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Waste Management Costs Reduction and the Recycling Profit Estimation from the Segregation Programme in Malaysia

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ABSTRACT

This study aimed to estimate the potential waste management cost reduction and the recycling profit from the segregation programme implemented in Malaysia. The assessment was done among the states that implemented a waste segregation programme in Malaysia, a Southeast Asia country with a GDP of 364.7 billion USD. The solid waste (tonnes) data were collected from the Solid Waste Management and Public Cleansing Corporation, Malaysia, and analysed using mathematical models. On average, 2.69 million tonnes per year (t/yr) of waste were disposed of in the landfills, and 1,680 t/yr of waste was segregated, equivalent to 0.06%. Plastic (30.49%–39.48%) and paper (31.35%–40.88%) were the major components of segregated waste. Implementing the waste segregation program avoids the cost of waste disposal in landfills, potentially at 61,000 USD/yr and generating 130,000 USD/yr recycling profits. Therefore, the government should strengthen the programme to increase the segregation rate and provide a significant income to the community.

Keywords: Economy, profit, recycling, segregation, waste

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INTRODUCTION

The global municipal solid waste (MSW) generation is expected to increase up to 70% from 2.01 billion tonnes in 2016 to 3.40 billion tonnes in 2050, where 33% of waste is mismanaged through open burning or dumping (Kaza et al., 2018). A person generates an average of 0.74 kilograms (kg) of waste or ranges from 0.11 to 4.54 kg. In 2050, the daily waste generation is projected

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to increase by 19% in developed countries and 40% in developing countries (Kaza et al., 2018). Population growth, social factors, economic transition, location, technology, legislation, and consumer behaviour are the factors that affect MSW generation (Hoornweg & Perinaz, 2012; Masebinu et al., 2017).

Among the Association of Southeast Asian Nations (ASEAN) countries, Indonesia generates a high amount of waste annually (64.0 million t/yr.), followed by Thailand (26.8 million t/yr.), Vietnam (22.0 million t/yr.), the Philippines (14.7 million t/yr.), and Malaysia (12.8 million t/yr.) (Jain, 2017). In terms of daily waste generation per capita, Singapore is the highest (3.72 kg/capita/day), followed by Malaysia (1.21 kg/capita/day) and other Asian countries (1.08–0.33 kg/capita/day) (Kaza et al., 2018). Malaysia has recorded an increased solid waste generation from 38,563 tonnes/waste/day in 2015 to 49,670 tonnes/waste/day in 2020, with a 5.19% increase rate (Ghani, 2021). The country's recycling rates increased from 10.5% in 2012 to 22% in 2020. However, this is still low compared to other developed regions such as Germany (67%), South Korea (65%), and Austria (59%) (Tiseo, 2021).

One of the challenges in waste management among developing countries like Malaysia is identifying an appropriate solution for reducing waste generation, waste collection, treatment, and disposal (Jereme et al., 2015b). Landfilling is the preferable method to manage waste due to its low cost of maintenance and operation and simple procedure to settle the collected waste (Imran et al., 2019). The country currently operates 141 non-sanitary landfills and 17 sanitary ones (JPSPN, 2021).

The Solid Waste and Public Cleansing Management Act (SWPCMA) 2007 or Act 672 was introduced in 2007 and was formally implemented on September 1, 2011. The Act aims to improve the quality of services (i.e., collection, transportation, treatment, and disposal), protect the environment and humans, standardise solid waste management, and ensure proper solid waste management in the country (Yiing & Latifah, 2017). However, the law is only implemented in some states in Malaysia. The states under Act 672 are Johor, Negeri Sembilan, Melaka, Pahang, Perlis, Kedah, and two Federal states, Kuala Lumpur and Putrajaya, which are under the supervision of the Solid Waste Management and Public Cleansing Corporation (SWCorp). Under Act 672, the Federal government entirely takes over the responsibility of solid waste management and privatisation of concessionaires from the local authorities due to financial and facility issues (Yiing & Latifah, 2017). Meanwhile, the private concessionaires are responsible for more than 50% of the amount of waste collected in their area, including sorting, storage, collection, transportation, transferring, processing, recycling, recovery, and disposal. The SWCorp targets to increase the recycling rate up to 40% by 2025 (The Star, 2020).

The Malaysian government has spent approximately 5.24 billion United States Dollars (USD) yearly to manage solid waste (Utusan Online, 2017). The cost of waste collection

and disposal alone take up to 60% of the local authority expenditure (Fauziah & Agamuthu, 2010). Besides, building up a new landfill in Malaysia requires more than 7.75 million USD (Zaipul & Ahmad, 2017). The current estimated cost for waste management in Malaysia, including collection, transportation, and disposal (landfill tipping fee), is about 36.21 USD/t/day of waste (KPKT, 2015). However, a huge amount of our waste is still being dumped in landfills. The national report also states that more than 90% of domestic waste is generated annually and dumped in landfills (JPSPN, 2021). Even in developed countries, for example, Austria, Germany, and Singapore, domestic waste is the main contributor to the total volume of waste (Ministry of Sustainability and the Environment, 2019; Pickin et al., 2018; Jaron & Kossmann, 2018).

The mandatory waste segregation policy programme was introduced and implemented under this act in September 2015. Households have to segregate their wastes into recyclable items such as plastic, paper, metal, aluminium, glass, and e-waste and non-recyclable items (general wastes). Failure to comply with the requirements will result in a fine not exceeding Malaysian Ringgit (RM) 1000 (Act 672, 2007). However, since implementing the waste segregation policy, there is limited evidence to address the contributions of the waste segregation programme in Malaysia. Therefore, this study was aimed to analyse the contribution of waste segregation policy from the perspective of waste reduction in landfills, waste management cost (i.e., collection, transportation, and landfill tipping fee) and the profits from recyclable trading based on the available data from 2014 to 2018. Findings from this study provide an overview of waste segregation policy contributions that can help the government in decision-making and improve waste management strategies in the future.

METHODOLOGY

Descriptions of the Study Area

Malaysia is a Southeast Asia country with a GDP of 336.66 billion USD in 2020 (Trading Economics, 2021) and a population of over 32.7 million, with an annual growth rate of 1.0% (DOSM, 2021). The country is a federation of 13 states and three federal territories, with the South China Sea separating the two regions, i.e., Peninsular Malaysia (11 states and two federal territories) and Borneo (2 states and one federal territory). Landfilling is the major way to dispose of waste in the country, where 90% of the generated waste is disposed of in landfills (JPSPN), 2021).

The enforcement of Act 672 started on September 1, 2011, in six states (i.e., Johor, Negeri Sembilan, Malacca, Pahang, Perlis, and Kedah) and two Federal states (i.e., Kuala Lumpur and Putrajaya), which were selected as the study area (Figure 1). Under Act 672, the Federal government is responsible for the solid waste management and privatisation of concessionaires from the local authorities (Yiing & Latifah, 2017). The JPSPN and SWCorp were established to assist in implementing and planning waste management in Malaysia.

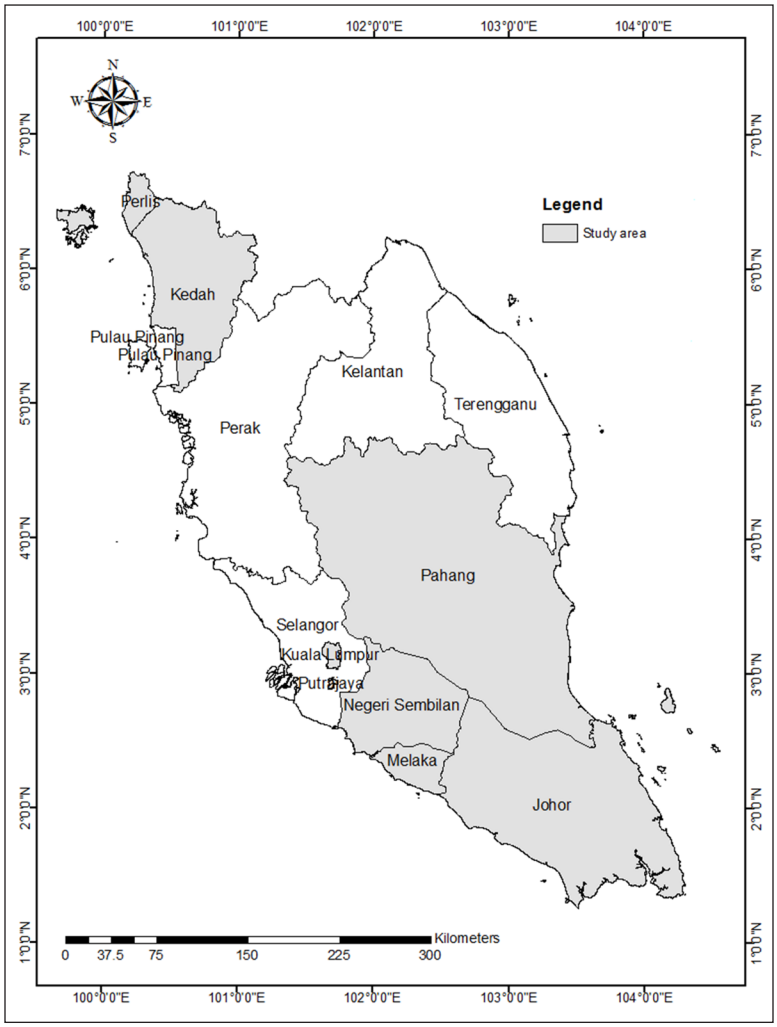


Figure 1. The states under Act 672 involved in this study

The waste segregation at source programme was introduced in the states under Act 672 in September 2015. Meanwhile, starting in 2016, the programme is mandatory where failure to comply with the requirements will be fined not exceeding RM1000. The programme aims to increase the recycling rate, reduce waste disposal in landfills, and protect the environment and human health. In addition, a new waste collection system, known as the 2 + 1 system, was also introduced. The system allows non-recyclable materials to be collected twice per week and once per week for recyclable materials. Under the supervision of SWCorp, the private concessionaires handle waste collection and transportation services in their areas. They are Alam Flora Sdn. Bhd (covering Kuala Lumpur, Putrajaya, and Pahang), Southern Waste Management Sdn. Bhd (Johor, Malacca, and Negeri Sembilan), and Environment Idaman Sdn. Bhd. (Kedah and Perlis). Generated waste in the study area is collected using

the compactor lorry for domestic waste and open tipper for recyclables, garden wastes, and bulky waste. The recyclable wastes are collected and transferred to the 38 drop-off points for waste separation and weighing (SWCorp, 2018).

Data Collection

This study analysed the secondary data sets of municipal solid waste (MSW) volume (i.e., landfilled domestic waste and segregated waste) provided by the SWCorp, Malaysia. The available data were obtained from the SWCorp in 2018 and managed in Microsoft Excel by the area (state), years (2014–2015), type, and category. The data were divided into domestic waste, bulky and garden waste, public cleansing waste, and segregated waste, as shown in Table 1. The segregated waste is categorised as plastic, paper, metal, aluminium, glass, e-waste, and other wastes (i.e., leather, hazardous material, and electronic waste). The volume of segregated waste was used to estimate the profits from selling recyclable materials; however, e-waste was excluded from the analysis due to unavailable data on its "unit" as the price for e-waste in Malaysia is in RM per unit. Data for the segregated waste volume were selected from 2015–2018, as the waste segregation programme had started in September 2015. The analysis of the study only incorporated the volume of domestic waste (i.e., landfilled domestic waste) and segregated waste in tonnes. These types of waste were chosen because 80% - 90% of collected domestic waste from households were dumped in landfills (JPSPN, 2021). The volume of segregated waste was applied in the analysis to report the segregation rate and its contributions to the avoided landfill cost and recycling profits in the states under Act 672. Hence, bulky and garden waste and public cleansing were excluded in the study analysis.

In this study, the data used for the analysis were the volume of collected waste in the states under Act 672 managed by the SWCorp. The reported data only represented the

Table 1
The descriptions of the data (collected waste) in the study area

Type of waste	Descriptions	Total collected waste in tonne, t (%)[a]
Domestic waste	Households waste is collected by private concessionaires twice per week.	13,472,664.23 (82.07%)
Bulky and garden waste	Large size waste such as household furniture and garden waste is collected by private concessionaires once per week.	2,132,223.66 (12.99%)
Public cleansing waste	Waste from public cleansing activity such as cleansing street drains and public areas, grass cutting, removing carcasses and clearing illegal dumped solid waste.	802,272.55 (4.89%)
Segregated waste (for recycling)	Household waste from segregation at source (SAS) activity.	802,272.55 (0.05%)

[a]Total volume of collected waste (tonne) in the states under Act 672 from 2014 to 2018.

volume of waste transported to the transfer station (weighed) and disposed of in 25 landfill sites, as indicated in Table 2. The volume of segregated waste is based on the volume of recyclable materials transferred and collected at the 38 drop-off points throughout the states under Act 672. Another limitation of the data is that it did not include the volume of waste disposed of in incinerators and 177 illegal dumping sites (SWCorp, 2018). Thus, the actual volume of waste generated in the study area might be higher than reported. Due to unavailable data (waste volume) on illegal dumping, the study analysed only available data provided by SWCorp.

Table 2
The facilities monitored by the SWCorp in the states under Act 672

States	Landfill site	Incinerator	Drop Off Point
Kuala Lumpur	0	0	1
Putrajaya	0	0	1
Pahang	8	2	10
Perlis	1	0	1
Kedah	2	1	9
Negeri Sembilan	5	0	5
Malacca	1	0	3
Johor	8	0	8
TOTAL	25	3	38

Study Variables and Statistical Analysis

The economic impact of the waste segregation program in this study was measured through five main variables, i.e., segregation rate (%), waste collection cost (CC), waste transportation cost (TC), waste tipping fee cost (TF), and recycling profits (RF). Table 3 highlights the mathematical equation in calculating the measurement of the study variables. The study used the Statistical Package for Social Sciences (SPSS) software to analyse and report the statistical data. First, descriptive analysis was performed to report the mean and standard deviation (SD) of the variables. Then, the analysis of variance (ANOVA) test was used to analyse the comparison between the variables. Finally, the Pearson Correlation test was run to report the relationship between the variables.

RESULTS AND DISCUSSION

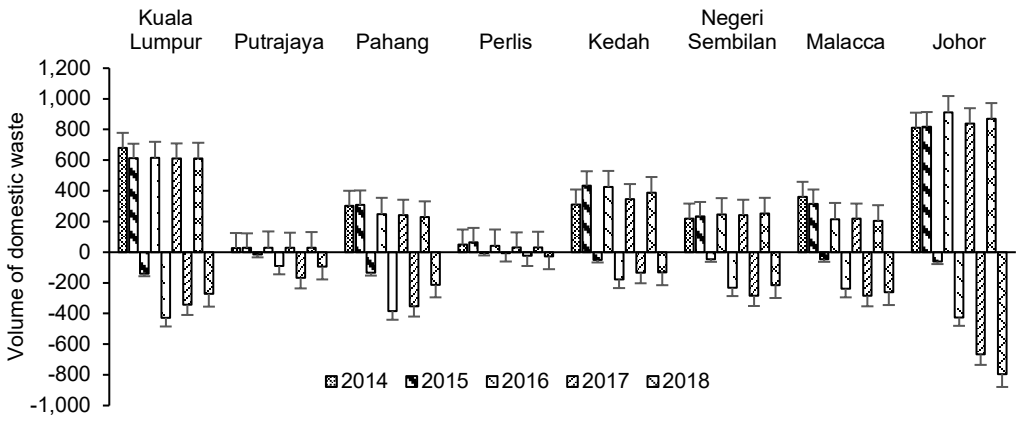
Figure 2 shows the total volume of disposed waste from 2014 to 2018 by area. On average, 2.69 million tonnes of waste were disposed of in landfills per year. The highest volume of waste disposed of in landfills was contributed by Johor (850 thousand tonnes/year) and Kuala Lumpur (625 thousand tonnes/year). The high population in Johor and Kuala Lumpur of 3,742.20 million and 1,795.20 million in 2018 is one of the possible factors that led to

Table 3
The mathematical equation used in the calculation of the study variables

Parameter	Unit	Equation	Description	Value	Source
Segregation rate (SR)	%	$SR = \sum[SW / MSWT] \times 100$	• SW = Volume of segregated waste (tonne) • MSWT = Total volume of municipal solid waste (landfilled and segregated waste) (tonne)	-	National Solid Waste Management Department (JPSPN, 2013).
Waste collection cost (CC)	MYR / USD	$CC = \sum[(VW \times CCw)]$	• VW = Volume of waste (landfilled or segregated waste) (tonne). • CCw = The waste collection charge	• CCw: MYR 66 (16.15 USD) per tonne of waste	Ministry of Housing and Local Government (KPKT, 2015)
Waste transportation cost (TC)	MYR / USD	$TC = \sum(VW \times TrP)]$	• VW = Volume of waste (landfilled or segregated waste) (tonne) • TrP = Transportation charge.	• TrP: MYR 40 MYR (9.79 USD) per tonne of waste	Ministry of Housing and Local Government (KPKT, 2015)
Waste tipping fee cost (TF)	MYR / USD	$TF = \sum[VW \times TFc]$	• VW = Volume of waste (landfilled or segregated waste) (tonne) • TFc = Tipping fee charge	• TFc: MYR 42 (10.28 USD) per tonne of waste	Ministry of Housing and Local Government (KPKT, 2015)
Recycling profits (RF)	MYR / USD	$RF = \sum[(SWi \times 1000)$	• SW*i* = Volume of segregated waste by composition (tonne) • 1000 = Conversion of tonne (t) to kilogram (kg). • RP = Recyclable material market price per kg.	• RP Plastic: MYR 0.35/kg (USD 0.09 /kg) • RP Paper: MYR 0.25/kg (USD 0.06/kg) • RP Metal: MYR 0.55/kg (USD 0.13/kg) • RP Aluminium: MYR 2.30/ kg (USD 0.56/kg) • RP Glass: MYR 0.20/kg (USD 0.05/kg) • RP Other waste: MYR 0.20/ kg (USD 0.05/kg).	(SWCorp, 2019; E-Idaman, 2019)

the high waste generation in a year. A similar observation was reported by Periathamby (2014), where Johor was the third major waste generator in the country after Selangor and Kuala Lumpur. Similarly, this study reported the lowest waste generation in Perlis (42 thousand tonnes/year), which is congruent to Periathamby (2014) and Jamil (2018).

Hoornweg and Perinaz (2012) highlighted other factors that had a tremendous impact on a region's waste generation, other than population growth, are high economic development and urbanisation levels. Johor and Kuala Lumpur have the top gross domestic product (GDP) at 5.7% and 5.9%, respectively (DOSM, 2017). Both states rendered major urban areas generate a high volume of waste due to their development, services, and job opportunities, boosting migration. For example, township projects, the Light Rail Transit Line (LRT3), mega supermarkets, job opportunities, and high wages entice people to migrate to these states. As a result, lifestyles might change as the living standards and consumption of goods and services increase. Moreover, Johor is also geared towards being a developed state in Malaysia, with rapid development, for example, the development of the Iskandar Malaysia region. The state also targets accomplishing a high impact project on various aspects such as physical environment, social, and economy by 2030 (JPBD, 2019). These could be the potential factors behind the high waste generation in Johor and Kuala Lumpur.



The volume of domestic waste (tonnes)		Kuala Lumpur	Putrajaya	Pahang	Perlis	Kedah	Negeri Sembilan	Malacca	Johor	TOTAL
2014	Landfilled	680,806.63	26,193.53	302,233.41	49,440.65	309,494.57	218,617.04	360,734.76	810,829.75	2,758,350.34
2015	Landfilled	613,561.50	28,649.16	308,009.50	63,792.00	433,996.39	233,137.48	313,950.85	818,515.73	2,813,612.61
	Segregated	-140.02	-16.26	-134.72	-4.29	-50.57	-45.54	-46.41	-60.52	498.33
2016	Landfilled	614,357.93	29,360.29	247,664.08	41,269.00	424,287.45	245,802.71	214,688.00	912,033.82	2,729,463.28
	Segregated	-429.38	-89.79	-385.50	-6.25	-178.07	-231.41	-238.55	-426.11	1985.06
2017	Landfilled	610,849.75	28,903.84	242,309.86	30,366.10	345,456.08	242,538.16	218,275.08	839,252.11	2,557,950.98
	Segregated	-342.75	-168.18	-353.16	-23.40	-134.95	-283.70	-284.43	-667.50	2258.07
2018	Landfilled	610,068.90	29,360.29	229,811.12	30,118.21	388,397.00	252,529.82	203,308.89	869,692.81	2,613,287.04
	Segregated	-272.90	-94.18	-212.59	-28.35	-131.48	-216.38	-261.41	-795.16	2012.45
AVERAGE (Landfilled)		625,928.94	28,493.42	266,005.59	42,997.19	380,326.30	238,525.04	262,191.52	850,064.84	2,694,532.85
AVERAGE (Segregated)		296.26	92.10	271.49	15.57	123.77	194.26	207.70	487.32	1,688.48

Notes: Positive vertical bar indicates the volume of landfilled domestic waste (thousand tonnes), and the negative vertical bar indicates the volume of segregated waste (tonnes).

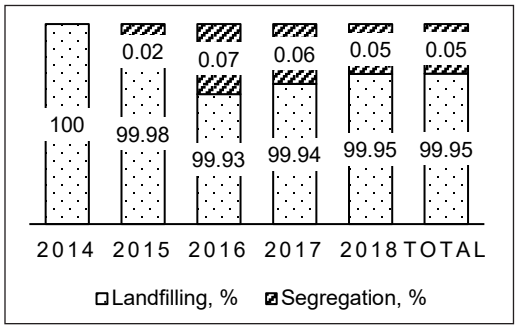
Figure 2. The trend of landfilled and segregated domestic waste among the states

Implementing the waste segregation program has collected 1.68 thousand tonnes of waste segregated per year. The waste segregation program has encouraged waste separation activity, resulting in increased waste segregation in most areas in the country. For instance, the volume of segregated waste in Johor has increased from 3% (60 tonnes) in 2015 to 41% (795 tonnes) in 2018. A similar trend was observed in Perlis, increasing from 13% (4 tonnes) in 2015 to 87% (28 tonnes) in 2018. Nonetheless, a fluctuating trend is noted in the volume of segregated waste in Kuala Lumpur, Putrajaya, Pahang, Kedah, Negeri Sembilan, and Malacca. Overall, the volume of segregated waste had increased from 7% in 2015 to 30% in 2018. It caused a reduction in the volume of landfilled domestic waste from 2.76 million tonnes (20%) in 2014 to 2.61 million tonnes (19%) in 2018. Figure 2 depicts reduced landfilled domestic waste volume observed in the west region of Peninsular Malaysia (Malacca: -12%), the north region (Perlis: -9%), the east region (Pahang: -6%), and the capital city of Kuala Lumpur (-3%).

The data also recorded an increased waste segregation percentage by states, as highlighted in Figure 3. The highest segregation rate was observed in Putrajaya at 0.40% in 2017, and the total average percentage was 0.20%, followed by Pahang (0.11%), Malacca (0.09%), Negeri Sembilan (0.08%), and Johor (0.06%). The findings confirmed that the waste segregation programme under Act 672 significantly impacted landfills waste and enhanced the recovery of recyclable materials at the source. In addition, it showed that the mandatory waste segregation at the source might encourage households to participate in the programme.

However, Table 4 shows a negative correlation between total waste generation and segregated waste volume, $r = -0.849$, p-value = 0.15. A greater than 0.05 p-value indicates inconclusive evidence about the significance of increasing waste segregation activities related to total waste generation. Malaysians still generate a high volume of waste despite increased waste segregation activity. Although the study data showed a diversion of waste from landfills through the waste segregation activity, it does not represent the overall segregation rate. It is only 0.06% of the total generated waste. Low 3R activity (i.e., reduce, reuse, and recycle) among the community is possibly due to the indigent attitude to participate in the programme. The willingness to participate in waste segregation programmes could be due to insufficient time, space and, accessibility to recycling facilities (Malik et al., 2015).

Lack of awareness about environmental issues, the absence of financial incentive provisions like a reward or penalty, and limited access to recycling facilities such as recycling bins might influence a household's participation in the recycling programme (Ali et al., 2015). On the other hand, the mandatory requirement of waste segregation at the source under Act 672 might encourage households to participate in the programme. Nevertheless, the inconsistent enforcement of the subsection could be the reason for the



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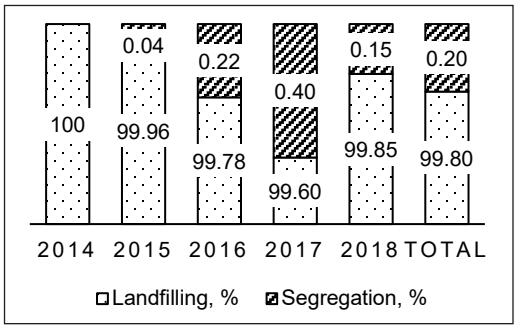

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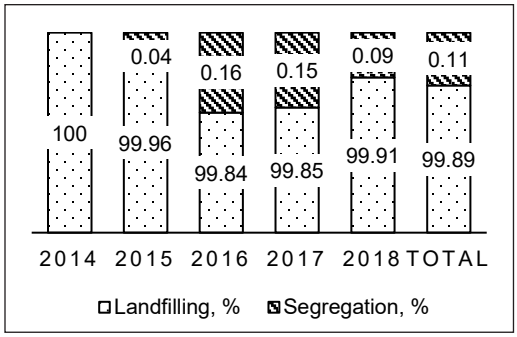

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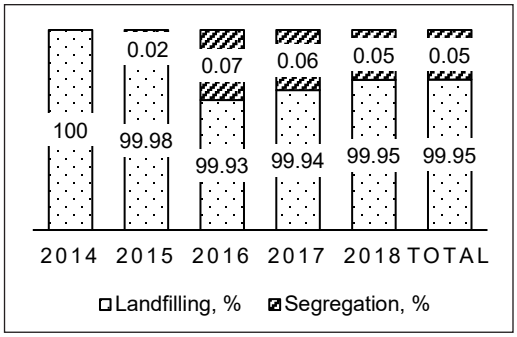

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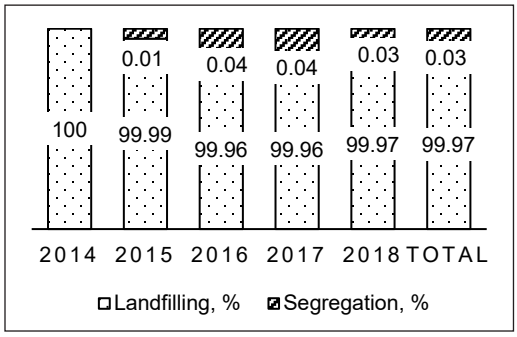

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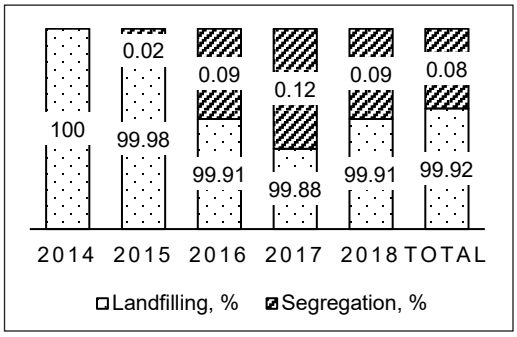

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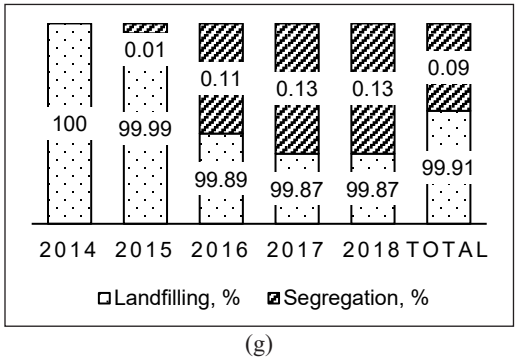

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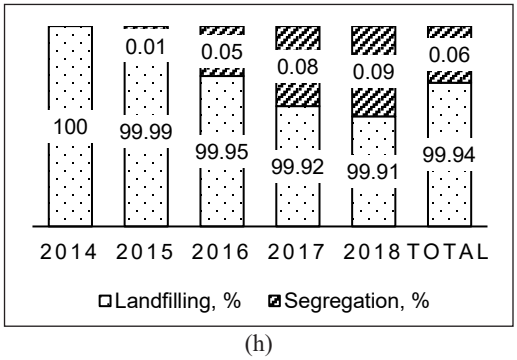

(h)

Figure 3. The percentage of waste segregation in the states under Act 672: (a) Kuala Lumpur; (b) Putrajaya; (c) Pahang; (d) Perlis; (e) Kedah; (f) Negeri Sembilan; (g) Malacca; and (h) Johor

Table 4
Significant relationship between total waste generation and waste segregation

Waste volume (tonne)	Mean (±SD)	Pearson correlation	p-value
Total waste generation (landfilled domestic waste + segregated waste)	2,680,266.96 (±114263.47)	-0.849	0.15
Segregated waste	1,688.48 (±807.87)		

low segregation rates obtained in this study. In contrast, few researchers argued that the waste segregation practice is more influenced by knowledge, attitude, awareness, facilities, and incentives rather than the enforcement of the law (Irina et al., 2014; Malik et al., 2015; Azilah et al., 2015; Low et al., 2016). In addition, the structure of Act 672 is more focused on waste management services and facilities, and the lack of supporting regulations related to recycling in the country also limit the success of the waste segregation campaign in this study (Agamuthu et al., 2011).

Based on the solid waste management hierarchy, the best option is the waste minimisation strategy (McDougall et al., 2001). Therefore, the government should focus on a strategy or approach to minimise the generated volume of waste—for example, strengthening the 3R programme (reduce, reuse, and recycle) and encouraging households to participate in the programme. Nonetheless, the government should also consider political, community, market, and technological acceptance before introducing a new policy (e.g., waste segregation programme) (Razali et al., 2017). In addition, knowledge and awareness on SWSR can be improved through good communication platforms such as school education, municipal leaflets, radio, television, newspaper, articles, and social media (e.g., Facebook, Instagram, and Twitter) (Otitoju & Lau, 2014).

Agamuthu et al. (2011) stated that government support through effective implementation of policy and legislation is the primary key to the success of the programme. Therefore, the government should empower the policy and legislation concerning waste management in Malaysia to encourage the community to segregate and recycle. For example, the implementation of "the polluter pay" policy in Switzerland, "the producer responsibility model" in Austria and Germany, "the government financial support" in South Korea, and "the effective recovery system" in the United Kingdom (UK) have encouraged the public to segregate and recycle, as well as increasing the recycling rates in the countries (Parker, 2019).

The comparison of segregated waste (tonnes/year) by composition indicates a significant difference in the volume between states ($p<0.05$) except for e-waste (Table 5). Johor significantly segregated the highest volume of paper (164.81 ±102.90 tonnes/year), followed by plastic (116.22 ±84.76 tonnes/year), glass (92.16 ±70.75 tonnes/year), and metal (81.18 ±49.46 tonnes/year) than other areas of study. Meanwhile, Kedah exhibit

Table 5
The comparison of segregated waste (tonnes/year) by compositions

State	Segregated waste compositions, tonnes/year (mean ±SD)						
	Plastic	Paper	Metal	Aluminium	Glass	E-waste	Other wastes
Kuala Lumpur	87.41 ±33.10	138.05 ±72.29	0.23 ±0.29	0.61 ±0.56	44.34 ±16.47	0.13 ±0.22	25.50 ±14.66
Putrajaya	35.71 ±23.56	39.94 ±29.62	7.73 ±5.59	0.47 ±0.17	4.45 ±2.46	0.16 ±0.30	3.65 ±3.29
Pahang	103.60 ±41.10	110.05 ±56.92	22.17 ±12.16	1.11 ±0.52	7.79 ±1.22	1.06 ±0.35	25.72 ±12.86 [a]
Perlis	8.10 ±5.59	5.39 ±5.62	0.93 ±0.34	0.57 ±0.40	0.11 ±0.15	0.10 ±0.15	0.39 ±0.33
Kedah	48.58 ±21.33	49.51 ±21.87	15.62 ±8.08	2.75 ±1.02 [a]	4.02 ±1.57	2.28 ±1.33	1.02 ±0.67
Negeri Sembilan	59.89 ±35.22	70.11 ±39.66	29.91 ±15.12	0.16 ±0.15	24.01 ±22.52	3.70 ±2.74	6.49 ±3.34
Malacca	68.38 ±36.75	96.47 ±51.27	37.82 ±20.31	0.03 ±0.05	3.27 ±2.42	0.94 ±1.00	0.80 ±1.07
Johor	116.22 ±84.76 [a]	164.81 ±102.90 [a]	81.18 ±49.46 [a]	1.86 ±1.97	92.16 ±70.75 [a]	11.75 ±14.39 [a]	19.34 ±16.44
F	3.03	3.67	6.76	4.82	5.59	2.28	5.99
p-value	**0.02**	**0.01**	**<0.001**	**0.002**	**0.001**	0.06	**<0.001**

high aluminium segregation (2.75 ±1.02 tonnes/year). Nevertheless, although the volume of e-waste showed no significant difference between the states, it is highly segregated in Johor (11.75 ±14.39 tonnes/year).

Figure 4 shows the percentage of segregated waste compositions from 2015–2018, where plastic (30% –39%) and paper (31%– 40%) are the significant components of segregated waste. It is followed by metal (7%–12%) and glass (9%–11%). Paper and plastic are convenient to handle and store, and these might be the possible factors behind the high volume of those segregated waste for recycling. For example, most government or private offices have a policy or recycling programme that encourages workers to recycle used papers. Moreover, they are widely used in daily lives, contributing 10.5% of paper and 24.8% of plastic to the total waste in the country, as reported by SWCorp (Adam, 2021). Similarly, high-income countries also highly generate paper and plastic wastes due to their daily use (Jain, 2017; Hoornweg & Perinaz, 2012).

The data showed that plastic wastes segregation was reduced by 8.69% through the years. The reduced amount of plastic waste for recycling could be due to an increase in the amount dumped in landfills. For example, in Malaysia, the volume of plastic waste dumped in landfills increased from 13.2% in 2005 to 20% in 2018 (Muzamir, 2020). The use of plastic for packaging and producing new products increases, leading to most of them ending

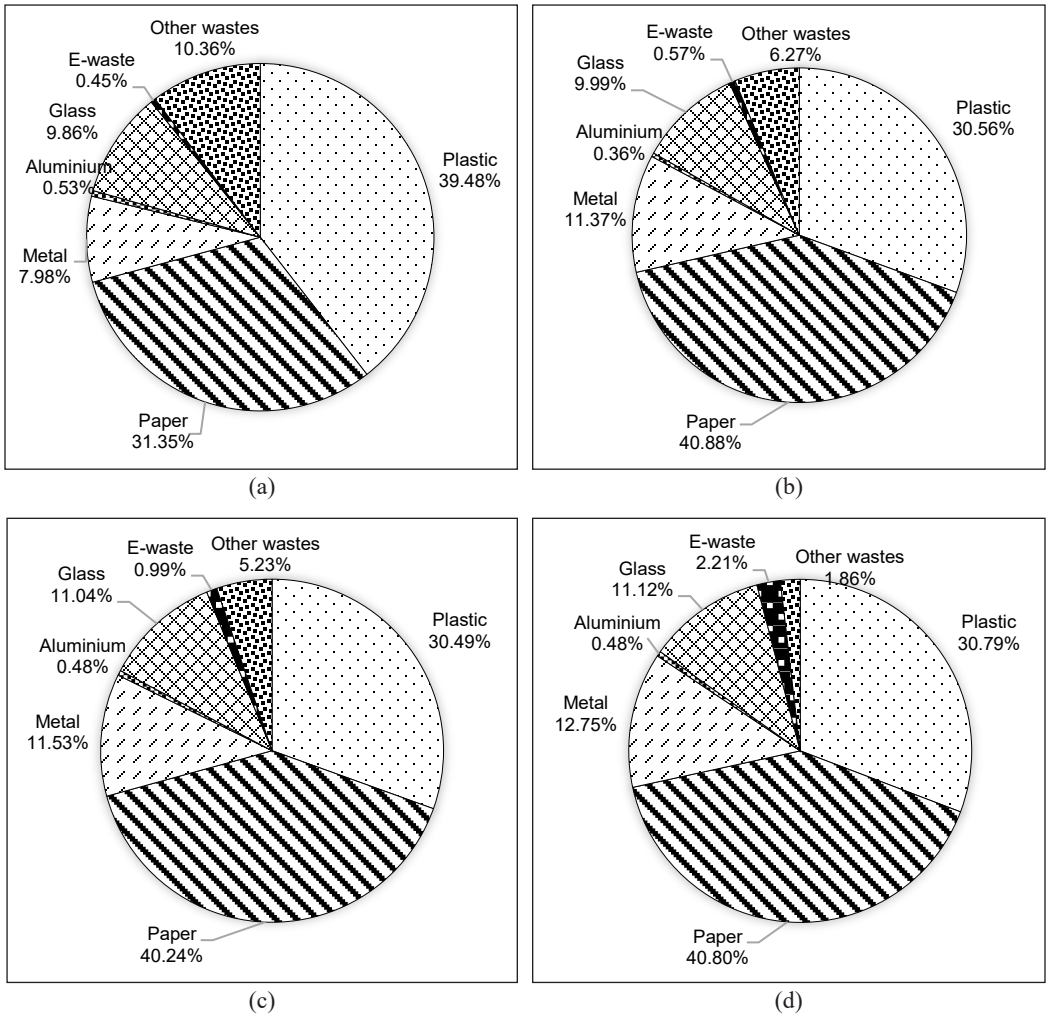

Figure 4. The percentage of segregated waste compositions from: (a) 2015; (b) 2016; (c) 2017; and (d) 2018

in dumpsites or landfills. The country dumped 79% of plastic waste in landfills, whereby 12% was burned, and only 9% was recycled (Liyana, 2021). Malaysia only focuses on plastic waste that is easily collected and has a high value, such as transparent polyethene terephthalate (PET) bottles. Plastics like food packaging, straws, and polystyrene products are commonly not recycled (MESTECC, 2018). For example, Singapore only recycled 4% of plastic bottles in 2021, and they have targeted to make it up to 70% in the next ten years (Ong, 2021). According to Milios et al. (2018), some factors need to be considered to increase plastic recycling, such as creating a proper scheme of plastic waste separation, well-functioning markets, and demand from plastic manufacturers.

Recently, a slight reduction in the number of segregated aluminium cans is noted, i.e., 0.05%. The possible factor is the increasing number of trending drink brands (i.e., hipster

drinks) such as boba or bubble tea drinks that use plastic cups. These drinks have become phenomenal, with more people enjoying them. Thus, the number of people buying drinks in aluminium cans might be reduced adversely, while the number of plastic waste (i.e., plastic cups) has increased. Also, low awareness, poor segregation, and recycling practices among the community are factors that influence the number of recyclables.

The low recycling activity affects waste management in terms of the increased number of landfills for waste disposal. It will lead to a high volume of waste being disposed of in landfills, reducing their lifespan, thus, requiring new landfills. Furthermore, to increase the recovery of valuable wastes such as paper, plastics, and aluminium, high-quality technologies, mechanisms, and experts are required to manage them properly, which are among the drawbacks of most developing countries in providing sustainable waste management methods (Nazym et al., 2020). Thus, in terms of economic impact, the cost of waste management will increase. For example, mismanaged waste in Malaysia requires RM1.9 billion per year (0.46 billion USD/year) for the government to collect, manage, and clean solid waste (The Star, 2020).

Table 6 shows the estimated cost of waste management based on the volume of domestic waste generated in the states from 2014 to 2018. Johor is one of the states that spent the highest waste management cost at 30 million USD/year for landfilling practice, followed by Kuala Lumpur (22 million USD/year) and Kedah (13 million USD/year). Putrajaya spent the lowest, i.e., about 1.03 million USD/year. The country spent a total of 97.57 million USD/year for waste management (landfilling), where the major costs were contributed by the waste collection (43 million USD/year), followed by the tipping fee (27 million USD/year) and transportation (26 million USD/year). It is a similar trend in developed countries, where waste collection costs are much higher (Bohm et al., 2010), influenced by the type of waste, population size, and waste segregation rates in a region (Greco et al., 2015).

Table 6 also indicates that the total avoided cost of waste management through the waste segregation programme in the country is 61.43 thousand USD/year. It is cost-saving, where the service for the waste collection, transportation, and landfill tipping fees is no longer needed. However, the other costs, such as fuel consumption and collection cost, may increase when the source segregation intensity increase (Di Maria & Micale, 2013). Nevertheless, the result is consistent with a previous study that reported the waste segregation at the source had reduced the processing cost at the intermediate treatment facilities by 11% (Chifari et al., 2017). In Vietnam, the study conducted by Hoang et al. (2020) demonstrated that reducing waste disposal at 75% through the waste segregation programme could save about 1,800 USD/day. Another study also stated that the cost of waste management in the healthcare setting was reduced from five thousand per month to two thousand per month after the waste segregation activity was implemented (Johnson et al., 2013). A case study in New Jersey, United States, supports these, whereby the

Table 6
The estimated cost of waste management

Parameter	State	Collection	Transportation	Landfill tipping fee	TOTAL Cost[b]
Landfilled waste, million MYR/year (USD/year)	Kuala Lumpur	41.31 (10.11)	25.04 (6.13)	26.29 (6.43)	92.64 (22.67)
	Putrajaya	1.88 (0.46)	1.14 (0.28)	1.20 (0.29)	4.22 (1.03)
	Pahang	17.56 (4.30)	10.64 (2.60)	11.17 (2.73)	39.37 (9.63)
	Perlis	2.84 (0.69)	1.72 (0.42)	1.81 (0.44)	6.37 (1.55)
	Kedah	25.10 (6.14)	15.21 (3.72)	15.97 (3.91)	56.28 (13.77)
	Negeri Sembilan	15.74 (3.85)	9.54 (2.33)	10.02 (2.45)	35.3 (8.63)
	Malacca	17.30 (4.23)	10.49 (2.57)	11.01 (2.69)	38.8 (9.49)
	Johor	56.10 (13.73)	34.00 (8.32)	35.70 (8.74)	125.8 (30.79)
	TOTAL[a]	**177.83 (43.51)**	**107.78 (26.37)**	**113.17 (27.69)**	**398.78 (97.57)**
Parameter	**State**	**Collection**	**Transportation**	**Landfill tipping fee**	**TOTAL avoided cost[b]**
Segregated waste, thousand MYR/year (USD/year)	Kuala Lumpur	-19.55 (-4.81)	-11.85 (-2.91)	12.44 (-3.06)	-43.84 (-10.78)
	Putrajaya	-6.08 (-1.49)	-3.68 (-0.90)	-3.87 (-0.95)	-13.63 (-3.34)
	Pahang	-17.92 (-4.41)	-10.86 (-2.67)	-11.40 (-2.80)	-40.18 (-9.88)
	Perlis	-1.03 (-0.25)	-0.62 (-0.15)	-0.65 (-0.16)	-2.3 (-0.56)
	Kedah	-8.17 (-2.01)	-4.95 (-1.22)	-5.20 (-1.28)	-18.32 (-4.51)
	Negeri Sembilan	-12.81 (-3.15)	-7.77 (-1.91)	-8.16 (-2.01)	-28.74 (-7.07)
	Malacca	-13.71 (-3.37)	-8.31 (-2.04)	-8.72 (-2.14)	-30.74 (-7.55)
	Johor	-32.16 (-7.91)	-19.49 (-4.79)	-20.47 (-5.03)	-72.12 (-17.73)
	TOTAL[a]	**-111.43 (-27.40)**	**-67.53 (-16.60)**	**-70.91 (-17.43)**	**-249.87 (-61.43)**

[a]The total costs of waste management in a year by the country
[b]The total costs of waste management in a year by the states
Note: 1 MYR = 0.24 USD on November, 2020;
Negative (-) indicates avoided costs of waste management

encouragement to recycle through waste segregation proved to be 60% more cost-effective than landfilling practice (New Jersey Waste Wise, 2015).

Therefore, in Sweden, South Korea, Canada, Australia, the US, and the UK, the Economic Instrument (i.e., environmental taxes and subsidies, product and input taxes, deposit-refund schemes, and waste collection charges) has been implemented to reduce waste generation and disposal in landfills as well as gains the revenues (Nahman & Godfrey, 2010). Maintaining the positive trend of waste disposal reduction in landfills saves the country's expenses and contributes to environmental sustainability (The Star, 2020).

The recovery of recyclable materials through the waste segregation programme has produced about 130.53 thousand USD/year recycling profits to the country (Table 7). Johor gained high profits from plastic, paper, metal, and glass waste selling. Meanwhile, Kedah gained high profits from aluminium, whereas Pahang benefited from other wastes.

On average, plastic waste selling generated the highest profits of 45 thousand USD/year followed by paper (41 thousand USD/yr), metal (26 thousand USD/yr), glass (8 thousand USD/yr), aluminium (4 thousand USD/yr), and other wastes (4 thousand USD/yr). It showed that selling valuable waste provide profits. In the US, aluminium (16%) and plastic (11%) are the top three contributors to the country economy (i.e., wage and tax) after e-waste recycling (29%) (EPA, 2020). The study by Han et al. (2021) also reported that recycling e-waste in Japan and Korea could generate profits of 5.10 USD (579.99 Yen) and 1.98 USD (225.08 Yen), respectively. Still, the profits gained from the recycling activity might differ based on the price market of the materials in a region.

Furthermore, Menikpura et al. (2013) have proved that recycling contributes to the environmental, economic, and social sustainability of the waste management system. However, it must be integrated with other strategies because implementing a sustainable recycling strategy could not stand alone (Menikpura et al., 2013). Based on the previous study in China, the preferable method of waste management is the combination of source separation, recycling, and incineration (Song et al., 2013). The environmental benefits

Table 7
The estimated profits of recyclable selling

State	Recyclable selling, MYR/year (USD/year)						
	Plastic	Paper	Metal	Aluminium	Glass	Others	**TOTAL**[a]
Kuala Lumpur	30,593.50 (7,521.45)	34,512.50 (8,484.95)	126.50 (31.10)	1,403.00 (344.93)	8,868.00 (2,180.21)	5,100.00 (1,253.84)	80,603.50 (19,816.48)
Putrajaya	12,498.50 (3,072.77)	9,985.00 (2,454.83)	4,251.50 (1,045.24)	1,081.00 (265.77)	890.00 (218.81)	730.00 (179.47)	29,436.00 (7,236.88)
Pahang	36,260.00 (8,914.57)	27,512.50 (6,763.99)	12,193.50 (2,997.79)	2,553.00 (627.66)	1,558.00 (383.04)	5,144.00 (1,264.66)	85,221.00 (20,951.70)
Perlis	2,835.00 (696.99)	1,347.50 (331.28)	511.50 (125.75)	1,311.00 (322.31)	21.00 (5.16)	78.00 (19.18)	6,104.00 (1,500.68)
Kedah	17,003.00 (4,180.21)	12,377.50 (3,043.03)	8,591.00 (2,112.11)	6,325.00 (1,555.01)	804.00 (197.66)	204.00 (50.15)	45,304.50 (11,138.17)
Negeri Sembilan	20,961.50 (5,153.41)	17,527.50 (4,309.16)	16,450.50 (4,044.38)	368.00 (90.47)	4,802.00 (1,180.58)	1,298.00 (319.12)	61,407.50 (15,097.12)
Malacca	23,933.00 (5,883.96)	24,117.50 (5,929.32)	20,801.00 (5,113.95)	69.00 (16.96)	654.00 (160.79)	160.00 (39.34)	69,734.50 (17,144.32)
Johor	40,677.00 (10,000.50)	41,202.50 (10,129.69)	44,649.00 (10,977.02)	4,278.00 (1,051.75)	18,432.00 (4,531.53)	3,868.00 (950.95)	153,106.50 (37,641.45)
TOTAL[b]	184,761.50 (45,423.87)	168,582.50 (41,446.24)	107,574.50 (26,447.34)	17,388.00 (4,274.86)	36,029.00 (8,857.78)	16,582.00 (4,076.71)	530,917.50 (130,526.81)

[a]The total profit from recyclable selling by the state
[b]The total profits from recyclable selling by its compositions
1 MYR = 0.24 USD on November, 2020.

of recycling include reducing landfilled waste disposal, reducing greenhouse gas (GHG) emissions in the landfills, preventing air, water and soil pollution, and conserving natural resources (Ham & Lee, 2017). In terms of economic sustainability, waste segregation at source will help recover more valuable materials such as plastic waste with high organic content and calorific value to generate energy (Lee et al., 2017) and gain profit through electricity selling (Rangga et al., 2018). In the view of social sustainability, waste separation at source activity will lead to more facilities such as the recycling facility, composting centre, and the incinerator plant that will provide job opportunities for people. Besides, waste segregation and recycling provide income opportunities, especially for waste pickers and buyers (Jereme et al., 2015a). It has been proven that the recycling industry has contributed to 45% of employment, 43% of wages, and 41% of tax contributions in the US (EPA, 2020)

CONCLUSION

Our findings have confirmed that the waste segregation policy has contributed significantly to the increased segregated waste volume and waste reduction in landfills. The programme also enhances the recovery of recyclable materials at the source. The policy has significantly contributed to reducing waste management costs in the landfills at 61 thousand USD per year through the waste segregation programme in the states under Act 672. The programme could also generate profits through recyclable trading at 130 thousand USD per year. The overall findings suggested that the programme needs to be strengthened and empower the country's policy and legislation of waste management. However, for developing countries like Malaysia, landfilling method is still the main method to manage and dispose of a huge amount of waste generated daily. Hence, landfill design needs to be improved to have less impact on the environment and human health.

The study only focused on waste generation in the states under Act 672. Thus, the findings of the study do not represent the scenario of the whole country. However, it can be used as baseline data for the other states that do not implement the programme to improve waste management and encourage segregation. Moreover, the study used secondary data obtained from the SWCorp. The estimation and prediction from available data could help stakeholders plan and improve future waste management strategies. This study recommends that future studies expand the study area, which may include states that do not implement the mandatory waste segregation under Act 672. Therefore, the study can compare the waste generation pattern between states under Act 672 and those not under the act. Moreover, in the analysis of waste management costs, a future study in Malaysia should consider the cost of waste collection and transportation based on the type of waste, the population size, collection rates and operation cost (i.e., fuel, maintenance, wages, and geographical area).

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