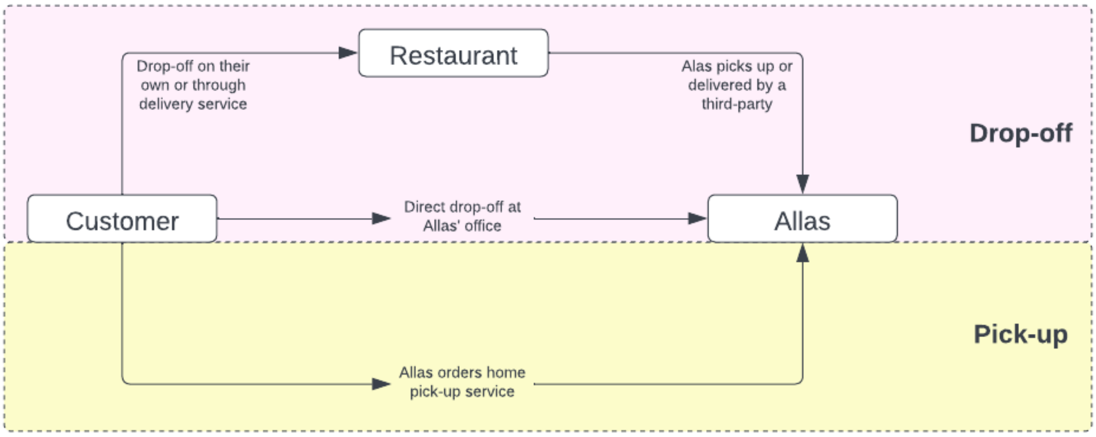


Figure 4 Allas' distribution networks consisting of drop-off and pick-up schemes

Allas offers two options of packaging return mechanisms to their customers in which entails different price point. Firstly, in drop-off scheme customers may return the packaging directly to Allas' office through a third-party transport service which is bookable through Westbike mobile app or send it to one of Allas' partner restaurants. Then, Allas arranges and pays for the pick-up from the restaurants every week or when the minimum number of containers is met.

Secondly, customers can pay for more for the home pick-up plan. In this case, Allas requests for the information necessary from the customers, e.g., location and time, for the booking of pick-up slots. Both orders from homes and restaurants are usually made at the same day, which is either Thursday or Friday.

Since the end of 2021, Allas has set up an arrangement with Westbike, the intracity delivery service provider using bicycles. Therefore, every pick-up order is created through a specifically designed button for Allas in Westbike mobile app as depicted in **Figure 5**. Allas can reserve for the deliveries in one day, which are then processed by Westbike dispatch offices to develop an efficient pick-up route. With multiple orders, one bike-rider could take three to four pick-ups in a single trip considering its lightweight and volume before reaching the destination.

The adopted logistic system as discussed above belongs to star system coined by Carrasco-gallego et al. (2009) as preliminarily discussed in Background chapter, where all packaging is required to return to one place for reconditioning, or cleaning in this case. In regard of the deposit system, it is shown as the prime example of a system with deposit-run return logistics as evidenced through the collective cases compiled by Kroon & Vrijens (1995). The deposit is paid for by the end-users in this case. Restaurants have a financial obligation that requires to be settled every month according to the number of packaging uses. The exchange of information between actors is further elaborated in subsequent section.

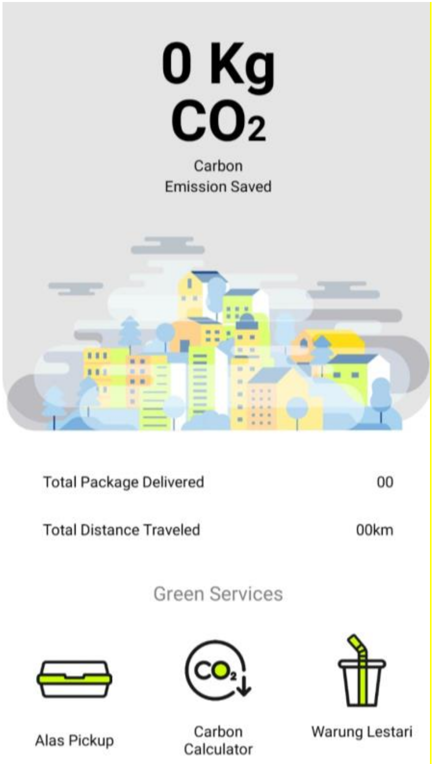


Figure 5 Westbike mobile app page with a special button for Allas to order pick-ups

2. Information flows

   Allas has established a standard procedure for both packaging return and redistribution in which partner restaurants regularly notify Allas of the movement of their packaging as depicted in **Figure 6** Packaging return information flow. It first starts with a weekly reminder by Allas' operator for the customers to return the packaging before the due date. The choice of return between drop-off and pick-up by the couriers depends on the members' subscription plan. Information of delivered packaging in the restaurants is compiled in a sheet of paper which is sent bi- or weekly to Allas via Whatsapp chat, while real-time notification is a more ideal method for Allas. All the returned packaging is sent to Allas using a third-party delivery service.

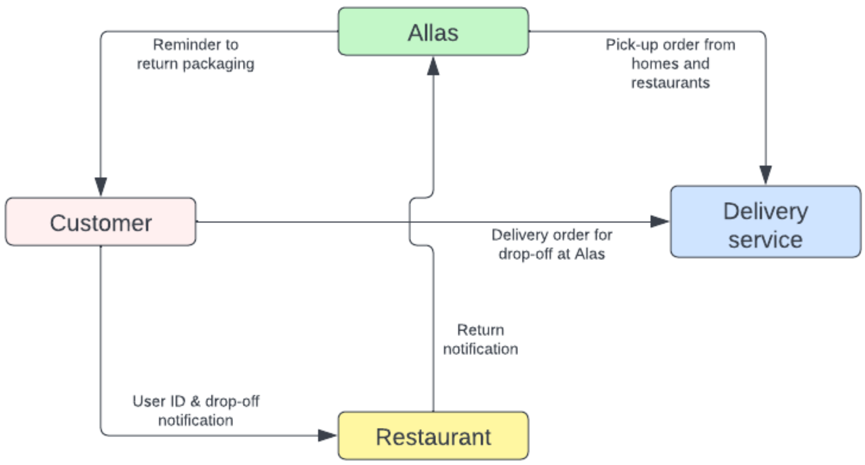


Figure 6 Packaging return information flow

While the reconditioning process is fully operated by Allas, still a part of the main operations is inventory management to match up between supply (return) and demand as shown in **Figure 7**. Both the tracking and inventory level control are performed manually in a spreadsheet, although Allas has set up a barcode system for ease of packaging identification and tracking. Once the partner restaurant reaches a bare minimum number of packaging, Allas accordingly restocks using the online delivery service. Depending on the order traffic, a few partner restaurants may receive a larger number of packaging for every shipping in comparison to other merchants with lower borrowing activities.

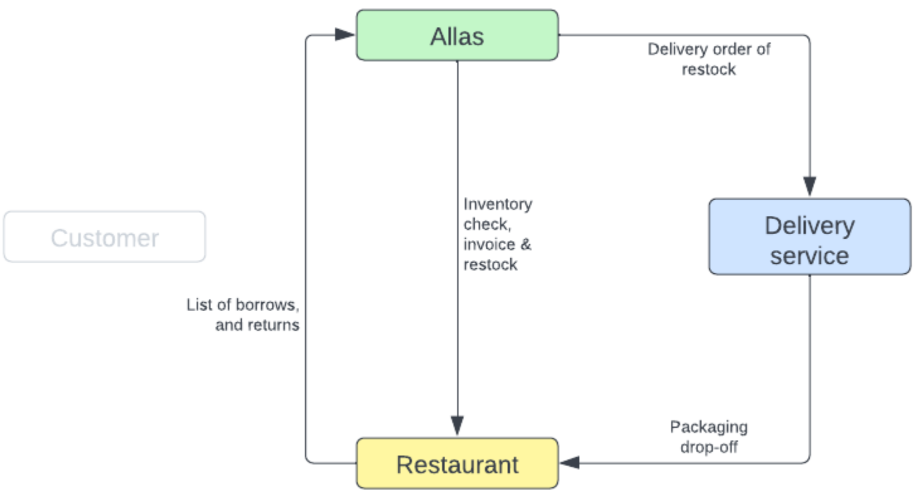


Figure 7 Information flow in the phases of operations management and redistribution

LCA PROCEDURE

The following section specifies the goal and scope, and LCI of this study are structured based on the LCA procedure by ISO 14040/14044 standards. Because this study not only involves LCA, Chapter 3 Methodology explains the general procedure, while this chapter describes the decisions made on system boundaries, choice of impact categories, assumptions, and allocations, as well as the reasoning behind it.

5.1 Goal and Scope Definition

5.1.1 Goal

The aim of the LCA study is to quantify environmental impacts associated with the use of food containers with reuse and single-use systems through online food delivery services. The result of impact assessment will be the input to further determine environmental BEP in comparison between reusable and single-use food containers. The key takeaways of the study can be utilized as recommendations for product development and marketing material of Allas by understanding the magnitude of impacts of each life cycle processes and implementing improvement measures.

Both the commissioner (initiator) and the practitioner (researcher) of this study are Nadhira Afina Wardhani and Putri Ghassani Ramadhina, students of Erasmus Mundus “International Master’s Programme on Circular Economy”, as a Master’s thesis project in Chalmers University of Technology, Sweden. The company partner is Allas Circular Packaging, a provider of food container reuse-system service for online food delivery in Jakarta, Indonesia. This thesis was supervised under Patricia van Loon, Assistant Professor at Supply and Operations Management, Department of Technology Management and Economics, Chalmers University of Technology. The study is accessible for public in the Chalmers University of Technology official webpage.

5.2 Scope

5.2.1 Functional Unit

The defined function is a container fit for one portion of meal delivered to customers using online food delivery services. The functional unit of “providing one portion of meal in a food-grade container within a single delivery service of 7 km to one person” was established. The distance was chosen from the average distance of delivery from restaurants to Allas’ customers. Reference flows were associated with the material flows within the life cycle phases, hence a weight parameter was chosen for the flow. For one portion of meal, a volume of 800 ml container was selected for the estimation of reference flows. The reference flows were differentiated between two product systems, which were ‘food container of 0.178 kg weight’ for reusable and ‘food container of 0.0268 kg weight’ for single-use packaging. Similar functional unit of both packaging was chosen to facilitate the inputs for BEP calculation.

5.2.2 Type of LCA

This study followed cradle-to-grave, attributional/accounting LCA, and simplified LCA guidelines. Cradle-to-grave analysis is the life cycle of a product, that begins with production until its disposal (Klöpffer and Grahl, 2014). This type of analysis was necessary to acquire environmental BEP, given the product systems in question includes the reusable system without any loop in the usage phase. Therefore, cradle-to-cradle concept was considered less appropriate, since the food containers were either treated in landfills or in open-loop recycling, in which the use of secondary product, in this case, was not determined. Attributional LCA aims to answer the question "what environmental impact can be associated with this product?" (Klöpffer et al, 2014) in relation to the "physical flows to and from a life cycle and its subsystems" (Ekvall, 2019). In this case of estimating and attributing environmental burdens to reusable and single-use food container product systems, attributional LCA was deemed more suitable for conducting the comparative LCA study. Additionally, simplified LCA is relevant, because it covers the whole life cycle with generic data, instead of specific marginal data (Pigosso & Sousa, 2011), in which this study mainly used aside from the primary data for the washing process under the limited resources of time and budget.

5.2.3 System Boundaries

Cradle-to-grave processes of reusable product system and single-use product start from the extraction of raw material (cradle) to disposal of food container in the end of life (grave). In terms of life cycle processes, the main distinction between the single-use and reusable product system is the use phase, where the latter creates a loop back to Allas for reconditioning and to be reused until reaching the end of its lifespan. The cut-off criteria were regulated by the resource-related criterion, where flows or processes were excluded from the system due to the restraints.

The geographical scope of the study covers across multiple countries. The raw material extraction and production of food container were assumed to take place in China. The washing processes at the use phase are in the customers' homes and Allas' hub is in Kemang, Jakarta, Indonesia. Meanwhile, the disposal sites, including recycling factories and landfills, were set in Tangerang or Bekasi and Bantargebang landfill in Bekasi, respectively.

5.2.4 Materials

The objects in this research are 800 ml single-use and reusable food containers. The single-use container is made of one type of material, PP thin-wall packaging, while reusable containers consist of two materials: PP for the lid and silicone rubber for the body, seal, and valve. Allas expects the reusable containers to reach 50 usage cycle throughout the lifespan. Both containers are displayed in **Figure 8**.

(a) (b)

Figure 8 (a) Single-use polypropylene and (b) reusable silicone food packaging

5.2.5 Choice and Analysis of Impact Categories

LCA guidelines by Guinée (2004) presents "baseline impact categories" based on SETAC working group as a basic list for LCA practitioners. It advises to include all the category in the list, otherwise selection of fewer categories need to be justified. The rationale behind this is that having "zero" or insignificant amount of certain impact categories are better than having the categories omitted in order to provide a proof from avoiding negligence. The baseline impact categories along with the other impact categories from ReCiPe 2016 and Pfister (2019) were selected for the first cycle of identifying the values of category indicator results. Then, four categories were shortlisted for further and more elaborate discussion, particularly global warming potential (GWP), human non-carcinogenic toxicity (HTPnc), terrestrial ecotoxicity (TETP), and water stress index (WSI). The three formers are potentially significant owing to the motorcycle use, while WSI was taken into account to analyze the main trade-offs of the use phase for reusable system by earlier publications (Almeida et al., 2018; Martin et al., 2018). WSI impact category represents how much water consumption can deprive other users of freshwater (Pfister et al., 2009). A complete list of the chosen impact categories is presented in **Table 3**.

Table 3 Impact categories choice and method

No	Impact categories	Unit	Methods
1	Terrestrial ecotoxicity	kg 1,4-DCB	ReCiPe 2016 Midpoint (H)
2	Human non-carcinogenic toxicity	kg 1,4-DCB	ReCiPe 2016 Midpoint (H)
3	Global warming	kg CO_2 eq	ReCiPe 2016 Midpoint (H)
4	Fossil resource scarcity	kg oil eq	ReCiPe 2016 Midpoint (H)
5	Marine ecotoxicity	kg 1,4-DCB	ReCiPe 2016 Midpoint (H)
6	Human carcinogenic toxicity	kg 1,4-DCB	ReCiPe 2016 Midpoint (H)
7	Freshwater ecotoxicity	kg 1,4-DCB	ReCiPe 2016 Midpoint (H)
8	Land use	m2a crop eq	ReCiPe 2016 Midpoint (H)
9	Ionizing radiation	kBq Co-60 eq	ReCiPe 2016 Midpoint (H)
10	Water consumption	m^3	ReCiPe 2016 Midpoint (H)
11	Ozone formation, Terrestrial ecosystems	kg NO_x eq	ReCiPe 2016 Midpoint (H)
12	Ozone formation, Human health	kg NO_x eq	ReCiPe 2016 Midpoint (H)
13	Terrestrial acidification	kg SO_2 eq	ReCiPe 2016 Midpoint (H)
14	Mineral resource scarcity	kg Cu eq	ReCiPe 2016 Midpoint (H)
15	Fine particulate matter formation	kg $PM_{2.5}$ eq	ReCiPe 2016 Midpoint (H)
16	Freshwater eutrophication	kg P eq	ReCiPe 2016 Midpoint (H)
17	Marine eutrophication	kg N eq	ReCiPe 2016 Midpoint (H)
18	Stratospheric ozone depletion	kg CFC11 eq	ReCiPe 2016 Midpoint (H)
19	Water stress index	m^3	Pfister, 2009

The main method selected for impact assessment was ReCiPe 2016 method that integrated Eco-Indicator 99 and CML methods in a more recent version (Acero et al., 2016). The updated method from ReCiPe 2008 was created by RIVM, Radboud University, Norwegian University of Science and Technology, and PRé Consultants. ReCiPe offers harmonized characterization factors at midpoint and endpoint levels, which refer to impacts of certain environmental flows throughout the impact pathways (i.e., GWP and TETP), that lead to three areas of protection at the endpoint (human health, ecosystem quality, and resource scarcity). Three perspectives were also presented to classify similar assumptions and choices in analyzing impact, divided into Individualistic, Hierarchist, and Egalitarian perspectives. In this case, this study used midpoint level of impacts since midpoint method had a closer relation to environmental flows with generally low uncertainty. Hierachist perspective was implemented to provide a neutral tone of research based on scientific consensus in respect to the time frame, compared to the others which based on short-term interest for the Individualistic and the longest time frame for the Egalitarian (Huijbregts et al., 2016).

5.2.6 Data Quality Requirements

The data collected in this LCA study were from existing data of Allas Circular Packaging in the period of 2021 to 2022, specifically for operational flows and transport-related data. Primary data of water consumption, soap usage, and weight of reusable containers were measured by the authors using manual equipment. Processes from raw material extraction until packaging reaching Allas' warehouse were mainly sourced from Ecoinvent 3.8 database with reference flows based on the existing literatures. For example, transportation data used Ecoinvent 3.8 as the provider for background processes with the modification of emission amounts from motorcycle testing results in Indonesia. Geographical boundaries of Rest-of-the-World (RoW) and Global (GLO) were used from Ecoinvent.

5.2.7 Initial Assumptions and Limitations

There are three sizes of food containers provided, the M size with the volume of 800 ml was used for assessment as the most used container size on average (Allas, personal interview, March 22, 2022). The study only recognized two-time washing, which was done by customers and by Allas, excluding the possibility of food containers being used and washed multiple times by customers before returning it to Allas. Although the case happened a few times where customers used Allas' containers for other purposes.

Containers from Allas were delivered to customers by motorcycles and returned from customers by a bicycle messenger courier within the area of service, omitting the occasional customers located outside Jakarta City. Finally, single-use container was assumed to enter the open-loop recycling scheme at the EoL phase, due to the recyclable nature of PP material and the common downgrade recycling practices in Indonesia. On the other hand, the reusable container was modeled to go to unsanitary landfill in Indonesia (Winahyu et al., 2019) because of the scarcity of the silicone recycling in industrial scale (Shit & Shah, 2013).

5.3 Life Cycle Inventory

5.3.1 Processes

The life cycle flowchart of single-use food container is depicted in **Figure 9**. The processes in the life cycle are as follow: PP granulates production, extrusion and thermoforming, forward transportation to customers, use phase, and EoL. PP granulates production process entails the extraction of raw material until the oil transformed into PP granulates. The granulates then are made into film by extrusion and to container components by thermoforming, finally producing the single-use container. The finished product is shipped from China to Indonesia, specifically to the retail distribution center. Restaurants procure single-use containers to be delivered to customers along with the food ordered.

After use, the containers are disposed of by the customers to the nearest recycling drop-off point or waste bank to be collected to recycling facility for open-loop recycling. In some cases, customers throw away the container in a normal trash bin, which are sorted and picked up to recycling junkshops eventually by scavengers or environmental department waste workers.

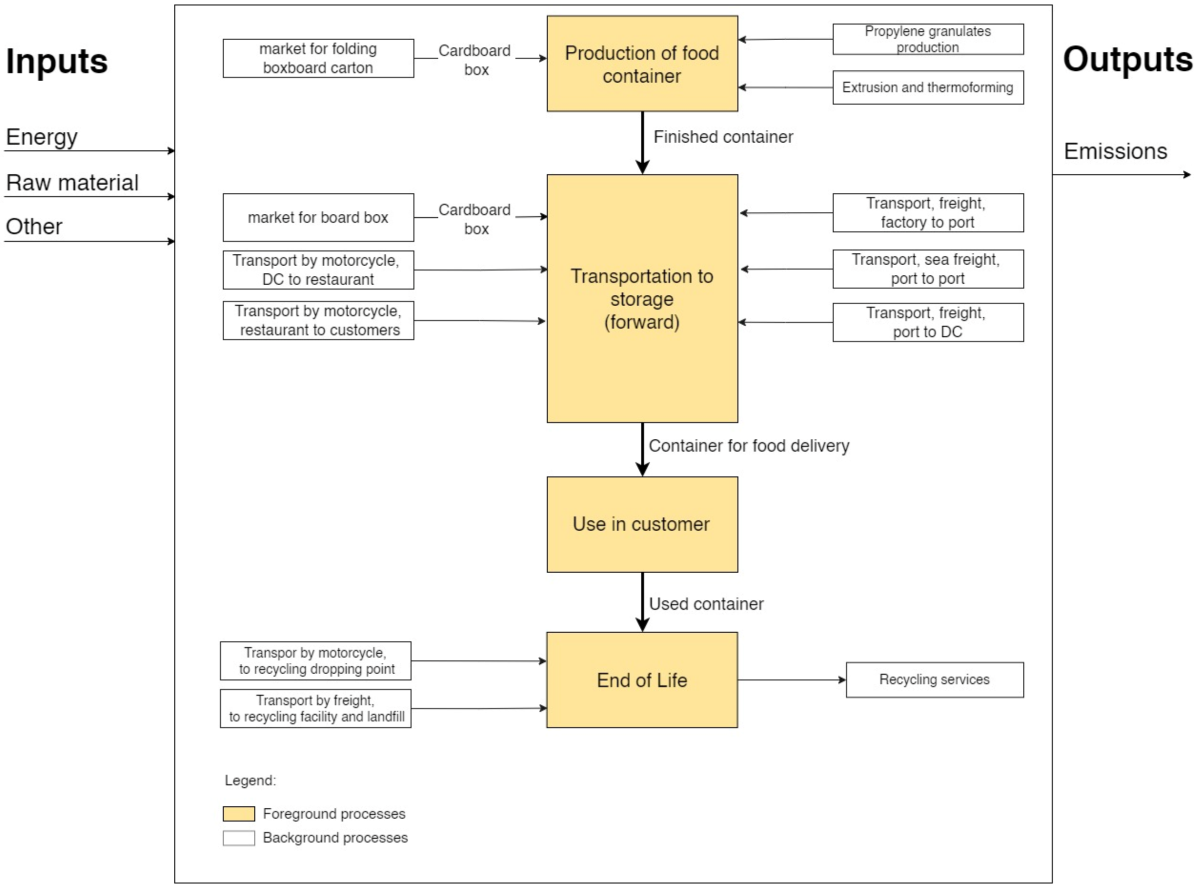


Figure 9 The system boundaries of single-use container

As for reusable food container, as shown in **Figure 10**, the output from silicone product production, and extrusion and thermoforming for every component of the container are assembled in production before being shipped to retail. In this case, Allas handles the procurement of reusable containers from retail and are responsible for delivering the containers to the restaurants. Customers order for food delivery and opt to use the Allas packaging service, then wash them after use, and return the container to Allas. The returned container is inspected and cleaned for the second time with standardized procedure. Finally, reusable container is ready to be delivered to restaurants for another use, resulting in the reuse loop in the life cycle of reusable container. When reusable containers are no longer appropriate to use, Allas keep the containers in a cabinet until reaching a certain number of damaged containers to drop them off to the nearest recycling points or waste bank. However, silicone material is modeled to be treated in the landfill for the aforementioned reasons.

5.3.2 Allocation and modelling

Allocation was defined as attributing environmental burdens to multi-input and multi-output processes during the life cycle, with the most common phases are co-production, recycling, and disposal (Klöpffer and Grahl, 2014). In this study, several allocations were applied to delivery transport and waste treatment phases. There are two types of allocation in transportation, firstly, according to weight (kg.km) for transport by lorry and ship, and secondly, depending on the number of containers delivered on a single trip by motorcycle. The second one allows distributing the environmental burden of several food container using the available unit in Ecoinvent, passenger.km, which is specified into the following list (Allas, personal interview, March 22, 2022).

a. Forward transportation
    a. From DC to Allas: 10 packaging
    b. From Allas to restaurant: 5 packaging
    c. From restaurant to customer: 2 packaging
b. Return drop-off: 2 packaging
c. Redistribution: 5 packaging
d. Recycling drop-off: 20 packaging

Waste treatment processes include open-loop recycling and unsanitary landfill. In the case of open-loop recycling, a cut-off rule was deployed to assess two systems separately. The environmental load of recycling was allocated to system A (the system under study) without considering system B, the other product that uses the recycled product as a result from food container recycling. Additionally, the allocation in landfill process was automatically calculated in Ecoinvent by using the weight of food container as the inputs for landfill treatment. The weight of food container as presented in **Table 4** was used for calculation to the functional unit conversion. Transport modelling distance in detail is presented in the Appendix C.

Table 4 Weight of containers' components

Components	Weight (kg)
1. Reusable container	0.186
Container	0.118
Lid	0.053
Rubber for lid	0.005
Valve	0.002
2. Single-use container	0.0268

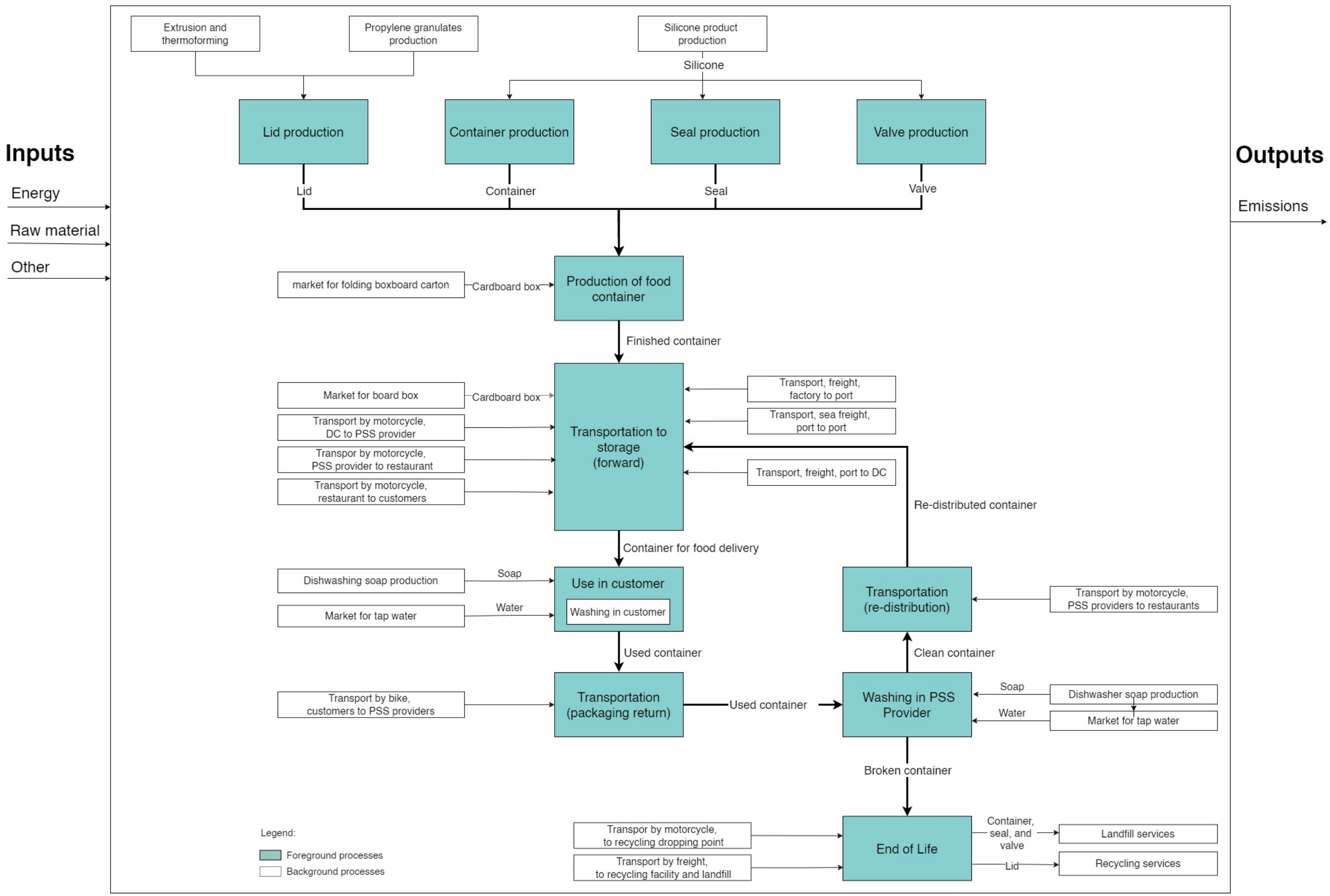


Figure 10 The system boundaries of reusable container

RESULTS AND DISCUSSION

6.1 Quantitative Results Using Life Cycle Assessment

The quantitative assessment of reusable silicone food container and single-use PP food container with life cycle assessment and BEP methodology are presented and discussed in this chapter. Following the methods constructed in the methodology chapter, assessment results are structured as follows: (1) life cycle impact assessment of single-use and reusable container in regard to one-time use, (2) interpretation of impact assessment, by assessing the BEP and sensitivity analysis of return scheme, transport distance, and usage cycle. The first and second research questions are answered in the former, while the third research question of BEP is discussed in the latter subchapter.

6.1.1 Life Cycle Impact Assessment

The environmental impacts are calculated using the built Life Cycle Inventory with ReCiPe Midpoint Hierarchist (2016) and water scarcity methods by Pfister et al. (2009) in OpenLCA software. All midpoint impact categories from ReCiPe (2016) were selected when running the impact assessment, then the four impact categories were chosen for further elaboration, namely GWP, HTPnc, and TETP as explained in Chapter 3 Methodology. Furthermore, it is important to highlight that the results of life cycle impact assessment are not a stand-alone result, but it is an initial procedure for calculating BEP for reusable container compared to single-use container. Thereby, the functional unit of "providing one portion of meal in a food-grade container within a single delivery service of 7 km to one person" was chosen for the impact assessment to provide data input for BEP calculation.

As displayed in **Table 5**, overall, the environmental impacts generated by a one-time use of reusable food containers are higher than the single-use. TETP, HTPnc, GWP, and WSI impacts of reusable food container are 5.1 kg 1,4-DCB, 1.6 kg 1,4-DCB, 1.5 kg CO_2-eq, and 0.009 m^3, respectively. In the same order, single-use container impacts are 2.3 kg 1,4-DCB, 0.6 kg 1,4-DCB, 0.40 kg CO_2-eq, and 0.001 m^3. All impact categories of reusable container are between 2 to 4 times larger, except for the WSI, which is 7 times higher than the single-use. One factor of the difference is due to the lighter weight of single-use container (26.8 gr), almost 6 times less than the reusable container (178 gr), which influences the impacts on production and transportation.

Table 5 Impact assessment of reusable and single-use container for one-time use

No	Impact categories	Total Impact Result		Unit
		Reusable	Single-use	
1	Terrestrial ecotoxicity	5.122	2.279	kg 1,4-DCB
2	Human non-carcinogenic toxicity	1.623	0.569	kg 1,4-DCB
3	Global warming	1.449	0.399	kg CO_2 eq
4	Fossil resource scarcity	0.508	0.164	kg oil eq
5	Marine ecotoxicity	0.091	0.029	kg 1,4-DCB
6	Human carcinogenic toxicity	0.084	0.025	kg 1,4-DCB
7	Freshwater ecotoxicity	0.070	0.021	kg 1,4-DCB
8	Land use	0.068	0.016	m^2a crop eq

No	Impact categories	Total Impact Result		Unit
		Reusable	Single-use	
9	Ionizing radiation	0.043	0.012	kBq Co-60 eq
10	Water consumption	0.021	0.002	m^3
11	Ozone formation, Terrestrial ecosystems	0.009	0.004	kg NO_x eq
12	Ozone formation, Human health	0.007	0.003	kg NO_x eq
13	Terrestrial acidification	0.006	0.002	kg SO_2 eq
14	Mineral resource scarcity	0.004	0.001	kg Cu eq
15	Fine particulate matter formation	0.004	0.001	kg $PM_{2.5}$ eq
16	Freshwater eutrophication	0.380	0.110	gr P eq
17	Marine eutrophication	0.110	0.027	gr N eq
18	Stratospheric ozone depletion	0.001	0.000	gr CFC_{11} eq
19	Water stress index	0.009	0.001	m^3

Figure 11 illustrates the contribution analysis of four impact categories between single-use and reusable packaging with pick-up scenario. The impacts from single-use container are mainly emitted by the logistics from the factory gate to customers with above 70% contributions to every impact category. Similarly, the forward transportation of packaging shipping to end-customers presides over the other activities in all impact categories excluding water stress index.

The first three impact categories entailed from the one-time use of reusable container exceed the total life cycle impacts of single-use packaging by more than 200%. Even so, the production of polypropylene produces almost negligible level of emissions (5% for GWP, 1% for TETP, and 2% for HTPnc) in comparison to that by the transportation (76% for GWP, 82% for TETP, and 75% for HTPnc), succeeded by recycling of the packaging waste (19% for GWP, 18% for TETP, and 23% for HTPnc).

Within the long shipping chain of Allas' containers from factory gate to the customers, the food delivery makes up the most significant impact due to the use of motorcycle. This is due to the nature of the operation, where a single trip only carries one order which goes as far as 7 km in average. Thus, the allocation of the impacts is completely given to two containers (the average number of food portions per order) weighing around 1 kg per trip. In parallel with the findings by Coelho et al. (2020), Garrido & Alvarez del Castillo (2007), and Martin et al. (2018), a decision on washing method has been shown to have a large influence on the environmental impact contributions, in addition to material selection, weight, and additional trips. As presented in **Figure 11**, the use of cold water and manual technique has put the impacts from washing activity in insignificant level about 2.5% for in the three impact categories.

Terrestrial ecotoxicity is mainly caused by the release of copper and zinc emission to air from motorcycle usage for transporting food container, with 44.5% of the impacts coming from forward transportation. Human non-carcinogenic toxicity impacts are in majority resulted from the production of food container (34%) and the treatment of material for motorcycle production in the upstream process. Silicone production and the use of motorcycle as a delivery vehicle have the biggest shares of global warming impacts category, as a result of electricity and heat consumption for silicone production as well as the carbon dioxide and methane emissions generated by motorcycle.

Meanwhile, life cycle of reusable container puts the WSI 6.7 times higher than the single-use owing to the high requirement of water use to produce silicone packaging and the washing activities. Although, the two-times handwashing method applied in this case does not put as much stress on freshwater consumption as automatic dishwashing as evidenced by Martin et al. (2018).

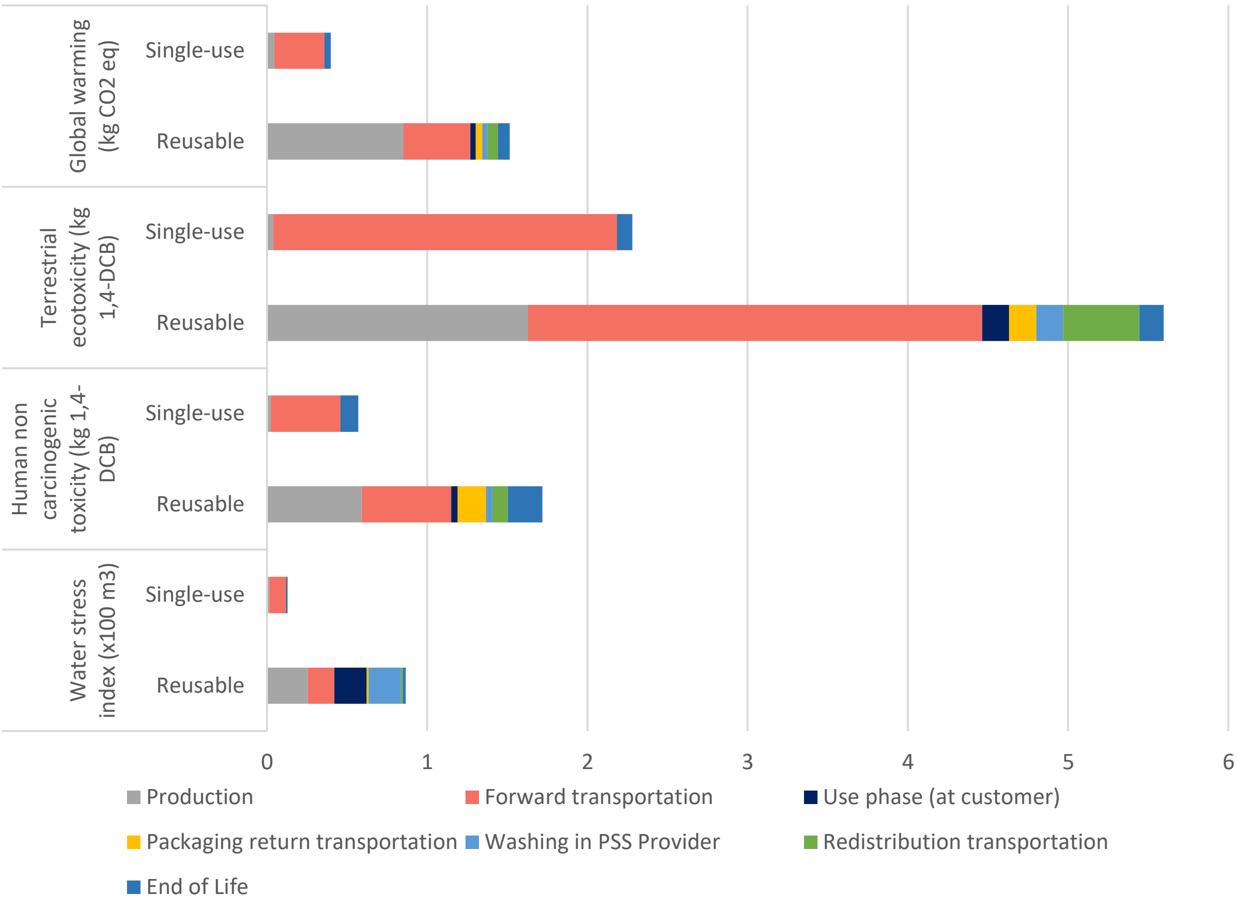


Figure 11 Contribution analysis of single-use and reusable packaging

Modeling choices that have potential influence on the impact assessment results are mainly in data sources and quality of data regarding geographical and technological representativeness. The primary data obtained were limited to water and soap volume, and the weight of food container and box packaging to Allas' cleaning hub. However, the water input used in OpenLCA is groundwater pumped by electric pump, excluding any allocation on the waterworks, since the tap water process for Indonesia was not available in Ecoinvent database. Furthermore, emissions from motorcycle usage had been adjusted to the Indonesian emission factor. The results would be more reliable if the market activities for motorcycle, maintenance, and gasoline also represented Indonesian market instead of Rest of the World or Global market.

Assumptions were made mostly in transportation routes, for instance, the production processes in China were derived from literature which was difficult to precisely determine the distance and type of vehicle used for the transport. The actual location of factory and distribution center were unknown, hence estimation based on literature and information from similar products was applied. In addition, there are widespread customer base locations, even reaching the neighboring city, which causes high distance variations from restaurants and to Allas' cleaning hub. Therefore, the average distance was selected for proximity. Indonesian-based processes are available for electricity and elementary water flows. Uncertainty on technological representativeness could be improved by using primary data from a recycling company for PP material and Jakarta environmental city department for the landfill processes (if available).

6.1.2 Interpretation

6.1.2.1 Product Efficiency, Use Phase Efficiency, and Break-even Point (BEP)

A BEP calculation was conducted to provide a fair comparison between reusable container and single-use container. The method was derived from Cottafava et al. (2021) to distinguish between product efficiency and use phase efficiency to understand the BEP components further. Product efficiency depicts the production and EoL impacts of reusable container compared to single-use container. If product efficiency is greater than 1, it indicates inefficiency in the production of reusable packaging or means more impacts than the single-use. Use phase efficiency compares the use phase impacts of reusable container with the impacts of a total life cycle of single-use container. Suppose the use phase efficiency is more than 1, which leads to a negative number of uses in the BEP value. In that case, reusable food containers will not reach environmental BEP with the current product system. The BEP of silicone food container is presented in **Table 6** as the minimum number of uses when reusable silicone container starts to perform better than the single-use PP container.

The product efficiency values of silicone container are more than one in all impact categories, indicating less efficient production and EoL processes as opposed to PP container. The production processes of silicone and PP, the weight of both containers, and the share of containers recycled at the EoL phase are the considerable factors defining the product efficiency. As presented in the contribution analysis (see section 5.1.1), the gap in impacts from the production of reusable and single-use containers is the main contributor to the product inefficiency, driven by the weight difference. According to our calculation using Ecoinvent background processes with a few adjustments, the production of 1 kg silicone product generates higher TETP, HTPnc, and WSI impacts than producing a similar amount of PP container.

Table 6 Break-even point of reusable container

Impact categories	Product efficiency	Use phase efficiency	Break-even point
Terrestrial ecotoxicity	2.0	0.4	4
Human non-carcinogenic toxicity	2.4	0.6	6
Global warming	3.4	0.4	6
Water stress index	3.4	3.4	-*

*A negative BEP is shown with a hyphen symbol

On the contrary, the use phase efficiency shows better results by having less than 1 score on the impacts of TETP, HTPnc, and GWP. It conveys that the washing and reverse transport in the use phase of reusable container generate fewer impacts than the full life cycle of single-use container. The efficient use phase leads to positive BEP, confirming that the reusable container could perform better than the single-use container after 4 to 6 uses according to the respective impact categories. The number of uses to fulfill the BEP is quite achievable, considering with the BEP from other studies within the range of 2 to 8 for TETP, 1 to 37 for HTP, and 3 to 55 for GWP (Cottafava et al., 2021; Gallego-Schmid et al., 2019). Although none of these studies include silicone container, it compares thin-wall PP container with other materials such as PLA, PET, glass, and aluminium, which could give insights on the BEP range among different container materials. Moreover, Allas mentioned the average cycle usage of their reusable container has range from 3 to 4 uses since the beginning of their business (Allas, personal interview, May 20, 2022 However, optimizing the cycle usage of every packaging in circulation at a minimum of 6 uses is recommended to gain environmental benefits from reusable service system.

The only negative BEP is shown by the WSI impact, reflecting that reusable product system would not reach BEP in this particular impact category. The logic behind this is that the use phase of reusable container includes the washing at customer, packaging return transportation, washing at Allas' office, and redistribution transportation, already contribute to the impacts three times higher than the entire life cycle of single-use container from production to EoL phases. Consequently, with the repeating cycles of usage throughout the lifespan of reusable container, the WSI impacts will always be higher than the single-use container. Similar results have been found by Cottafava et al. (2021), with negative BEP in WSI impacts when PP, PLA, PET, and glass reusable cups are compared with PP single-use cups. Since the water use of handwashing method is already lower than the machine dishwashing method (Martin et al., 2018), managing water consumption for the washing process could reduce the WSI impact generated. For instance, applying water-efficient appliances (e.g., faucet aerators or faucet with sensor) can reduce water consumption between 9-12% if the washing duration does not increase to obtain the same volume of water as before (Inman & Jeffrey, 2006; Mayer et al., 2003).

Considering the scope of this study involves only four impact categories, it would be useful to include more impact categories to establish a more robust BEP for the reusable silicone container. Within the selection process of impact categories, BEP was calculated for all impact categories in the ReCiPe (2016) Hierarchist method, presented in Appendix D. The result shows that the other impact categories, such as human carcinogenic toxicity, land use, and stratospheric ozone depletion, need further assessment due to the greater number of uses to achieve BEP range between 20 to 62 uses.

Therefore, Allas can prioritize which impact categories the company aims to reduce while also being aware of the trade-offs on the other impact categories.

6.1.2.2 Sensitivity analysis

Sensitivity analysis was conducted to research the influence of certain variables on the impact assessment results and test the methodology's robustness for BEP calculation. The first method uses scenario analysis by adding two more return scheme mechanisms other than the baseline scenario. The scenarios are based on the packaging return options offered by Allas, in which customers choose between pick-up by bicycle to Allas, drop-off by motorcycle to Allas, or drop-off by motorcycle to restaurants then taken to Allas by bicycle to return their rented food containers. The second method utilized the one-way sensitivity analysis method that changed the values of one parameter at a time to build two sensitivity analyses: (1) transport distance from Allas to restaurant and (2) usage cycle for reusable food container. In total, three sensitivity analyses were studied and presented in this chapter. The exclusion of water stress impacts in the transport-related sensitivity analysis was decided due to the low relevancy to the transport processes and emissions.

6.1.2.2.1 Return scheme scenarios

Currently, all three scenarios listed above are available options for the customers and chosen based on the customers' convenience as discussed in Case Company chapter. Sensitivity analysis on three return scenarios was conducted to determine which performs environmentally best, in the consideration of changing the transport modes and routes. Although the TETP and GWP impacts of reverse logistics are less than those of redistribution flow to restaurants, the change of transport modes from bicycle to motorcycle in other scenarios might shift packaging return transportation to be a significant contribution to the environmental impacts.

Table 7 presents the environmental impacts resulted from the two options of return mechanisms: pick-up and drop-off as illustrated in **Figure 4**. As drop-off scenario entails longer distance of transportation and higher carbon footprint owing to the use of motorcycle, overall impacts in global warming, human non-carcinogenic toxicity and terrestrial ecotoxicity are higher than its counterpart. Owing to the partnership between Allas and Westbike, both parties can ensure an efficient way for the return by handling three to four pick-ups at a single trip on the account of the packaging volume-saving feature. Therefore, pick-up scenario is shown to yield a more favorable result.

In drop-off scenario, customers may return the packaging in every way they could: while out engaging in a normal activity, using third-party delivery service, or having someone else drop the packaging off (e.g., a driver). Thus, too wide-ranging vehicle leads us to assume that most customers opt for online delivery service to return the packaging to either Allas' hub or any merchant restaurant, either place closest to their location. Drop-off to restaurants requires an additional 4.4-km ride before all of the packaging returned being compiled and shipped to Allas' hub for cleaning, which results in the highest environmental impacts out of all scenarios. In comparison, direct drop-off to Allas' cleaning hub from customer bases entails another transportation as far as 7 km.

Table 7 Environmental impacts contributions from three different return mechanisms: pick-up, drop-off at Allas, and drop-off at restaurants

Impact categories	Home pick-up	Drop-off at Allas	Drop-off at Restaurants	Unit
Global warming	2.7	3.1	3.15	kg CO_2 eq
Human non-carcinogenic toxicity	3.5	3.9	4.1	kg 1,4-DCB
Terrestrial ecotoxicity	13.7	17.1	17.3	kg 1,4-DCB

6.1.2.2.2 Redistribution distance from Allas to restaurants

The transport from Allas to restaurants occurs when delivering the first inventory to restaurants and redistributing the containers to merchant restaurants. The sensitivity analysis for transport distance of this route was decided under the consideration of Allas' decision to selectively partner up with restaurants close to Allas' office base. TETP and GWP impacts of this activity also surpass the impacts of packaging return transportation. In addition, this phase falls under the responsibility of Allas concerning transport mode options and distance to restaurants when offering restaurants to partner as merchants. Thus, it would be useful to determine the environmental impacts of increasing the distance range of Allas' service. The sensitivity analysis results on TETP, HTPnc, and GWP impact categories are presented in **Figure 12** along with the BEP calculation in **Table 8**, with the omission of WSI impact category considered less applicable in the transportation process.

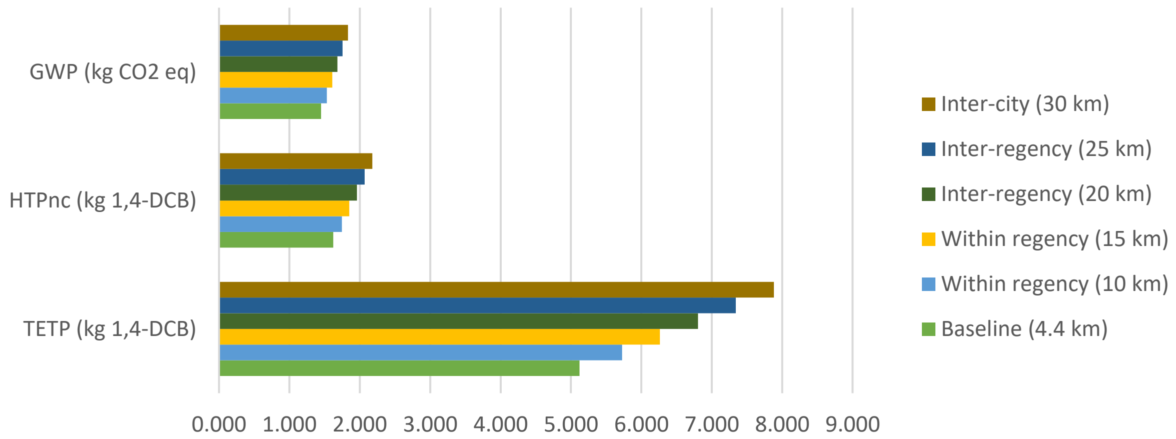


Figure 12 Sensitivity analysis of transport distance from Allas to restaurants

Adjustment in transport distance from Allas to restaurants contributes to the most significant effect on TETP impact categories with 11% increase per 5 km additional distance, whereas HTPnc and GWP impact categories incline for 7% and 5%, respectively. Referring to the contribution analysis (see section 5.1.1), TETP impact is mainly caused by the direct emission of copper and zinc to the atmosphere from motorcycle, the transport mode for distributing food containers from Allas to restaurants. Sensitivity analysis results can be applied to calculate BEP, estimating the maximum distance between Allas and restaurants for maintaining the ability to reach BEP. Reusable containers will be able to pass the BEP, as long as the distance between Allas and restaurants is within the regency, South Jakarta, ranging from 10 to 15 km for the maximum distance. Noted that with the increase of distance, BEP also grows to 30 uses and 20 uses for TETP and GWP within 15 km distance, as well as 14 uses for HTPnc within 10 km distance. Therefore, in order to reach the BEP even with increased distance, Allas must consider their distance to restaurants for future expansion planning. For instance, deploying a new cleaning hub in other regency or emphasizing on the use of bicycles for transport. As displayed in **Table 8**, further distance requires Allas to reach the minimum cycle usage at 7 to 30 uses depending on the impact categories.

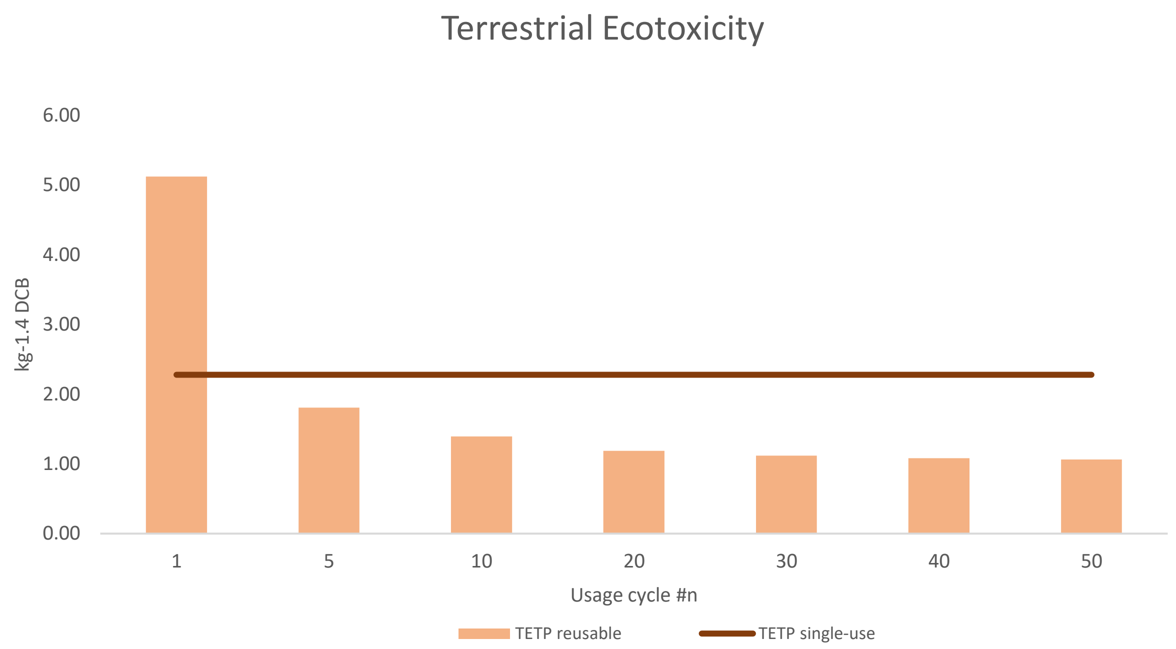
Table 8 Break-even point of transport distance sensitivity analysis

Impact Categories	**BEP**					
	Baseline (4.4 km)	**Within regency (10 km)**	**Within regency (15 km)**	**Inter-regency (20 km)**	**Inter-regency (25 km)**	**Inter-city (30 km)**
Terrestrial ecotoxicity	4	7	30	-	-	-
Human non-carcinogenic toxicity	6	14	-	-	-	-
Global warming	6	9	20	-	-	-

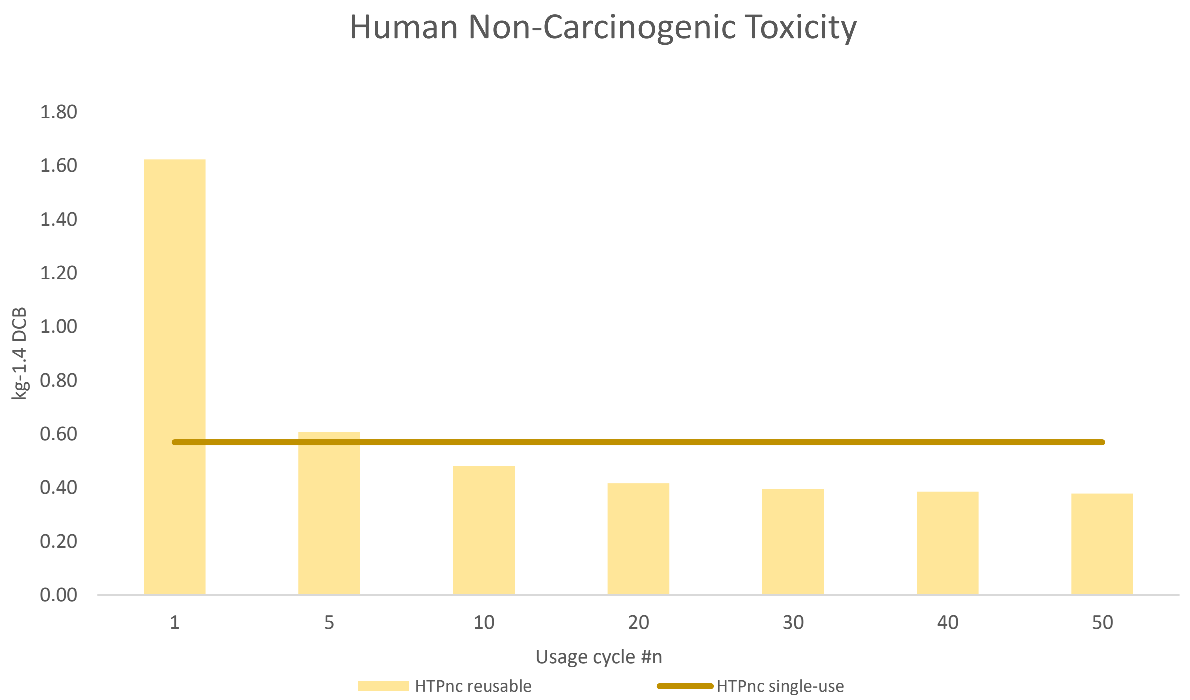
6.1.2.2.3 Usage cycle

Sensitivity analysis of the usage cycle aims to confirm the robustness of BEP calculation methodology. The environmental impacts at different points of use are illustrated in **Figure 13** with the production, forward transportation, and EoL impacts allocated according to the usage cycle, in addition to the use phase impacts. The first use of reusable container is the baseline discussed in earlier section (see section 6.1.1). The usage cycle of 5 to 50 uses shows the impact at that specific number of uses along with the other allocated impacts. The findings of comparing the sensitivity analysis to the BEP calculation as follows.

Firstly, TETP impact category of reusable container needs to reach 4 uses at minimum, which aligns with the sensitivity analysis that displays lower impacts than the single-use impacts after five uses. Secondly, the comparison of reusable and single-use container between HTPnc and GWP impacts confirms that the BEP is crossed over when it reaches 6 uses. Lastly, sensitivity analysis on WSI impact category provides evidence on reusable container with negative BEP would never perform better than the single-use regardless of the cycle usage.


Terrestrial Ecotoxicity
6.00
5.00
4.00
3.00
2.00
1.00
0.00
kg-1.4 DCB
1
5
10
20
30
40
50
Usage cycle #n
TETP reusable
TETP single-use

(a)


Human Non-Carcinogenic Toxicity
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
kg-1.4 DCB
1
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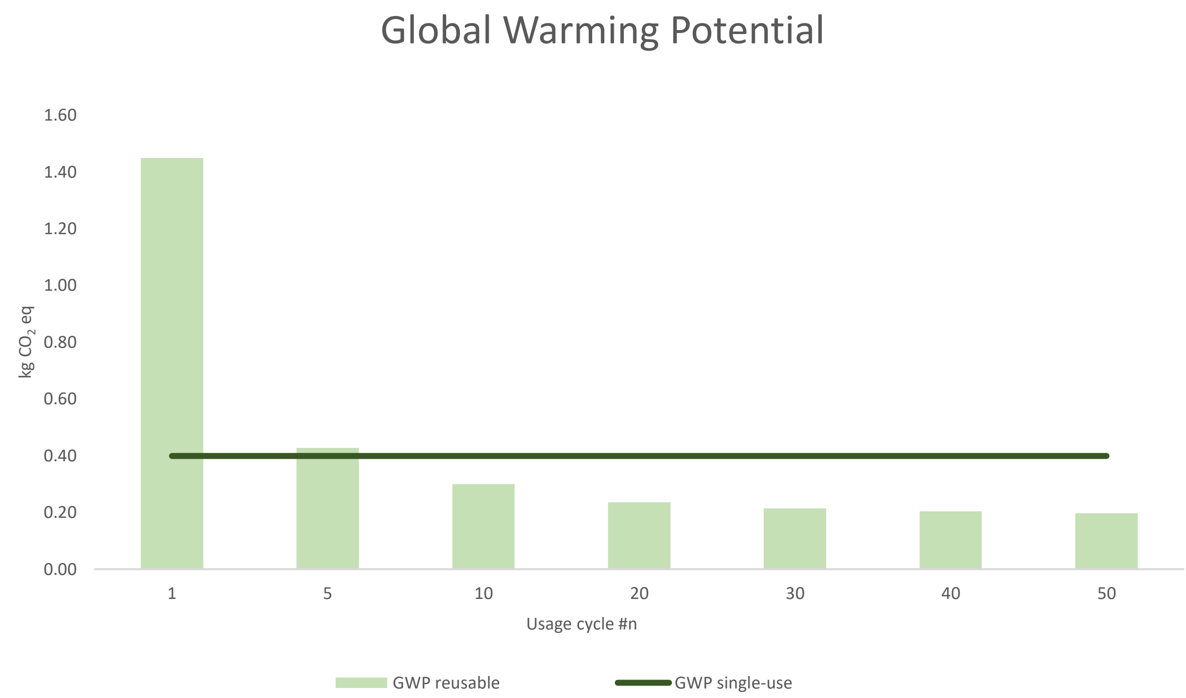
Usage cycle #n
HTPnc reusable
HTPnc single-use

(b)



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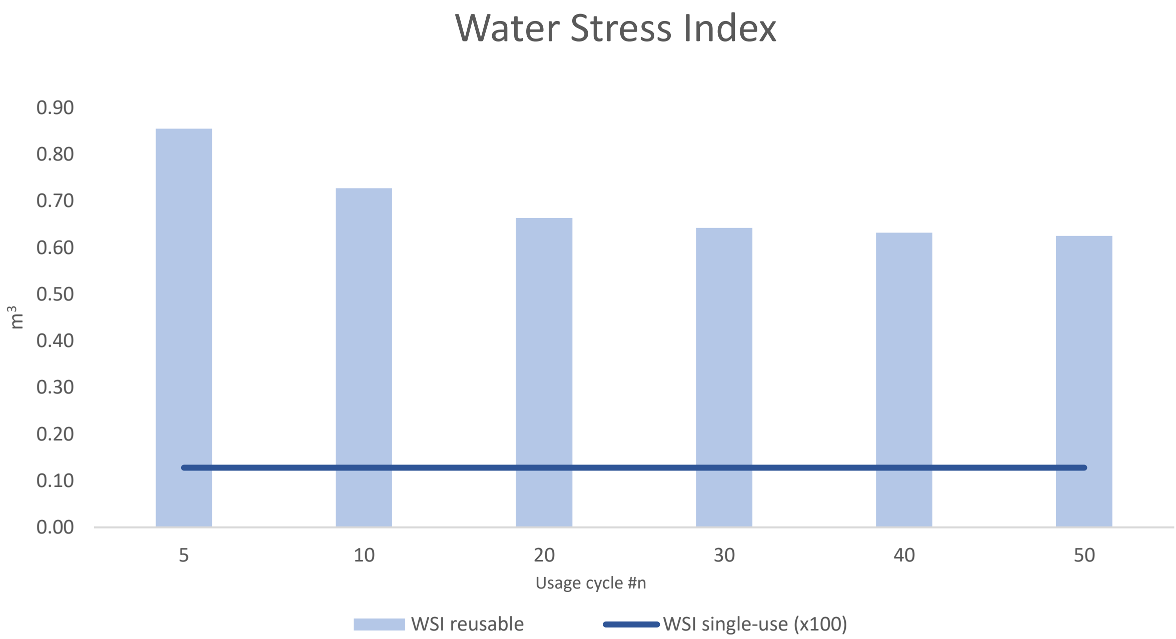

(d)

Figure 13 Sensitivity analysis of packaging cycle usage on impacts (a) terrestrial ecotoxicity, (b) human non-carcinogenic toxicity, (c) global warming potential, and (d) water stress index.

6.2 Qualitative Analysis of Closed-loop Supply Chain of Allas

In addition to the environmental impact analysis, it is necessary to scrutinize the challenges arising from the supply chain using qualitative analysis to examine the fourth research question. As explained previously in the Methodology chapter, the analysis involves coding and data analysis to find key factors influencing the success of reuse business model. Underlying findings from the interviews are developed and further elaborated from the following categories: Communication with actors in the value chain; Tracking and record mechanism; Product recovery/return; Inventory management; and Redistribution. For instance, the 'tracking', 'data record', 'cycle usage' codes belong to the 'Tracking and record mechanism' category. These codes are in line with the relevant literature discussed in the Background chapter which will be investigated in this section, while a new finding concerning the Packaging Design and Customer Touchpoint emerged. Full codes used in the research are listed in Appendix A. Then, all findings were analyzed and elaborated into five key logistical challenges listed below.

1. Visibility across the supply chain

   A common problem with reuse scheme is the lack of control once the reusables are out in circulation, which is faced by Allas. According to them, 12 packaging had been lost thus far, three of which are known to occur in at-consumer stage, while the rest are declared disappeared. The losses were discovered upon the mismatch between the actual packaging number in restaurants and one recorded in the database. Moreover, no sanction has been prescribed to either customer or restaurant for the sake of maintaining relationship, as iterated by McKerrow (1996) that there is substantial investigation cost compared to the price per unit. This is further exacerbated by numerous findings showing that customers tend to use the packaging for personal uses within 14 days. This behavior arouses concerns for the cycle usage of the packaging (Carrasco-gallego et al., 2009).

2. Optimal return mechanism

   Currently, Allas operates two types of return mechanisms simultaneously, as depicted in Chapter 4: Case Company. More than half of their customer prefer the pick-up option as it is more convenient, which is not a surprising finding according to Long et al. (2020), who connect reuse business model with service touchpoints. As the majority of orders are delivered straight to the doorstep, the ideal return would be a home pick-up service considering the people living in households as the target market. Allas professed, nevertheless, that drop-off to restaurants was the most favorable option based on the least return trips with a large batch of return in a single trip.

   Fundamentally, Allas prefers the return mechanism that grants them the most control of tracking and handling. Considering Allas' preferred choice, drop-off option works dependent on the reports of returned packaging from restaurants as well as the customers, which is the opposite way they would perform best. While the deposit scheme is to ensure the packaging is returned, the fact is that only a handful have specifically asked to claim back the deposit. Allas research (2021) also reveals that the deposit is deemed not sufficient to push customers to return the packaging before the due date, and the amount is considered insignificant.

   As shown in section LCA result, the pick-up scheme offers a lower carbon footprint compared to its counterparts owing to the use of bicycles. Moreover, considering the already established unofficial partnership with Westbike, Allas can propose for a longer-term relationship to develop an integrated information system to enable a more efficient pick-up scheme compared to having a huge transaction cost with giant online delivery service providers. Although, the conditions must be set up and met: a minimum number of packaging serviced against the cost of transportation, optimal distance and route to Allas hub, and convenient time for the customers. Therefore, Allas should revamp its data management and consider the costs between partnering with a third-party logistics provider or putting the responsibility on the customers, regarding customer convenience on using the service.

Nevertheless, drop-off scheme would have had a standing reason to be a promising return option if restaurants were able to perform packaging washing. Despite the simple reconditioning process (Carrasco-gallego et al., 2009), the quality is not guaranteed due to the lack of standardization of washing for establishments in place. Therefore, Allas has a good reason for pursuing a centralized cleaning hub. This resonated with the condition in restaurants that are lacking separate cabinets for for-use and used packaging. There has been a case where a merchant restaurant sent out the used packaging from a customer's drop-off instead of the one from Allas cleaning hub. This may compromise customer experience of not receiving the best service.

3. Customer touchpoint

Their user journey mapping indicates that the first step most customers do is searching for food they crave and the restaurant through the food delivery app. Thus, the main customer touchpoint is through the online food delivery app, where Allas has no full control, since restaurant is the operator and receiver of the order from the customers. In order to use Allas' service, the customers have to think of having a zero packaging waste option at first, then followed by typical food order. This poses a concern in decision-making of borrowing activities for both customers and restaurants.

Customers must memorize their user ID and the partner restaurants to be able to use the service. However, there lacks a feedback mechanism from the restaurants to the customers to confirm the order. On the other hand, the restaurants do not possess the access to the database of active memberships. They are required to be capable of identifying active user IDs and available borrow slots when such information is only held by Allas. The user ID is manually typed in by the customers in the note section within the order page of the app, which restaurants find it difficult to acknowledge whether the customer has an active membership. At the moment, Allas has to broadcast to every partner restaurant on Whatsapp for every inactive user ID so that the restaurants are aware not to lend the packaging to the customer. Restaurants are also unable to cross-reference the number of packaging orders and the availability slots per user ID, putting Allas at risk.

From customers' perspective, the appearance of Allas packaging feature on the order page of the app varies from one merchant to another, which is related to the user experience. For instance, one restaurant only sells two menus to be packaged with Allas, while another puts a permanent Allas packaging option on every menu. According to our interview with one of the merchants, many customers interested in trying out the service go straight to the restaurant order page without checking out Allas' social media but could not use the service due to the lack of how-to information on the order page. This is a likely challenge in gaining traction to boost Allas' new users.

4. Delays in information flows

   Considering the simplicity of the reconditioning process, reusable packaging is supposed to be quickly put back in the rotations (Twede & Clarke, 2005). However, the delay in information flow may cost the company. As an example, restaurants sending out notifications of borrows and returns once every one to two weeks in a handwritten form may influence customer convenience as a consequence of the hindrance. There is a case where Allas sent out a reminder to a certain customer who had returned the packaging because the restaurants had not notified Allas about the returned packaging on time. Technically, Allas has put QR codes to let restaurants scan each borrowed and returned packaging. However, without a system integration that puts the restaurants inside the loop of the information they have to record the activities per user ID which they are more familiar. There is also a risk of misconduct considering the manual recording method.

5. Packaging cycle usage tracking

   Allas has expressed their interests in the cycle usage of their packaging. It helps track the lifetime of each packaging and indicates if a condition appears after reaching a certain number of uses. Despite the concern, at the moment it is not taken into account to the warehouse management system as well as the redistribution policy. Their current stocking policy does not pay attention to categorizing containers into the number of cycle usage. Therefore, the cycle usage varies a lot from 1 to more than 10 times owing to the decision according to Allas' database.

   Furthermore, Allas has not considered using information on demand forecast, and attention on logistics cost for their purchasing policy, which shapes the inventory management and control system (McKerrow, 1996a). The company has made frequent purchases for the past year with a low number of items per trip on the basis of new partnerships and unusual customer requests. This behavior leads to distributing but also disrupting flows of packaging with a large variation of cycle usage into circulation, further aggravated by manual data input that increases the difficulty in looking into the cycle usage of each reusable container. They also have risks from packaging design changes from the manufacturer in the future which may affect the branding and marketing aspect since as of now, Allas packaging is not custom-made.

6. Conflicting goal between branding and sustainability

   The reuse scheme is often deemed inferior to recycling despite the successful results of material decoupling by slowing the loop (Coelho et al., 2020). Therefore, Allas is one of the first contenders for sustainability practices in the food delivery business, where recyclable and compostable products are more favored. The packaging design is even lauded by both partner restaurants and customers, owing to the capability to save volume and keep the heat. Size variations make it convenient to pack a wide range of menus without sacrificing storage capacity. However, iterating from the LCA results, selection of the material ought to be one of the key considerations in the purchasing policy as silicone is not viable for commercial recycling yet.

> Furthermore, the universal design for all partner restaurants has created a trade-off between branding and sustainability. Allas' market research (2021) finds that several merchant restaurants are unwilling to pack all of their menu in Allas packaging for the sake of branding. It also shows that the understanding of sustainability differs among actors. Most 'green' restaurants adopt the notion that any biodegradable and fiber-based material is the best for the environment. Some may be strict about using plastics for both single-use and reusable as attributes to their packaging. For example, they opt for cassava-made bags to deliver the food, while more common restaurants use cloth bags that can be used more than once. On top of that, they also consider cost as the number one factor for packaging selection, so if Allas reusable packaging has a similar price as their current packaging, they favor using reusable ones. Thus, addressing the disparity in the view of 'sustainability' between actors is as important as the other aspects of the supply chain.

As the packaging owner, Allas certainly faces several challenges commonly found in the reuse business as elaborated above, also some interesting ones particularly unique to this case. According to McKerrow (1996b), reusable packaging system should be well managed with appropriate responsibility, authority, and incentives set by the packaging ownership structure. Allas has clarified the roles and responsibilities of each actor in the value chain by centralizing the reconditioning process, establishing communication channels to all actors (including the customers), information-based redistribution policy, and pooled return mechanism. However, there is apparent power dynamic, although it is not of particular concern in this study, between Allas and restaurants, when restaurants repeatedly need to be reminded to send a list of borrows and returns, i.e., holding necessary information, thus showing a lack of authority. Furthermore, the different takes on "sustainable packaging" and cost factor have influenced the nature of the partnership between Allas and restaurants. Lastly, the incentive system falls short for prompting users to take care of and return the packaging, e.g., low deposit amount and no sanction for losing the containers.

RECOMMENDATION AND CONCLUSION

The rapid growth of food delivery in urban areas has spurred the use of single-use plastics. Even with an adequate waste management system, plastic waste has become unmanageable given its capability to turn into microplastics, endangering the marine ecosystem. Plastic recycling is hailed as the savior of solving the problem. However, the majority of single-use plastics are difficult to recycle due to material or operational feasibility, namely polystyrene, and polyethylene which are mostly found in plastic bags and utensils. Therefore, container reuse is a viable option for offsetting the environmental impacts entailed in the food delivery business, as it offers material decoupling and less waste strategy.

7.1 Conclusion

Despite the potential, reuse scheme prompts additional processes, which are transportation as part of the reverse and redistribution logistics and the reconditioning to revert the packaging back to its original quality for another use. These processes add complexity to the forward supply chain as commonly applied in food delivery using single-use packaging. It certainly requires similar level of participation between actors to realize the closed-loop supply chain (CLSC). Furthermore, considering that reusable packaging weighs more than single-use one to be able to last long for multiple uses by various users, and coupled with environmental impacts risen from the additional processes, packaging reuse is argued to meet a minimum level to offset its high environmental impacts compared to the single-use, called environmental break-even point (BEP). Following findings are answered in short according to our research questions mentioned in Chapter 1: Introduction.

RQ 1. What are the environmental impacts of one portion of single-use packaging using online delivery services in Jakarta, Indonesia?

Using LCA the authors found that one time usage of single-use PP container was estimated to generate 2.3 kg 1,4-DCB of terrestrial ecotoxicity (TETP), 0.6 kg 1,4-DCB of human non-carcinogenic toxicity (HTPnc), 0.40 kg CO2-eq of global warming potential (GWP), and 0.001 m^3 of water stress index (WSI) impact categories.

RQ 2. What are the environmental impacts, and which processes contribute to the highest impacts of providing one portion of a meal in a single online delivery service using reuse scheme in Jakarta, Indonesia?

The environmental impacts of using Allas' reusable food container for one meal are 5.1 kg 1,4-DCB for TETP, 1.6 kg 1,4-DCB for HTPnc, 1.5 kg CO2-eq for GWP, and 0.009 m^3 for WSI. This study established that packaging material selection, and transportation vehicles and distance are the defining factors of the environmental impacts. The production contributes a considerable impact due to the heavier weight of container and higher impacts from silicone manufacture. The use of motorcycle also places great emphasis on the contribution analysis of GWP and toxicity impacts. On the other hand, washing processes shows negligible impacts (2.8%) for all impact categories except WSI, because of the use of handwashing method with non-heated water.

RQ 3. What is the least number of uses to offset the environmental impacts of reusable food containers against the single-use option?

Allas' reusable container requires four to six uses to balance out the impacts of single-use in the categories of TETP, HTPnc, and GWP. However, in comparison to single-use alternative where no cleaning is required, the BEP for WSI from reusables will never be reached in any number of uses, making single-use is a better choice for this impact category alone. The sensitivity analysis reveals that environmental impacts from the production and EoL phases of reusable packaging will stabilize after reaching 20 uses.

RQ 4. What are the identified hotspots of the reuse scheme within the closed-loop supply chain framework?

Reuse system run by Allas has six aspects in terms of the supply chain to be further improved. Allas is currently running two options of return mechanisms where customers have to pay for the more expensive subscription plan for home pick-up service. Since Allas partners with Westbike, bicycle delivery service, for the service, Allas is able to measure the CO_2 emission reduction from avoiding the use of motorcycles and uses for marketing purposes. By pooling the orders from Allas to Westbike, it enables riders to collect from multiple locations and drop many packaging off at once. In addition, considering how customers receive their orders at home or office, it is more appropriate to send the packaging back in the similar manner. Therefore, while drop-off is more convenient for Allas, pick-up option is more efficient for route planning and scheduling, and results in lower environmental footprint compared to its counterpart.

Several findings concerning the supply chain are either echoed in the existing literatures or recently emerged from the interviews. For example, while Allas suffers from the lack of clarity across the value chain, widely noted that it is a common issue among all reuse systems. In addition, the cycle usage tracking as well as the communication between actors in the value chain is of particular concern for Allas are resonated in existing studies. In doing so, it must be equipped with a purchasing policy of new packaging in order to prevent a mix of packaging with too wide-ranging cycle usage in circulation. Allas is encouraged to improve their communication and reporting mechanism with restaurants and the user interface to reduce the time delays and chances of miscommunication that may put customer experience at risk. On the other hand, product recovery mechanisms and differences in sustainability perceptions by each actor are prominent factors emerging from this case study, which require further investigation in another setting.

7.2 Recommendation

The results presented in this study could be useful for Allas' further improvement in their business operations, as well as their relationship with all actors involved in the value chain. Recommendations derived from the study results are listed as follows.

- Considering packaging material with lower environmental footprints and specifically designed for recycling, for example, a durable PP container
- To reduce the water consumption in washing process, Allas could upgrade to a more efficient water appliances, such as faucet aerators or faucet with sensors
- As motorcycles are mainly used for delivery and re-distribution, the maximum distance between Allas' cleaning hub and restaurants should be set around 10 to 15 km as part of the recommendations for development plan. If Allas has more restaurants with farther location from their cleaning hub to become partner merchants in the future, deploying multiple cleaning hub and prioritizing the use of bicycle as logistic vehicles are suggested
- Instead of simultaneously running two packaging return mechanisms, focusing on only pick-up for all packaging yields positive results in both environmental and logistical aspects, as

Westbike is able to offset greenhouse gas emissions from delivering the service efficiently with minimal trips

- In order to sort out the low cycle usage number average, Allas is recommended to implement a stricter purchasing policy with detailed list of conditions indicating the appropriate time to use the new packaging, and stocking policy according to packaging cycle usage in the cabinets
- Improving the customer touchpoint in the third-party food delivery apps would enhance customer experience in using the service, e.g., universal button of Allas packaging selection in the menu display and an option to start membership through these apps
- Setting automatic borrow reporting mechanism for the restaurants to lessen the workload from having to manually insert the user ID
- Upholding deposit return would signify the maintenance of the packaging and ensure high rates of on-time return to Allas

Considering the scarcity of the discussion in regard to the online food delivery impacts in academic setting and on top of our newly emerged findings, we could claim to the best of our knowledge that this is the first study that assessed online food delivery services in Southeast Asia making use of motorcycles and handwashing technique. Therefore, in order to significantly improve this business in trend, further research on material comparison for delivery packaging is recommended, for example, biodegradable or compostable food packaging. In addition, expanding the packaging system to include secondary packaging, e.g., plastic bags, and cutleries and scaling up the study scope into a citywide scale will provide a clearer picture surrounding the environmental impacts resulted from food delivery activities. From the initial assessment, there are other impact categories that would be interesting to be further examined due to high break-even point or low use phase efficiency, such as human carcinogenic toxicity, land use, and mineral resource scarcity. Modeling a scenario where online food delivery service provider is the owner of the packaging may bring forth another perspective to produce empirical findings as part of Janairo (2021). Lastly, quantitative analysis of the distribution networks, especially the pick-up scheme, will assist businesses in determining the most appropriate logistics plan and further scientific journals on reuse model.

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Appendix A. Codes of CLSC qualitative analysis

Following table lists all the codes emerged from the interviews with Allas, Feelgood Food restaurants, and Westbike Messenger Service.

Table A1. Codes of CLSC qualitative analysis

Forward & Reverse Logistics	**Operations**	**Redistributions**
Product recovery	Washing	Return lead time
Packaging ownership	Quality inspection	Stock level
Pick-up	Dashboard/database	Scheduling
Drop-off	Tracking	Storage
Purchasing	Communication with restaurant	Inventory
Communication with customer	Wear and tear	Restock
Transport mode	Digital record	
Customer base	Data record	
Company interest	Washing standardized method	
Stock level	Cycle usage	
Customer convenience	Secondary packaging	
Cycle usage	Damaged packaging	
Route	Recycling	
Product sales	QR code	
Packaging size	Location code	
Location	Customer experience	
Relationship between Westbike & Allas	Deposit refund mechanism	
Lead time	Stock management	
Pick-up hours	Financial flow	
Pick-up hub	Packaging design	
Food delivery service	User ID	
	Training/onboarding	

Appendix B.1. Interview questions setlist

Allas

1. How should customers or restaurants notify you about the packaging return?
2. Why did you decide 14-day limit of packaging return?
3. Who is responsible for claiming the returned packaging from customers?
4. Which vehicle do you use to claim the returned packaging?
5. How do you track the positions of your packaging?
6. Are you planning to have a more advanced tracing method? What kind of information do you need in tracing?
7. What are the challenges concerning drop-off mechanism?
8. What are the challenges concerning pick-up mechanism?
9. Which one do you prefer the most, only considering your benefits: drop-off or pick-up?
10. Do you have a protocol for inspection and washing operation?
11. What are the advantages and drawbacks of current inspection and washing method?
12. Where do you perform the inspection and washing operation?
13. How do you handle the packaging that is not qualified after inspection process (QC)? Do you send them to recycling center?
14. How do you deliver your promise on the hygiene of the packaging to customers and restaurants?
15. How often does your packaging become discontinued?
16. How do you restock the packaging to your partner restaurants?
17. Do you increase the stock level of the packaging frequently?
18. What kind of partnership do you have with your partner restaurants?
19. How often do you ship the packaging back to stock in restaurants?
20. Which vehicle do you use to send the packaging to the restaurants?
21. Do you have the data of the food delivery locations?
22. Do you know if your customers are still working from home or at office?

Appendix B.2. Interview questions setlist

Allas Operational

1. What are your job descriptions?
2. How often do you communicate with the restaurants? And for what purpose mainly?
3. Please show us the dashboard of monitoring of the packaging status.
4. How many of your customers select drop-off and pick-up options?
5. Do you know if the drop-off location is similar to that of the original food order?
6. In average, how many packaging does one customer rent for a single trip or order? How many packaging does one customer return for a single trip?
7. How many packaging are discontinued or unqualified per month?
8. How do you determine the stock level of packaging of each restaurant?
9. How do restaurants pay Allas for the packaging use?
10. Do you apply first-in-first-out type of management for your packaging inventory?
11. How often do you wash the packaging?
12. How many packaging do you wash for a period of time?

Appendix B.3. Interview questions setlist

Restaurants

1. Please state your name and current position.
2. What do you do when you receive a delivery order using Allas packaging?
3. What do you do when a customer returns the packaging?
4. In average, how many packaging is returned at the same time?
5. Where do you store for-use and after-use Allas packaging?
6. How do you do data recording and reporting of returned packaging to Allas?
7. How do you do any regular data recording and reporting? (e.g. online payment or credit card transactions)
8. Do you regularly check the quality of Allas for-use packaging? What do you think of the packaging in terms of the quality? (e.g. cleanliness)
9. How responsiveness is the packaging restock request?
10. What drives you to establish a partnership with Allas?
11. Do you have some comments on your ongoing partnership with Allas? (e.g. size variation, redistribution, storage, hygiene concerns)
12. Do you have a plan to switch to 100% reusable packaging?

Appendix B.4. Interview questions setlist

Westbike: transport delivery provider

1. Please state your name and current position.
2. How did you first establish your partnership with Allas?
3. How does customers order a pick-up service through Westbike app>
4. How do you process the pick-up requests? How long does it take to process the request and deploy the riders?
5. Where are Westbike hubs? What do they look like?
6. How does the regular route planning look like? Do you have temporary drop points before reaching final destination?
7. How many courier riders are working for Westbike?
8. What time and days do you operate? Do you practice working shifts?
9. How many people do you usually deploy for pick-up? Is there a maximum number of Allas packaging for pick-up per trip?
10. Is there a maximum volume or weight to be carried by a rider?
11. How often do you receive pick-up requests from Allas?
12. How do you practice the operations during pandemic times?
13. Will you in the future work with e-commerce? Are you planning to become food delivery service provider?

Appendix C. Transport modelling

Table C1. Transportation distance modelling

Transport service of	From	To	Modes of transportation	Type of modes	Distance (km)	Reference distance/location
Production of Containers						
Main product						
PP Granulates for lid	Unknown, China (PP granulates factory)	Unknown, China (Food container factory)	Truck	freight, lorry 16-32 metric ton, EURO3	150	Gallego, 2019 (raw materials to factory)
Silicone rubber for container, seal, and valve	Unknown, China (Silicone product factory)	Unknown, China (Food container factory)	Truck	freight, lorry 16-32 metric ton, EURO3	150	Gallego, 2019 (raw materials to factory)
Finished food container	Unknown, China (Food container factory)	Shanghai, China	Truck	freight, lorry 16-32 metric ton, EURO3	150	Gallego, 2019 (raw materials to factory)
	Shanghai, China	Tanjung Priok, Jakarta, Indonesia (Port)	Ship	Transoceanic tanker	4673	Sea-distances, 2022
	Tanjung Priok, Jakarta, Indonesia (Port)	Tangerang, Indonesia (Ataru distribution center)	Truck	freight, lorry 16-32 metric ton, EURO3	50	From the port in Jakarta to the product brand DC, estimated in Tangerang due to most factory are located in supporting cities around Jakarta, one of it is Tangerang City. Distance estimation from google maps
	Tangerang, Indonesia (Ataru distribution center)	Kemang Village, Jakarta, Indonesia (Ataru area distributor)	Truck	freight, lorry 3.5-7.5 metric ton, EURO3	50	From the product brand DC to product retail, estimated in Kemang Village because it is the closest distance Ataru retail to Allas. Distance estimation from google maps
	Kemang Village, Jakarta, Indonesia (Ataru area distributor)	Kemang Timur, Jakarta, Indonesia (Allas office)	Motorcycle	Scooter, low-sulfur petrol	2.5	From the product retail to Allas office, location knows from Allas interview. Distance estimation from google maps
	Kemang Timur, Jakarta, Indonesia (Allas office)	Jakarta, Indonesia (Restaurants)	Motorcycle	Scooter, low-sulfur petrol	4.40	Value: average Allas's merchant distance, with range of +- 1.5 km Brought by Allas operations
	Jakarta, Indonesia (Restaurants)	Jakarta, Indonesia (Customer)	Motorcycle	Scooter, low-sulfur petrol	7	Allas interview
Auxilliary material						

Transport service of	From	To	Modes of transportation	Type of modes	Distance (km)	Reference distance/location
Cardboard for packing	Tangerang, Indonesia (Cardboard factory)	Kemang Village, Jakarta, Indonesia (Ataru area distributor)	Truck	freight, lorry 3.5-7.5 metric ton, EURO3	50	From the cardboard or bubble wrap factory to product retail, the factory is estimated in Tangerang due to most factory are located in supporting cities around Jakarta, one of it is Tangerang City. Distance estimation from google maps
Bubble wrap	Tangerang, Indonesia (Cardboard factory)	Kemang Village, Jakarta, Indonesia (Ataru area distributor)	Truck	freight, lorry 3.5-7.5 metric ton, EURO3	50	
Use and Reuse						
Main product: Used container (for sensitivity analysis scenarios)						
Pick-up (reference)	Jakarta, Indonesia (Customer)	Jakarta, Indonesia (West bike depot)	Bicycle		7	Westbike Interview, from depot location in Kemang
	Jakarta, Indonesia (West bike depot)	Kemang Timur, Jakarta, Indonesia (Allas office)	Bicycle			Westbike Interview, from depot location in Kemang
			or			
Drop-off restaurant	Jakarta, Indonesia (Customer)	Jakarta, Indonesia (Restaurants)	Motorcycle	Scooter, low-sulfur petrol	7	Allas interview
	Jakarta, Indonesia (Restaurants)	Kemang Timur, Jakarta, Indonesia (Allas office)	Bicycle		4	Value: average Allas's merchant distance, Brought by Allas operations
			or			
Drop-off Allas	Jakarta, Indonesia (Customer)	Kemang Timur, Jakarta, Indonesia (Allas office)	Motorcycle	Scooter, low-sulfur petrol	7	Allas interview
Recycling						
Used lid	Kemang Timur, Jakarta, Indonesia (Allas office)	(Recycling drop-off)	Motorcycle	Scooter, low-sulfur petrol	2	Assumptions: To waste bank or recycling dropbox
	(Recycling drop-off)	(Recycling center)	Truck	freight, lorry 7.5-16 metric ton	50	Assumptions: Recycling centre in Tangerang or Bekasi
Landfill						
Used container, lid silicone, and seal	Kemang Timur, Jakarta, Indonesia (Allas office)	Bantargebang, Bekasi, Indonesia (Landfill)	Truck	freight, lorry 7.5-16 metric ton	40	Distance to TPST Bantargebang, Bekasi, Indonesia

Appendix D. Life cycle inventory

The life cycle inventory in this Appendix mostly presented with 1 kg as the output unit instead of the functional unit, unless the unit specified otherwise. The conversion to functional unit were conducted in OpenLCA software with multiplying the background processes with global parameter (e.g., weight of container, efficiency factor of PP granulates production) to obtain the appropriate results of LCI. The selected processes described in this chapter are the processes that one or several values had been changed from Ecoinvent database or derived from literature. Adjustments only in provider of flows (e.g., electricity generation in China or in Indonesia) was not included, classified in the Table D1. At the end, the unit processes were combined with a process labelled 'life cycle of reusable/single-use container' for modelling purposes.

Table D1. Classification of processes with adjustment provider and values

Background processes with adjusted flow provider	Processes with adjusted values (presented in this Appendix)
Extrusion and thermoforming	Production of PP granulates
Silicone product production	Motor scooter usage
Injection moulding of silicone	Washing at customer and at Allas (PSS provider)
Water pump operation	Forward transportation
Market for municipal solid waste	Return transportation
Polypropylene recycling, granulate, amorphous	Redistribution transportation
	Recycling (with transport)
	Landfill (with transport)

1. Production of PP granulates

Table D2. Inventory of PP granulates production

Flow	Amount	Unit	Source	Provider
Inputs				
electricity, medium voltage	4.00E+00	MJ	(An et al., 2022)	market group for electricity, medium voltage | electricity, medium voltage | Cutoff, U - CN
naphtha	1.64E+00	kg	(An et al., 2022)	market for naphtha | naphtha | Cutoff, U - RoW
propylene	1.11E+00	kg	(An et al., 2022)	market for propylene | propylene | Cutoff, U - RoW
water, completely softened	2.34E-03	kg	(An et al., 2022)	market for water, completely softened | water, completely softened | Cutoff, U - RoW
Outputs				
Benzene	1.50E-03	kg	(An et al., 2022)	
Carbon dioxide, fossil	1.21E+00	kg	(An et al., 2022)	
Chloroform	1.50E-07	kg	(An et al., 2022)	
COD, Chemical Oxygen Demand	1.40E-04	kg	(An et al., 2022)	
Nitrogen, organic bound	3.70E-02	kg	(An et al., 2022)	
NMVOC, non-methane volatile organic	2.77E-03	kg	(An et al., 2022)	

compounds, unspecified origin				
Particulates, > 10 um	1.00E-04	kg	(An et al., 2022)	
Particulates, > 2.5 um, and < 10um	4.00E-05	kg	(An et al., 2022)	
PP granulates	1.00E+00	kg	(An et al., 2022)	
Sulfur dioxide	1.21E-02	kg	(An et al., 2022)	
Toluene	4.60E-06	kg	(An et al., 2022)	
Trichloroethane	5.80E-03	kg	(An et al., 2022)	
waste plastic, mixture	4.18E-01	kg	(An et al., 2022)	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | Cutoff, U - RoW
wastewater, average	2.34E-03	m3	(An et al., 2022)	market for wastewater, average | wastewater, average | Cutoff, U - RoW

2. Motor scooter usage

Table D3. Inventory of motor scooter usage by passenger

Flow	Amount	Unit	Source	Provider
Inflows				
maintenance, motor scooter	1.82E-05	Item(s)	(Wernet et al., 2016)	maintenance, motor scooter | maintenance, motor scooter | Cutoff, U - RoW
motor scooter, 50 cubic cm engine	1.82E-05	Item(s)	(Wernet et al., 2016)	market for motor scooter, 50 cubic cm engine | motor scooter, 50 cubic cm engine | Cutoff, U - GLO
petrol, low-sulfur	2.29E-02	kg	(Wernet et al., 2016)	market for petrol, low-sulfur | petrol, low-sulfur | Cutoff, U - RoW
road	8.38E-05	m*a	(Wernet et al., 2016)	market for road | road | Cutoff, U - GLO
road maintenance	1.17E-03	m*a	(Wernet et al., 2016)	market for road maintenance | road maintenance | Cutoff, U - RoW
Outflows			(Wernet et al., 2016)	
Acetaldehyde	1.55E-06	kg	(Wernet et al., 2016)	
Ammonia	1.70E-06	kg	(Wernet et al., 2016)	
Benzene	1.10E-04	kg	(Wernet et al., 2016)	
Cadmium	4.17E-10	kg	(Wernet et al., 2016)	
Cadmium	5.45E-11	kg	(Wernet et al., 2016)	
Cadmium, ion	5.45E-11	kg	(Wernet et al., 2016)	
Carbon dioxide, fossil	2.04E-02	kg	(Rusdiani & Boedisantoso, 2018)	
Carbon monoxide, fossil	7.42E-03	kg	(Rusdiani & Boedisantoso, 2018)	
Chromium	4.79E-09	kg	(Wernet et al., 2016)	
Chromium	2.60E-10	kg	(Wernet et al., 2016)	
Chromium VI	3.44E-12	kg	(Wernet et al., 2016)	
Chromium, ion	2.60E-10	kg	(Wernet et al., 2016)	
Copper	2.78E-07	kg	(Wernet et al., 2016)	
Copper	3.65E-09	kg	(Wernet et al., 2016)	
Copper, ion	3.65E-09	kg	(Wernet et al., 2016)	

Flow	Amount	Unit	Source	Provider
Dinitrogen monoxide	8.49E-07	kg	(Wernet et al., 2016)	
Formaldehyde	3.34E-06	kg	(Wernet et al., 2016)	
Lead	1.40E-08	kg	(Wernet et al., 2016)	
Lead	2.24E-09	kg	(Wernet et al., 2016)	
Lead	2.24E-09	kg	(Wernet et al., 2016)	
Mercury	6.89E-13	kg	(Wernet et al., 2016)	
Methane, fossil	1.92E-04	kg	(Wernet et al., 2016)	
Nickel	4.60E-09	kg	(Wernet et al., 2016)	
Nickel	7.05E-10	kg	(Wernet et al., 2016)	
Nickel, ion	7.05E-10	kg	(Wernet et al., 2016)	
Nitrogen oxides	2.05E-04	kg	(Wernet et al., 2016)	
NMVOC, non-methane volatile organic compounds, unspecified origin	2.15E-03	kg	(Wernet et al., 2016)	
PAH, polycyclic aromatic hydrocarbons	3.43E-10	kg	(Wernet et al., 2016)	
Particulates, < 2.5 um	1.45E-05	kg	(Wernet et al., 2016)	
Particulates, > 10 um	6.81E-06	kg	(Wernet et al., 2016)	
Particulates, > 2.5 um, and < 10um	7.69E-06	kg	(Wernet et al., 2016)	
Selenium	3.44E-10	kg	(Wernet et al., 2016)	
Sulfur dioxide	3.67E-07	kg	(Wernet et al., 2016)	
Toluene	2.53E-04	kg	(Wernet et al., 2016)	
transport, passenger, motor scooter - ID	1.00E+00	p*km	(Wernet et al., 2016)	
Xylene	2.23E-04	kg	(Wernet et al., 2016)	
Zinc	1.16E-07	kg	(Wernet et al., 2016)	
Zinc	1.54E-07	kg	(Wernet et al., 2016)	
Zinc, ion	1.54E-07	kg	(Wernet et al., 2016)	

3. Washing at customer and at Allas (PSS provider)

Table D4. Inventory of handwashing process

Flow	Amount	Unit	Source	Provider
Inflows				
cleaning consumables, without water, in 13.6% solution state	8.96E-03	kg/FU	Primary data with conversion calculation	market for cleaning consumables, without water, in 13.6% solution state | cleaning consumables, without water, in 13.6% solution state | Cutoff, U - GLO
Food container, delivered	1.78E-01	kg/FU	Primary data	
water pump operation	1.80E+00	kg/FU	(Wernet et al., 2016)	water pump operation, 1 kg of water
water, completely softened	6.88E-02	kg/FU	Primary data with conversion calculation	market for water, completely softened | water, completely softened | Cutoff, U - RoW
Water, unspecified natural origin, ID	1.80E-03	m3/FU	Primary data	
Outflows				
Food container, used	1.78E-01	kg/FU	Primary data	
Use phase	1.00E+00	Item(s)		
wastewater, from residence	1.88E+00	l/FU	Mass balance calculation	market for wastewater, from residence | wastewater, from residence | Cutoff, U - RoW

4. Transportation

The source and allocation of transportation inventory are displayed in Appendix C and Chapter 5 (LCA Procedure, Allocation).

Table D5. Inventory of transportation

Flow	Amount (Reusable)	Amount (Single-use)	Unit	Provider
Forward Transportation				
Inflows				
corrugated board box	2.37E-02	2.37E-02	kg/FU	market for corrugated board box | corrugated board box | Cutoff, U - RoW
folding boxboard carton	1.15E-02	1.03E-03	kg/FU	market for folding boxboard carton | folding boxboard carton | Cutoff, U - RoW
transport, DC to PSS Provider	2.50E-01	2.50E-01	p*km/FU	Transport, distribution center to PSS provider
transport, freight, lorry 16-32 metric ton, EURO3	8.90E+00	1.35E+00	kg*km/FU	market for transport, freight, lorry 16-32 metric ton, EURO3 | transport, freight, lorry 16-32 metric ton, EURO3 | Cutoff, U - RoW
transport, freight, lorry 16-32 metric ton, EURO4	2.67E+01	4.05E+00	kg*km/FU	market for transport, freight, lorry 16-32 metric ton, EURO4 | transport, freight, lorry 16-32 metric ton, EURO4 | Cutoff, U - RoW
transport, freight, lorry 3.5-7.5 metric ton, EURO3	8.90E+00	1.35E+00	kg*km/FU	market for transport, freight, lorry 3.5-7.5 metric ton, EURO3 | transport, freight,

Flow	Amount (Reusable)	Amount (Single-use)	Unit	Provider
				lorry 3.5-7.5 metric ton, EURO3 | Cutoff, U - RoW
transport, freight, sea, container ship	8.32E+02	1.26E+02	kg*km/FU	market for transport, freight, sea, container ship | transport, freight, sea, container ship | Cutoff, U - GLO
transport, PSS provider to restaurant	8.80E-01	-	p*km/FU	Transport, PSS provider to restaurant
transport, restaurant to customers	3.50E+00	3.50E+00	p*km/FU	Transport, restaurant to customers
Outflows				
Food container, delivered	1.78E-01	2.70E-02	kg/FU	
Forward transportation	1.00E+00	1.00E+00	Item(s)	
Packaging waste, paper and board	3.52E-02	2.47E-02	kg/FU	
Return packaging transport				
transport, passenger, bicycle	3.50E+00	-	p*km/FU	market for transport, passenger, bicycle | transport, passenger, bicycle | Cutoff, U - GLO
Re-distribution transport				
transport, passenger, motor scooter - ID	8.80E-01	-	p*km/FU	transport, passenger, motor scooter - ID

5. Recycling

The end-of-life modelling in this study used the material flow logic, setting the waste product flow (e.g., waste PP) as the output with positive value. Furthermore, in the waste treatment process (e.g., incineration, and landfill) the waste flow was categorized as an input with positive value (Greendelta, 2020).

Table D6. Inventory of recycling with transportation

Flow	Amount (Reusable)	Amount (Single-use)	Unit	Provider
Inflows				
PP material, disposed	5.30E-02	2.70E-02	kg/FU	
transport, freight, lorry 7.5-16 metric ton, EURO3	2.65E+00	1.35E+00	kg*km/FU	market for transport, freight, lorry 7.5-16 metric ton, EURO3 | transport, freight, lorry 7.5-16 metric ton, EURO3 | Cutoff, U - RoW
transport, passenger, motor scooter - ID	1.00E-01	1.00E-01	p*km/FU	transport, passenger, motor scooter - ID
Outflows				
Recycling	1.00E+00	1.00E+00	Item(s)	
waste polypropylene	5.30E-02	2.70E-02	kg/FU	polypropylene recycling, granulate, amorphous, recycled | Cutoff, U - ID

6. Landfill

The type of landfill utilized was not sanitary landfill since the existing process in Bantargebang landfill operates differently than the planned sanitary landfill (Winahyu et al, 2013). Hence, the "unsanitary landfill, very wet infiltration class (1000 mm) | waste glass | Cutoff, U" will be used, considering the average precipitation in Bekasi is between 1100-2000 mm/year in 2013 to 2017, and the total precipitation in 2020 is 6672 mm/year (Badan Pusat Statistik Kota Bekasi, 2019, 2020). The ""unsanitary landfill, very wet infiltration class (1000 mm)" process defined for mean annual precipitation (MAP) of 1900 mm/year, and net infiltration of 1000 mm/year. In regards to material under treatment, landfill for silicone products was not found in Ecoinvent database or any literatures (Shit & Shah, 2013). Hence, "treatment for waste glass" process was designated as an alternative, considering both silicone rubber and glass are inert material and made of Silica (Shin Etsu Company, 2016).

Table D7. Inventory of landfill with transportation

Flow	Amount (Reusable)	Unit	Provider
Inflows			
transport, freight, lorry 7.5-16 metric ton, EURO3	5.00E+00	kg*km/FU	market for transport, freight, lorry 7.5-16 metric ton, EURO3 | transport, freight, lorry 7.5-16 metric ton, EURO3 | Cutoff, U - RoW
Outflows			
Landfill	1.00E+00	Item(s)	
waste glass	1.25E-01	kg/FU	treatment of waste glass, unsanitary landfill, very wet infiltration class (1000mm) | waste glass | Cutoff, U - GLO

Appendix E. Break-even point for all impact categories in ReCiPe

No	Impact categories	Product efficiency	Use phase efficiency	Break-even point
1	Terrestrial ecotoxicity	2.0	0.4	4
2	Human non-carcinogenic toxicity	2.4	0.6	6
3	Global warming	3.4	0.4	6
4	Fossil resource scarcity	2.7	0.4	5
5	Marine ecotoxicity	2.5	0.7	7
6	Human carcinogenic toxicity	2.5	1.0	62
7	Freshwater ecotoxicity	2.6	0.7	8
8	Land use	3.4	0.8	20
9	Ionizing radiation	2.9	0.6	8
10	Water consumption	11.9	1.9	-13
11	Ozone formation, Terrestrial ecosystems	1.8	0.3	2
12	Ozone formation, Human health	2.0	0.3	3
13	Terrestrial acidification	3.1	0.5	6
14	Mineral resource scarcity	2.4	1.1	-41
15	Fine particulate matter formation	2.6	0.3	4
16	Freshwater eutrophication	0.0	0.0	0
17	Marine eutrophication	0.0	0.0	0
18	Stratospheric ozone depletion	0.0	0.0	0
19	Water stress index	3.4	3.4	-1

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