

Materials Flow Analysis: Singapore and Brunei Darussalam

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Abstract: Materials Flow Analysis (MFA) is a method for the analysis of the utilization of resources and its effect on a country's economy and environmental status. MFA has been utilized to analyze the flow of critical substances such as pollution and proper recycling of materials. In this study, Brunei Darussalam and Singapore, both small countries in Southeast Asia, have undergone an MFA. Data were gathered from various sources, particularly from the United Nations and Asean Waste Management reports. Brunei and Singapore's data on materials footprint per capita and Domestic Material Consumption per GDP was gathered, showing an upward trend for Singapore with Brunei being consistent all throughout, attributed to Brunei's abundant natural resources, particularly fossil fuels, compared to Singapore has few natural resources. For both countries with their GDP against Domestic Processed Output (DPO), Carbon dioxide emission, and DMI remain relatively decoupled. Both countries have high GDP and the highest in the Human Development Index (HDI), which indicates a good quality of life, and the countries' economic prowess. Despite having numerous differences in domestic extraction and consumption, the results of both countries' different actions resulted in their similar economic standing. This was performed in the study to cover the research gap of updating MFA data and clustering both countries to compare their similarities and differences while providing policy implications and recommendations to improve their material consumption in relation to the economy.

Key Words: economy; resources; material flow accounting; consumption; fossil fuels

1. INTRODUCTION

Brunei Darussalam and Singapore share the highest rating for Human Development Index (HDI) with Singapore being the highest followed by Brunei Darussalam (United Nations, 2020). This indicates the exemplary quality of life of its constituents, where access to public health, free education, and a basic standard of living, along with this both countries' high GDP, where Brunei's exports of oil and natural gas constitute 90% of its GDP and with Singapore focusing on tourism as its main source of GDP, agriculture, and worldwide trade with many other countries. Both

Singapore and Brunei are similar in terms of their country size or population and wealth, whereas both countries are small and wealthy. However, Brunei focuses more on crude oil and natural gases, while Singapore focuses on its tourism, trade, agricultural, and fishery industries. Other sectors in farming and agriculture for both countries are not as strong as their top industries. This is due to their lack of land, leading them to more restrictions to improve these sectors. As a result, they either rely on their limited resources or establish bilateral and multilateral agreements with other countries rich in agricultural and fisheries resources to ensure adequate supply.

As such, the material flow account of these

countries having strong economic performance yet limited natural resources is worth investigating. Material flow analysis (MFA) assesses and provides indicators of a country's extraction of natural resources, consumption of these materials, as well as the intensity and efficiency of resource use. MFA also considers the waste output of the socio-economic system, thus a relevant indicator to guide decisions and policies on waste management and recycling systems.

Recent developments in MFA are the accounts and reports performed in developing and emerging countries. The initial MFA study for Singapore (Poinapen et al. 2021) was related to the vision of Singaporean Ministries and governmental agencies to strive for zero-waste generation and a circular economy for their Sustainable Singapore Blueprint initiative. The MFA was able to identify challenges or risks in floods but had little concern for social, financial, and governmental aspects, indicating that policies and urban planning have been meaningful and lucrative. However, there are no other MFA reports published aside from the report by Poinapen et al. (2021), indicating that MFA reports are not a known practice in Singapore and have recently become vital to be researched. Furthermore, this recent study has no significant bearing on the data presented, as the focus of their study only concerns itself with flood risks.

On the other hand, an MFA on the complete economy of Brunei has not yet been done, but one was done on the Brunei River and its economic trade flows with the European Union (EU), which was used to evaluate its planning system and water evaluation, regarding a high flow of 2.7 cubic meters per second to preserve its natural and diverse ecosystem along the river and its susceptibility to low flow streams (Sharms, Rezo, & Azad, 2021). This study may also help reflect the current low DPO, attributed to the low emissions to water, of the country as 93% of the population of Brunei has access to clean potable water (Department of Economic and Social Affairs, 2020). With the current lack of literature on Materials Flow analysis for Brunei, the study remains to be novel. The material flows trade between Brunei and the European Union has continued to have a negative trade balance between Brunei and the EU with its current bilateral agreements and with high demand for oil and natural gas (Anaman & Al-Kharusi, 2003).

While Singapore completed an MFA report last 2021, Brunei has not yet had a report for the whole country. However, Singapore does not have any traces of prior versions of the MFA report on its country as a whole. This presents the need to continuously update and present MFA reports to their countries due to the rise in importance of MFA in countries. In addition, the trends observed in the current period may either change

or continue based on forecasts, and the MFA will be able to validate them. The indicators of MFA utilized in this study are compared with socio-economic indicators such as Gross Domestic Product (GDP) and population. Sudden economic activities and events may also occur that may cause unexpected changes in the trends of past MFA, so there is a need to update records. With this, data would be real-time and more reliable for future use.

The objective of the study is to conduct a cluster analysis of Singapore and Brunei through an updated MFA to analyze the current situation and provide recommendations aligned to their current status. The scope of the study covers a forty-seven-year period, from 1970 to 2017 for both countries, where relevant economic events are considered in the trends of GDP and other indicators, where data are sourced from online databases provided by known organizations.

2. METHODOLOGY

In the study, Materials Flow Analysis (MFA) is used as a tool for the study after the identification of the problem of the study is identified to be the lack of updated MFA reports for Singapore and Brunei and their comparison to one another. The problem is identified through a review of related literature and an assessment of their previous MFA reports. With the gathered information and data, MFA is applied, where it is a method for the analysis of the utilization of resources of a country affecting the economy and environmental status. MFA is composed of different material flows such as domestic extraction, importation, exportation, consumption, stocking, recycling, and disposal. MFA has been utilized to analyze the flow of critical substances such as pollution and proper recycling of materials for both Singapore and Brunei.

The MFA data are taken from the manual by the United Nations Environment Programme (UNEP) (2021), where the manual serves as a basis for the material flow accounts and calculations of indicators. These are based on the guidelines of the Statistical Office of the European Union (Eurostat) and the Organization for Economic Co-operation and Development (OECD). The researchers gathered data on the country's resources, consumption, inputs, and outputs from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) database where they are compiled and formed by collaborative efforts of established organizations and universities. The database contains information on 150 countries from the period 1970 to 2017, primarily on flow types of Domestic Extraction (DE), Domestic Material Consumption (DMC), Direct Material Input (DMI), Export, Import, and Physical Trade Balance (PTB), where these are

measured in tonnes per year. The data for Domestic Processed Output, are taken from multiple sources through governmental organizations.

These MFA indicators form the general overview of the physical and socio-economic systems of the country as shown in Figure 1, where the solid box represents the domestic border of the country under study. On the input side, DE shows the natural resources available and being extracted in the country, DMI accounts for all resources (import and locally sourced) that enter the socio-economic system of the country, and DMC provides insights into the structure and changes over time of the physical metabolism. The PTB shows whether a country is resource dependent (import>export) or resource provider (export>import). On the output side, DPO is a proxy indicator for pollution to water, air, and land as it covers the quantity of air emission, discharge of wastewater, and solid wastes disposal (Fischer-Kowalski et al. 2011; UNEP 2021).

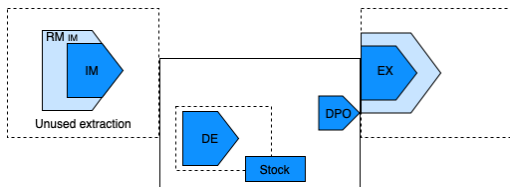


Fig. 1. Overview of Material Flow Analysis in the socio-economic system (UNEP 2021)

The MFA reports generated for both countries are assessed and compared to one another to accomplish the objective of the study, which is to provide updated MFA reports and comparisons between the cluster of Singapore and Brunei in terms of their performance in resource utilization and economy.

Figure 2 shows an overview of the methodology performed in the study, which covers the steps performed by the researchers.

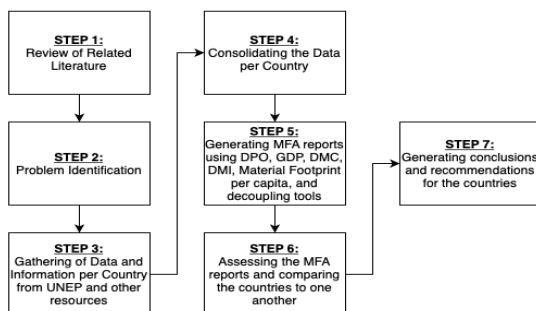


Fig. 2. Overview of the Methodology

3. RESULTS AND DISCUSSION

This section presents the presentation of data on MFA of Singapore and Brunei, where there are comparisons stated based on their performances. They are presented in a two-axis graph, where it is presented as time vs the index growth of the specified focus of the study. The importance of the use of this graph is that this will signify any decoupling in illustration. Furthermore, a straight horizontal line would indicate only a small growth, which signifies that there is a greater relative increase of one data against the other.

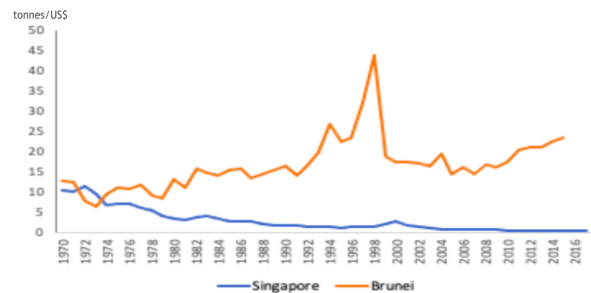


Fig. 3. DMC/GDP Graph for Singapore and Brunei

Based on Figure 3, comparing the trend behaviors of Singapore and Brunei, Singapore appears to have a stronger and more successful performance; however, comparing their individual ratios for DMC and GDP, Brunei is more superior due to ratios yielding less than 1, or precisely, 0.1. Brunei performs better in using less DMC while having a good GDP growth. However, comparing the country profiles and socio-economic statuses of both countries, the trend is supported by their strengths and weaknesses in industries. Singapore is less rich in terms of natural resources, which explains the higher DMC and struggle to improve GDP more than the consumption, whereas Brunei is rich in natural gas and other non-renewable resources that allow their country to have less consumption and boost GDP through trade and other industries that are utilize their resources. Overall, Brunei is able to be more productive in its resources to boost GDP and attain less DMC.

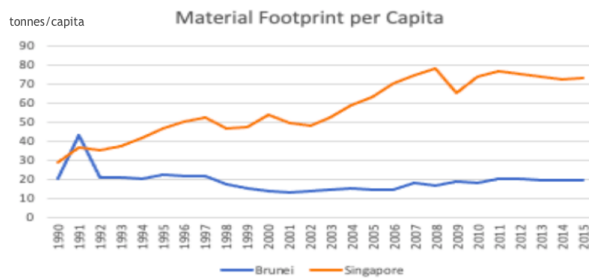
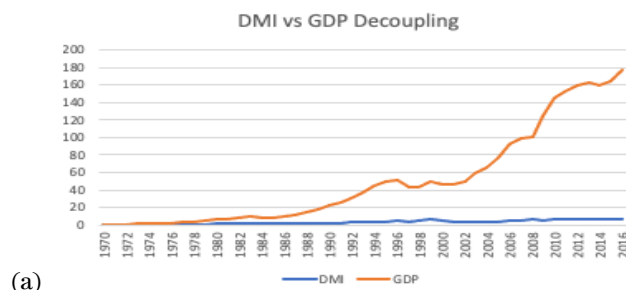
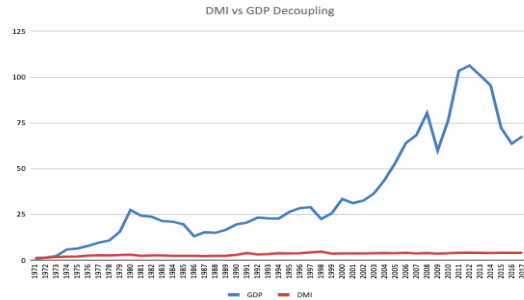


Fig. 4. Material Footprint per Capita Graph for Singapore and Brunei

Based on Figure 4, aside from the differences in the covered periods for the material footprint values, there exists a difference in their trend behaviors over the years, but they are similar in the change of trends. Both Singapore and Brunei have upward and downward trends present, where peaks are shown in more than one (1) year. However, comparing the trends of both countries from 2005 to 2017, Brunei generally has a higher material footprint. This implies that Singapore has less material consumption in its supply chain as compared to Brunei. In relation to the DMC and GDP, although Singapore has more DMC, the results in the material footprint present that the country is able to better consume its materials along the supply chain from raw material to its consumption by the end-user. This further implies that they generate fewer wastes and may have a cleaner manner of consumption, where materials are utilized down to their waste. Brunei may need to improve on this aspect, where further monitoring of the supply chain improvements may be made to conduct a cleaner manner of consumption. This may be performed by establishing policies and conducting inspections for companies on their consumption procedures for monitoring and tracking.

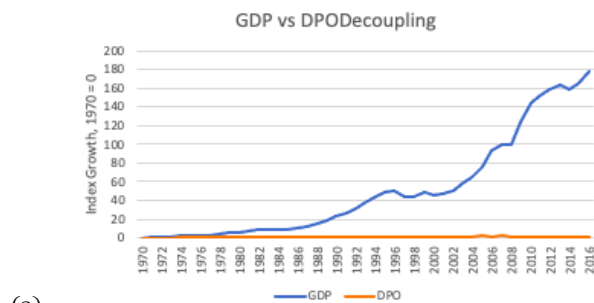


(a)

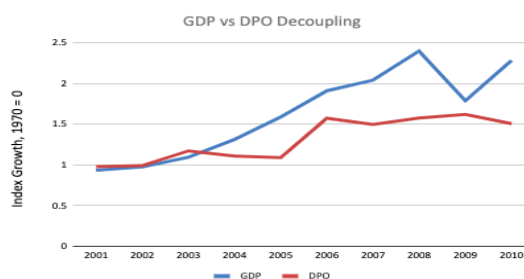


(b)
 Fig. 5. DMI/GDP Decoupling of (a) Singapore and (b) Brunei

It can be seen for both Brunei Darussalam and Singapore's GDP vs DMI decoupling that they remain relatively decoupled throughout the years. However, Brunei has an early onset of decoupling compared to Singapore. It can be seen that during 1973 they have already started to decouple, while Singapore has decoupled during 1973. However, Singapore's GDP remains relatively stable compared to Brunei's GDP as it is erratic, affected by local recessions and their immediate reliance on their oil and petroleum manufacturing.



(a)



(b)

Fig. 6. DPO vs GDP Decoupling of (a) Singapore and (b) Brunei

For both Brunei Darussalam and Singapore's GDP vs DPO decoupling graphs, Figure 6. It can be seen here that Singapore has better decoupling than Brunei. However, it can be attributed to the fact that Brunei's

data only encompasses from 2000 to 2010, while Singapore's data covers from 1970 to 2017 where a more prominent decoupling can be seen. However, with the limited data retrieved, Brunei still has relative decoupling and remains decoupled starting in 2004. As also previously stated, Brunei is also encouraged by the international community to invest in renewable sources of energy, as their source of fossil fuels would deplete soon, and to also reduce their DPO in the process. Furthermore, Singapore's trend for their DPO attained a negative slope, indicating an almost perfect decoupling.

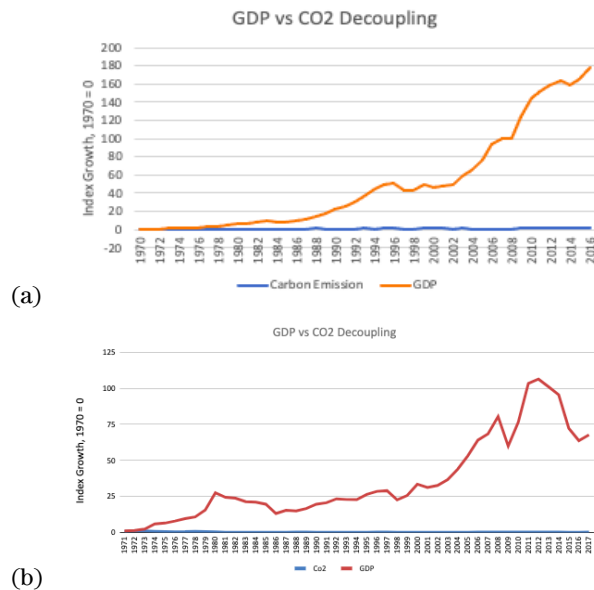


Fig. 7. CO₂ vs GDP Decoupling of (a) Singapore and (b) Brunei

For both Brunei Darussalam and Singapore's graphs, Figure 7, on GDP vs Carbon dioxide emissions, it is evident that Brunei has decoupled earlier in 1973, while Singapore decoupled later during 1978. A continuous trend for both countries is to remain decoupled with Carbon dioxide as their GDP rises. Both countries also almost consistently never increase their carbon dioxide emissions and remain the same, via utilizing the index growth of their data. Overall Brunei Darussalam and Singapore's graphs on GDP vs DMI, DPO, and Carbon dioxide remains decoupled and continues to do so. However, more data should be gathered for Brunei's DPO to view if they have truly achieved decoupling. Brunei's supposed criticism of the utilization of fossil fuels for energy would significantly drop and follow Singapore's negative slope regarding their DPO.

4. CONCLUSIONS

With both countries performing well with their high GDPs and high ranking in the Human Development Index, they should still be open to improvements. Singapore should continue to safeguard its sources of GDP, with more policies that supplement the National Family Campaign which aims at a steady yet growing population, to maintain their GDP per capita ratio to increase. The country still needs to improve further in its agricultural and fisheries sectors since these areas produce waste and pollution, and they have known industries in Singapore. Much focus is given to green cities but there is a lack of implementation of this goal in other industries. More policies are recommended to cover for the agricultural and fisheries industries to allow them to also perform excellently as with the tourism and trade industries.

As for Brunei, the country should also open itself to start establishing access to greener renewable sources of energy, as their reliance on oil and natural gas is still at 99% which will deplete soon, and the implications of their utilization of climate change should also be reduced. However, with their current DPO, it can be seen that the carbon dioxide emission is overshadowed by the large GDP and in relation to their country's size. Investing soon in these new greener and renewable technologies, while their income is still sustainable, could protect the country from future recessions when their sources of fossil fuels start to lack.

For further research, MFA may be produced for both countries in the future to update the reports. Clustering may also be improved by adding more similar countries in their economic performances for detailed comparisons.

5. ACKNOWLEDGMENTS

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