UNIVERSITI MALAYA

SUSTAINABLE FUTURE:

Analyzing Waste Management Practices Across Countries

Group 4

Anis Munirah Binti Mohd Asri U202140
Aqilah Salihah Binti Ismail Yusoff U2101806
Noor Irham Mardhiah Binti Noor Azmi U2102210
Nur Qistina Imani Binti Mohammad Fadhly U2101068

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

PROBLEM STATEMENT & OBJECTIVES

SDG12 aims to substantially reduce waste generation by 2030.

However many regions face challenges in waste management, hindering progress towards this goal.

To address this problem, we aim to analyze global waste management practices specifically to:

1. To analyze patterns of general waste management
2. To find relationship between the features and total MSW generated
3. To cluster countries based on GDP and waste treatment recycling percentage
4. To develop a prediction model for total waste generation per capita

TOOLS & DATA SOURCE

Tools

Power BI

Data Source

THE WORLD BANK

INTERNATIONAL MONETARY FUND

ABOUT THE DATASET

	A	B	C	D	E	F	G	H	I	J	K	
1	iso3c	region_id	country_na	income_id	gdp	population	total_msw	compositio	compositio	compositio	compositio	cor
2	ABW	LCN	Aruba	HIC	3.54E+09	103187	88132.02					
3	AFG	SAS	Afghanistar	LIC	1.43E+10	34656032	5628525					
4	AGO	SSF	Angola	LMC	1.07E+11	25096150	4213644	51.8	6.7	4.4	11.5	
5	ALB	ECS	Albania	UMC	1.89E+10	2854191	1087447	51.4	4.5	4.8	15.21	
6	AND	ECS	Andorra	HIC	3.35E+09	82431	43000	31.2	8.2	2.6	11.6	
7	ARE	MEA	United Arat	HIC	5.07E+11	9770529	5617682	39	4	3	10	
8	ARG	LCN	Argentina	HIC	6.31E+11	42981516	17910550	38.74	3.16	1.84	15.36	
9	ARM	ECS	Armenia	UMC	1.95E+10	2906220	492800	57	3.2	3.4	17.4	
10	ASM	EAS	American S	UMC	8.71E+08	55599	18989.49	19.7	3.4	7.9	25.6	
11	ATG	LCN	Antigua and	HIC	1.87E+09	96777	30585	46	7	7	12	
12	AUS	EAS	Australia	HIC	1.69E+12	23789338	13345000	48.44	3.81	19.38	3.46	
13	AUT	ECS	Austria	HIC	4.71E+11	8877067	5219716	31.4	7	4.4	18.5	
14	AZE	ECS	Azerbaijan	UMC	7.87E+10	9649341	2930349	45.19	5.28	3.49	13.73	
15	BDI	SSF	Burundi	LIC	3.34E+09	6741569	1872016	81	2.9	2.1	3.2	
16	BEL	ECS	Belgium	HIC	5.83E+11	11484055	4765883	14.18	3.1	1.91	40.14	
17	BEN	SSF	Benin	LIC	1.74E+10	5521763	685936	52.1	1.6	1.6	34.3	
18	BFA	SSF	Burkina Fas	LIC	1.88E+10	18110624	2575251	21	1	1	61	
19	BGD	SAS	Bangladesh	LMC	4.60E+11	1.56E+08	14778497	80.58	0.44	0.5	8.59	
20	BGR	ECS	Bulgaria	UMC	9.03E+10	7025037	2859190	24.35	5.83	1.98	17.93	
21	BHR	MEA	Bahrain	HIC	4.44E+10	1425171	951943	59.1	3.4	2.1	15.2	
22	BHS	LCN	Bahamas, T	HIC	1.29E+10	386838	264000	46	7	7	12	
23	BIH	ECS	Bosnia and	UMC	2.45E+10	3535961	1248718				92.7	
24	BLR	ECS	Belarus	UMC	7.28E+10	9489616	4280000	30	8	2	35	
25	BLZ	LCN	Belize	UMC	2.83E+09	359288	101378.8	47	8	5	5	
26	BMU	NAC	Bermuda	HIC	7.55E+09	64798	82000	17	9	6	26	
27	BOL	LCN	Bolivia	LMC	4.4E+10	10724705	2219052	55.19691	2.903475	2.501931	22.7027	6.
28	BRA	LCN	Brazil	UMC	1.92E+12	2.08E+08	79069584	51.4	2.4	2.9	16.7	
29	BRB	LCN	Barbados	HIC	5.7E+09	280601	174815.4	18.3	3.7	4.9	5.7	
30	BRN	EAS	Brunei Dar	HIC	1.67E+10	423196	216253.2	36	3	4	15	
31	BTN	SAS	Bhutan	LMC	2.77E+09	686958	111314.1	58	4	1	7	
32	BWA	SSF	Botswana	UMC	2.04E+10	2014866	210854.4	8.1		0.1	91.9	

Shape: **217 countries x 51 columns**

Summary of columns:

- Country names and ISO3 code
- Country Region
- Income category
- Population
- Total municipal solid waste generated (tpy)
- Special waste generated (tpy)
- Composition of waste (%)
- Waste management policies

Total NULL values: 6208

DATA PREPROCESSING

1. **Select Relevant Columns**
2. **Drop columns where Null values make up the majority**
3. **Rename columns for readability**
4. **Created new column population category**

Population Range	Category	Value Counts
Less than 1,000,000	Small	58
1,000,000 to 9,999,999	Medium	75
10,000,000 and above	Large	84

Remaining 22 columns

```
Data columns (total 22 columns):
 #   Column
---  ------
 0   iso3c
 1   region_id
 2   country_name
 3   income_id
 4   gdp
 5   population
 6   total_msw_generated
 7   food_organic_waste_percent
 8   glass_percent
 9   metal_percent
 10  paper_cardboard_percent
 11  plastic_percent
 12  other_percent
 13  special_waste_e_waste_tons
 14  special_waste_hazardous_waste_tons
 15  waste_treatment_recycling_percent
 16  solid_waste_management_info_system
 17  national_agency_enforcing_waste_laws
 18  national_law_governing_solid_waste_management
 19  ppp_rules_and_regulations
 20  public_waste_info_summary
 21  population_category
```

DATA PREPROCESSING

Even after removing some columns, there were still a significant number of null values: 880. Different techniques were employed to handle these missing values.

1

Manually Filling

For columns with only one or two missing values, the data was manually filled in using information from other reliable sources.

	iso3c	region_id	country_name	income_id	gdp	population	total_msw_generated
198	TWN	EAS	NaN	HIC	NaN	23434000	7336000.0

Country Name	Country Codes	
	ISO3	Code
Syrian Arab Republic		SYR
Taiwan		TWN
Tajikistan		TJK

https://wits.worldbank.org/wits/wits/witshelp/content/codes/country_codes.htm

```
[175] #fill in the null value since only few missing values we can
      data.loc[data['iso3c'] == 'TWN', 'country_name'] = 'Taiwan'
      data.loc[data['iso3c'] == 'TWN', 'gdp'] = 669250000000
```

	iso3c	region_id	country_name	income_id	gdp	population	total_msw_generated
198	TWN	EAS	Taiwan	HIC	6.692500e+11	23434000	7336000.0

Evolution: Annual GDP Taiwan		
Date	Annual GDP	GDP Growth (%)
2022	$760,460M	2.4%
2021	$774,728M	6.6%
2020	$669,250M	3.4%

https://countryeconomy.com/gdp/taiwan

DATA PREPROCESSING

2

Mean Substitution

For numerical data, the mean was calculated based on countries with similar region, income category, and population categories, and used to replace missing values.

	iso3c	region_id	country_name	income_id	gdp	population	population_category	total_msw_generated
183	SXM	LCN	Sint Maarten (Dutch part)	HIC	1.537089e+09	37685	Small	NaN
186	TCA	LCN	Turks and Caicos Islands	HIC	1.138809e+09	34900	Small	NaN

subset dataset for countries with similar regions, income and population and calculate mean

	iso3c	region_id	country_name	income_id	gdp	population	population_category	total_msw_generated
0	ABW	LCN	Aruba	HIC	3.544708e+09	103187	Small	88132.0167
9	ATG	LCN	Antigua and Barbuda	HIC	1.867733e+09	96777	Small	30585.0000
20	BHS	LCN	Bahamas, The	HIC	1.289740e+10	386838	Small	264000.0000
27	BRB	LCN	Barbados	HIC	5.699950e+09	280601	Small	174815.4444
46	CUW	LCN	Curacao	HIC	3.075181e+09	153822	Small	24703.8132
47	CYM	LCN	Cayman Islands	HIC	6.844827e+09	59172	Small	60000.0000
104	KNA	LCN	St. Kitts and Nevis	HIC	9.656389e+08	54288	Small	32892.1400

mean = 19.0633

3

Standardization and Categorization

Standardized the capitalizations and created a new category "unknown" to handle null values.

```
national_law_governing_solid_waste_management
Yes     176
NaN      23
No       17
yes       1
Name: count, dtype: int64
```

```
national_law_governing_solid_waste_management
Yes          177
Unknown       23
No            17
Name: count, dtype: int64
```

1 **How does the total municipal solid waste (MSW) generated vary across different regions ?**

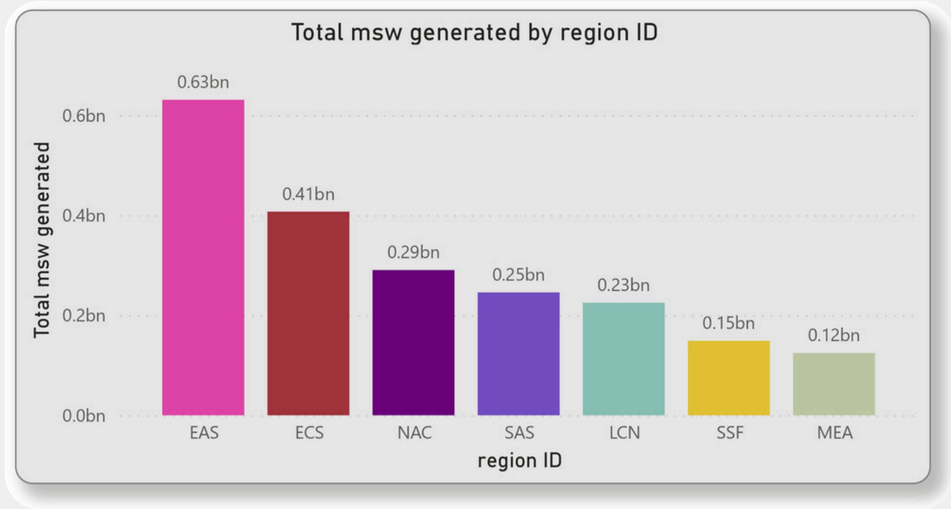
WASTE GENERATION PATTERNS

2.1B TOTAL MSW GENERATED

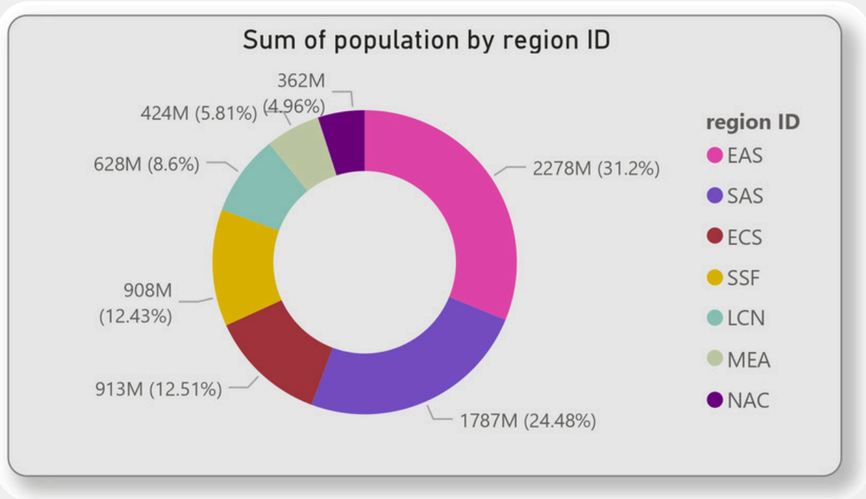
7.0B SUM OF POPULATION

465.5B AVERAGE OF GDP

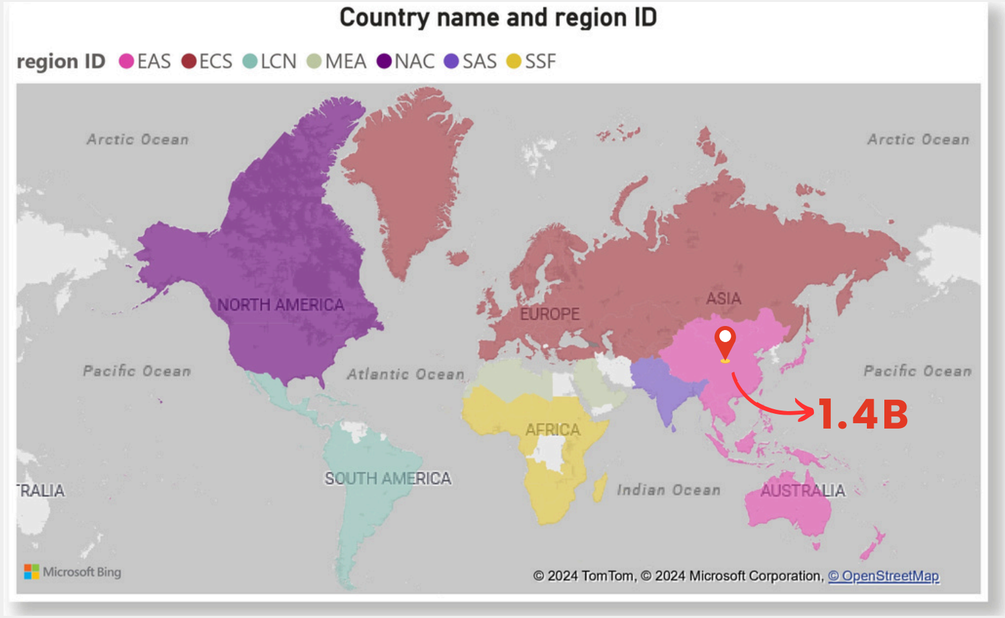
IN THE WORLD



The graph shows the total municipal solid waste generated by different regions, with **EAS** producing the highest amount at **0.63B** units and **MEA** producing the lowest at **0.12B** units.

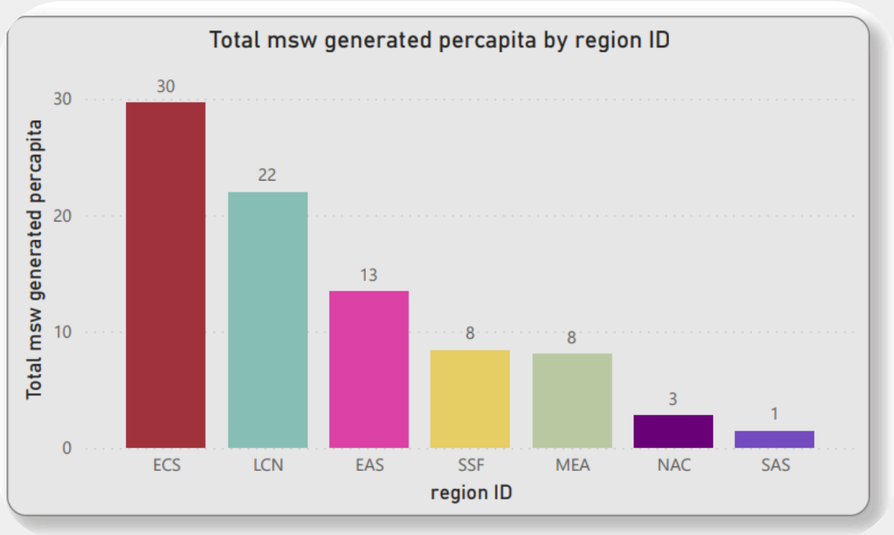


EAS has a much larger population than **MEA**. For instance, China alone has over **1.4 billion** people, contributing significantly to the waste generated in the region



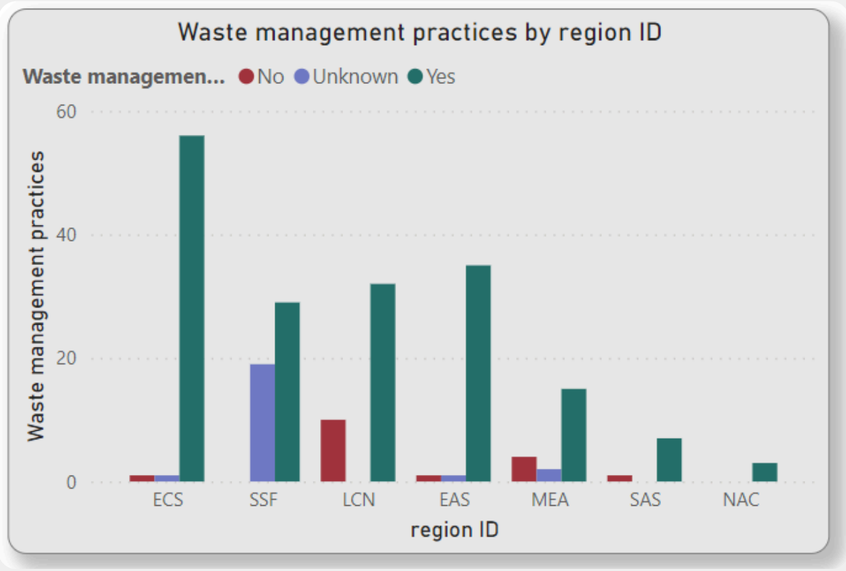
East Asia & Pacific · Europe & Central Asia · North America · South Asia · Latin America & Caribbean · Sub-Saharan Africa · Middle East & North Africa

WASTE GENERATION PATTERNS



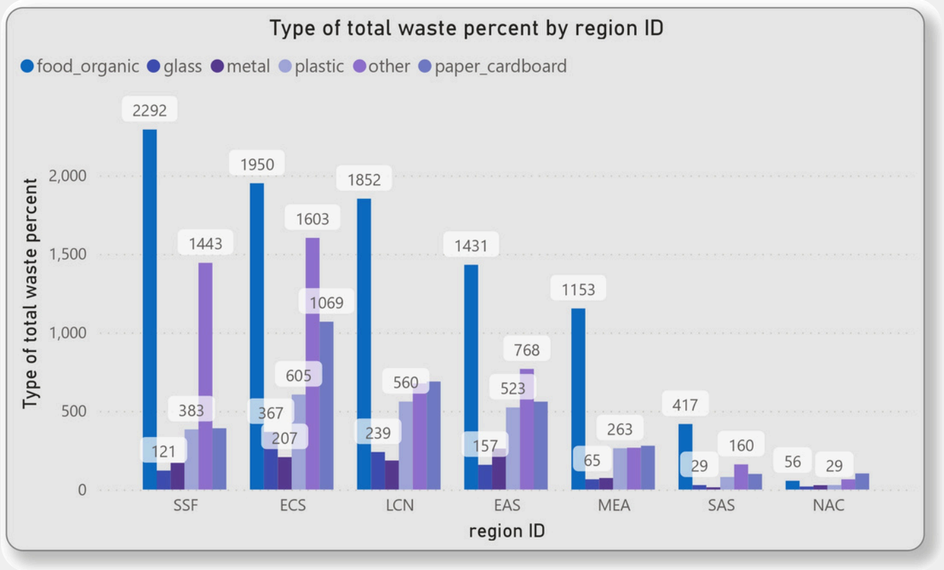
The graph clearly shows a disparity in the generation of municipal solid waste per capita across different regions.

ECS has better waste management practices result in more comprehensive and accurate collection and processing of waste, leading to **higher reported per capita waste generation**



2 How does the composition of waste generated vary across different regions?

SSF region has the **highest food/organic** waste sum percent while **EAS**, **LCN** and **ECS** regions show varying waste compositions and higher total MSW per capita due to differences in economic development, industrialization and consumption patterns.



East Asia & Pacific | Europe & Central Asia | North America | South Asia | Latin America & Caribbean | Sub-Saharan Africa | Middle East & North Africa

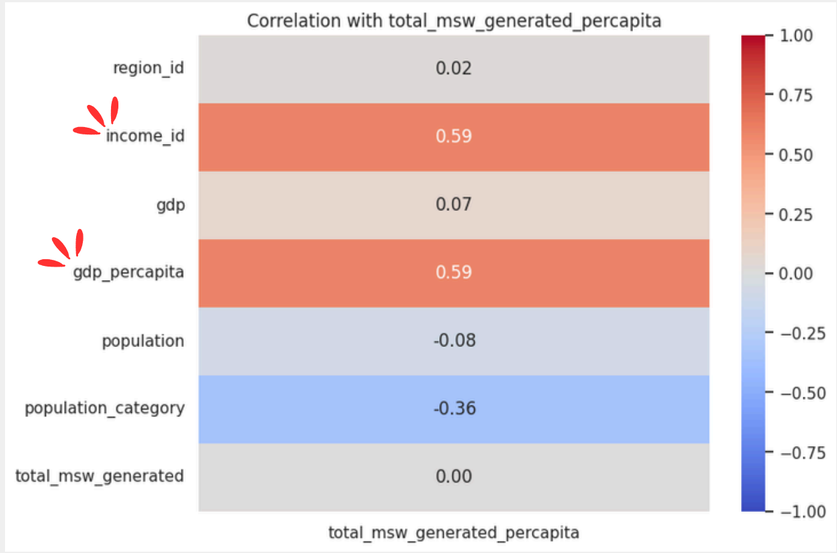
WASTE GENERATION PATTERNS

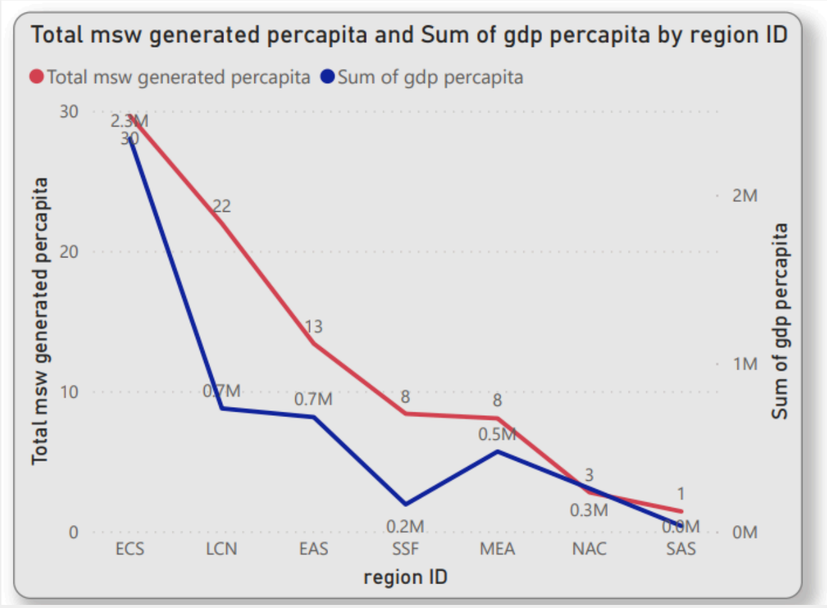
3 How does GDP per capita correlate with total municipal solid waste (MSW) generated per capita?

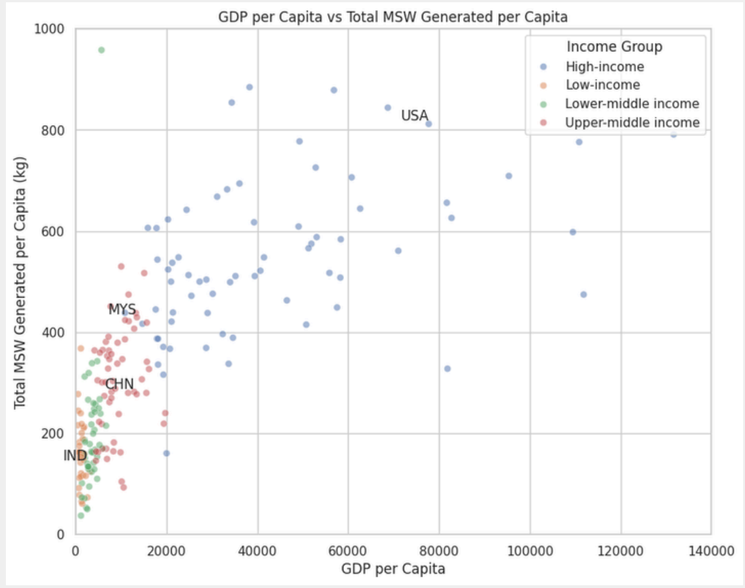
There is a noticeable trend where regions with **higher GDP per capita** tend to generate **more MSW per capita**. This could be due to higher levels of consumption and production associated with wealthier economies.

Regions with higher GDP per capita (**ECS**, **LCN**, **EAS**) tend to generate more MSW, indicating a correlation between GDP per capita and waste generation.

High-income countries tend to generate more MSW per capita than **low-income** countries.







STATISTICALLY SIGNIFICANT

P-VALUE < 0.05 (PEARSON)

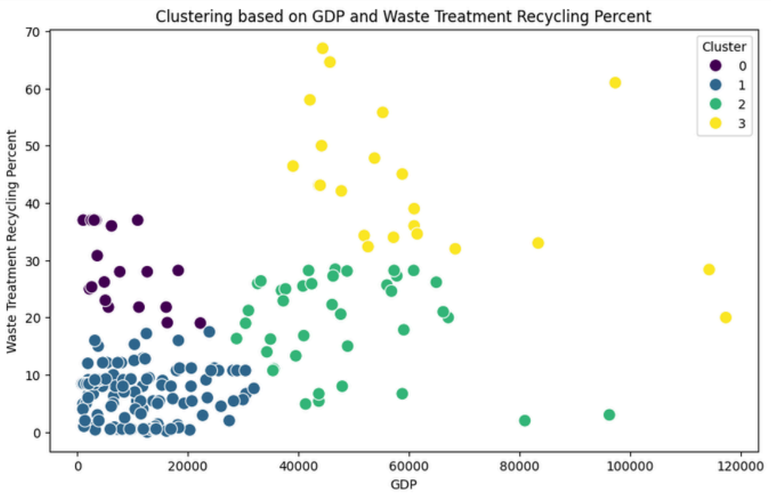
POSITIVE RELATIONSHIP

BETWEEN GDP PER CAPITA AND TOTAL MSW PER CAPITA

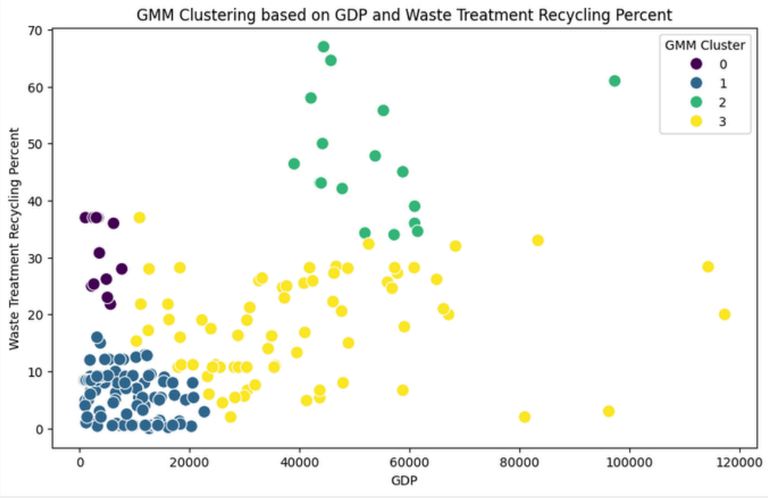
East Asia & Pacific · Europe & Central Asia · North America · South Asia · Latin America & Caribbean · Sub-Saharan Africa · Middle East & North Africa

CLUSTERING MODEL

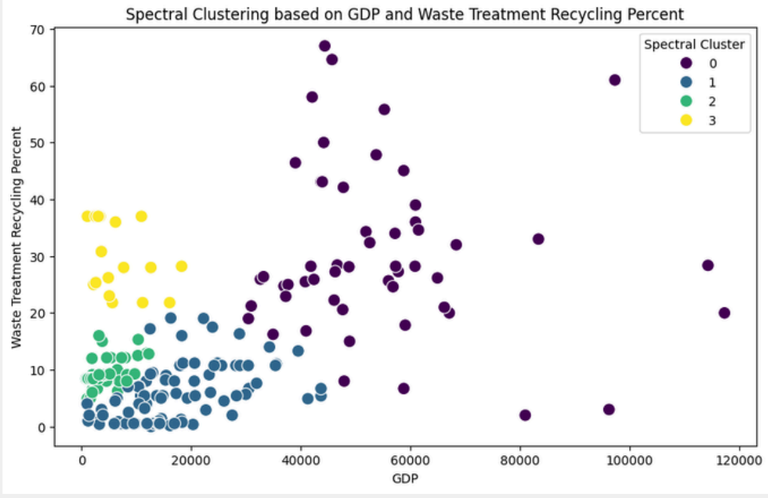
K-Means Clustering



Gaussian Mixture Model



Spectral Clustering



gmm_cluster	gdp	waste_treatment_recycling_percent
0	3810.991650	31.676558
1	7925.102611	6.296381
2	52910.021701	46.943365
3	39688.246055	17.541938

Cluster Analysis:

Cluster 0 (**Purple**)
- Countries with **very low GDP** but **high waste treatment recycling percentages**.
- These countries likely prioritize recycling despite limited economic resources.
- e.g. : Cambodia, Timor Leste

Cluster 1 (**Blue**)
- Countries with **low GDP** and **very low recycling rates**.
- These countries may face economic challenges that limit their waste management infrastructure and recycling programs.
- e.g. : Afghanistan, Venezuala

Cluster 2 (**Green**)
- Countries with **high GDP** and the **highest recycling rates**.
- These are likely affluent countries with well-developed waste management systems and strong environmental regulations.
- e.g. : South Korea, Singapore

Cluster 3 (**Yellow**)
- Countries with **moderate to high GDP** and **moderate recycling rates**.
- These countries have substantial economic resources but may not prioritize recycling as much as those in Cluster 2.
- e.g. : Malaysia, Italy

4 What are the distinct patterns in waste management practices among countries with varying economic statuses?

REGRESSION MODEL

Regression model - predict waste generation trends based on factors like income type and GDP per capita. By using GDP forecast data for the next decade, we were able to estimate how much waste each person is likely to generate in the coming years.

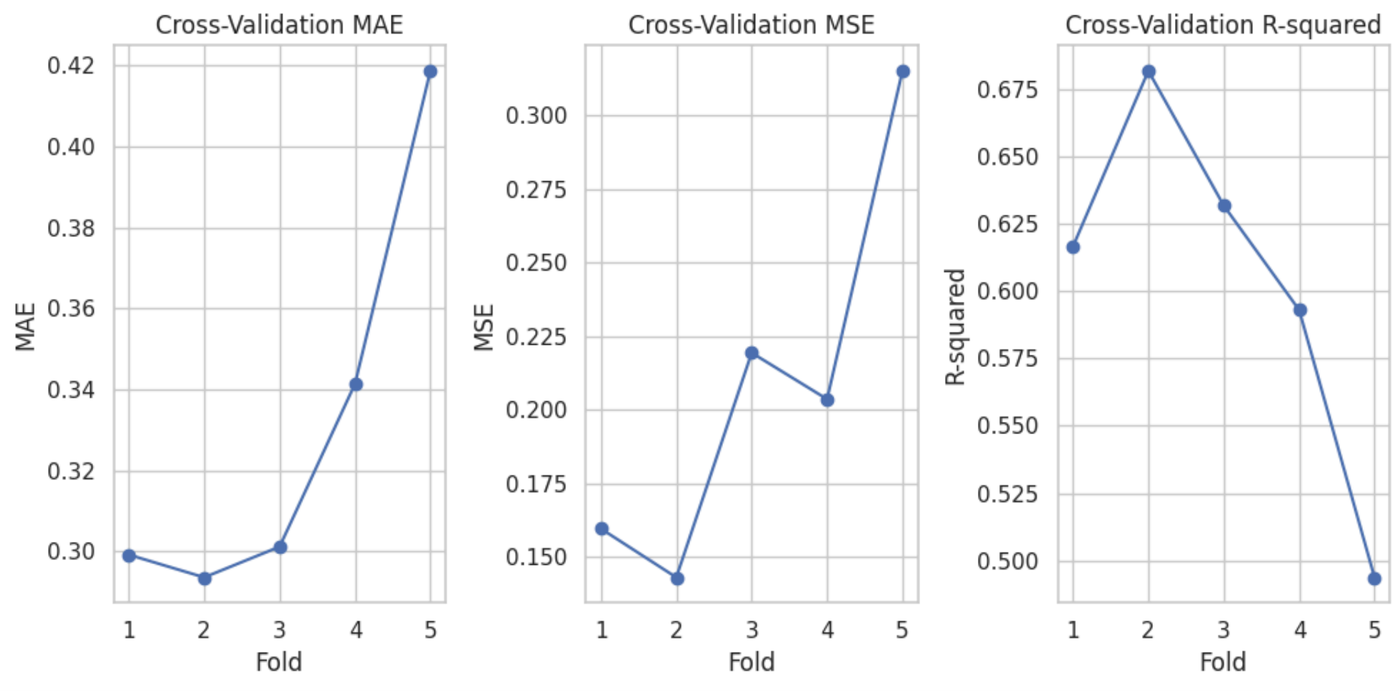
Results of the Regression Model

60.33%

of total MSW generated per capita is influenced by GDP per capita

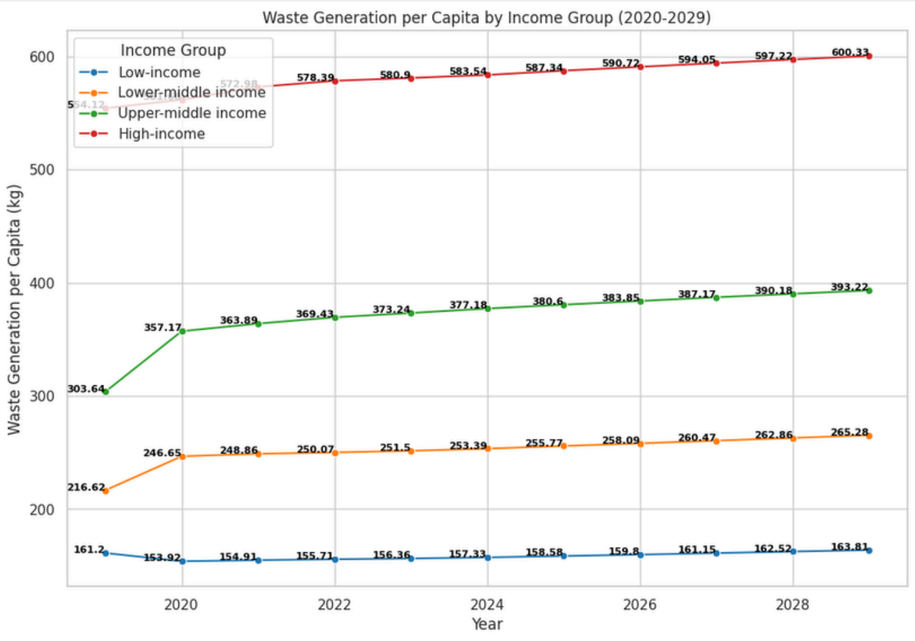
```
Mean MAE: 0.3307566483903654
Mean MSE: 0.208143423022797 87
Mean R-squared: 0.6033219220362078

Feature Importance:
log_gdp_percapita    0.323723
income_id            0.100856
dtype: float64
```

Cross-validation



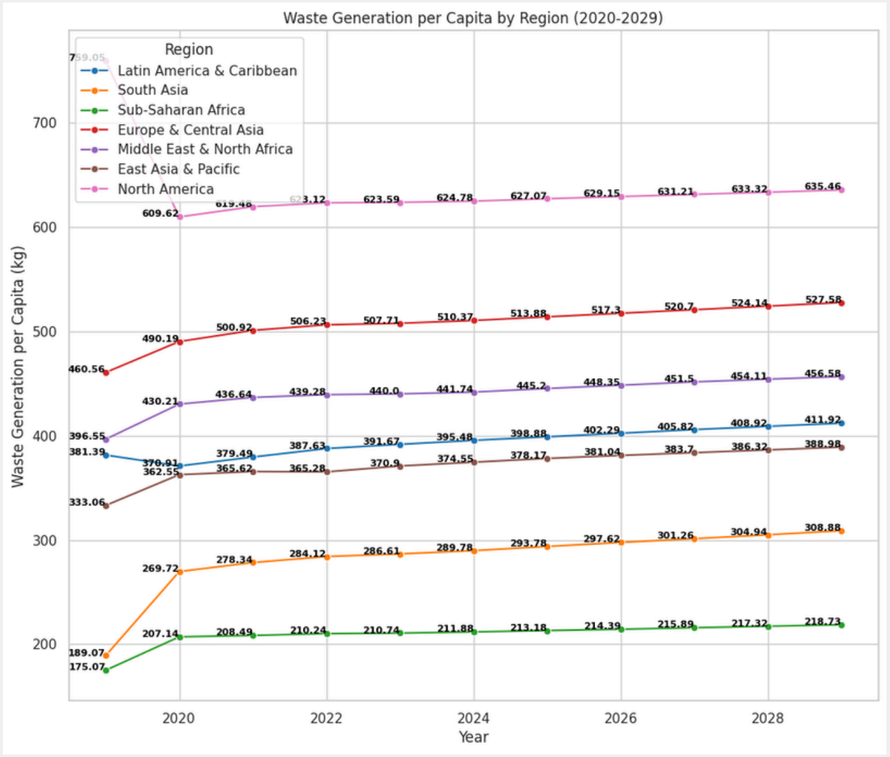
REGRESSION ANALYSIS

5 How is the waste generated per capita expected to change globally over the next decade?



Waste generation per capita across different income groups over a ten-year period (2020-2029)

The **High-income** group consistently generates the **highest amount of waste**, followed by the **Upper-middle income** group, **Lower-middle income** group, and finally the **Low-income** group.



Waste generation per capita across different regions over a ten-year period (2020-2029)

North America, starts around 759 kg **(highest amount of waste)** before 2020 and experiences slight fluctuations but remains relatively stable. Followed by **Europe & Central Asia**, **Middle East & North Africa**, **Latin America & Caribbean**, **East Asia & Pacific**, **South Asia,** and lastly, the **lowest** amount of waste by **Sub-Saharan Africa**

RECOMMENDATIONS

Several measures can be taken based on the patterns of waste generation, which can help to address the issue of excessive waste in the future.

Issues	Initiatives	Impacts
Unequal Waste Generation & Overconsumption	**Promote sustainable consumption:** • Encourage consumers to buy less • Choose durable and reusable products	Reduce the overall amount of waste generated
Limited Waste Management	**Investment in Waste Management** • Support developing countries through financial aid & technological expertise to build proper waste collection, recycling, & composting infrastructure.	Reduce pollution, improves public health
Public Awareness	**Public Education Campaigns** • Raise awareness about the environmental impact of waste and promote responsible disposal methods.	• Long-term behavioral changes • Individuals become more mindful consumers & responsible waste disposers

CONCLUSION

SIGNIFICANT FINDINGS

Higher per capita waste generation driven by higher consumption patterns

GDP per capita and total MSW per capita have a positive relationship

Regional waste composition depends on economic development, industrialization and consumption patterns.

High recycling rates in lower GDP countries indicate that effective policies and strong governance can overcome economic limitations to some extent

Prediction on total waste per capita is expected to steadily increase over the next 10 years

Recommendations have been proposed to minimize waste generation & responsibly manage resources

LIMITATIONS

Some countries have incomplete or outdated waste management data.

Though GDP is a strong indicator of waste management practices, it does not capture nuances such as cultural attitudes and behavioural patterns

SPSS has limited flexibility for custom analysis compared to programming languages like Python or R.