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Assessment on Health Impacts and Costs of Fine Particulate Matter from Passenger Transport in Bangkok Metropolitan Region

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Abstract

The world has faced fine particulate matter ($PM_{2.5}$) problems affecting human health. Globally, $PM_{2.5}$ has caused 4.14 million pre-mature deaths, which is the fourth leading cause of death in the world. According to the annual report of the Pollution Control Department, the $PM_{2.5}$ value in Bangkok exceeded the national standards for 89 days in 2022. Transport was the dominant source of fine particulate matter in Bangkok. This research aims to develop an emission inventory and assess the health impacts and health costs of fine particulate matter from passenger transport in the Bangkok Metropolitan Region. The emission inventory was divided into two parts : fuel use and fuel production. Health impacts and health costs were quantified in the units of disability-adjusted life years (DALY) and Baht, respectively. According to research results in 2022 and 2027, the scenario that shifts 30% of private passenger transport to electric trains can reduce health impacts to 15,202 DALY/year and 9,011 million Baht (in 2022) and to 17,178 DALY/year and 10,883 million Baht (in 2027). Future policies should promote electric public transport and minimize the use of private vehicles.

Keywords : Air pollution; Fine particulate matter; Life cycle assessment; Vehicle emission

Introduction

Currently, $PM_{2.5}$ pollution is a major issue across all regions of Thailand, including the Bangkok Metropolitan Region. According to the STATE OF GLOBAL report for 2020, air pollution was the primary factor causing premature deaths, ranking fourth globally with 4.14 million fatalities. Moreover, air pollution has been linked to chronic obstructive pulmonary disease (COPD), resulting in 28% of deaths, diabetes with 21%, and a further 19% of deaths due to ischemic heart disease in the high-risk group aged 70 and above. Additionally, 9% of deaths in this age group were attributed to air pollution, while air pollution is also responsible for 5% of deaths in children under the age of 5 [1].

The $PM_{2.5}$ concentration was reported to exceed the permissible limit in all areas. Bangkok exceeded the standard limits of 89 days in 2021 [2].

Statistical analysis of passenger transport data in 2019 revealed that roads, trains, and water accounted for 38%, 33% and 14% of the total transport in Bangkok. Emissions data from inland water transport in 2019 showed that the total annual emission of NO_x, NH_3, SO_2 and $PM_{2.5}$ was 317.5, 0.03, 0.6 and 12.1, respectively. In 2019, the main source of 44.7% of the $PM_{2.5}$ emissions from inland water transport was the Chao Phraya boats, followed by Saen Saep boats which were responsible for 33.8% of $PM_{2.5}$ emissions [3]. In addition, it was also calculated that the vehicles travelling in the Bangkok Metropolitan Region between 2024 and 2029 are expected to emit 8,965 and 7,234 tonnes of pollutants, respectively. These emissions will cause a loss of 47,513 and 41,731 DALY [4].

The current study investigated the health impacts and health costs of passenger's transport modes such as road, water and railways in the Bangkok Metropolitan Region. This study aims to (1) develop and analyze an emission inventory of pollutant emissions that contribute to the formation of $PM_{2.5}$ from passenger transport modes of road, water, and rail; (2) assess the health impacts and health costs resulting from the release of $PM_{2.5}$ emissions from passenger transport by road, water, and railways; and (3) assess the significance of reducing the health impacts and health costs of fine particulate matter emissions caused by changes in travel patterns.

Methodology

1) Sampling and study area description

A study was conducted to examine the health impacts and health costs of road, water, and rail transport in Bangkok, Pathum Thani, Nonthaburi, Samut Prakan, Nakhon Pathom, and Samut Sakhon provinces of Thailand. The study was divided into two parts. In part 1, the type of vehicles used and the pollutants emitted via exhaust pipes by fuel burning were discussed. Part 2 focused on the contribution of oil and electricity generation to pollution levels. The pollutants investigated were $PM_{2.5}$ and its precursors which are NO_x, NH_3, and SO_2. The study focused on the three modes of transport to determine the travel modes of the population. Transportation options include road transport such as cars with passenger cars < 7 seats, passenger cars > 7 seats, private motorcycles, public motorcycles, buses, public water transport including; cross river ferries, Chao Phraya boats and Saen Saep boats, and rail transport such as electric trains and trains.

The research unit studied road, water, and rail passenger transport in the Bangkok Metropolitan Region in 2022 and made predictions for the year 2027 using data from 2022.

2) Study scenarios

Table 1 depicts the scenario assessed using the transport development strategy of Thailand.

3) Emission inventory

Road transport

Pollution from road transport was calculated using the European Monitoring and Evaluation Program (EMEP)/European Environment Agency (EEA) Air Pollution Emission Inventory Guidebook 2019. Equation 1 is used to estimate the emission of $PM_{2.5}$, NO_x and NH_3, while equation 2 is used for SO_2. The emission factors of exhaust emissions from road transport are shown in Table 2.

Table 1 Study Scenarios

Scenarios	Description
BAU (2022)	Business as Usual (BAU) in 2022
2 (2022)	In 2022, the number of passenger's car was decreased by 30%, and shifted to bus mode.
3 (2022)	In 2022, the number of passenger car was decreased by 30%, and shifted to water transport option.
4 (2022)	In 2022, the number of passenger's car was decreased by 30% and shifts to electric trains.
1 (2027)	the number of passengers is predicted in 2027.
2 (2027)	In 2027, the number of passenger's car was decreased by 30%, and shifted travel by to bus. shifted to bus mode.
3 (2027)	In 2027, the number of passenger car was decreased by 30%, and shifted to water transport option.
4 (2027)	In 2027, the number of passenger's car was decreased by 30% and shifts to electric trains.

Table 2 Emission factors of exhaust emissions from road transport

Type	Age(year)	Technology	Fuel	$PM_{2.5}$ (kg $_{PM2.5}$/pkm)	NO_x (kg $_{NOx}$/pkm)	NH_3 (kg $_{NH3}$/pkm)	SO_2(kg $_{SO2}$/pkm)
Passenger Car < 7	1< to 5	Euro 4	Gasoline	9.57E-07	5.30E-05	2.97E-05	6.09E-06
			B7	2.51E-05	5.06E-04	8.07E-07	5.22E-06
			B20	2.18E-06	5.09E-04	8.70E-07	5.22E-06
			LPG	9.57E-07	4.87E-05	2.94E-05	1.46E-05
			CNG	9.57E-07	4.87E-05	2.94E-05	5.22E-06
Passenger Car < 7	6 to 10	Euro 4	Gasoline	9.57E-07	5.30E-05	2.97E-05	6.09E-06
			B7	2.51E-05	5.06E-04	8.07E-07	5.22E-06
			B20	0.00E+00	0.00E+00	0.00E+00	5.22E-06
			LPG	9.57E-07	4.87E-05	2.94E-05	1.46E-05
		Euro 4	CNG	9.57E-07	4.87E-05	2.94E-05	5.22E-06
Passenger Car < 7	11 to 15	Euro 3	Gasoline	9.57E-07	8.43E-05	2.97E-05	6.09E-06
			B7	3.13E-05	6.74E-04	8.70E-07	5.22E-06
			B20	0.00E+00	0.00E+00	0.00E+00	5.22E-06
			LPG	9.57E-07	7.83E-05	2.94E-05	1.46E-05
		Euro 4	CNG	9.57E-07	4.87E-05	2.94E-05	5.22E-06
Passenger Car < 7	16 to 20	Euro 3 + 2	Gasoline	1.53E-06	1.67E-04	6.63E-05	6.09E-06
			B7	3.88E-05	6.44E-04	8.70E-07	5.22E-06
			B20	0.00E+00	0.00E+00	0.00E+00	5.22E-06
			LPG	1.53E-06	1.25E-04	6.43E-05	1.46E-05
		Euro 4	CNG	9.57E-07	4.87E-05	2.94E-05	5.22E-06
Passenger Car < 7	>20	Euro 2+1	Gasoline	1.91E-06	3.55E-04	8.37E-05	6.09E-06
			B7	5.95E-05	6.09E-04	8.70E-07	5.22E-06
			B20	0.00E+00	0.00E+00	0.00E+00	5.22E-06
			LPG	1.91E-06	2.92E-04	8.02E-05	1.46E-05
		Euro 4	CNG	9.57E-07	4.87E-05	2.94E-05	5.22E-06
Passenger Car > 7	1< to 5	EURO 4	Gasoline	9.17E-07	5.33E-05	2.52E-05	8.33E-06
			B7	3.11E-05	6.99E-04	1.00E-06	6.67E-06
			B20	2.73E-06	7.06E-05	1.00E-06	6.67E-06
			LPG	9.17E-07	4.67E-05	2.82E-05	1.40E-05
			CNG	9.17E-07	4.67E-05	2.82E-05	5.00E-06
Passenger Car > 7	6 to 10	Euro 4	Gasoline	9.17E-07	5.33E-05	2.52E-05	8.33E-06
			B7	3.11E-05	6.99E-04	1.00E-06	6.67E-06
			B20	0.00E+00	0.00E+00	0.00E+00	6.67E-06
			LPG	9.17E-07	4.67E-05	2.82E-05	1.40E-05
		Euro 4	CNG	9.17E-07	4.67E-05	2.82E-05	5.00E-06
Passenger Car > 7	11 to 15	Euro 3	Gasoline	9.17E-07	1.08E-04	2.52E-05	8.33E-06
			B7	5.96E-05	8.66E-04	1.00E-06	6.67E-06
			B20	0.00E+00	0.00E+00	0.00E+00	6.67E-06
			LPG	9.17E-07	7.50E-05	2.82E-05	1.40E-05
		Euro 4	CNG	9.17E-07	4.67E-05	2.82E-05	5.00E-06
Passenger Car > 7	16 to 20	Euro 3 + 2	Gasoline	1.52E-06	1.58E-04	5.56E-05	8.33E-06
			B7	7.73E-05	9.62E-04	1.00E-06	6.67E-06
			B20	0.00E+00	0.00E+00	0.00E+00	6.67E-06
			LPG	1.47E-06	1.20E-04	6.16E-05	1.40E-05
		Euro 4	CNG	9.17E-07	4.67E-05	2.82E-05	5.00E-06
Passenger Car > 7	>20	Euro 2+1	Gasoline	1.92E-06	3.77E-04	6.74E-05	8.33E-06
			B7	8.90E-05	1.03E-03	1.00E-06	6.67E-06
			B20	0.00E+00	0.00E+00	0.00E+00	6.67E-06
			LPG	1.83E-06	2.80E-04	7.69E-05	1.40E-05
		Euro 4	CNG	9.17E-07	4.67E-05	2.82E-05	5.00E-06
Public Buses	1< to 5	Euro 3	Gasoline	0.00E+00	3.74E-04	1.16E-07	9.56E-07
			B7	7.69E-06	3.81E-04	1.16E-07	9.56E-07
			B20	7.01E-06	3.87E-04	1.16E-07	9.56E-07
			LPG	3.98E-07	3.98E-04	0.00E+00	5.58E-06
			CNG	3.98E-07	3.98E-04	0.00E+00	1.99E-06
Public Buses	6 to 10	Euro 3	Gasoline	0.00E+00	3.74E-04	1.16E-07	9.56E-07
			B7	7.69E-06	3.81E-04	1.16E-07	9.56E-07
			B20	0.00E+00	3.87E-04	1.16E-07	9.56E-07
			LPG	3.98E-07	3.98E-04	0.00E+00	5.58E-06
			CNG	3.98E-07	3.98E-04	0.00E+00	1.99E-06
Public Buses	11 to 15	Euro 3+2	Gasoline	0.00E+00	3.95E-04	1.16E-07	9.56E-07
			B7	7.88E-06	4.02E-04	1.16E-07	9.56E-07
			B20	0.00E+00	0.00E+00	0.00E+00	9.56E-07
			LPG	3.98E-07	4.78E-04	0.00E+00	5.58E-06
			CNG	3.98E-07	4.78E-04	0.00E+00	1.99E-06
Public Buses	16 to 20	Euro 2+1	Gasoline	0.00E+00	4.26E-04	1.16E-07	9.56E-07
			B7	8.17E-06	4.34E-04	1.16E-07	9.56E-07
			B20	0.00E+00	0.00E+00	0.00E+00	9.56E-07
			LPG	3.98E-07	5.98E-04	0.00E+00	5.58E-06
			CNG	3.98E-07	5.98E-04	0.00E+00	1.99E-06
Public Buses	>20	Euro 2+1	Gasoline	0.00E+00	4.08E-04	1.16E-07	9.56E-07
			B7	1.54E-05	4.16E-04	1.16E-07	9.56E-07
			B20	0.00E+00	0.00E+00	0.00E+00	9.56E-07
			LPG	6.97E-07	6.42E-04	0.00E+00	5.58E-06
			CNG	6.97E-07	6.42E-04	0.00E+00	1.99E-06
Motorcycle	1< to 5	Euro 3	Gasoline	3.18E-06	1.76E-04	1.73E-06	3.64E-06
Motorcycle	6 to 10	Euro 3	Gasoline	3.18E-06	1.76E-04	1.73E-06	3.64E-06
Motorcycle	11 to 15	Euro 3+2	Gasoline	8.36E-06	1.82E-04	1.73E-06	3.64E-06
Motorcycle	16 to 20	Euro 2	Gasoline	3.55E-05	1.82E-04	1.73E-06	3.64E-06
Motorcycle	>20	Euro 2+1	Gasoline	3.55E-05	1.82E-04	1.73E-06	3.64E-06

Note: Low pollution   Medium pollution   High pollution

Emission$_{(PM2.5,\ NOx,\ NH3)}$ = Emission Factor * Transport Volume (pkm) (1)

Emission$_{(SO2)}$ = 2 * Typical fuel consumption * Sulfur content in fuel * Transport Volume (pkm) (2)

where emission represents the total emissions of air pollutants (kg/year), emission factor denotes the emission factor for each type of pollutant (kg/pkm), fuel consumption is the amount of fuel consumption in (kg/pkm), transport volume (pkm) represents the passenger perkilometer (pkm/year).

Water transport

Pollution from water transport was calculated using the USEPA (2010) shown in equation 3 for $PM_{2.5}$, NO_x, NH_3. and SO_2. The emission factor of exhaust emissions from water transport is shown in Table 3.

Emission$_{(PM2.5,\ NOx,\ NH3,\ SO2)}$ = (Cruising Emission factor + Idling Emission factor) * Transport Volume (pkm) * 10^{-3} (3)

where emission represents the total emissions of air pollutants (kg/year), cruising emission factors denote the pollution during travel (kg/pkm), idling emission factors represent pollution during mooring between ports (kg/pkm), and transport volume (pkm) represents the passenger per kilometer (pkm/year).

Rail transport

Pollution from rail transport was calculated using the European Monitoring and Evaluation Program (EMEP)/European Environment Agency (EEA) Air Pollution Emission Inventory Guidebook 2019. The exhaust emission of electric trains and trains are calculated using equation 4 and 5. The emission factor of exhaust emissions from rail transport is shown in Table 4.

Emission of electric trains = Emission Factor * electricity * Transport Volume (pkm) (4)

Emission of train = Emission Factor * Fuel consumption * Transport Volume (pkm) (5)

where emission represents the total emissions of air pollutants (kg/year), electricity represent electricity consumption per 1 Km of a passenger car (kwh/pkm), fuel consumption denotes the consumption of fuel by the engine (tonnes/pkm), and transport volume (pkm) represent the passenger per kilometer (pkm/year).

4) Health impact assessment

Health impact assessment use LCA approach will be applied to find the characterization factors of $PM_{2.5}$ and secondary $PM_{2.5}$ both indoors and outdoors.

The health impact gained from the multiplication of the emission and characterization factor is shown in Equation 6.

Health Impacts = Emission from step 3 * Characterization factor (6)

The characterization factors were obtained from Chavanaves et al. [4], as shown in Table 5. The spatial differentiation in impact assessment of direct emissions and supply chain emissions in Thailand was considered based on the Thai Spatially Differentiated Life Cycle Impact Assessment (ThaiSD) method [5].

Table 3 Emission factor of exhaust emissions from water transport

Type of boat	Cruising Emission Factor (g/pkm)				Idling Factor (g/pkm)			
	Primary $PM_{2.5}$	NO_x	NH_3	SO_2	Primary $PM_{2.5}$	NO_x	NH_3	SO_2
Cross river ferries	1.13E-01	1.97E+00	2.30E-04	3.68E-03	2.82E-02	2.11E+00	2.30E-04	3.68E-03
Chao Phraya boats	4.60E-02	8.06E-01	9.39E-05	1.50E-03	1.15E-02	8.62E-01	9.39E-05	1.50E-03
Saen Saep boats	2.38E-02	4.17E-01	4.86E-05	7.78E-04	5.96E-03	4.46E-01	4.86E-05	7.78E-04

Table 4 Emission factor of exhaust emissions from rail transport

vehicle	Fuel	$PM_{2.5}$ Emission Factor (kg /tones)	NO_x Emission Factor (kg /tones)	NH_3 Emission Factor (kg /tones)	SO_2 Emission Factor (kg /tones)	Electricity (kWh/PKM)	Fuel consumption (tones /PKM)
Train	B7	1	39.9	0.01	0.05	-	3.00E-06
BTS	Electricity	0	0	0	0	5.60E-02	-
MRT	Electricity	0	0	0	0	7.81E-03	-

Table 5 Characterization factor for Bangkok Metropolitan Region and global average

Area	Characterization factor (DALY/kg of pollutants emitted)				**Ref.**
	$PM_{2.5}$	**NH_3**	**SO_2**	**NO_x**	
Bangkok	6.06E-03	1.45E-04	8.46E-05	1.71E-05	[4]
Pathum Thani	1.12E-03	1.45E-04	8.46E-05	1.71E-05	[4]
Nonthaburi	5.20E-04	1.45E-04	8.46E-05	1.71E-05	[4]
Samut Prakan	6.86E-04	1.45E-04	8.46E-05	1.71E-05	[4]
Nakhon Pathom	1.42E-03	1.45E-04	8.46E-05	1.71E-05	[4]
Samut Sakhon	1.61E-03	1.45E-04	8.46E-05	1.71E-05	[4]
Global average	4.90E-03	2.60E-04	1.50E-04	3.10E-05	[6]

5) Health costs assessment

The health cost assessment was based on the Budget Constraint method based on [7]. It is a way of considering the willingness to pay to regain good health.

The budget constraint method is considered using two indicators: quality-adjusted life year (QALY) represents the number of healthy years, and DALY represents the number of healthy years lost. For the above reasons it can be concluded that the value of 1QALY is equal to - 1DALY.

The health costs assessment is derived from the conversion of health impacts into the value of health costs in Baht, as shown in Equation 7.

Health cost = value of DALY * Health impact (7)

Results and Discussion

$PM_{2.5}$ emission in 2022

The calculated emission levels in the Bangkok Metropolitan Region in 2022 were determined to be consistent with business as usual (BAU). The exhaust emissions of $PM_{2.5}$, NH_3, SO_2, and NO_x were estimated to be 1,248, 1,766, 602, and 38,582 tonnes per year, respectively, In contrast energy production were estimated 1,288, 78, 23,535, and 11,695 tonnes per year, respectively. In comparison to various scenarios with BAU. It was found that scenario 4 (in 2022), due to the increased use of electric trains resulted in lower pollution emissions compared to business as usual in 2022. The $PM_{2.5,}$ NH_3, SO_2, and NO_x emissions generated by exhaust emissions and energy production were 13%, 26%, 14%, and 22%, respectively. The minimum reduction in 2022 is represented by scenario 3, resulting in increased use of water transport and a 26% reduction in NH_3 emissions from exhaust emissions and energy production. However, $PM_{2.5}$, SO_2, and NO_x emissions were increased by 67%, 26%, and 82%, respectively.

$PM_{2.5}$ emission projection in 2027

The results of the emission calculations for the Bangkok Metropolitan Region in 2027 were found in scenario 1 (2027). The exhaust emissions of $PM_{2.5}$, NH_3, SO_2, and NO_x were estimated at 1,139, 1,761, 714, and 38,981 tonnes/year, respectively, while energy production was estimated at 1,614, 97, 28,957, and 14,750 tonnes/year. In the comparison of various scenarios with scenario 1 (2027), it was found that scenario 4 (2027) resulted in the greater decrease in pollutant emissions due to the increased use of electric trains. There was a reduction in the exhaust emissions and energy production of $PM_{2.5}$, NH_3, SO_2, and NO_x by 11%, 27%, 14%, and 21%, respectively. The lowest reduction was found in scenario 3 (in 2027) because of an increase in water transportation, which led to an increase in $PM_{2.5}$, NH_3, SO_2, and NO_x exhaust emissions and energy production of 74%, 71%, 15%, and 96%, respectively.

The most notable decrease in pollutants occurred in scenario 4 in 2022 and 2027. Incorporating electric motors into rail transport has led to this result, as less fuel is burned and fewer airborne pollutants are emitted during operation. Higher levels of air pollutants emission and air pollution were observed under scenarios 3 in 2022 and 2027, compared to the BAU in 2022 and scenario 1 (2027), respectively. Modern automobiles use more emission-friendly engines (Euro 3 and Euro 4) than boats (Pre Euro), which emit significantly lower levels of pollutants. As a result, the older boat engines release more pollutants into the air [3].

NO_x is the air pollutant with the highest concentration in all scenarios. This is because most vehicles in the system use diesel fuel, which uses a compression-ignition method instead of the spark-ignition method used by gasoline and liquefied petroleum gas engines. This incomplete combustion process leads to the production of more NO_x than other types of fuels [8]. On the other hand, the lowest level of pollutants found is NH_3, which is generated from the three-way catalyst (TWC) process that can reduce CO and HC in the exhaust pipe. Vehicle types significantly increased total emissions of $PM_{2.5}$ in the Bangkok metropolitan Region in 2022 and 2027 [9].

Significant decreases in pollutant concentrations were observed in scenario 4 in both 2022 and 2027.This result is attributed to the use of electric motors to power rail transport, which reduced fuel combustion and, thus minimized the emission of airborne pollutants during operation.

Compared to the BAU in 2022 and scenario 1 in 2027, scenario 3 resulted in the least reduction in air pollutants and, thus, caused higher pollution levels. This is because current water transport engines use older technology (Pre Euro), and they emit more pollution than cars (Euro 3 and Euro 4), which use engines with lower emissions due to advanced technology. Consequently, the older ship engines emitted more pollutants into the air [3].

The study of road transport has compared the amount of pollution that occurs in Bangkok with the research of Kim Oanh (2020) [3] and Chavanaves et al. (2021) [4] found that the $PM_{2.5}$ NH_3 NO_x pollution was lower than the comparable research because the types of cars studied were different. But SO_2 is higher because our research involved a study of fuel production.

The study with the research of Hathairat et al. (2023) [10] found that No_x was the same in all scenarios.

Total emissions of $PM_{2.5}$ by pollution in the Bangkok Metropolitan Region in 2022 and 2027, are shown in Figure 1.

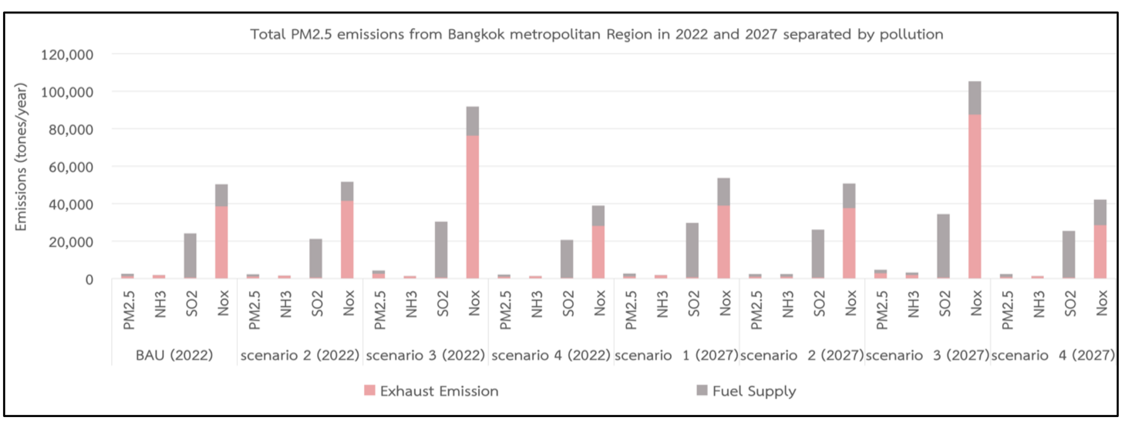

Figure 1 Total $PM_{2.5}$ emissions from various pollution in the Bangkok Metropolitan Region in 2022 and 2027

Health impacts and health costs, in 2022

The health impacts and health costs of air pollutants emitted by passenger's transport in the Bangkok Metropolitan Region have been calculated. Exhaust emissions has health impact of 7,613 DALY per year in 2022, which is equivalent to 4,513 million Baht. Energy production has a health impact of 10,225 DALYs per year, which is equivalent to 6,061 million Baht.

When comparing various scenarios with scenarios 1 (2022), it was found that scenario 4 (2022) resulted in a higher reduction in health impacts and health costs due to the increased use of electric trains. A 15% reduction was reported in both exhaust emissions and energy production. Scenario 3 in 2022, shows the minimum reduction in exhaust emissions and energy production, due to an increase in water transport resulting in an increase in health impact and health costs by 68%.

Health impacts and health cost, in 2027

The results of the health impacts of passenger transport in the Bangkok Metropolitan Region were estimated. In scenario 1 (2027), exhaust emissions have a health impact of 7,078 DALY/year, equivalent to 4,484 million Baht. On the other hand, energy production has a health impact of 12,737 DALY/year, equivalent to 8,070 million Baht.

When comparing various scenarios with scenario 1 (2027), it was found that scenario 4 (2027), due to the increased use of electric trains, resulted in a higher reduction in health impact and health cost. As a result, a 14% reduction in exhaust emissions and energy production was reported. There was a decrease in exhaust emission and energy production reported in scenario 3 in 2027, resulting in a 72% increase in health impacts and health costs due to increase in water transport.

In short, the highest pollutant was found to be $PM_{2.5}$ in all scenarios due to its direct release from exhaust pipes and ability to enter the body immediately through the respiratory system and penetrate the lungs and bloodstream, causing various diseases. The least amount of pollution was caused by NH_3, a precursor to $PM_{2.5}$ that undergoes several atmospheric processes and is converted into $PM_{2.5}$.

The study with the research of Hathairat et al. (2023) [10] found that it was found that there are differences in health impact of $PM_{2.5}$ using the CF value that comes from the Thai Spatially Differentiated Life Cycle Impact Assessment (ThaiSD) method, but in the case of ozone, CF values from RcCiPe 2016 are used, which results in differences.

Figure 2 displays the health effects and health costs in the Bangkok Metropolitan Region in 2022 and 2027.

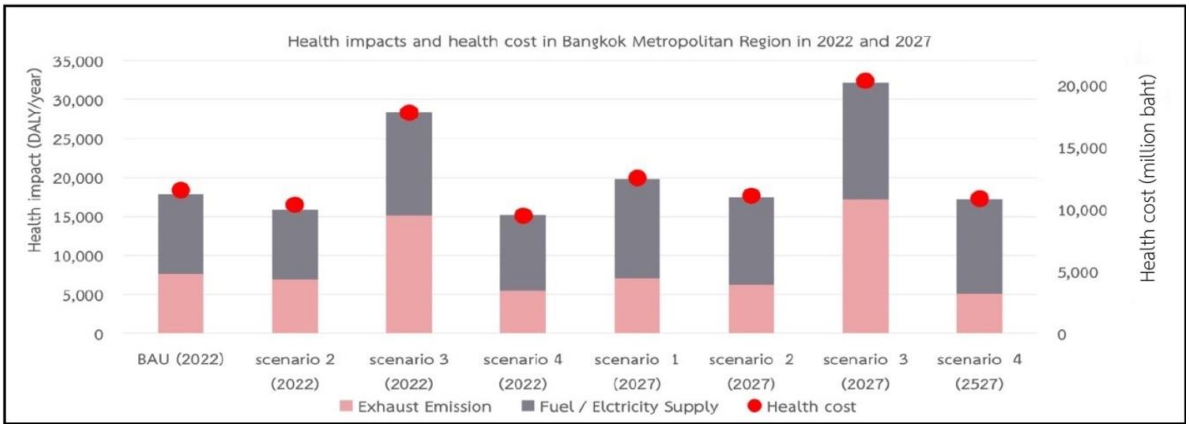

Figure 2 Health impacts and health costs in Bangkok Metropolitan Region in 2022 and 2027

Conclusions

The study examined commuters' transport habits in the Bangkok Metropolitan Region. The study examines $PM_{2.5}$, NO_x, SO_2, and NH_3 emissions. In 2022, the emissions of the exhaust pipe and energy production were 78,795 tonnes/year, with a health impact of 17,838 DALY/year and a health costs of 10,573 million Baht. Similarly, in 2027, the emissions projected were 88,013 tonnes/year, with the health impacts of 19,816 DALY/year and health costs of 12,554 million Baht.

The results of the comparison of various scenario revealed that the increase in rail transport by electric trains in 2022 and 2027 has the highest reduction in health impacts and health cost. Exhaust emissions and energy production contributed to a yearly decrease of 63,259 tonnes of $PM_{2.5}$ emissions in 2022. The health impact was 15,202 DALY, equivalent to 9,011 million Baht. Exhaust emissions and energy production are expected to decrease by 71,401 tonnes per year by 2027. The health impacts are expected to be 17,178 DALY/year, equivalent to 10,883 million Baht. The number of cars on the road is reduced and thus air pollution is reduced because of the high passenger capacity of electric trains. The electric trains are powered by electric motors, which do not emit pollutants into the atmosphere during operation.

The study results showed that reducing the number of passenger cars and increasing the use of electric trains by 30% can significantly reduce health impacts and costs. Therefore, future policy should promote and support the use of public transport, with a plan consisting of three phases: a short-term phase of reducing passenger cars and increasing public transportation with low emissions during the manufacturing process, a medium-term phase of modernizing and diversifying public transport systems to be convenient, fast, safe, and cost-effective from home to destination to encourage people to choose public transport; and a long-term phase of using full-scale public transport systems.

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