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ORIGINAL PAPER

EXPLORING THE CIRCULAR SUPPLY CHAIN TO REDUCE PLASTIC WASTE IN SINGAPORE

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ABSTRACT. **Background:** The COVID-19 changes our lifestyle and triggers the rapid development of online shopping resulting in massive use of plastic for packaging for each parcel. Hence, plastic waste management has become a worrying concern in some countries. This research proposes that the circular supply chain could be a way to reduce plastic waste with regards to the triple bottom line: economy, social, and environment. It applies the life-cycle assessment (LCA) and target sampling method.

Methods: The data about plastic waste, including the production, consumption, and the end-of-life stage from target developed countries were collected and analyzed. By comparing practices applied in Germany and South Korea, this research investigates a framework for both the upstream and the downstream through the implementation of the 4R concept: reduce, reuse, recycle, and recovery.

Results and conclusions: This study provides new insights of the circular supply chain from the perspective of the government, producers, and consumers and call for more attention from the demand perspective (involving more efforts from authorities and consumers) of the plastic industry instead of only concentrating on the supply perspective.

Key words: circular supply chain, plastic waste management, life-cycle assessment, the 4R concept, triple bottom line, bioplastic.

INTRODUCTION

Over the last 50 years, plastic has become an integral part of modern life because it is lightweight but strong to carry and low cost in daily use [Van Eygen et al. 2017]. Plastic has infiltrated into every aspect of life, at the same time, it has been designed to meet the varying needs of customers such as plastic bags, plastic containers (Styrofoam), and PET bottles. Hence, in order to cater to the material needs of plastics, there is a growing development in the plastic industry. It is reported that the continuously growing trend is expected to double in the next 20 years [World Economic Forum 2016]. Given the characteristic that plastic packaging protects the distributing and the end-delivery stage, it contributes a critical role in supply chain management [Bovea et al. 2016]. Especially under the tremendous impacts of the COVID-19, individuals change their living habits to "online shopping style", such as online delivery service food and groceries. From the food catering industry's perspective, the plastic packaging and containers could preserve chemical and physical conditions of food during the purchasing, distributing, and delivering activities [Verghese and Lewis 2007]. Besides, the appropriate packaging could reduce the high levels of food waste; hence, it is necessary to implement packaging management within the food catering industry.

There is no doubt that the plastic packaging and food catering industry brings convenience and ease-of consumption during the COVID-19 situation. However, the "throw-away" society has posed threats to the planet's

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materials and resources because traditional plastic items cause irreversible environmental impacts. Plastic leakage into the environment, and single-use plastic packaging commonly found in oceans and coastal areas [Ocean Conservancy 2017], which bring around 5-13 million tons of plastic items, end up in the ocean. For enterprises, the awareness of environmental concerns, as well as the triple bottom line dimensions of sustainability, are increasingly vital for organizations. In this case, companies should integrate supply chain management with social, economic, and environmental sustainability to better maximize profits and minimize cost.

In this perspective, the implementation of the green supply chain not only aims to minimize the utilization rate of resources but also decrease waste generation through "closing the loop". The green supply chain and reverse logistic call for environment-friendly awareness to cater to the sustainability trend. However, the overview and board perspective about the green supply is missing in the current stage, while the circular supply chain could provide a more comprehensive management system. Besides, the circular supply chain requires innovations from the product design, delivery of the final product, and end-of-life treatments [Cascini et al. 2014], which targets long-term efficient operations and strategies. Hence, this paper will investigate how the circular supply chain mitigates plastic waste in the food catering industry.

This paper will provide a comprehensive view from the perspective of the triple bottom line (TPL): social, environment, and economy to explain the practical implementations of the circular supply chain. First of all, this study starts with the theoretical background and framework related to the plastic industry, the circular supply chain, and the 4R concept. Then, it reveals and defines the research gap for the green supply chain, which triggers the research question. The life-cycle assessment (LCA) methodologies and case studies will be applied in data collection and analysis in sections five and six. Moreover, section seven provides further discussion and recommendations for Singapore to manage plastic waste better. And finally, it comes to a conclusion with the limitations.

LITERATURE REVIEW

The definition of circular economy

In the stage of Industry 3.0 period, organizations and manufacturers implement take-make-dispose, which drives global environmental changes as well as environmental issues such as soil pollution and resource depletion [Northrop 2014]. Those environmental challenges lead to the increasingly critical decline in stocks of raw materials. Therefore, the shortage of raw materials and breakthroughs of high technologies trigger the fourth industrial revolution.

Considering the social impacts, more organizations aim to minimize waste, reduce raw materials, at the same time, close loops within the industrial system. Those potential values could be achieved by implementing a circular economy, which has gained more attention in the last few decades. The circular economy was proposed by several governments and several businesses around the world because it could effectively create economic gains. [Deselnicu et al. 2018]. In this case, the circular economy could be implemented in three levels: macro, meso, and micro-level from countries and regions to the product level. According to McDowall et al. [2017], identify the issues from the international perspective: China and Europe pay attention to different aspects of the circular economy. On the one hand, China's policies aim to mitigate pollution during rapid growth by identifying the challenges. These actions play as the hard action to drive and enforce the undertaking of CE. On the other hand, European countries focus on green product design and resource efficiencies that trigger business opportunities [Yuan, Bi, and Moriguichi 2008].

First of all, the circular economy could be defined as the ecosystem that transfers today's products into tomorrow's raw materials by closing the loop. Secondly, the "zero waste system" is introduced into the CE; therefore, no materials are wasted or underused. In this case, based on these characteristics, this study defines the circular economy as a regenerative system that maximizes the services produced

from natural resources and materials input while minimizing the emission and energy leakage by narrowing and closing material and energy loops. Moreover, CE requires long-term planning and orienting towards economic and environmental impacts [Korhonen, Honkasalo, and Seppälä 2018; Geissdoerfer et al. 2017].

Packaging as a service

In this section will narrow down to the food catering industry, investigating the current packaging waste and the typical types of packaging. Due to the nature of food, the food catering industry could depend heavily on the packaging; hence, contributing to the entire environmental impacts. As this industry creates common value from providers to customers, the food catering industry is regarded as the dominant service logistics (SDL) in this paper [Yazdanparast, Manuj, and Swartz 2010]. During the process, food acts as a type of resource that delivers value to the service. Therefore, packaging could be considered a part of service, preserving the food quality it contains throughout the supply chain processes from production to consumption. In fact, the packaging revolution has integrated with the entirety of the food catering industry.

In fact, there are many types of packaging materials in general use, such as plastics, paper, metals, glass, and multi-material multilayers. Plastic plays a significant role since it takes up more than 40% of the demand. Consider the advantages of plastics: durable, light, and cheap, there are over 30 types of family-use plastics, which could be made in different kinds of plastics products for various purposes. With the expanding use of plastics, plastic production is becoming another challenging issue nowadays. Over the last 50 years, plastic production has surged from 15 million tons to 311 million tons [World Economic Forum, 2016]. Moreover, as predicted, global plastic production will continually double in the next 20 years.

The single-use food and drink plastic packaging could be seen as everyday items in the oceans and coastline from a global perspective. According to the report from the Ocean Conservancy [2017], the overwhelming majority of plastic waste ends up in landfills and finally floats into oceans each year. From the ecological perspective, the widespread use of plastic debris negatively impacts wildlife and the environment at every level, causing irreversible harm to oceans.

Meanwhile, with the increasing environmental protection awareness, 40% of consumers frequently store plastic shopping bags out of habit. However, only 8.5% of stored plastic bags were recycled because consumers could forget to bring them or run into unplanned shopping trips (Edgington 2019). To better understand the significant incentives of plastic usage habits, research has been conducted to investigate how initiatives impact the use, reuse, and disposal of plastics. Martinho, Balaia, and Pires [2017] point out that plastics' tax implementation could lead to a 74% reduction in plastics bag consumption. Meanwhile, the financial incentives and penalties are significant to enhance existing behaviors of plastics reuse. Therefore, the usage of plastic bags dropped more than 90% after the involvement of consumers.

Although consumers' involvement could significantly reduce plastic packaging, no one can deny the significant role of recycling from the manufacturing and retail perspective. First of all, the material flow under recycling refers to reprocessing the plastics into a secondary material for future plastics generation, reducing plastic waste [Geyer, Jambeck, and Law 2017]. At the regional level, more countries realized the importance of recycling plastics. For all Europe 28 states, the material recycling rate was around 42%. Some specific goals urge more recycling processes and innovative plastics products: all plastic packaging should be reusable or recyclable in a cost-effective way by 2030 in the EU market [Foschi and Bonoli 2019]. However, compared to the EU, Japan's material recycling rate is around 23%, becoming a significant concern [Yolin 2015]. Thus, authorities promote the development and usage of petroleum-based plastics substitutes, cumulating a 25% reduction of single-use plastic waste by 2030. Meanwhile, call for higher utilization of reusable and recyclable design for packaging products: 100% effective use of circular

economy measures by 2035 [Japan Environment Quarterly 2019].

Research gap and research question

In all, the circular economy, together with the green supply chain and reverse logistics, is increasingly taking up the dominant stream within the supply chain management (SCM). Existing literature reviews have emphasized that the circular economy could be an effective method to reduce the negative impacts towards the triple bottom line (TPL) through implementing the 4R concept into operation management. Moreover, no one can deny the significance of plastic packaging's in the food catering industry: reducing food waste from physical and chemical damage. The 4R concept (Reduce, reuse, recycle, and recover) illustrates the benefits of applying the 4R concept and clarifies the challenges and issues towards different methods from both the macro-level and individual level.

Moreover, many academic papers evaluate waste management practice, including recycling and new types of bioplastics in developed countries. It is proven that those methods trigger the process of closing the loop and the green supply chain. While the recycling statistics of waste management are available in other developed countries, there are limited numbers of studies analyzing current plastic waste management challenges in Singapore [Van Eygen, Laner, and Fellner 2018]. Considering Singapore's geographical factor, most sorted recyclable plastics were discarded and exported after the first use. It is estimated that among 95% of discarded plastic value for around 157 billion SGD in 2018. Besides, the recycling rate dropped from 11% to 6% between 2013 to 2017, which holds excellent value without effective recycling [Singapore Environment Council 2018]. To sum up, plastics recycling management is relatively underdeveloped in Singapore. Given that the poor waste management towards plastics packaging could lead to a high social, economic, and environmental loss, plastic waste management could still benefit the food catering industry until a better plan of the 4R concept. In this case, the research question is defined as "How the circular economy helps mitigate the plastic waste in Singapore, considering the triple bottom line?"

RESEARCH METHODOLOGY

According to Yin [2014], there are three main types of case study: exploratory case study, descriptive case study, and explanatory case study. In order to better explain and explore plastics waste strategies, this paper combines these two types of case studies based on the explanatory and exploratory case study characteristics. Meanwhile, the explanatory case study aligns with the life-cycle assessment to investigate how and why the circular supply chain could help address the plastic waste's pressure on the environment. Life cycle assessment (LCA) can be used to quantify each component of plastics' environmental impacts from raw material extraction to end-of-life. This internationally acknowledged assessment specifies the impacts on climate change, human health, ecosystem quality, and nonrenewable resources.

In this sense, the exploratory case study's application promotes a theoretical circular supply chain system to address plastics waste based on practical strategies. Based on the case studies and target sampling, the study aims to make a horizontal comparison and observe the methodical view within the circular supply chain. Considering different degrees of economic development, this paper aims to collect data from developed countries: Germany and South Korea. The next section undertakes the target sampling method that implicitly represent the "developed" and "Asian country" characteristics of all the countries in the world. Therefore, it could imply the effective plastic management system and actions for the plastic waste management in Singapore.

First of all, it begins the data collection from European Union and Germany data because the EU was the first region to implement circular economy practices in 2015. Besides, the EU has obtained huge benefits and returns in terms of plastic waste management so far. Moreover, among the 27 member states, Germany has the highest demand for plastics while maintaining the EU's highest plastic

recycling rate, which worth investigating into the circular supply chain system. After that, this study narrowed the scope to the target country: South Korea. Among Asian countries, South Korea ranks as one of the five best countries with the best plastic management, while others are all European countries. In this case, it makes sense to compare to Germany, South Korea, and Singapore because these countries are all developed countries with strong environmental awareness. In the end, the target sampling contributes to the findings because it analyzes the plastics waste management in other developed countries, which helps to generate a mature framework and system for plastics waste management.

DATA COLLECTION AND ANALYZE

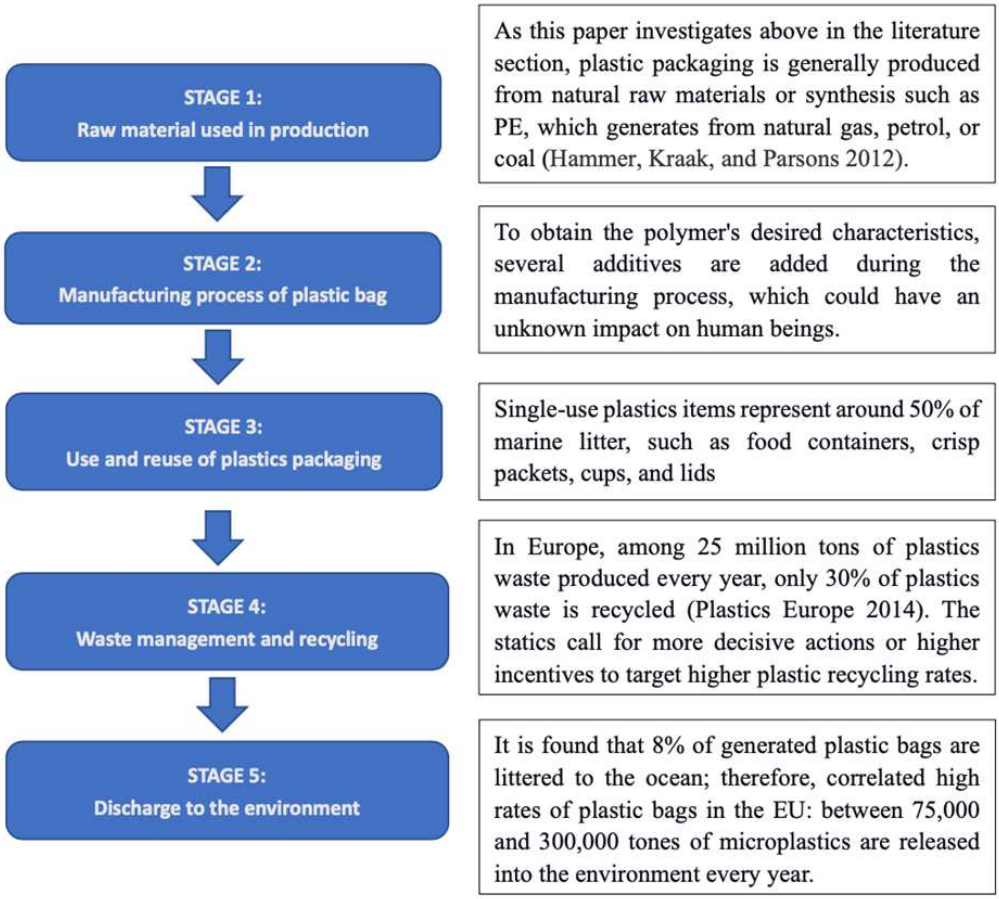
The plastic waste management in the EU

In 2017, plastics production worldwide reached 348 million tons compared to 2018; it increased to 359 million tons. While the global plastics production developed rapidly, the plastics production in Europe decreased from 64.4 million tons, representing almost 17% of the plastics production. It is a significant achievement that the EU has controlled plastics' demands and mitigated the negative impacts on the environment through the circular economy action that was enforced in 2015. In the EU, post-consumer plastic packaging waste is included in the mixed municipal solid waste (MSW) for compatibility among different countries. In this case, the MSW is defined by Eurostat as waste from the same or similar sources produced from the household (majority), commerce, office, and public institutions [Dahlbo et al. 2018]. In Europe, the packaging industry takes up the most sectors in plastics demand, around 39.9% share in 2018, and per capita, plastic consumption in Western Europe is approximately 100kg/year. Meanwhile, most plastic packaging is discarded after the first use, which leads to a short service life of plastics and ends up contaminating the environment [Commission of the European Communities 2020].

On the one hand, plastic waste could bring a tremendous irreversible impact on the environment and human beings because it could break into microplastic and leak into the ground. Therefore, it is significant to realize that the 3R concept could reduce plastic waste, especially "recycling". Although the average recycling rate (30%) is higher than other continents, the recycling rate varies differently between EU countries. For example, Germany has the highest demand and the highest recycling rate at 56.1%, while Romania's recycling rate is 5% [Zero Waste Europe 2018]. Meanwhile, the after-use activities related to recycling plays a significant role in reducing plastic waste in the EU. According to the report, only around 32.5% of collected plastic post-consumer waste is recycled for another use, while 42.6% is incinerated for energy recovery, and 24.9% ends up landfilling [European Commission 2020].

On the other hand, Europe's plastic industry creates more than 1.5 million jobs for citizens and brings around 350 billion turnovers annually. As [European Commission 2020] mentioned, innovation, digitization, and decarbonization are the three main factors leading the plastics industry to be stronger and more competitive worldwide.

In this case, plastic brings more benefits to human beings than damage to the environment if every part of society takes their responsibilities. In other words, the growing concern for resource-efficient and circular economy promotes sustainable and green product policy initiatives. The core of this policy aims to widen the eco-design beyond energy-related products: make it deliver on circularity. The next section will apply an incremental approach: life-cycle assessment (LCA) to assess a plastics bag's steps considering the European production, use, and particularly legislation. There are five stages to better identify the major activities during the lifecycle of a plastic bag: raw material for production, manufacturing phase, use and reuse, waste and recycling management and discharge to the environment.



Source: own work

Fig. 1. Five stages of life-cycle assessment in the EU

According to the plastic life-cycle assessment outline, it could be divided into two major processes: upstream (including production and transportation) and downstream (including use, reuse, recycle, and reproduce). Within the LAC analysis, the circular economy asks organizations and authorities to lay more attention to the downstream section; therefore, achieving sustainability and a circular supply chain. Here are the policies and strategies that the EU has applied in the last few years:

- Targeted policies: Circular economy package
- Apply the EU waste framework directive to clear the priority
- Set measurable targets for stakeholders

As the EU is in the leading position towards plastic waste management, it receives respect to its policies for achieving specific targets, including reducing, reuse, recycling, and recovery. Consequently, according to the circular economy package, at the end of this year, the target is set for 45% recycling (in 2020); at the same time, targets for MSW recycling and reuse rate is suggested to reach 65% by 2030 [Zero Waste Europe 2018]. According to the European Commission [2018], the crucial step to enhancing the alternatives is stimulating eco-design packaging. The mandatory goal is achieving 100% recyclable plastic packaging by 2030, encouraging consumers' behaviors to utilize better compostable and biodegradable plastics [Foschi and Bonoli 2019]. Also, there is a five-step framework that shows the "waste hierarchy" in the EU. According to the priorities, the waste framework directive shows the importance of (i) Prevention, (ii) Preparing for reuse, (iii) Recycling, then it considers (iv) other recovery and (v) Disposal. This waste framework aligns closely with the 4R concept

and extends packaging waste, which helps guide the EU member states to achieve the circular economy [UNEP 2019]. With the instruction of the targeted policy, measurable and specific targets encourage the improvement of recycling infrastructure. It also regulates the product design, production, and transportation activates through the extended producers responsibility (EPR) system. Since the packaging levies are part of the EPR system, it could help reduce the production and disposal waste of plastics packaging; finally leads to greener plastic production.

Plastic waste management strategies in Germany

As the largest producer of plastic in the European countries, Germany has the leading plastic industry with sales of EUR 92 billion; thus, providing not only innovative plastic products but also job opportunities domestically. Instead, with the highest demand (25%) of plastic within the EU countries, the recycling rate in Germany is amazingly high at 56.1% (OECD 2018)

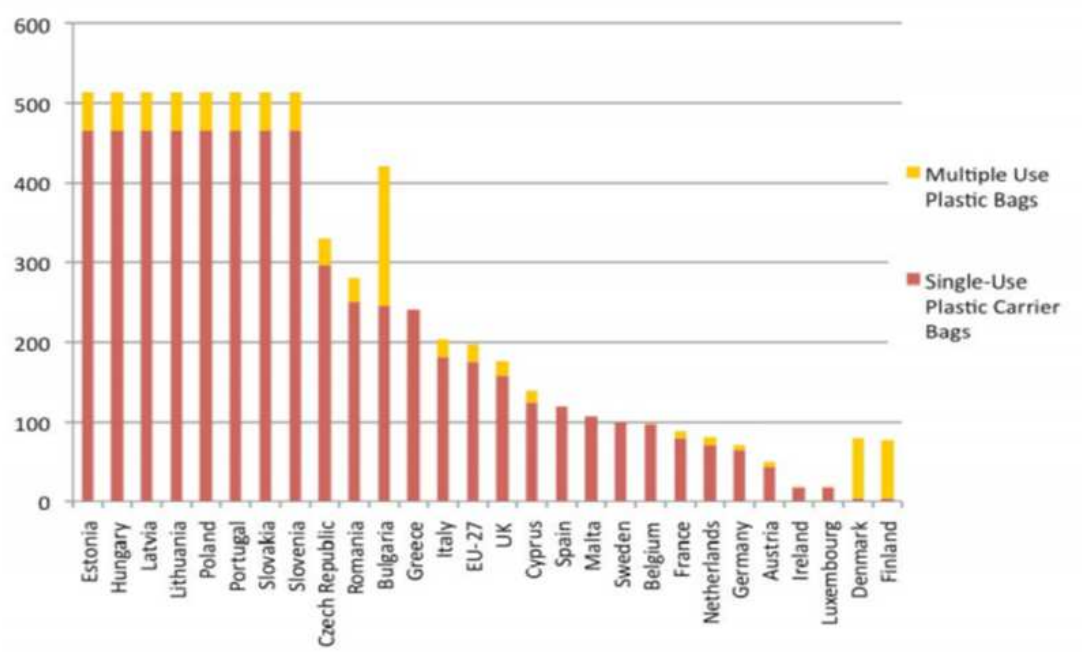
Becoming the world innovation leader: from raw material to R&D

In order to grant the high technological standard, the plastics value chain in Germany encourages universities, companies, and other institutes to contribute to the research and development of sustainable and green plastic items.

Plastic innovative cluster to attract more investors

There are different types of knowledge transfer in Germany to provide onsite services and utilities: innovative plastics industry networks, specialized chemical parks, and go-cluster. Those creative clusters trigger the world-class knowledge transfer and help to maintain the leading position of innovation leader. Moreover, the German government provides funds to support new production or R & D activities by reducing eligible investment costs.

Incentives for citizens to call for greener plastic usage habits



Source: Barbière [2015]

Fig. 2. Plastic bag consumption among the EU members

From the perspective of the EU countries, plastic using habits vary significantly within different EU member states. Some countries lead the consumption rate of more than 450 bags per person because citizens undertake single-use plastics more often, such as Estonia, Hungary, and Latvia [Barbière 2015]. Conversely, some countries such as France and Germany rely more on multiple-use plastics packaging leading to a lower consumption rate below 100 bags per person [European Parliamentary 2017].

In Germany, manufacturers created "the Green Dot" system (in 1991) to increase the recycling rate, which aims to collect waste from households and businesses. "The Green Dot" system is required by legislation and calls for valuable raw materials pick up from produced plastic products; hence, enhancing the circularity of plastic items and recycling rate [Baughan and Evale 2004]. Also, it is reported that citizens' awareness and various actions can significantly reduce plastic waste through reuse, reduce, and recycle practices. The self-motivation activities such as "say no to plastic products", "minimize the use of plastic items", and "use bioplastic products" could help to shift from antagonist to agonist behavior [Cecere, Mancinelli, and Mazzanti 2013].

The plastic waste management in Asia

In fact, no one can expect a world without plastic because plastic has become a significant part of today's society. Therefore, large-scale production has increased since 1970: from 35 million tons to 381 million tons in 2015; at the same time, half of the generated plastic was produced in recent 13 years. Compared to plastic material production in Europe, China alone accounts for more than 27% of the global resin. In this case, the Asia area, including Japan, South Korea, and other SEA countries, take up to 48.8% of all. In this case, the plastic waste in Southeast Asia is becoming the most concerning issue to the ocean environment: threatening wildlife.

The severe plastic pollution in Asia could be blamed for the high demand and inappropriate use habits during the consumption and end-of-life stage. Asia's majorities are developing countries without data technology and public awareness, so the data and statistics greatly vary between Asian countries. Moreover, considering the population and land area, some states could generate a tremendous amount of plastic in total. Still, when measuring the capita consumption per day, they could have lower numbers than other countries, such as China and Japan. According to the report, among the Asian countries, China, with the largest population in Asia, produces nearly 60 million tons of plastic annually, followed by Japan at 7.99 million tons in 2010 (Jambeck et al. 2015). However, the most effective way to measure plastic waste in different countries is the annual consumption per capita. Five states represent the typical cases, and Malaysia is highest among these five countries: 73 kilograms annually per capita, followed by Singapore at 69.35 kilograms, Japan at 62.05 kilograms. Meanwhile, the statistics in China and South Korea are relatively low compared to other countries: China generates 43.6 kilograms of plastic waste, and South Korea generates 40.15 kilograms per capita [Jambeck et al. 2015].

After the production and the consumption phase, the states about plastic end-of-life directly determine if it becomes waste or raw material; therefore, the recycling rate is the key point to measure. Compared to the European Union, the recycling rate in the Asia area is significantly lower: only 9% of plastic is recycled, which means around 79% of plastic (8.3 billion tons) leak into the environment. This phenomenon is blamed not only for the economy and the manufacturing industry of the developing countries but also for poor waste management policies and strategies. From the food catering industry's perspective, the majorities of plastic waste are Styrofoam and PET bottles. According to the news, it is said that the recycling rate of PET bottles in Asia only takes up to 54%, while Asia-pacific is the fastest growing market. Many reasons are resulting in the low PET recycling rate: poor packaging design, collection coverage, and accessibility [Green Queen 2019].

The plastic waste data and management in South Korea

Plastic packaging related to the food industry, such as beverage bottles and snack bags, accounts for 82% of total waste in South Korea, easily found on coastal lines [Jang et al. 2020]. With the development of the single-housing family trend, the food catering industry in South Korea is expected to increase, and it also results in higher demand for plastic packaging. Four essential elements significantly impact plastic waste in the food catering industry: consumption amounts, consumption frequency, the sales of products, and the number of fair deliveries in South Korea. This section will estimate plastic consumption that is commonly applied in plastic packaging, such as PET drinking bottles, single-use plastic cups and bags, single-use plastic containers, and cutlery for food delivery. The statistics released by the South Korean government report that based on these four items, the annual plastic demands reach around 637.7 units resulting in 602,900 tones of single-use plastic waste.

The demand for plastic material has been increasing during the last ten years of its outstanding physical properties in daily life. Throughout 2010-2018, the domestic market for plastic risen from 5.1 million tones to 6.5 million tones. As of 2018, the primary demand for plastic or synthetic resins in South Korea is PP, followed by PVC, LDPE, and HDPE. In South Korea, most manufactured plastic was used for packaging and containers: 2.7 million ton and represent 46.5% of the whole plastic production rate, while the second large section is building and construction (1.4 million ton, 24.7%). After the production and consumption stage, it is found that households could be the second-largest fraction source generating disposal bags and recyclables. Specific departments could separate recyclables from families such as food waste, plastic vinyl bags, and multi-layer films at South Korean authorities. However, the material flow analysis shows that the plastic recycling rate in the case of household waste was calculated by only 13%. Compared to the EU's plastic recycling rate (30%), it is considerably lower in South Korea. The deciding reasons underlying behind are that low economic benefits in sorting and recycling, low quality of mixed plastic waste, especially limited demands for recycled products from the upstream.

In order to enhance the efficiency of plastic material flow, South Korean authorities encourage both individuals and enterprises to take action. From the citizens' perspective, in the disposable stage, those non-recyclables are paid by households based on their weight, which is known as pay-as-you-throw (Miafodzyeva and Brandt 2013). It is proven that income and "pay-as-you-throw" has a positive impact on willingness to pay (WTP) regarding different types of housing (e.g., apartment) [Lee and Paik 2011]. Hence, those plastic products are collected at collection centers by the local government for better waste management. In general, those disposal bags were treated by shredding, sorting, and separation to recover material resources before incineration or landfilling. From the perspective of plastic producers, they are regulated by the extended producer responsibility (EPR) system, including manufacturing processes of PET bottles, foamed resins, and other synthetic resins [Jang et al. 2020; Kim and Mori 2015]. With the EPR system regulation, manufacturers must collect and recycle the specific quantities assigned to the long-term recycling target. Be members of the South Korea Packaging recycling Cooperative or producer responsibility organization (PRO); producers fulfill their obligations by collecting and recycling waste from plastic products or contributing fees to the PRO. In this case, the EPR system encourages manufacturers to increase the recycling rate and triggers the circular economy; otherwise, those who fail to achieve the recycling target have to pay a fine more than recycling.

The picture shows the recycling system for packaging waste regarding material, funding, and reporting flows in South Korea. Compared to the supply chain management: information flow, material flow, and cash flow, the reporting flow of the EPR system not only plays the role of information but also is regarded as the decisive political oversight to encourage the plastic recycling system.

At the current stage, the EPR system relies heavily on the manufacturers' contribution: intensive labor works towards sorting and separation methods. Although the development of the EPR system since 2003 has been nurtured, the poor working environment, low quality of recycling products, and fluctuations in the overseas recycling market still pose significant challenges to the recycling system in South Korea. Hence, it is urgent to develop and apply modern technologies to the plastics recycling industry. Moreover, expanding the investment of green plastic products such as bioplastic also triggers the current plastic waste management.

Current plastic demand in Singapore

Singapore is a developing country located in Southeast Asia, heavily relying on imported materials regarding food, daily consumer products, and an incredible number of plastic products. It is because plastic plays a vital role in everyday life, and there is a great demand for plastic: people in Singapore use about 1.76 billion plastic items annually. Since living and using habits drive plastic usage, plastic items' need includes 820 million plastic bags from supermarkets, 476 million PET bottles, and 473 million plastic takeaway containers [Singapore Environment Council 2018]. To be more specific, according to the fact that citizens take 2 to 4 plastic bags per trip to the supermarket, plastic bags' land areas equal 126 Gardens by the bay. Also, the consumption of PET bottles in Singapore is three times the landmass of Sentosa island. In fact, the generated waste in Singapore has substantially grown during the last few decades, from 1970 to 2017. There is a sevenfold increase in disposal waste: 1,260 tons per day to 8,443 tons per day (Singapore Environment Council 2018). Moreover, the majority of solid waste is plastic waste, including PET (bottled water), plastic bags, and Styrofoam. It is estimated that 95% of plastic waste consumption still holds a high economic value of SGD157 billion.

However, with only one landfill option in Singapore, most plastic wastes were incinerated at 4,320 tons per day, leading to a low recycling rate of plastic. The plastic waste recycling rate dropped from 11% to 6% between 2013 and 2017 (Singapore Environment Council 2018). It is not only to blame the poor waste management in Singapore, but it is also worth noticing that the ban on imported plastic in China also results in a low recycling rate. The poor waste management strategies such as incineration and landfill could cause irreversible damage to the environment as well as the loss of energy for next stage production. According to the report released by Singapore Environment Council (SEC), the usage of "single-use" plastic could be the biggest problem in Singapore because they provide a few minutes of convenience but pose significant threats to the environment after use.

Comparison between the EU, Asia; Germany, South Korea, and Singapore

It is obviously shown above in Table 1 that plastic consumption and recycling rates vary differently between the EU and Asia. First of all, the difference could be mainly explained through development: the majority of the EU members are developed countries with higher education levels. It is reported that the higher education level encourages more innovative technologies [Szopik-Depczyńska et al. 2020]; therefore, businesses can better recycle and recovery from plastic waste. In this case, the current plastic recycling rate is about three times higher than the recycling rate in Asia. Moreover, the EU has a common goal shared among members that could lead to a better waste management system, such as the Waste Framework Directive 2008/98/EC (WFD). However, compared to the EU, Asian countries focus more on their development; thus, the ASEAN region and Asia-Pacific have minimal reports about plastic waste management. Also, considering the different political structures and geographical factors, setting the shared targets for countries is meaningless. Finally, since the plastic industry is snowballing in the Asia market, no one can deny the importance of plastic waste management in Asia. Indeed, some countries, such as Japan and South Korea, are leading the position to manage plastic waste while taking advantage of plastic packaging.

Table 1. The comparison (plastic consumption and recycling management strategies) between the EU and Asia

	Plastic production	Plastic consumption	Recycling rate	Recycling	Plastic production
The European Union	359 million (t) 17 % of the world	100 kg/year/capita	30%	Reach 65% by 2030	Produce 350 billion tones each year
Union	381 million (t) 48.8% of the world	25 kg/year/capita	9%	Vary differently	The fastest growing market

Source: own work

Table 2. The comparison between Germany, South Korea, and Singapore

	Plastic industry	Recycling rate	Strategies
Germany	Sales: EUR 92 billion	56.1%	- Encourage innovation - Incentives for more investors - Incentives for greener usage habits
South Korea	Demands: 6.5 million tons	53.7%	- Enhance public awareness and WTP - Extended Producer Responsibility
Singapore	1.76 billion plastic items annually	6%	Refer to the recommendation section

Source: own work

In Table 2, the plastic industry brings not only financial gains but also environment-friendly benefits in both Germany and South Korea. These two developed countries were fully aware of the environmental damages that plastic waste could bring and call the joint efforts from authorities, enterprises, as well as citizens to take their social responsibilities.

Key challenges in plastics waste management for Singapore

First and foremost, the EU aims for 90% recovery of single-use plastic items by 2025, at the same time, switching the plastics usage habit to reusable plastic packaging by 2030 [European Commission 2018]. Besides, there are policies to stimulate producers for the eco-design in packaging, for example, using bioplastic. The eco-design not only adds social value to the plastic items but also encourages consumers to behave in a more responsible way [Filho et al. 2020]. Secondly, it can be observed from the strategies from South Korea that the high recycling rate was driven by the framework: "Comprehensive Measures for Plastic Waste Recycling Management". The South Korean governments set the recycling target to 70% by 2030 while expanding green manufacture by increasing the number of products from 43 to 63 in the EPR system. In this sense, it is found that under the supervision of the government, laws and regulations are a powerful driver for plastic waste management.

To sum up, analyzing the strategies from the EU and South Korea, both the upstream and the downstream play a crucial role for the success of plastics waste management. Policies and strategies implementation, as well as priorities settings, are the driving factors undertaking to reduce, recycle, and recover strategies. While the consumer's environmental awareness and plastic usage habits could bring practical impacts at the purchase and disposal phase; hence, triggering the reduce and reuse strategies. With the joint efforts from upstream and downstream, the implementation of better plastic waste management could speed up the transformation from a linear supply chain to a circular supply chain.

As Singapore targets the "Zero Waste Nation", the government designated the "zero waste" in 2019 to call for less consumption of materials through reuse, recycle, and recovery [Towards Zero Waste 2020]. Meanwhile, the circular supply chain, including the prevention of waste, recycling, and recovery of plastic items, is complex to undertake because it involves the whole lifecycle of plastic. All in all, there are challenges and opportunities under three main stages: production, consumption, and distribution that require profound changes. As compared to the European countries as well as some developed countries in Asia, the low recycling rate (7%) and the throwaway culture of plastic could be the biggest barrier to "zero waste". First of all, the low recycling rate could be blamed for

consumer habits and overpackaging. The weak environment-protecting awareness results that people are used to over-packaging food in the hawker center and delivering food with many plastics layers. Although those single-use plastic items could bring great convenience and physically protect the food during the distribution and transportation stage, untreated waste plastics could damage the Earth. Secondly, Singapore's low recycling rates could be attributed to the lack of awareness about the types of plastic that can be recycled. For example, about 70% of respondents are not aware of different recyclable plastic types, while only 45% of respondents could assess useful information about different types of recyclable plastic in Singapore. Thirdly, the improper recycling technologies and infrastructure result in municipal landfills and dumps. Hence, the lack of recycling technologies makes only 2 percent of recycled plastic products maintain the same quality, causing potential health concerns when recycled plastic is in contact with food [Packaging Europe 2017]. To sum up, the limited environmental awareness for recycling results in the low plastic recycling rate in Singapore.

Moreover, the lack of market demand is a hidden problem in the current situation. Since human beings take advantage of the fossil fuel economy, although the oil price could impact plastic's price, the raw materials are cheap for manufacturing [The Ellen MacArthur Foundation 2017]. In particular, there is a typical scenery of mixed or dirty plastics, which leads to a low recycling rate because they cannot be recycled through current mechanical tools. In this case, the cost of recycled plastic products is higher than traditional plastic, which leads to low demand for recycled plastic. Finally, the most significant barriers that stop the development of plastic waste recycling are economic issues. The research and development cost of bioplastic takes up a generous share of investment; hence the higher economic factors make it difficult to be competitive as conventional plastic [Hopewell, Dvorak, and Kosior 2009].

RECOMMENDATIONS

Policy instruments towards an effective waste management system

Redesign the waste management system could be a strong and effective action to raise Singapore's plastic recycling rate from 7% to the EU's 30% standard. With the right information and knowledge about plastic waste management, effective governance could encourage manufacturers to create a conducive environment and call for responsibilities for the environment and society. Meanwhile, policies could regulate the behaviors by reducing disposable containers and packaging and improved the collective and recycling of used plastics. Singaporeans should introduce more stringent policies to contribute to the reduction of single-use plastic and increase the recycling rate. In fact, according to the NEA, the ministry did not implement the mandatory levy on plastic bags because plastic bags are used for responsible and hygienic bagging [Tan and Boh 2017]. However, it is observed that the policy "ban the banning" could be an effective solution to reduce the plastic in supermarkets to 60-80% after the Chinese government banned non-bioplastic [Walker and Xanthos 2018].

For example, the Japanese government adopted the "Resource Circulating Strategy for Plastic" in 2019 to clarify the specific goals: enhance the effective utilization to 100% of used plastic items by 2035. Moreover, South Korea also implemented a set of policies to regulate plastic using habits: increasing the recycling rate to 70% by 2030 [Korea times 2018]. However, only a few countries have laws to prevent packaging and packaging waste. Thus, from the board view, authorities should provide a specific framework, practical tools, technologies, information as well as obligations carried by general laws.

Enhance social awareness and public pressure

It is proven that education levels have positively correlated with the policy effects, and there are many leading countries adopting regulations and policies to control plastic

waste. "Bag leakage: The effect of disposable carryout bag regulations on unregulated bags". Public awareness and education are essential to shape and trigger the shift from the traditional economy to the circular economy. Be aware of the throwaway culture of plastic usage in Singapore; authorities could also ask the corporation with the food industry and consumers through mandatory reports and legislations. Governments can apply strategies to persuade and educate the citizens in a wide range, such as public videos and school and youth events. By these practices, individuals are more aware of reuse and recycling plastic resources; at the same time, taking their responsibilities to minimize plastic waste. Also, in order to prevent the overuse of single-use plastic items, plastic products that are difficult to recycle should be banned or phased out in the food restaurant or food catering industry. Then, after the consumption stage, a sustainable approach to control the plastic recycling rate is tackling the excessive consumption of plastic disposables in Singapore. According to the NEA report, most of the respondents are willing to reuse and recycle plastic products if they have information about recyclable plastic. Hence, authorities should provide more details on recycling plastics and improving the accessibility to recycling facilities. The plastic waste could be easily collected through the well-designed recycling infrastructure within the circular supply chain, which makes "plastic logistics" more viable.

Promote the eco-friendly alternatives

In Singapore, the limited market for recycled products is the hidden issue under the high volume of plastic waste and low recycling rate, which results from the small market demand and high cost of eco-friendly alternatives. In order to shift from fossil-based to bioplastic and trigger the development of bio-based plastic, the government should limit fossil-based activities (Kakadellis and Harris 2020). Considering the limited recyclability and degradability of bioplastic, authorities should also encourage the necessary infrastructure to provide effective bioplastic waste management, at the same time, promote the use of bioplastic [Arikan and Ozsoy 2015]. Compared to the traditional plastics, the eco-friendly alternatives have many advantages: lower carbon footprint and non-renewable energy loss. Although the bioplastic cannot benefit the micro-enterprises because of the high financial cost, it could still be applicable in macro-businesses. By introducing economic incentives, MNC would take its responsibilities to use more recycled plastics items, for example, Coca-Cola and Unilever.

Lastly, the implementation of the circular supply chain in Singapore calls for joint efforts from the consumer level (downstream) and upstream. Findings from the recommendation part show that the circular supply chain could definitely benefit the environment because it triggers the non-reusable energy reduction recovery during both production, consumption, and collection stage. Secondly, from the manufacturers' perspective, the circular supply chain strategy for plastic production would positively impact enterprises because enterprises cater to the sustainability trend and contribute their efforts to make the living environment better. Finally, although the circular supply chain would bring a higher cost in the short run, it could benefit the company in the long run.

CONCLUSION AND LIMITATIONS

As this paper has shown, although plastic is a useful and valuable product in daily life, it generates wastage and cause environmental pollutions. Especially under the COVID-19 situation, the plastic industry's incredible growth due to online sales brings severe environmental impacts during the production and the disposal stage. Thus, it is important to implement the circular supply chain into plastic waste management by minimizing the natural environment's pressure and maximizing society's profit and reputation. In other words, this study's research objective is to investigate effective practices to avoid the negative impacts of plastic waste while taking advantage of plastic packaging to make daily life more convenient.

This paper applies the life-cycle assessment (LCA) and the case study to analyze the current situation and the strategies in the EU, Asia, Germany, and South Korea. From the

case studies, it is found that regulation, policies, and extended producer responsibility (EPR) system in the upstream, together with the citizens using habits and environmental awareness, could help Singapore achieve the plastic waste management goal. Based on the examples of the waste management strategies in Germany and South Korea, the implications and recommendations of the study are threefold. First of all, regulation and policies could be an effective method to enhance public awareness and promote bioplastics development. Secondly, from the perspective of producers, although the cost of bioplastic and recycling management is higher than conventional plastic, the circular supply chain will benefit the organization in the long run. Hence, the EPR system is a vital but practical tool to regulate the product design's environmental impacts on the end-of-life stage. Finally, the downstream recycling efforts also promote Singapore's recycling rate through the end-of-life stage, such as the Bring Your Own (BYO) campaign.

Although this paper provides some useful solutions and tools for better plastic waste management practices in Singapore that are mere consideration of the triple bottom line (TPL), it still has some limitations. First of all, there is only little data that can be collected about the current plastics' situation in Asia. Because in Asia, regions or non-government organizations have not paid as much attention as compared with the EU, and most of the reports about the plastic waste are out-of-date. Secondly, this study refers to the strategies and policies undertaken in Germany and South Korea but more studies can be done with more countries for comparison.

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ŁAŃCUCH SUROWCÓW WTÓRNYCH JAKO SPOSÓB NA OGRANICZENIE ODPADÓW PLASTIKOWYCH W SINGAPURZE

STRESZCZENIE. **Wstęp:** COVID-19 zmienił nasz styl życia i wpłynął na drastyczny wzrost zakupów dokonywanych on-line, co z kolei związane jest ze znacznym wzrostem użycia opakowań plastikowych. Z tego też powodu zagadnienia gospodarki odpadami plastikowymi zdaje się być coraz ważniejszym tematem w wielu krajach. W pracy proponowane jest rozwiązanie zamkniętego obiegu opakowaniami plastikowymi na trzech poziomach: ekonomicznym, społecznym i środowiskowym. Jest to powiązane z zarządzaniem cyklem życia (LCA).
Metody: Zebrano i poddano analizie dane dotyczące odpadów plastikowych, obejmujące produkcję, konsumpcję oraz cały cykl życia w krajach rozwiniętych. Poprzez porównanie stosowanych praktyk w Niemczech i Południowej Korei stworzono ramy wdrożenia koncepcji 4R: redukcja, ponowne użycie, recycling i odzyskiwanie surowców wtórnych.
Wyniki i wnioski: W pracy zaprezentowano nowe spojrzenia na zamknięty łańcuch dostaw z punktu widzenia rządu, producentów oraz konsumentów oraz zwrócono uwagę na istotność uwzględniania możliwości przemysłu wyrobów plastikowych (co wymaga zaangażowania zarówno ze strony rządu jak i konsumentów) a nie tylko oczekiwań konsumentów.

Słowa kluczowe: łańcuch dostaw surowców wtórnych, zarzązanie plastikowymi odpadami, zarządzanie cyklem życia, koncepcja 4R, potrójna linia dolna, bioplastik

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