Review

A Review of Future Household Waste Management for Sustainable environment in Malaysian Cities

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Abstract: In recent years, Malaysia has faced environmental challenges caused by municipal solid waste, especially household waste, during the Covid-19 pandemic. Among all the household waste, plastic and paper are the most prominent waste that causes environmental hazards. Several recycling associations in Malaysia have carried out their practices for better waste sustainability and management to curb the increasing amount of household waste. However, the effectiveness is still vague in achieving smart and effective household waste management. Therefore, this paper aims to investigate Malaysia's household waste management, mainly in three significant municipalities in Malaysia for Kuala Lumpur, Penang and Melaka, in becoming a resilient and sustainable city by addressing two main research questions 1) What are the key factors for ensuring the more success move for future household waste management in cities? and 2) How will the 3 municipalities address their waste issues based on the key factors from RQ1, respectively? This paper reviewed 13 waste management articles and explores the potential of the four factors of waste management from the perspective of technology and data, economy, social and governance. The discussed factors and models contributed to an integrated future-proofing framework that focuses on smart waste tracking, an gamified awareness education, and strict policies to control waste management are the way forward for the future of smart cities household waste management.

Keywords: Household waste, household waste management, sustainable city, integrated waste management model, Malaysia cities.

1. Introduction

Municipal Solid Waste (MSW) is the waste generated, collected, transported, and disposed of within the jurisdiction of a municipal authority (Periathamby, 2011; Organisation for Economic Co-operation and Development (OECD), 2021). For example, MSW generally consists of biodegradable (food, paper, organic waste), non-biodegradable (plastics, metals, polystyrene foam), hazardous materials (oil, batteries, paints, e-waste) or construction waste (Public Health Solutions, 2017; Department of Environment Malaysia, n.d.). The management of solid waste is the most significant task facing by the authorities in developing nations' small and major cities, and the municipal waste managing budget has increased due to the increasing generation of such solid waste. Household waste, which the 'garbage' or 'trash' generated by the domestics, contributes to part of the MSW. The world currently generates 2 billion tons of household waste per year, containing more than 60 tons of waste every second (The World Counts, 2021).

According to Rahman et al. (2020), an estimation showed Malaysia would generate more than 25,000 tons of household waste per day as the urbanization and population increase rapidly. The increasing amount of unmanaged household waste that consists of kitchen, organics, and inorganic components that emit Greenhouse gas (GHS) (Boldrin et

al., 2009) have led to climate crisis like an amplification of extreme weather and directly linked to severe flood, e.g., Zhengzhou's flood that causes damage to 9,000 homes or equivalent to the loss of 2 billion USD (United Nations, 2021). Malaysia's flash flood declared by the country's government as a "once in a century disaster" caused eight states to lose their homes and affect more than 125,000 people. That happened during the year 2021 is also affected by climate change, and it has one of the worst ecological footprints in ASEAN (Kua, 2021). Align with the ecological footprint, Malaysia's plastic production due to burning had caused a high carbon emission reaching 860 million tons in 2019 and was more significant than the sum of Thailand, Vietnam and the Philippines (WWF, 2020; Reuters, 2020). Besides, inappropriate single-use plastics waste management are also the main cause of microplastic pollution, which will cause widespread plastics particles into the drinking water, food and diet (Ma et al., 2020; Rocha-Santos & Duarte, 2015). Due to these statistics, Malaysia's household waste management has to be improvise to avoid or reduce the occurrence of such natural tragedies.

Subsequently, this study issues 2 research questions. 1) What are the key factors for ensuring the better move for future household waste management in cities? and 2) How will the 3 municipalities of Malaysia cities address their waste issues based on the key factors identified from RQ1, respectively? This paper starts with a literature review on household waste management in Malaysia. Next is the explanation of article review method / steps. From the review findings, four key factors are identified and Malaysia waste management practices for the 3 municipalities are discussed, followed by the proposal of an integrative framework of Future-Proofing Waste Management Model for Malaysia and lastly, the discussion and conclusion.

2. Household waste, waste management and its impact on the environment in Malaysia

Household waste is waste that is generated from residential environment, it contains of household daily disposal in any type of material and also known as domestic waste. Managing household waste including waste collection, transportation, and treatement. It is a global problem, whereby circular economy and recycling have to be promoted (Wang, 2014; Rousta, 2019).

Among all types and categories of household waste, plastic is ranked as the third-largest waste contributor globally due to its functionality and versatility (Chen et al., 2021). The world produces more than 400 million tons of plastics every year. The recent data estimated that only about 9% of the world's plastic waste had been recycled, whereas most of the plastic waste (79%) is dumped in the landfills or open environment, followed by 12% incinerated (UNEP, 2018). Malaysia is ranked 8th among the top ten countries globally due to the mismanagement of plastic waste (an estimated 0.94 million tons were produced) (MESTECC, 2018). According to Penang Green Council (2020), the challenge arises in Malaysia, where the penetration for petroleum-based plastics is much more affordable for consumers than bioplastic production due to its higher cost from renewable resources. Hence, it was suggested that the government issue a clear guideline on the types of bioplastics that can be traded and utilized in Malaysia, which minimizes the carbon footprint and the wastes that can be biodegraded safely back to the environment (Penang Green Council, 2020).

According to UNEP (2018), nearly 40% of plastics produced globally are commonly used for packaging that we account for in our everyday lives, and they are designed for single-use and immediate disposal. The dumped plastic waste will mainly result in landfills, open environments, or lingering on the ocean surface or beaches (Noor et al., 2020). In Malaysia's market segment, packaging stood the highest (48%) in the plastic market share as compared to plastic use in other industries, as seen in Figure 1 (Ritchie et al., 2018;

JPSPN, 2011, MPMA, 2018) . It was proven that Malaysia still relies heavily upon plastic packaging as part of its economic support.
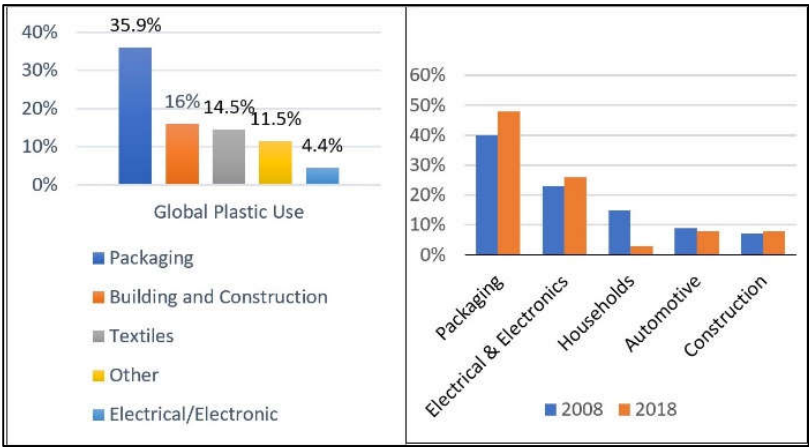

Figure 1. A comparison of Global Plastic use (left) and market share of Plastic in Major Market Segments in Malaysia, 2008 and 2018. (Ritchie et al., 2018; JPSPN, 2011, MPMA, 2018)

Furthermore, the media source shown in Table 1 discovered that plastics stood the second highest (13.2%), followed by diapers (12.1%) among all household waste compositions in Malaysia (UNEP, 2017). Consumers in Malaysia still often depend on plastic packaging due to the convenience of carrying and protecting goods.

Table 1. Type of waste material and percentage of composition (%) in Malaysia (Radhi, 2020)

Type of Waste Materials	Percentage (%) of Composition
Food waste	44.5
Plastics	13.2
Diapers	12.1
Paper	8.5
Garden waste	5.8
Glass	3.3
Textiles	3.1
Metal	2.7
Rubber	1.8
Tetra Pak	1.6
Wood	1.4
Household hazardous waste	1.3
Leather	0.4
Others	0.5

Malaysia faced the challenge mainly due to inadequate waste infrastructure development and relying much on disposing of solid waste to sanitary landfills (Ng & Iacovidou, 2020). Additionally, the awareness of protecting the environment and recycling rate among Malaysian citizens is still considered low (Ng & Iacovidou, 2020). Therefore, Malaysia is still yet to hit the targets of diverting 40% of the waste from landfills and increasing recycling rates to 22% (Ng & Iacovidou, 2020). By contrast, industrialized nations

create a substantial volume of plastic and paper garbage, contributing to the municipal solid waste's higher heating value due to its lower moisture content and carbon content. (Nanda & Berrutti, 2021).

A Brief Survey on Malaysia's household packaging waste during MCO

To investigate further the issue of household waste, a brief online survey with 10-items was conducted using convenient and snowball sampling methodology. The items asked about packaging waste was filled by 113 participants from major cities such as Kuala Lumpur, Penang and Melaka from July to August 2021. However, 105 participants responded fully to the survey and their data was used for further analysis.

The survey consisted of demographic questions like their age, gender, location and cities they are based on, followed by the product they bought from online, and how they manage the plastic and paper packaging after received online purchase item from the seller. Besides, only Malaysian living in the municipalities are chosen to participate in this study. In this survey, the three principal municipalities cover most of the 105 participants, 49.9% from Kuala Lumpur and Selangor municipalities, 20.2% from Penang and 14.4% from Melaka and 15.5% from other states in Malaysia.

Table 2 and Table 3 show how they managed their household plastic and paper packaging. There are four options provided: give to relatives or neighbours, keep for recycling, repurpose for other usage and throw as garbage.

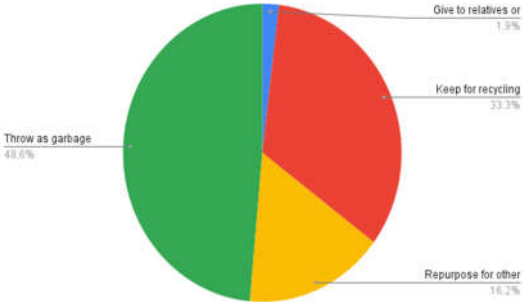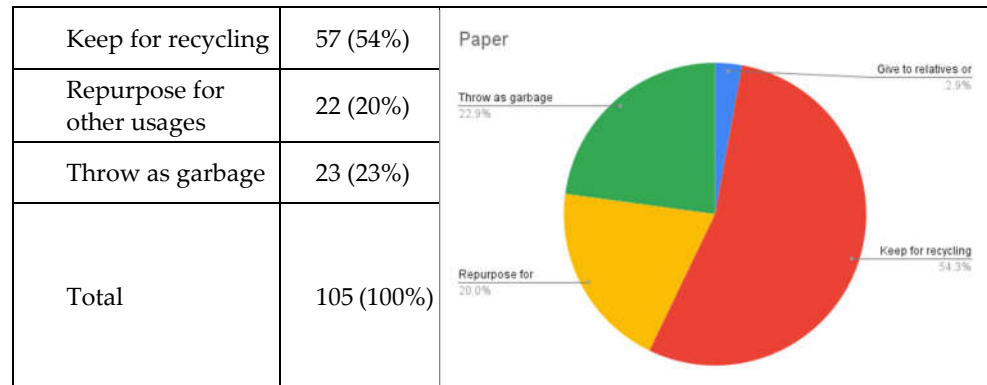**Table 2.** Plastic household waste management responses from 105 participants.

Plastic household waste management	Response
Give to relatives or neighbors	2 (2%)
Keep for recycling	35 (33%)
Repurpose for other usage	17 (16%)
Throw as garbage	51 (49%)
Total	105 (100%)

Table 3. Paper household waste management responses from 105 participants.

Paper household waste management	Response
Give to relatives or neighbors	3 (3%)

Keep for recycling	57 (54%)	Paper
Repurpose for other usages	22 (20%)	
Throw as garbage	23 (23%)	
Total	105 (100%)	

2.1 Growth of the household waste during COVID-19 pandemic period

Although the increasing amount of household waste is linked to the rapid urban migration and growth of the population (Kaza et al., 2018), the arrival of a global Covid-19 pandemic has also significantly impacted the amount of household plastic packaging waste. E-commerce activities have become necessary and the leading choice for consumers to purchase household items, basic needs, and food as people stay at home due to the 'lockdown' implemented (Sardjono et al., 2021; OECD, 2020). The adoption of online purchasing among households has increased significantly, but online shoppers' waste management behavior is still not on par with a sustainable city. For instance, the unmanaged and unethical disposal of e-commerce packaging waste, e.g. "plastic wrappers, papers, bubble wrap, air packets, tape and cardboard cartons" from the parcels and deliveries can significantly cause environmental damage like pollution and climate change (Wang & Hu, 2016).
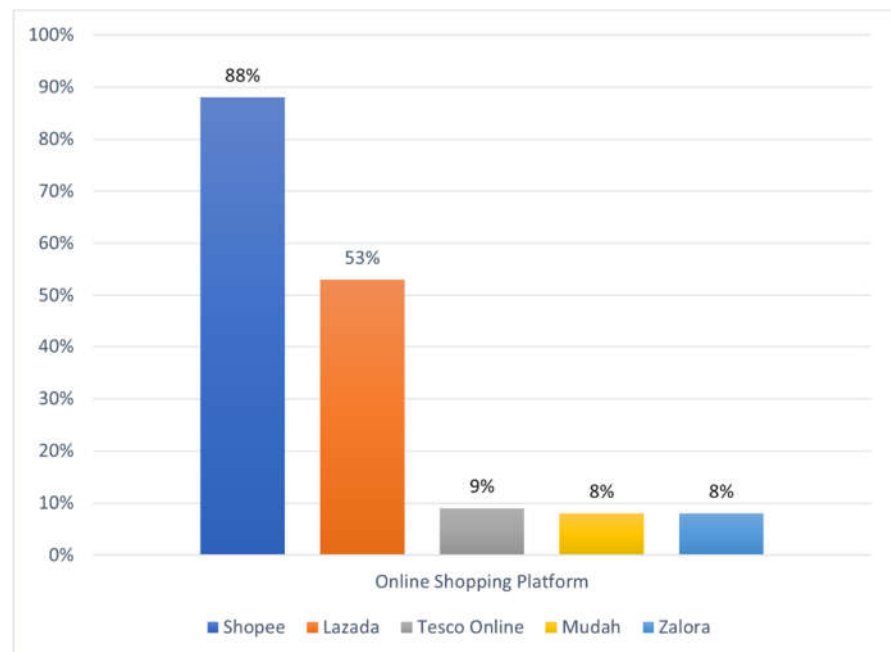

Figure 2. Leading e-commerce platforms in the Movement Control Order (MCO) period during the COVID-19 outbreak in Malaysia as of April 2020
(Statista, 2021)

Besides, Covid-19 pandemic also generated a large scale of clinical and packaging waste as most of it was made by single-use heavy-duty plastic (Hong Kong Government

Environmental Protection Department, 2017). Based on the Covid-19 cases in July 2020, hazardous medical waste produced an estimation of medical waste (35.41 tons/day) in Malaysia (Sangkham, 2020). Malaysia has reported a 27% (by weight) increase in the generation of clinical waste, mainly attributed to Covid-19 related waste (Agamuthu & Barasarathi 2020). The situation of waste management is now aggravated by the excessive use and consumption of single-use plastics, which include personal protective equipment such as masks and gloves. Plastic use and waste agenda should be a critical agenda by creating more awareness and actions of various parties, including the enforcement of policies and government to protect the public interest for greener environment solutions (Silva et al., 2020). Clinical wastes are projected to increase in lockstep with the increase of Covid-19 patients. According to a remark made by the Minister of Environment and Water at a November 2020 session in Dewan Rakyat, clinical waste generated in the country will grow by 20% during the Covid-19 epidemic." (DOSM, 2020)

2.2 Future of household waste in cities

Currently, East Asia and Pacific region produce the most waste in the world, accounting for 23%, while the Middle East and North Africa region produce the least waste accounting for 6% (Kaza et al., 2018). It is expected that global waste will reach 3.40 billion tons by 2050 (The World Bank, 2018). Malaysia is categorized as one of the upper-middle-income countries, and the waste generation among all upper-middle-income countries is expected to increase from 655 million tons to 1,004 million tons by 2050 (Figure 3) (Kaza et al., 2018; World Bank Group, 2020). Furthermore, the production of residential wastes depends upon the economy and size of the residential area. The higher the income value and larger the residential area, the more production of household wastes and waste management issues (Khan et al., 2016; Noor, 2020). The condition worsens when packaging waste has penetrated the e-commerce industry.
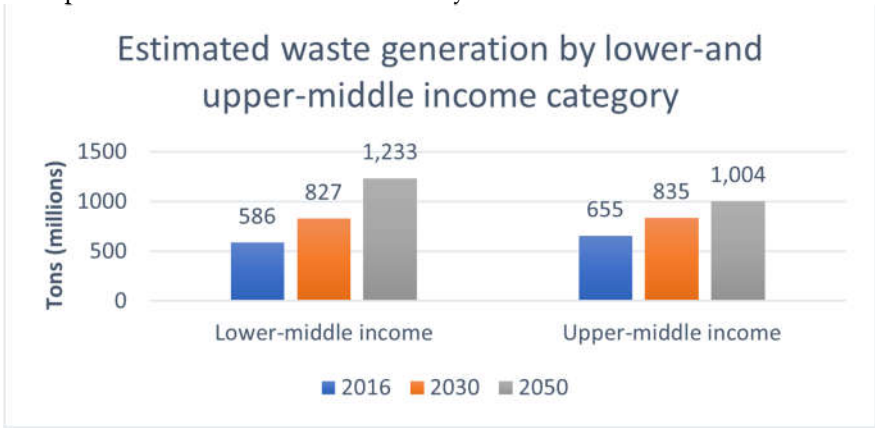

Figure 3. – Estimated Waste Generation by country Income Category, 2016, 2030, 2050 (Kaza et al., 2018; World Bank Group, 2020).

Therefore, this paper aims to provide an overview of Malaysia's household waste management and suggest an integrative model from the currently available model from Malaysia's waste management organizations, mainly on three significant municipalities.

3. Methods

Srivastava's (2007) 4 steps research method has been used to collect and evaluate the literature by identifying the unit of analysis, categorizing the terms into relevant contexts, and gathering them to access the important elements from the publications. This steps by Srivastava are highly cited and used in green research article. The literature has been

analyzed in three broad categories: (1) Waste management, its practices for smart cities, (2) Period, (3) Cities in Malaysia. Besides, the terms excluded are conventional recycling, industrial waste, rural waste management, general waste, non-biodegradable waste, e-waste, global waste, and global health.

To further scoping the search, the inclusion and exclusion criteria are considered to make sure articles are acceptable academically and fulfill the context for the future of household waste management for sustainable cities.

The relevant studies have been searched through ScienceDirect, Inspec, PubMed, Taylor and Francis & Google Scholar databases sources from 2019 to 2021. These terms can be mixed and matched to answer research questions 1 and 2.

Besides, these databases facilitated the authors' discovery of a diverse array of papers. The search tool's features allowed the authors to narrow their search by keyword, document category, nation, and year of publication. Notably, the generated charts for the publication year aided the writers in identifying and locating any previously undiscovered conventional and new publications relating to the keywords. From the preliminary search terms and inclusion and exclusion criteria, 13 articles were selected, and the information was plotted in Table 6. Table 6 shows the authors, title of the article, objectives, future suggestions, success factors and key findings. Success factors will be discussed in Section 3.0, while the future suggestions led to the Section 4.0 framework from the reviewed articles.

As shown in table 4, preliminary search is the first step to filtering the appropriate text to match the relevant articles to investigate household waste management in smart cities during the covid-19 period. Then, the filtered paper from the preliminary search will be further defined with the inclusion and exclusion criteria, as shown in Table 5. After the inclusion and exclusion criteria, reviewed papers are finalized and reported in Table 6 which explains the authors, title, objective, future suggestions, success factors and practices, and critical findings to address RQ1 and RQ2.

Table 4. Preliminary term search for inclusion and exclusion for selecting Malaysia's household waste management article.

Terms included	Terms excluded
Waste Management, Waste management practices for Smart Cities - Data and Technology - Economy - Social factor - Governance - Waste management - Household waste - Packaging waste - Plastic packaging - Microplastics pollution - Hazards and pollution Period - Covid-19 - pandemic Malaysia cities	- Conventional recycling - Industrial waste - Rural waste management - General waste - Non-biodegradable waste - E-waste - Global waste issue - Global Health issue

- Kuala Lumpur - Penang - Melaka	

Table 5. Inclusion and exclusion criteria after preliminary search

Inclusion criteria	Exclusion Criteria
-Academic and municipalities report articles between end of 2019 – 2021	-Non positive sustainable cities outcome
- Sustainable cities related	- Non English articles
- Data and technology centric management	- Non Covid-19 period
- Social factors on waste management	
- During Covid-19 period	

Table 6. Summary of selected articles on Malaysia's household waste management.

No	Authors	Title	Objective	Future Suggestions	Success factors and practices	Key Findings
A1	Amirudin & Gim, (2019)	"Impact of perceived food accessibility on household food waste behaviors: A case of the Klang Valley, Malaysia"	"Perceived food accessibility, measured in terms of perceived time and perceived effort, and its impact on household food waste"	- "Over purchase are to prevent wastage and waste creation - Recycling behavior and preventive behavior are needed"	- "Changing leftover routines, reducing shopping trips per week."	- "Three significant paths are found in the model connecting food waste with effort levels, environmental concern, and price importance." - "Policymakers may consider improving access to food sources to reduce household food purchase efforts."
A2	Melaka (2019)	"Resilient Melaka – Creating a striving, livable and smart Melaka"	"Resilient Melaka sets a vision for "a vibrant city, where smart governance, collective leadership, sustainable mobility and protective infrastructure supports a thriving, healthy community that is proud of Melaka's outstanding universal values as a world heritage city.""	- "Green City Action Plan (2017-2030)" - "Promote sustainable ways awareness campaign" - "Creating a Circular Economy for solid waste action" - Improving Solid Waste Collection Systems Action	- "This strategy was developed in collaboration with over 320 city stakeholders from the government, private sector, academia and the general public (i.e., Online engagement surveys and social media, Workshops, Discussions and Interviews)"	- "This report builds upon existing strategies by highlighting expanding initiatives to include a resilience approach and identifying new opportunities to incorporate disaster risk management and climate change adaptation in the city's development."
A3	Yusof et al. (2019)	"Community Participation and Performance of Waste Segregation Program in Malacca:	"This paper reviews the current practice and challenges of community's participation on waste segregation program in Jasin Malacca	- "At the authority level, provision of integrated structure and stakeholders should be formulated by	- "Various Waste Separation at Source awareness program were initiated by the local authority agencies such as SWCorp and Malacca Green	- "Through various efforts and campaigns on waste separation at source, the performance has been steadily increased from 2015 to 2017. It is expected that the initiative shall be rigorously promoted

		Towards Sustainable Waste Management"	since 2015-2017 towards achieving the Sustainable city in year 2022."	providing the necessary facilities, including funding equipment, incentives and waste disposal area." - "The local authority should play their role in working closely with the community committees to address feedback and problems encountered during the period execution."	Technology Corporation (PTHM)." - "Many workshops and programs in educating the kids in school have been implemented and to nurture the "Recycling Culture" into the heart of younger generations."	as to achieve the 30% recycling rate in 2020."
A4	GAIA (2019)	"Making a Case for Zero Waste: Laying the Groundwork for Zero Waste"	"To discuss Penang state's waste segregation challenges and future expectations of Penang's zero waste program."	- "Penang will continue to strive for a low-carbon city by 2022 by increasing the recycling rate from 42% to 70% and reducing their landfill-bound waste by 50%"	"Awareness is important among all the communities to be responsible for their disposal of waste."	- "A public consultation on Budget Dialogue in 2012 with the stakeholders cleared one thing: all of them prioritized cleanliness. Cleanliness includes a vast array of things; and recycling, composting, and upcycling are inseparable aspects of it."
A5	Penang Green Council (2020)	"Stakeholder Consultation on Penang's Green initiatives: Solving Plastic Pollution at Source"	"To discuss and deliberate on the various green initiatives that have taken place thus far in relation to tackling plastic pollution at source in Penang, as well as planning the way	- "Hoping to enforce 'Single-use plastics ban' by 2023." - "Continue education, monitoring & enforcement of WSAS"	- "Applying WSAS policy" - "Total ban on polystyrene packaging, No Plastic Day Campaign, and No Single-use Plastic Campaign were implemented in order to	- "The discussions and key takeaways during the stakeholder consultation provided valuable inputs to the project team to further develop the case study according to the Terms of Reference and how to get multi-stakeholders on board."

			forward for 2020 including the know-how in embedding Circular Economy solutions within the Island and mainland's ecosystem."	- "Introduce incentives/recognition for WSAS for plastic and other materials for recycling." - "Polluter Pays Principle and Waste Directory should be adopted in the WSAS Policy." - "A case study for long-term community behavioral change requires the involvement of various stakeholders."	divert and reduce the number of waste." - "Many green initiatives were done by local authorities to reduce the usage of single-use plastics included educational talks, distribution of recycled bags at Bazar Ramadan during the fasting month, and distribution of "Say No to Single-Use Plastics" posters to food and beverage outlets on the island." - "Initiatives by organizations in supporting Penang's state vision and protecting the environment."	
A6	Tan & Saad, (2020)	"Public Survey: The Impacts of Movement Control Order (MCO) Towards Waste Generation in Penang Island"	"To investigate the impacts of MCO (Malaysia's lockdown) influence on household waste generation and consumer purchasing behavior. To provide data and insights in order to assist policymakers and other related agencies to better deal with similar crises in the future. "	- "Suggestions from respondents to increase the number of recycling bins at public areas." - "Medical waste or hazardous waste bins should be set up in public areas." - "Incentives from government and businesses could help motivate	- "It is essential to heed public opinions as they allow the identification of critical elements that form the foundation in developing effective strategies to tackle this problem."	- "52% of respondents noticed waste generated in home has increased" - "MCO had no influence on Waste segregation practice" - "There is general agreement (51%) about MCO causing the increase of single-use plastics" - "The use of face masks has become a norm." - "Covid-19 pandemic has remarkably changed consumer behavior."

				the public to practise 3R.”		
A7	Ma et al. (2020)	"Microplastic Pollution and Health and Relevance to the Malaysia's Roadmap to Zero Single-Use Plastics 2018–2030"	- "To discuss the rising threat from microplastics and potential impact to human health."	- "it is vital that each relevant stakeholders, including the federal government, state government, non-government agencies, manufacturers and the general public to work together in order to achieve the goal in 2030 ."	- "plastic straws, wrappers and cutlery should be banned and replaced with more eco-friendly materials."	- "low rate of recycling plastic waste, lack of awareness on sustainable behaviors and habits, lack of integrated waste management, inadequate biodegradability products and high cost of plastic alternatives, and lack of cooperation and enforcement from relevant governmental stakeholders."
A8	Hanim & Azham (2021)	"Extended Producer Responsibility (EPR) in Malaysia – Towards a Sustainable Waste Management System"	- "To discuss the opportunities of EPR legal system in Malaysia, especially in supporting management of plastic solid waste"	- "Governance must be strengthened to form a strong foundation. - Communications & awareness are vital to create a paradigm shift in mindset." - "Polluter-pay-principle instruments need to be further explored." - "Government must set a good example by implementing GGP." - "3R initiatives require strong	- "The 11th Malaysia Plan (2016-2020) establishes guiding principles for effective and sustainable waste management for 2016-2020, focusing on green growth for sustainability and resilience. A clear path forward for improving Malaysia's solid waste management system, from changing societal mindsets to enhancing waste database collection systems and mandating or strengthening a single governing body to implement	- "Formation of a Producer Responsibility Organization (PRO) responsible for the organization of all tasks associated to the proposed EPR system." - "A sustainable regulatory framework on EPR covering for example specific types of goods including packaging products, on deposit system, waste disposal tax and amount of waste to be utilized in production and collection, sorting and recycling targets." - "material or of packaging, consumer goods companies, distributors, retailers, consumers, waste management operators, government and other public authorities including local municipalities."

				inter-Agency co-ordination and collaboration.” - “Clear and definitive roles of stakeholders ranging from manufacturers of packaging” - “Enhancement of recycling programs through sustainable extensive public education and publicity campaign.”	and enforce relevant legislation to ensure waste optimization and minimization in Malaysia.”	- “Strengthening of institutional capacities, technical and skilled staff and sufficient financial resources to monitor and control implementation of EPR system.” - “Charging of fees based on the packaging's degree of recyclability.”
A9	Puluhulawa & Puluhulawa, (2021)	“Plastic Waste : Environmental Legal Issues and Policy Law Enforcement for Environmental Sustainability”	“To discuss the environmental issues that related to plastic waste. Especially due to people's habit, changing entrenched habits and law enforcement at the empirical level.”	- “Participation of stakeholders is essential in establishing policies on the provision of the protection of environmental sustainability to ensure the fulfill the rights of citizens.”	- “Restricting the use of single-use plastic packaging (food and beverages) for the coastal community and visitors.” - “Practicing the habit of proper garbage disposal, i.e., providing trash bins, sorting types of waste (plastic waste and other waste).” - “Banning all people from dumping litter at the beach.” -“Imposing sanctions for those who violate the rules.”	- “Preventive approach is important to keep out from the undesirable results caused by the waste” - “The absence of imposing sanctions turns to be a problem in plastic waste reduction and management.”

A10	(Tang et al., 2021)	"Malaysia Moving Towards a Sustainability Municipal Waste Management"	"This paper aims to discuss the application of energy recovery from municipal solid waste in Malaysia."	"The government should put effort into solving the current issue by promoting recycling in public, enforcing the legislation, and approaching new technologies for better solid waste management practice in the future."	"The recovery system and refuse-derived fuel plant achieved expectation."	- "The solid waste management practices lacking separation and recycling sources become an obstacle for development." - "The application of (waste to energy) WtE technologies, especially incineration is unavoidable in the future in order to reduce the volume of waste being disposed in the landfill."
A11	Nasir et al. (2021)	"Forecasting Solid Waste Generation in Negeri Sembilan and Melaka"	"The solid waste produced in Negeri Sembilan and Melaka is forecasted to one year ahead and to see whether the landfills in both states are still able to accommodate the solid waste produced."	-"Restrictions on the use of plastic bags and food containers need to be tightened." -"The government must enforce instructions on the use of grocery bags -Awareness of 3Rs in society needs to be increased to save the earth from solid waste."	- "ARIMA model in forecasting the solid waste generation is effective to forecast the waste and enable the public to be aware with the alarming increase of waste."	- "The estimated solid waste generation for both states also is approaching the maximum landfill capacity, and this issue should be taken seriously so that environmental damage can be reduced."

A12	(Hewiagh et al., 2021)	"Waste management system fraud detection using machine learning algorithms to minimize penalties avoidance and redemption abuse"	"To analyze a waste management system and develop a machine learning model to detect online fraud in the system."	- "The proposed machine learning models can be a solution that can provide the recycling organizations with the ability to detect fraudulent activities during their waste collection process activities."	- "Smart waste management tools system able to track the recycling activities and assist communities in recycling."	- "Machine learning approaches are useful in detecting fraud of waste management with high accuracy."
A13	(Chen et al., 2021)	"The plastic waste problem in Malaysia: management, recycling and disposal of local and global plastic waste"	"Outlines the current state of plastic waste production and management in Malaysia, including options for landfill, recycling and incineration."	- "It provides data on the volume and risks of plastic waste in the country (i.e. microplastics, landfill, and incineration), summarizes key plastic waste management policy initiatives (including plastic alternatives such as biodegradable plastics), and identifies key impediments to these initiatives' success."	- "While resolving the issues raised by plastic in Malaysia would require persistent effort on a variety of fronts, positive experiences in other nations provide some reason for optimism."	- "The paper closes by discussing options for and constraints on the switch to biodegradable alternatives and proposes a model of plastic management based on a circular economy approach and solid waste management hierarchy."

4. Malaysia waste management practices

3 main municipalities', Kuala Lumpur, Penang and Melaka were discussed in the following subsections in their actions in household waste management practices and strategies in social, economy, information technology and governance to achieve success for a better sustainability of the environment.

4.1.1 Kuala Lumpur

Kuala Lumpur, Malaysia's main economy-driven area, adjoining the Selangor state area with the highest population density of 6.56 million compared to Penang and Melaka states in 2021 (DOSM, 2021). The higher density of population potentially leads to higher Municipal waste, where this is important, especially on the citizen, need to be disciplined and understand the consequences of the waste may affect the environment. The government should promote activities that can create awareness among households, i.e., reuse and recycling activities (Yusoff & Asmuni, 2021). One of the ways to reduce plastic packaging is the use of green packaging, which is closely related to sustainable Development Goals 12 – Responsible consumption and production, where the responsibility of managing the waste sustainably holds on the consumer and producer. Findings from Kuala Lumpur's consumers have shown that environmental awareness, inconvenience of support, cost and lack of government enforcement is most discouraging for green packaging. In Klang, there is The Ecogen Recycle Bank App which is a pilot effort by the council to engage the people of Bandar Bukit Rajah in a recycling cause. The software will assist in tracking the weight of recyclable goods disposed of by individual houses in accordance with the various categories. Besides the social and governance aspects, the technology aspects like the waste-to-energy (WTE) incinerator and material recovery facility are considered circular economy projects that will regenerate income from waste (Afiq, 2021).

4.1.2 Penang

Penang is located in north-western Peninsular Malaysia with a total estimated population of 1.77 million (Island and mainland) and total area of 1,049 km2 (Sebastian, 2020; DOSM, 2020). Penang is one of the States that do not adopt the Solid Waste Management and Public Cleansing Act 2007 [Act 672], instead follows the Local Government Act 1976, which allows the local authority to have the power to manage waste and carry out sanitary services differs from the Federal level by working together with the local councils (Penang Green Council, 2020). The current approach in managing solid waste from both island and mainland is still landfilling which will be sent to Pulau Burung Sanitary Landfill located at Nibong Tebal, Pulau Pinang (Penang Green Council, 2020). Penang State had already enforced the Waste Segregation at Source (WSAS) Policy (separation of solid waste into recyclable waste and general waste) since June 2017 in order to increase the recycling rate and prolong the lifespan of the landfill (Penang Green Council, 2020). Since then, Penang had achieved the highest recycling rate of 44.04% among all States in Malaysia, and the government is continuing to pursue more sustainable solutions in the future, for instance, the improvement of segregation and management of rubbish, including plastics (Local Government Division Penang, 2020).

4.1.3 Melaka

Melaka is located in the west of Peninsular Malaysia, with a total estimated population of 0.93 million and a total area of 1712 km² (DOSM, 2021). Melaka was declared as a Develop State in 2010 by the OECD (Yusof et al., 2019). Since then, the state has implemented a Green City Action Plan (GCAP) to establish numerous green programs and initiatives, especially related to green technologies. One of Melaka's primary goals is to become a "Zero Waste" state, particularly to mitigate the emission of waste-related Greenhouse Gas (GHG) (Yusof et al., 2019). Currently, Melaka adopted the practice of " '2+1' Municipal Waste Collection System" introduced by Solid Waste and Public Cleansing Management Corporation (SWCorp) and SWM Environment since 2013- a solid waste

management enforcement agency that is responsible to ensure that the municipal waste is properly segregated, collected, and transported to the landfill (Yusof et al., 2019). Based on the '2+1' waste collection schedule, organic and non-recyclable wastes will be collected twice a week while recyclable waste (paper, plastic, etc.,) are collected once a week (Yusof et al., 2019). Starting from 1st September 2015, the SAS campaign was implemented whereby all households in Melaka are required to practice waste segregation at source (Yusof et al., 2019). The Melaka government had also initiated three days of 'No Plastic Bag Day' (for every Friday, Saturday and Sunday) in 2014 where consumers were encouraged to bring their own bags and it was extended to every day since January 2016 (Bernama, 2016).

4.1.4 Four key aspects and other factors of future waste management in Malaysia

From the 13 articles reviewed that were labeled from A1 to A13, showed the future suggestions and success factors as the solutions towards Malaysia's sustainable cities based on different areas have been identified.

The Four factors from Table 7 would hold for smartness criteria for future cities / smart cities as reviewed in Table 6. Many elements rely on intelligent devices and infrastructure that are presumed to successfully unlock circular economy potentials (Ellen MacArthur Foundation, 2016). However, other elements such as value-creating thinking, creativity and cultural change are equally important. The partnerships of high degree commitment and collaboration among key stakeholders are required. Other factors such as regulation, policy, product design strategies, and technology on waste management are among the future directions to be giving some emphases. Based on the needs and future suggestions and practice, Table 7 shows the four recommended critical factors to improve Malaysia's city waste management.

Table 7. Adapted Success Factors of Waste Management for the Future Cities and reviewed success factors from articles in Table 6 (Esmaeilian et al., 2018)

Four factors	Elements
Data and Technology	"Automatic product lifecycle data collection" Real-time data analysis Data-driven decision making Data sharing, open data Data security and citizen privacy Intelligent & connected devices, new data acquisition and communication technologies Resilient infrastructure Standardization of technology
	Articles: A10, A12, A13
Economy	Novel business models Sharing economy, circular economy models
	Articles: A1, A2, A8, A11, A13
Social factor	Citizen's participation, green behavior Smart collaboration among stakeholders

	Technologies compatible with local culture Reward-based systems
	Articles: A2, A3, A4, A6
Governance	Strategic planning Non-governmental parties' involvement Laws and regulations compatible with circular economy concept
	Articles: A5, A7, A9, A13

4.2.1 Technology and Data

In Malaysia, Klang Valley's iCycle is one of the leading companies to provide the internet of waste things and utilize machine learning to manage waste. They are using the data-centric system to track users' recycling based on their bin location and create a recycling report for the users. For example, applications from AI to detect fraud waste management activity (Hewiagh et al., 2021).

Meanwhile, according to the 10th and 11th Malaysia plans, the government of Malaysia proposed the development of waste-to-energy incineration plants in every state, particularly focusing on transforming plastic wastes into 'green energy' (Chen et al., 2021). The Green Economic Working Group (2020) also mentioned the proposed plan, which suggested that Penang, and Yusof et al. (2019) on Melaka state government should explore incineration technologies as a sustainable waste disposal option impact to the environment has to be considered. In addition, the Penang state government had developed a Trash2Treasure (T2T) smartphone App to encourage the local citizens to turn "trash into cold hard cash or trade them in for valuable items." Besides, practical waste-to-energy technology can also reproduce energy from anaerobic digestion to treat organic waste without combustion, is a good option and is 30% more efficient than incineration (Tang et al., 2021).

4.2.2 Circular Economy

Circular Economy is a systematic approach to green economic development which is transformative and characterized by new business models, innovative approaches to product design, distribution and refurbishment/remanufacturing products (de Jesus et al., 2021). Peter (2012) emphasizes 3 principles in a sustainable resource, resource conservation, cost efficiency and human-centred design adaptation. Chen et al. (2021) proposed that Malaysia should take a step forward by implementing a circular economy model with integrated solid waste management as a sustainable solution for complying with the 'New Plastics Economy.'
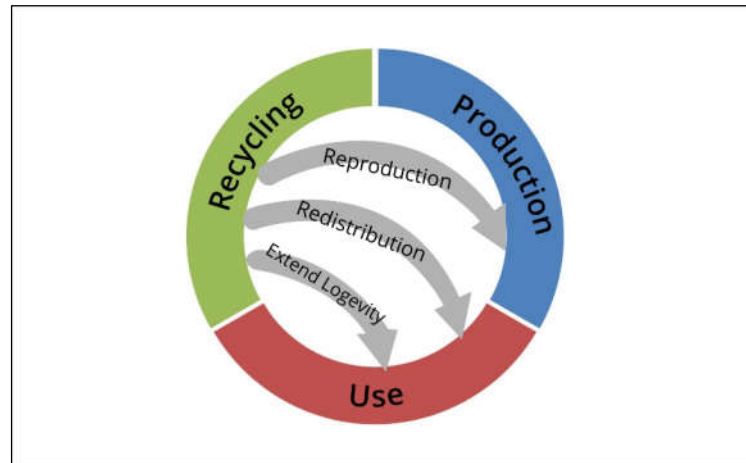
Figure 4. Circular Economy concept for recycling plastic as reusable resources (Chen et al., 2021)

According to Matt Benson et al. (2021), Penang was proposed to establish an innovative Waste Industry Plan to encourage better waste management and a circular economy in the state. Similarly, Resilient Melaka (2019) mentioned that the state government plans to investigate embedding the circular economy principles into their city's waste management system. The proposed idea was to focus on mitigating the amount of waste generated to the city environment, making wastes as resources to generate economic value through continuous reuse and recycling, promoting sustainable solution to local waste management system, and creating new employment and investment opportunities. However, this initiative will require the participation and engagement of local entrepreneurs as well as citizens to achieve a successful circular economy in waste management.

4.2.3 Social factor and Education at all Levels / Roles of Media and Public Service

Education and awareness is the key to reduce waste (Zaipul & Ahmad, 2017). The amount of waste generated will continue to increase without a conscious (Zaipul, A. Z., & Ahmad, R. S., 2017). Education since younger age / at all levels is the long-term solutions in addressing the waste management issue in the long term and at grassroot level.

A.   Social service on Penang

In Penang, Penang City Council has made a lot of green efforts in educating the local community and students on reducing single-use plastics, such as: educational talks, campaign, distribution of recycled bags at Bazar Ramadan during the fasting month, and distribution of "Say No to Single-Use Plastics" posters to food and beverage outlets on the island. They are likely to continue their effort in educating the public, especially on Waste Segregation at Source Policy as well as introducing recycling banks in schools (Penang Green Council, 2020). Due to the disruption of the Covid-19 pandemic, all environmental campaigns and workshops organized in Penang are transferred to 'online' using a digital platform, for example, conducting a virtual classroom for the program of 'Virtual Green Adventure Series' to educate the students and more younger generations about environmental care and green practices. The program is based on the United Nation Sustainable Development Goals (UNSDGs) and is a game-based learning method that provides the students and children with fun and interactive online sessions.

B.   Public survey on the impact of MCO on waste generation

Conducting a public survey is important to take public opinions into consideration as it allows critical factors to be identified, which serve as a basis for establishing effective

strategies to address new emerging issues. According to a recent public survey in Penang Island (Tan & Saad, 2020), it was revealed that single-use plastics such as: 'plastic bags', 'containers', 'cutleries' and 'straws' were in high in demand due to the shift towards online shopping and food delivery services during the pandemic and lockdown. Besides, the locals in general were aware that the unmanaged PPE waste (i.e., face masks) could cause harm to the environment and hence looking forward for solutions for these issues like suggesting for more recycling bins including PPE waste bins to be placed in public areas or incentive programs can be initiated by government and businesses to encourage the public to practice 3R or bring their own reusable bags/food containers. The findings and recommendations from the locals had provided valuable insights that can assist the policymakers and other related agencies in better cope with future similar crises.

C.   A goal to "Zero Waste" Model

Usually, zero waste is an ideal concept, a move to zero waste as a goal. It is a social movement from grassroots green initiative. The model of zero waste / or minimization of waste has been recently getting high attention by the youth.

GAIA (2019) Penang's Zero Waste network focuses on preventing waste by strategically redesigning the life cycles of Earth's precious resources through recycling. Among the objective are: (1) To build a zero-waste economy via carbon footprint reduction, (2) To shorten the travelling time of environmentally-conscious individuals, and (3) To increase the time-cost efficiency of recycling."

3.2.4 Governance: Enforcement education / Policy Law Enforcement

Among all states in Malaysia, there are only six states (Perlis, Kedah, Pahang, Negeri Sembilan, Melaka, Johor) and two federal territories (Kuala Lumpur and Putrajaya) have accepted and complied with Act 672 (Figure 5). The remaining seven states (Penang, Selangor, Perak, Kelantan, Terengganu, Sabah and Sarawak) and one federal territory (Labuan) are not under the administration and enforcement of Act 672 (Iacovidou & Kok, 2020).

Under the Ministry of Housing and Local Government, the Municipal solid waste has set up the National Solid Waste Management Department as the regulatory body and the Solid Waste and Public Cleansing Management Corporation to conduct the operations. However, local authorities would continue to monitor and enforcement, and reduction in plastic and waste disposal approach can be made with the enforcement of policy law and sanction imposed to the public (Puluhulawa & Puluhulawa, 2021). According to Zaipul and Ahmad (2017), enforcement of regulations can control people behaviors and address current problems in maintaining the environment.
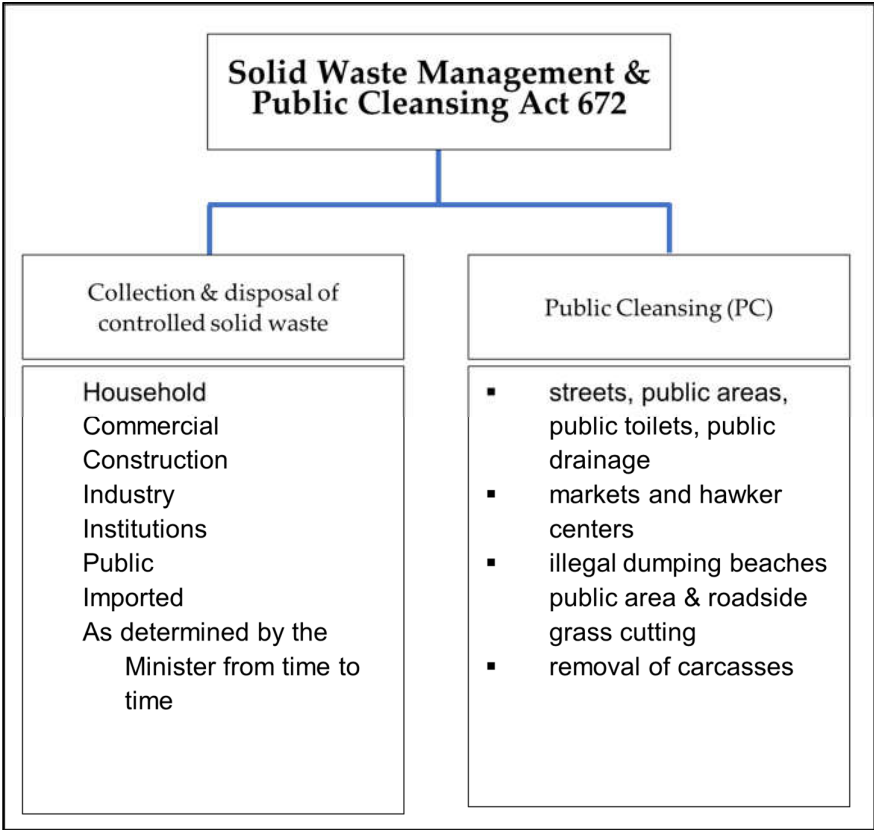
Figure 5. Solid Waste Management & Public Cleansing Act 672 (PEMANDU, 2015)

A Governance on Kuala Lumpur

Kuala Lumpur is the largest city in Malaysia, and it also has the highest density of population in the country. Smart Selangor, which is the Selangor state government program, has come out with a Smart Selangor Action Plan to 2025 report, with the smart government plan for smarter communities and economy to make use of technology as a catalyst of change, the vision is to make Selangor a liveable Smart State in ASEAN by the year 2025, and nature and environment is part of the plan for cleaner and greener public areas in handling domestic waste efficiently and promote environmentally conscious communities. Besides, Smart Selangor has rated reducing domestic waste in 6th place as the citizen prioritization needs and rated clean and green Selangor and reduce domestic waste in Selangor in 9th and 10th place for citizen needs prioritization by the district. (SSDU, 2020)

B Governance on Melaka

According to Resilient Melaka (2019) report, one of the major strategies to approach resilient in the city is the extended Green City Action Plan (2017-2030) aimed to improve areas in "solid waste management, energy, local industry development, energy efficiency and transport." However, Melaka faced the present challenges in SWM that is not sustainable in the long run, insufficient material-sorting facilities and infrastructure, rapid growth of population, lack of public (residents, businesses and industry) awareness of waste issues in the city as well as lack of maintenance of the existing dump sites (Resilient Melaka, 2019). Therefore, Melaka government (MBMB) will continue to promote sustainable waste awareness campaign to enhance the awareness of recycling practice and proper waste disposal among the residents, visitors, and businesses to protect the environment and human health.

C Governance on Penang City

While looking specifically on how the state government (City Council) green initiatives in reducing plastic waste, Penang was the first State that implemented 'No Free Plastic Bag Policy' (imposed charges for plastic bags) since 2009 and 'No Single-use Plastic Policy' since 2018 (to reduce plastic wastage) in "to be in line with 'Malaysia's Roadmap towards Zero Single-use Plastics 2018-2030' under the federal government's efforts to encourage eco-friendly products to substitute single-use plastics" (Chow Kon Yeow, 2019; Penang Green Council, 2020). Additionally, Penang had taken a step further in 2019 to ban on the usage of Styrofoam/polystyrene packaging totally, plastic bags, even if the shoppers are willing to pay as well as plastic straws by default among supermarket, food and beverage premises (Sebastian, 2020; Penang Green Council, 2020). According to the City Council of Penang, they are "aware of the plastic pollution issues" and therefore will look into the matter seriously, especially hoping to enforce 'Single-use plastics ban by 2023' for the sake of the future generation (Sebastian, 2020). On the other hand, the State government are also working towards Penang 2030 vision, which aim to improve the "liveability, economy, civil participation and balanced development to achieve a 'Family-focused, Green and Smart State' that inspire the nations" (Mohamed, 2019)

5. An Integrative Framework of Future-Proofing Household Waste Management Model for Malaysia
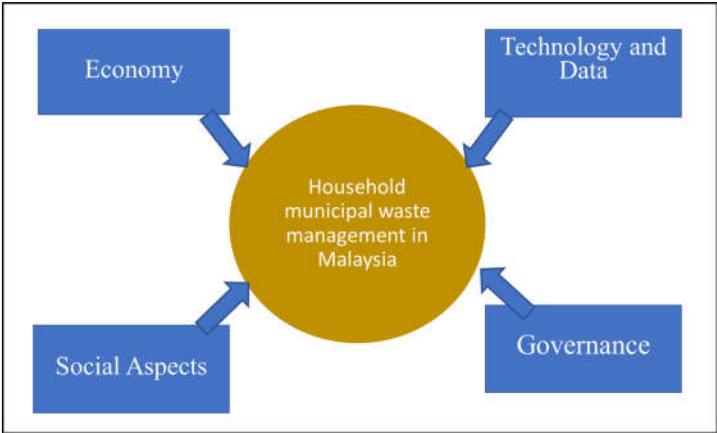

Figure 6. A framework of Malaysia integrative future-proofing householdwaste management

Adapted from Esmaeilian et al. (2018) and the review of Malaysia municipal waste management articles, waste management can be categorized into four specific areas, and the waste management factors are further recommended based on the future suggestions shown in Table 6. The following are the suggested solutions: 1) Economy, Technology and Data, 2) Economy and Governance, and 3) Social factors

5.1 Economy, Technology and Data

A. Decision Support System (DSS) and Model of Waste Tracking

In supporting Waste Separation Enforcement (effective on 1 Aug 2019), a module Decision Support System (DSS) that manages and tracks municipal waste analysis and data for major townships and cities. At the moment, there is no DSS that has been developed for waste management systems that has the impact on policies, challenges and strategies for municipal waste management in Malaysia (Zaipul & Ahmad, 2017). Smart solutions on waste management have been attempting to be able to capture reliable information about quantities, types, and the amount of materials. More on the waste tracking system and moving forward to foster / facilitate (efficient support) the implementation of

EPR (Extended Producer Responsibility) scheme from a linear to a circular economy to address plastic pollution issues that will be discussed in Section 4.2.

B. DSS model

With fast growing populations, developing countries like Malaysia is facing several critical challenges concerning the sustainable waste management, i.e., the improper waste collection management, treatment, and disposal of solid waste. Undoubtedly, managing waste can be a complex and resource intensive process. There is a need for systems like DSS that offer benefits in areas of estimation of waste volumes and types, intelligent tracking and collection, identification of disposal facility to help industrial and municipal decision-makers on proper waste management. Local and federal government authorities can consider the strategic value in DSS for its use in the control and management of the solid waste generated in urban centers.

To enhance solid waste management in Malaysia, more research about DSS adoption can be conducted to manage and track municipal waste analysis and data for major township and cities. There are many available research publications regarding innovative DSS that can be explored. DSS can be developed using rational and scientific approaches such as information and communication technologies (ICTs), optimization algorithms, statistical analysis and linear mathematical programming, probabilistic methods (Angelina et al., 2017).

Zhang and Anthony (2014) mentioned that a DSS framework based on rule-based reasoning and RFID technology was developed to assist waste management companies in tracking, intelligent scheduling and handling cases of waste movement to enhance the effectiveness of recycling and reuse of materials. RFID is used to record tracking inventories such as the volume, weight, location, and container movements in the design. The managers in the waste management companies relied on the knowledge-based system to decide on scheduled waste logistics to treatment plants and give staff instructions on how to deal with the waste. The use of RFID with augmented capabilities and cloud-based software (Catarinnucci et al., 2020) capable of accurately managing captured data associated with the waste collection process will be essential to achieving an efficient waste management system (Mishra et al., 2020). Besides, Islam et al. (2012) stated that a system capable of real-time monitoring and tracking of trucks and containers was proposed with the use of RFID along with a wireless network to collect data from tags and send the data to a computer system without any physical connection.

Geographic Information System (GIS) has been applied to multi-criteria decision analysis to assist decision-makers in determining a suitable site for landfills and an adequate capacity of waste containers (Pires et al., 2011). The selection of a potential site needs to consider three major factors related to environmental (types of soil, land decline, ecosystem and geology, groundwater), social (population acceptance, proximity to archaeological sites) and economic (access and distance to waste generation sites, access to roads, distance from residential units) (Gbanie et al., 2013). In Tao (2010), a DSS based on web-GIS was developed to support planning and decision-making managers. The system visualizes the material flow in real time and automates the tracking of waste collection. Tralhao et al. (2010) proposed using GIS and the mathematical multi-objective programming method to define potential locations for the installation of green recycling sites for selective collection of waste aimed at recycling. Other GIS work includes identifying the level of sustainable development in urban residential sites for trend analysis to aid decision-makers in planning future public policies (Xu & Coors, 2012; Zeeshan et al., 2018).

Besides, a genetic algorithm is applied to optimize the number of routes in waste collection to minimize operational cost such as fuel consumption, labor cost, and

environmental impact. A cognitive diffuse map method that integrates RFID and the genetic algorithm was presented to monitor and track waste types in the logistic process (Trappey et al., 2010). The application of DSS can also be observed in the decision-making dealing with factors of social, economic, and environmental uncertainty (Fan et al., 2012; Dandong & Yifan, 2020).

At the moment, there is no DSS that has been developed for waste management systems (Zaipul & Ahmad, 2017). Smart solutions on waste management have been attempted to capture reliable information about quantities, types, and the number of materials. More on the waste tracking system and moving forward to foster continuous support on the implementation of Extended Producer Responsibility (EPR) scheme from a linear to a circular economy to address waste pollution issues.

5.2 Economy and Governance

EPR Model

WWF-Malaysia has come up with a report that emphasizes the importance of responsible consumption. In the report, WWF identifies the Extended Producer Responsibility (EPR) scheme as a critical and effective policy tool in holding manufacturers accountable for the end-of-life impacts of their plastic products and packaging. EPR as a policy instrument also encourages adoption of holistic eco-design among the business sector.

EPR is a practice and a policy approach in which producers take ownership of their products or packaging at the end of their useful life. Financial responsibility, bodily responsibility, or a combination of the two are all forms of accountability. EPR shifts the financial burden of recycling away from ratepayers and governments and onto the producers and consumers of the recycled items and packaging. The theory underlying this approach to materials management extends back to a 1990 report by Professor Thomas Lindhqvist of Lund University in Sweden, who argues that internalizing end-of-life costs would promote more ecologically friendly design.

In current difficult economic times for recycling, EPR proposes a sustainable finance approach for material management that does not rely on local governments and ratepayers for revenue. Stable funding provided by EPR protects local recycling programs from market risk, as producers are required to reimburse the expenses of recycling (or a defined percentage thereof) regardless of the money gained by recovered commodities. Producers in bad years would bear the extra financial burden, and no one would pay higher fees to fund the system; in succeeding years, their rates would decrease.

Recycling initiatives would continue to operate in the face of these ups and downs. Packaging of low value or non-recyclables (e.g. all kinds of composites items, polyethylene, etc.) ends typically in sanitary landfills, dumpsites (unsanitary landfills), or are littered in the environment. So far, there is no systematic separation and recycling of the low-value recyclables (WWF-Malaysia, 2020)

5.3 Social factors

Gamified recycling activities

In Malaysia, the overall recycling rate is estimated to be 10.5%, with construction and demolition debris accounting for the majority of it. Domestic recycling is not widespread in Malaysia, and the rate of MSW recycling is mostly unknown but could be quite low. There is a dearth of information about the processes involved, from garbage generation and collection to waste transportation, treatment, and disposal. This lack of understanding and public awareness is concerning (Iacovidou & Kok, 2020).

Gamification is a creative approach to persuading people to engage in activities they perceive to be less appealing and encourage participation through engaging practice. Recycling has been a neglected issue for environmental sustainability advocates. Gamified learning's primary objective is to maintain learners' interest and motivation while incorporating with technology tools and reward-centric activities, assisting them in attaining their learning objectives while having fun (Cheng et al., 2021). The use of games in education has been demonstrated to be effective in the educational setting (de-Marcos et al., 2014). Students could experiment freely without fear of failure, which increased their participation in the learning process (Lee & Hammer, 2011). The advancement of technologies also contributed to a new standard of entertainment or fun towards activities from the accessibility of information instantly, people also think in the way of having more fun within the least time, this is also aligned with nowadays social media where people have the most satisfaction from the content they consume with the least amount of time (Zhan, 2016).

The public, particularly the residents in cities, should be exposed to beneficial activities that favorably affect any good cause in cities, such as recycling. The interaction between residents in housing areas is a good way to influence each other's, as social influence can be enhanced through fun engagement and the good caused of the recycling and sustainable activity itself. Besides, with modern technology nowadays, it was proven that social influence is mediating the relationship between gameplay experiences from gaming technology and characteristics in fit profile and enjoyment (Fang et al., 2009).

6. Discussion and conclusion

This study reviewed 13 articles from three main municipalities in Malaysia (Kuala Lumpur, Penang and Melaka) to understand their different practices and future suggestions on the importance of enforcing the integrative household municipal waste framework. It is also recommended that technology and data, economy, social and governance are the four main factors on the way forward toward a smarter future for household waste management.

The Covid-19 pandemic period shows the best time to reflect on the existing waste management problems. This study has given household waste packaging management output mainly on Kuala Lumpur, Penang, and Melaka during the MCO period. A sizable proportion of homes in Melaka, particularly in rural regions, lack access to regular or appropriate rubbish collection services. These households typically bury or burn their garbage, resulting in environmental deterioration, pollution, and increasing danger to human health. Through collaboration with outside contractors and professional NGOs, MBMB (Melaka City Council) will improve the efficiency and coordination of waste collection services in rural areas.

Due to high cost, The Penang government plans to adopt an incinerator technology to manage waste for their state, they opt for a much suitable and safer for the environment (Lim, 2019). Study on EPR scheme assessment for packaging waste in Malaysia shows that the requirement of value chain of waste management from separation at source over multiple aggregation steps to a range of manufacturers who produce resin or pellets end products from recycled material. There are three main industrial areas with a concentration of aggregators and processors, i.e. in the North-West around Penang, in the area beyond KL including Klang and Nilai, and in the South in Johor Bahru. The recycling industry is not as developed on the East Coast of Peninsular Malaysia and the Borneo states of Sabah and Sarawak, with feedstock from these regions being transported to the other main

processing centers (WWF-Malaysia ,2020). While the first processing steps require very limited initial investments, processing the recycling material into pellets or resin requires significant investments into equipment.

Hence, Covid-19 addresses the critical need of effective Municipal Solid Waste Management (MSWM) on a local and global scale to reduce and prevent health crises and environmental pollution. The ability to safely handle and dispose of waste is a key component of effective emergency response (Messenger 2020; World Bank Group, 2020).

EPR Model is also identified to achieve SDG 11, 12 and 13 in areas of environmental issues. Three case studies on major cities in Malaysia are also reviewed on their waste management policy and models. It is found that the lack of awareness in managing plastic, paper boards and other packaging material waste was identified during the Covid-19 pandemic. This has led to the environmental issues of climate change in a resilient city. Therefore, it is deemed crucial to instill awareness in waste management based on the EPR model and Sustainable Goal 11, 12 and 13. The implications from this study will lead to policymakers to have a proper guideline in waste management for cities.

In Malaysia, the increase in waste has led to a higher recycling rate, according to the Compendium of environment statistics. Waste separation and recycling are methods to curb the problems of environmental hazards. Waste management is also a way to save economic and environmental resources. Besides, people perceive recycling as a time-consuming activity rather than spending on unproductive activities.

The environmental subsystem, including flora and fauna, climate, weather and natural resources, is critical in understanding the underlying circumstances for the life and livelihoods of social distance. Natural hazards and changes in the environment require communities to cope and possibly adapt to new environments. In 2018, the Energy, Science, Technology, Environment & Climate Change Ministry had come up with a blueprint titled "Malaysia's Roadmap Towards Zero Single-Use Plastics 2018-2030". The environmental subsystem is very sensitive to human action and influences. Through the exploitation of natural resources, human interaction with ecological systems can change and affect the system's resilience. As a result, human and ecological systems undergo interdependent changes over time.

6.2 Limitation

This is a review paper that only focuses on Malaysia's problem, particularly in cities area of Kuala Lumpur, Penang and Melaka, that also happens in other areas around the globe, household municipal waste such as paper and plastic waste has been a multipurpose tool that helps humanity, but the misuse and ignorance of different parties have turn plastic into a disastrous threat that never before happened in the human history.

There are also certain of government policies that did not discuss in the national solid waste management policy like Solid Waste and Public Cleansing Management Act SWMA that has not been enforced, thus highlighted many policy gaps.

6.4 Conclusion

Sustainable cities in Malaysia practice waste management with the integrated framework of future-proofing household waste management is believed to be an actionable quest for Malaysians. Particularly in Technology and Data with DSS model that offers smart solutions for tracking, collecting, and analyzing waste through ICT. It will create

smart and efficient waste management solutions for citizens in saving time and energy to understand the waste types and study how to manage waste in their municipalities. Business owners must play their part to be more responsible for their production and the consequences that may incur to the environment and the government plays the role of making sure the rules and policy are strict and actionable enough based on the current situation.

Lastly, although technology has simplified the process of waste management in different areas like internet of things, waste-to-energy technologies as strategies to reduce waste from sendinf to landfill (Okedu, 2022). Businesses also play their role in utilizing the technology and sustainable strategies to reduce cost and environmental pollution. Good governance can control the citizens' actions to a certain degree. However, education is important as an awareness of the consequences of improper waste management, and the social factors are the anchor point to realize the sustainable cities initiatives that many countries have targeting.

As mentioned earlier, climate change and natural disasters have been occurring more frequently than many years before due to the irresponsible from different parties that only focuses on development but neglect the condition of earth is in serious trouble. It shows an invisible sign of notice for humankind to appreciate the natural resources given to us.

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