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Transportation energy consumption and emissions - a view from city of Indonesia

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Abstract

The purpose of this study is to investigate fuel consumption and road emissions of the transportation sector, thus providing a potential improvement in reducing fuel consumption and emissions. A system dynamics model for road transportation was developed in this study to mimic the fuel consumption and road emission trends of the sector. With the increase of road vehicles population, it is predicted that total fuel consumption and road emission from transportation sector in 2050 will be 62 and 65 times higher than in 2013 level. The increase in the number of private vehicles plays an essential role in escalating road emissions in Padang. The model also predicts that the reduction in the number of private vehicles and integrated public transportation system can result in about 34% reduction of fuel consumption and road emission in 2050. The results provide essential information and can be used by policy makers to meet challenges of decision making to support urban development process.

Keywords: Transportation, Fuel consumption, Road emission, System dynamic, Policy mitigation

Background

In the last few decades, fuel consumption and emission became a serious concern of researchers and policy makers. Global warming, climate change and side effect to human health are problems that face human kind [1–4]. Strategic options have to be taken to face this situation. According to the data published by the International Energy Outlook 2011, the consumption of fossil fuels, in the global scale, will increase from 354 quadrillion Btu in 1990 to 770 quadrillion Btu in 2035 [5]. A significant increase is predicted to occur in Non-OECD countries such as Malaysia [6, 7], Singapore [8], Brunei [9], and 40 other countries, including Indonesia. Previous studies showed that the most significant increase fuel consumption and emissions is taking place in cities, where rapidly increase in urbanization and concentrated economic activities [2, 10, 11].

Furthermore, on a global scale, using the year of 2008 as a reference, transportation sector is predicted to have a contribution of 82% to the total increase in the usage of liquid fuels in 2035 [5]. In the last three years, the sector experienced the largest annual growth rate, reaching 6.45% per year compared to the other sectors [12]. From the total energy consumption, 30% of the consumption came from the transportation sector.

Road transport has gradually become an essential part of the transportation system in cities of Indonesia. As result, road transport contributes more than 90% to the total oil consumption and is responsible the increase in the concentration of Greenhouse gases (GHG) and other pollutants. Air pollutants from transportation sources include carbon dioxide (CO_2), methane (CH4), nitrous oxide (N_2O), carbon monoxide (CO), hydrocarbon (HC) and particulate matter (PM) [13]. Furthermore, about 91% of the total GHG emissions were produced by road transportation, only about 1% and 8% of the total of GHG emission were produced by marine and air transport, respectively [14].

Hence, fuels (gasoline and diesel fuel) consumed by road transportation activities should be put as the priority action in order to reduce road emissions in the future. Through this study, a system dynamics model is developed to estimate and predict the transportation and emissions trends. In light of these study goals, the model was designed consists of two sub models, i.e., transportation model and emission model. Later on, three scenarios (a normal growth, a partial effort scenario and an

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Fig. 1 Case Study (Padang, Indonesia)

integrated transportation scenario) are designed to illustrate the road transportation and emission trends.

Methodology

Over view of this study site

In this study, a transportation model has been developed to estimate the fuel consumption and emission in a city of Indonesia. The system dynamics based on the computer simulation model was used to mimic the transportation and emissions system. Padang, the capital city of West Sumatera was chosen as boundary study. Three categories of vehicles such as motorcycles, cars, buses, are used in this model as representing the common transportation in the study area, including private vehicles (cars and motorcycles) and public vehicles (microbuses, buses, and taxi). However, since this is a local level study, shipping, air and long distance fright transportation were omitted in this model.

This study is based on the case of Padang city that located in the West Sumatera, Indonesia, as shown in Fig. 1. Padang is the largest city in the west coast of Sumatera Island, and the capital city of West Sumatera province. The city covers an area of 694.96 km^2 and has a population of 876,678 in 2012 [15].

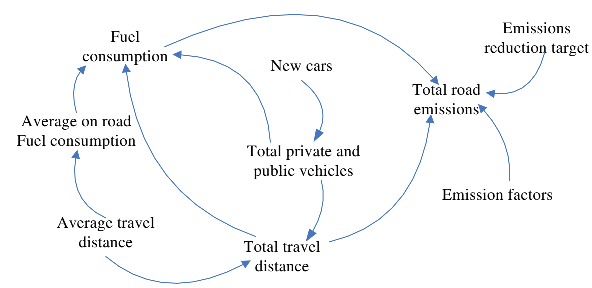

Fig. 2 Basic causal loop of road transportation

Table 1 Average Fuel Consumption

Type of vehicle	Average Travel Distance (km/day)	Fuel Consumption (km/l)	Fuel Consumption (l/vehicles/year)
Car	18	12	548
Motorcycle	18	43.85	150
Microbus (petrol)	100	12	3,042
Buses (diesel)	126	10	4,599
Taxi	24	12	730

Similar to other city in developing countries, Padang faces a rapid transformation, an increase in population, a significant economic growth, and also a rise in the number of vehicles. To support the recovery and development processes, Padang should have a comprehensive study on urban energy consumption. This study can be integrated with the long-term urban planning toward sustainable development.

Related to the transportation sector, according to the Indonesian Transportation Department, the ratio of the population of private vehicles and public vehicles is 98% : 2%. During the period of 2000–2013, the growth of private vehicles reached 12% per year, while the growth of vehicles used in public transportation sector was only 2% per year and shows a downward trend. The population of motorcycles had the highest increase. It reached 250 motorcycles per 1000 people respectively.

Concept of system dynamics

The model is a simplified representation of the real - world phenomenon to make it easier to understand. In the urban context, system dynamic modeling can help the policy maker to meet challenges of decision making to support the urban development process [16]. Therefore, to develop the transportation and emission models, a commercial simulation program called STELLA is used. In order to understand the relationship among various variables in the transportation sector and road emission, a causal loop diagram is developed (Fig. 2).

The two main drivers of fuel consumption are the total kilometers travelled by the vehicles and vehicle population. Increasing fuel consumption, in turn, positively affects the total of road emissions. The strong link between road emission and fuel consumption provides an important insight into the growth of the transportation demand.

The model basically consist two sub – models, namely transportation and emission sub-models representing the correlation between road transport and emission in cities.

Transportation sub-model

In this study, the number of private and public vehicles is estimated from the historical data of Padang from 1994 to 2013. The travel distance of public transportation is estimated by multiplying the average distance of the average trip per day. Table 1 shows an assumption that is used in the calculation of fuel consumption.

Emission model sub-model

With respect to the emissions model, data related to emissions and other urban pollutants produced by fuel combustion were calculated based on fuel consumption and the distance travelled by different transportation modes. Emission factors to trace GHG emissions and other air pollutants of various types of vehicle are estimated according to the EURO emissions standard, as shown in Table 2.

Model development

A system dynamic model for transportation and emissions is developed based on a causal loop diagram (Fig. 2). Total vehicles from road transportation are quantified based on the number of vehicles and average

Table 2 Emission Factors (g/km)

Pollutant/vehicle	Car	Motorcycle	Auto Rickshaw	Microbus	Bus	Taxi
CO_2	223.6	26.6	26.6[a]	515.2	515.2	208.3
CO	2.2[a]	2.2[a]	5.5[a]	4[a]	3.6	0.9
NOx	0.2	0.19	0.3[a]	12	12	0.5
CH_4	0.17	0.18	0.18	0.09	0.09	0.01
SO_2	0.053	0.013	0.029	1.42	1.42	10.3
PM	0.03	0.05	0.2	0.56	0.56	0.07
HC	0.25	1.42	1[a]	0.87	0.87	0.13

Source: Ramachandra and Shetmala, 2009 [10]
[a]Ministry of environment regulation, No.04/2009 [20]

Table 3 Detail of simulation scenarios

Variables	Scenario 1	Scenario 2	Scenario 3
	Normal Growth (reference scenario)	Partial effort	Integrated transportation
Private vehicle growth	Continue to increase: 12% p.a	Continue to increase: 12% p.a	Starting in 2020, the level gradually decreases by 8%
Public transport growth	Gradually decrease by 1% p.a (bus type) and gradually increase by 2% p.a (microbus type)	From 2020, gradually increase by 1% (Bus rapid transit)	From 2020, it gradually increase by 3% p.a (integrated transportation (Bus rapid transit, rail transport)
Emissions standard	Euro II	Euro III	Euro III
Split mode between private and public transportation	53:47 (based on 2010 condition)	Starting in 2020, the level of public transportation gradual increases to 50%	From 2020, gradually increase to 70%

The above assumptions of future trends are adapted from Transport Master Plan of Padang 2030, and the authors' own rationales
Emission standard is adopted from the Ministry of Environment Regulation

growth rate of vehicles in a year per different vehicle type, which is given by:

$$TV_i(t) = TV_i(t-dt) + (V_i \times GRV_i) \times dt \quad (1)$$

Where, TV_i = total vehicles per type (i); V_i = vehicles per type (i); GRV_i = growth rate of vehicles per type (i).

Fuel consumption is calculated based on the multiplication of vehicle mileage and fuel economy of each type of vehicle, and is given by:

$$TFC = \sum (V_i \times AD_i) \times FE_{i,km} \quad (2)$$

Where, TFC = fuel consumption; V_i = vehicles per type (i); AD_i = average distance of vehicle per type (i); $FC_{i,km}$ = fuel economy from vehicle type (i) per driven kilometer.

Furthermore, emission from road transportation is estimated based on the number of vehicles and total travel distance per different vehicle type, and is given by:

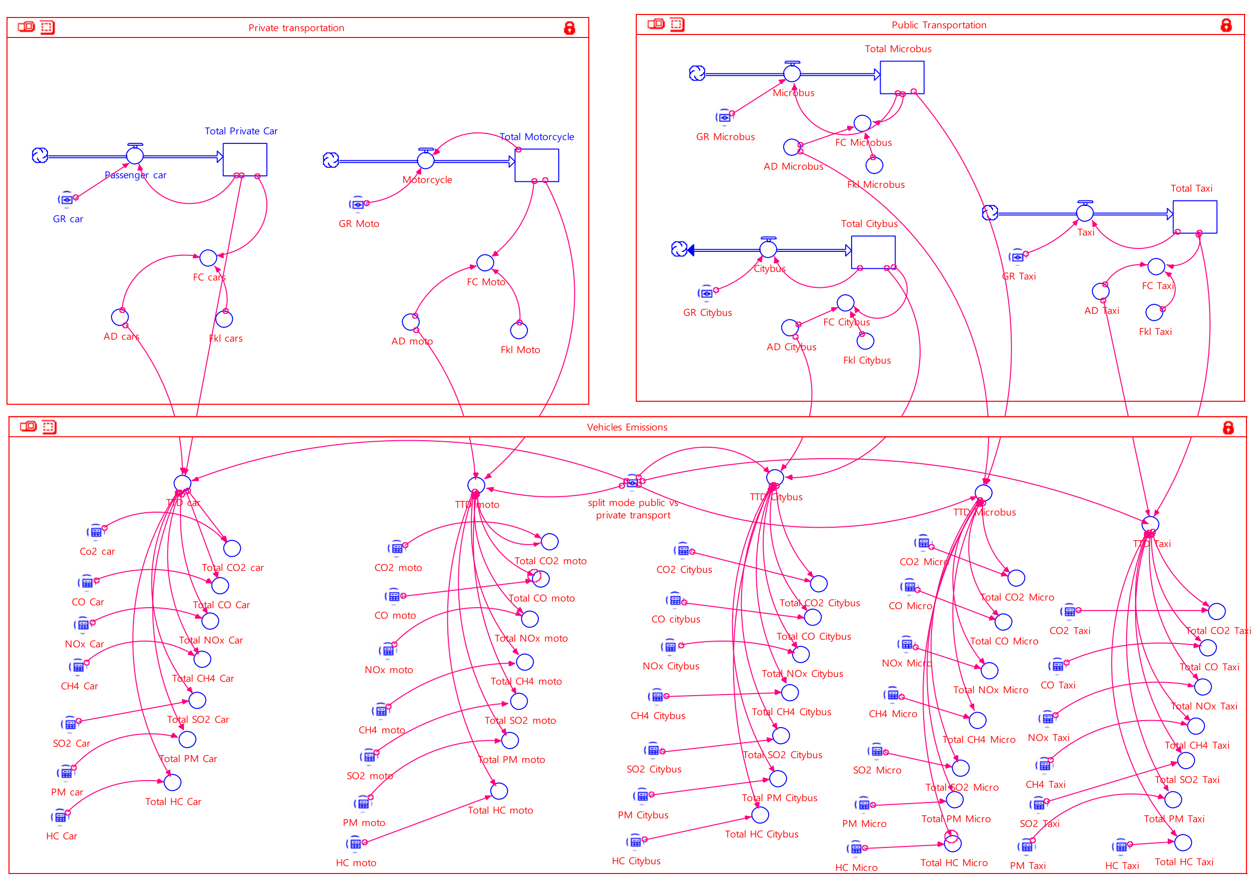

Fig. 3 The stock - flow diagram of transportation and emissions model

Table 4 Energy consumption in the transportation sector (Thousand BOE)

	2006	2007	2008	2009	2010	2011	2012	2013
Gas	42	49	124	191	195	181	154	185
Fuel types								
Avgas	19	12	11	9	12	13	14	16
Avtur	14,303	14,845	15,526	16,262	20,779	20,983	22,967	24,499
premium	92,901	98,847	111,377	121,226	130,486	144,330	160,910	166,800
Bio premium	9	326	257	617	0	0	0	0
Pertamax	2,947	2,752	1,736	3,478	3,985	3,643	3,884	4,934
Bio pertamax	0	58	95	118	0	0	0	0
Pertamax plus	748	921	669	829	971	1,717	870	931
Bio solar	1,408	5,692	6,041	15,558	28,503	46,583	60,132	70,932
Kerosene	22	22	18	11	6	4	3	3
ADO	57,268	55,241	60,812	67,328	70,655	59,672	61,092	54,940
IDO	105	57	34	29	35	26	20	15
FO	314	269	194	163	244	158	215	124
Total Fuel	170,044	179,042	196,770	225,628	255,676	277,129	310,107	323,194
Electricity	41	52	50	68	54	54	66	79

Source : [21]
ADO automotive diesel oil, *IDO* Industrial Diesel Oil, *FO* fuel oil, *BOE* barrel oil equivalent

$$E_i = \sum \left(V_j \times TD_j \right) \times EF_{i,j,} \quad (3)$$

Where, E_i = emission (i); V_j = vehicles per type (j); $EF_{i,j}$ = emission factor of emission (i) from vehicle type (j).

In this transportation and emissions model, it is assumed that future fuel consumption and air emission trends are mainly affected by vehicle growth rate, emission standard, and split mode between private and public uses as shown in Table 3. Three test scenarios are carried out using this model in order to investigate and predict future fuel consumption and air emissions trends.

Scenario 1 is called a reference scenario whereby it is assumed that the simulation runs based on the existing trend of vehicle growth rate and transportation split mode. In scenarios 2 and 3, it is assumed that, starting from year of 2020 it has major change in several conditions. Prior to 2020, the trends are assumed to be the same as scenario 1, and based on the implementation of Transport Master Plan of Padang 2030 some major improvements on public transportation system will be taking place on/after the year of 2020. Detailed overview of the test scenarios and the stock - flow diagram of the transportation and emissions produced are shown in Table 3 and Fig. 3.

Result and discussion

Current status

Table 4 shows the historical fuel consumption level of road vehicles in Indonesia from 2006 to 2013. From the table, it can be inferred that the fuel consumption level increased from 170 thousand BOE to 323 thousand BOE per year, equivalent to an annual growth rate of 8.1%. It is also can be seen that premium and ADO had the highest growth rate. This was due to the high intensity in motor vehicles usage. The Indonesian National Police reported that from over 86 million vehicles in 2013, 80% were motorcycles, 11% were passenger cars, 6% were trucks, and 3% were buses [17]. Over the past 5 years, the Indonesia's vehicles market was grew over 20% and continue increase [18].

Reference scenario

In the reference scenario, the current growth rate of various type of vehicles (private and public) will continue to happen until the year of 2050 without any major

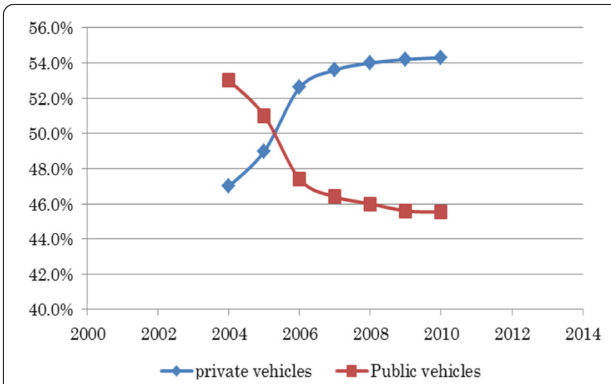

Fig. 4 Trend of transportation modes

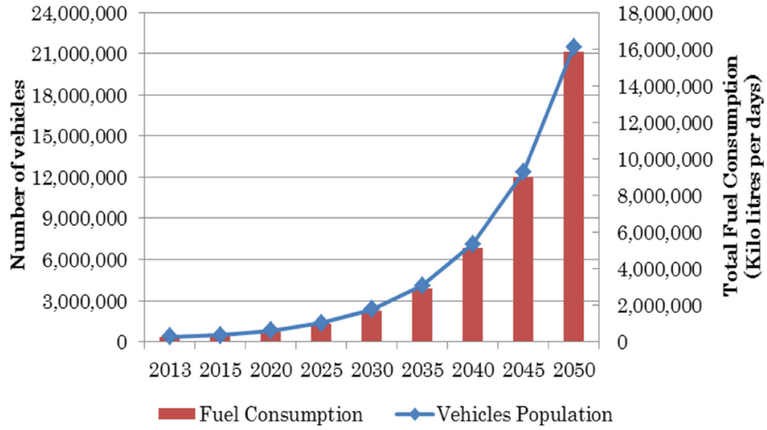

Fig. 5 Scenario 1- vehicle population and fuel consumption

interruption from the present policy. As a part of the public transportation, the growth rate of city buses gradually decreases by 1% per year, while microbuses continuously increase by 2 % per year. The decrease in the growth rate of city buses was assumed due to the shift, from city buses to other vehicle types (microbuses or motorcycles), made by passengers. This phenomenon can be seen from the General Plan for Road Transport Network (RUJTJ) of Padang for the years of 2004–2013 (Fig. 4). When scenario 1 was applied to the model and setting the split mode ratio between private and public vehicles equals to 53:47, the model predicted that population of vehicles and the amount of fuel consumed will increase, as depicted in Fig. 5.

Moreover, from Table 5, it also can be seen that the predicted emission level in 2050 is 65 times higher than the emission level in the year of 2013. Emission analysis based on vehicle type reveals that motorcycles contribute higher CO_2 and other pollutant compounds in the year of 2050 (CO_2: 53.8%, CH_4: 91.4%, CO: 90.8%, HC: 98.7%, NOx: 85%, PM: 93.3%, SO_2: 65%) compared to other road vehicles such as buses, microbuses, taxi and cars.

Overall simulation

Figures 6 and 7 present the predicted population of private and public vehicles in Padang.

In scenarios 2 and 3, it was assumed that major changes will be made by the government in the year of 2020. As a consequence, the model predicted that the population of the vehicles for each scenario will be equal from the year of 2013 to 2020, as shown in the figure above. Due to the various changes starting from the year 2020 such as vehicle growth rate, implementation of rail transport, and split mode transportation, several results of scenarios were seen after the year of 2020. Under the reference scenario (S1), both of vehicle populations (private and public) experience a steady increase until year 2050. Regarding private vehicles, the model predicted that the number of motorcycles in 2050 will be 66 times higher than the number in 2013 and the population of passenger cars in 2050 will be 24 times larger than their population in 2013. Even though with partial effort by implementation of bus rapid transit (BRT), the number of private vehicles was predicted to be same as their population in the reference scenario. In this scenario, a slight increase in the number of vehicles used as a means of public transportation was due to the increase in the population of city buses. According to the master plan of Padang transportation 2010–2030, the implementation of BRT is one of the alternative solutions to decrease the usage of privately owned vehicles. When scenario 3 was applied to the model, it was predicted that, with the implementation of an integrated transportation system

Table 5 Scenario 1- Total emissions from road transport (Kg/km)

Vehicles type	2013							2050						
	CO_2	CH_4	CO	HC	Nox	PM	SO_2	CO_2	CH_4	CO	HC	Nox	PM	SO_2
Citybus	4,424	0.8	30.9	7.5	103	4.8	12.2	3,050	0.5	21.3	5.2	71	3.3	8.4
Microbus	50,850	8.9	395	85.9	1,184	55.3	140.2	105,803	18.5	821	178.7	2,464	115.0	291.6
Taxi	1,115	0.8	11.0	1.2	1.0	0.1	0.3	1,611	1.2	15.9	1.8	1.4	0.2	0.4
Car	170,652	130	1,679	191	153	22.9	40.4	4,138,954	3,147	40,723	4,628	3,702	555.3	981.1
Motorcycle	74,860	507	6,191	5,403	535	141	37	4,958,141	33,551	410,072	357,881	35,415	9,320	2,423

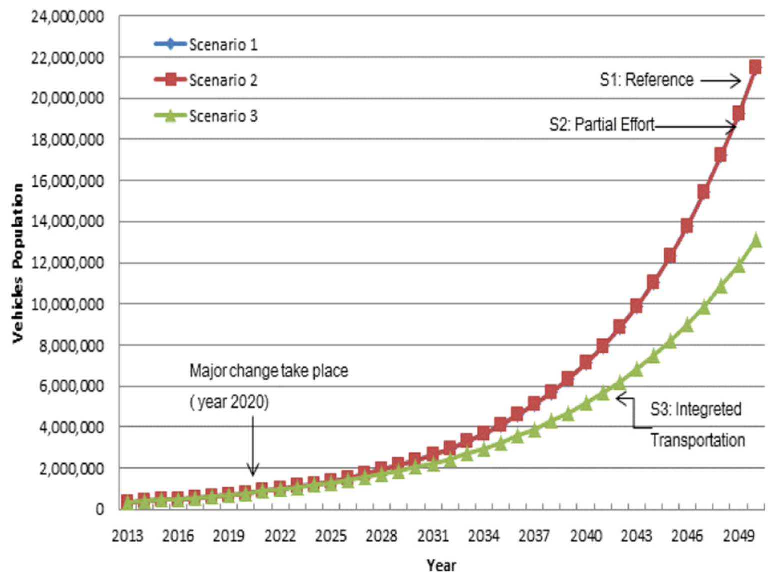

Fig. 6 Private vehicle population

consisting of BRT and rail transport, the total number of vehicles used as a means of public transportation will be decreased. This is due to the decrease in the number of microbuses (seven passengers). Furthermore, the model also predicted that the implementation of an integrated mass transportation system will lead to the reduction in the number of microbuses and private vehicles. Under scenario 3, the population of microbuses will be reduced to 30%.

In terms of fuel consumption, the simulation result is shown in Fig. 8. For scenarios 1 and 2, the total fuel consumption almost has the same pattern. This is due to the partial effort applied to both scenarios. A better result is shown in scenario 3. The total fuel consumption in 2050 is successfully suppressed to 36 times lower than that of the consumption in 2013. The reason for this is the implementation of an integrated public transportation system.

With the implementation of an integrated public transportation system, which was set to happen in 2020 in the simulation, the decrease in road emissions level produced by road vehicles can be observed in Table 6. It was found that the emission level of scenario 3 was 34% lower than the emission level of scenario 1, and 17% lower than the

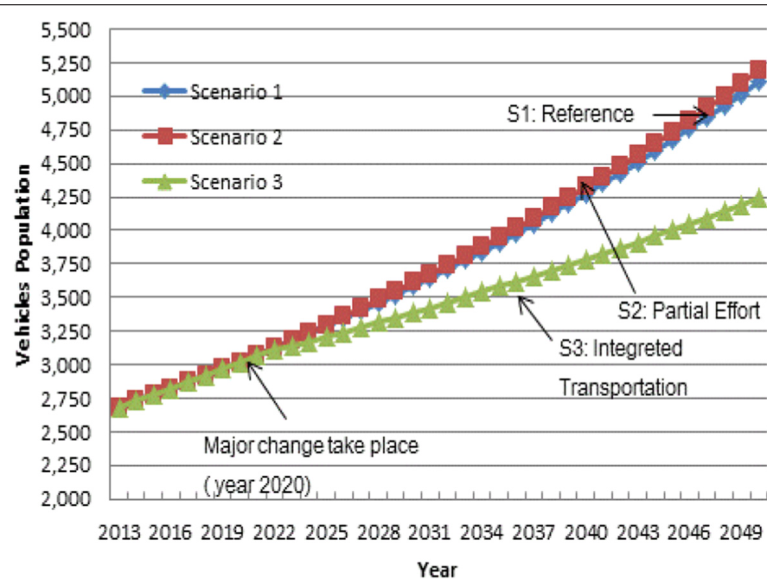

Fig. 7 Public vehicle population

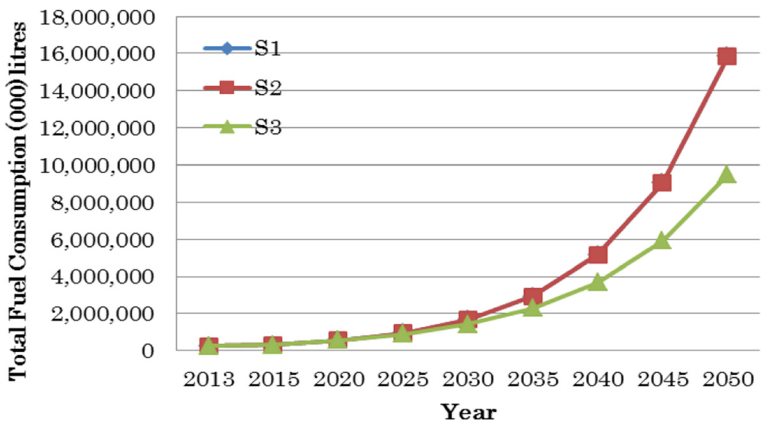

Fig. 8 Public vehicles population

emission level of scenario 2. The important point presented from these results is the emissions produced by motorcycles. From the simulation, it was found that the reduction in the population of private vehicles and the implementation of an integrated public transportation system played a significant role in decreasing emission from road transport. Presently, about 70% of the total amount of emission is caused by motorcycles.

Thus, from the overall results it was found that having a split mode of 70:30 between private and public transportation provided a good result in terms of fuel consumption and emissions. However, to implement this scenario in the real world is not easy. Hence, this element must be a priority for urban energy studies in the future, and should be integrated with the long-term urban planning toward sustainable development.

Policy mitigation and opportunities to reduce road transport emissions

In order to follow up the Bali Action Plan at the Conferences of Parties (COP 13) to the United Nations Frameworks Convention on Climate Change (UNFCCC) and obtain the same results as that from COP-15 in Copenhagen and COP-16 in Cancun, the Government of Indonesia commits to reduce greenhouse gas emissions by 26% by its own efforts, and reach 41% if it receives international assistance in 2020 from the condition without an action plan. To comply with this commitment, the President of the Republic of Indonesia issued Presidential Decree No. 61 in 2011 regarding the National Action Plan for Reducing Emissions of Greenhouse Gases (RAN-GRK) [19]. It is a working document containing measures to reduce greenhouse gas emissions in Indonesia. Hence, the Ministry of Transportation proposed nine main strategies for energy conservation in the transportation sector [14], as listed in Table 7.

Table 6 Total emissions of scenario 3- year 2050 (kg/day)

Vehicles type	CO_2	CH_4	CO	HC	Nox	PM	SO_2
City bus	6,140	1.1	43	10	143	7	17
Microbus	50,750	9	394	86	1,182	55	140
Taxi	1,028	0.8	10	1.1	0.9	0.1	0.2
Car	4,223,145	3,211	37,774	4,722	3,777	567	1,001
Motorcycle	3,883,347	26,278	291,981	43,797	21,899	7,300	1,898

Based on the RAN-GRK, there are seven action plans proposed in Padang, Indonesia, including (1) the reformation of a Bus Rapid Transit (BRT) system; (2) the renewal of public transportation vehicles; (3) socialization and training of smart driving; (4) non-motorized transport development; (5) intelligent transport system development; (6) the implementation of Traffic Impact Control (TIC); and (7) parking Management Application. The plan adopts a new paradigm of enhancing sustainable transportation development to reduce energy consumption and GHG emissions from the transportation sector, called the *avoid-shift-improve* approach [3]. *"Avoid"* or *"reduce"* can be achieved by reducing the need of travel through infrastructure planning and trip management. The *"shift"* means switching from private vehicles to the environmentally friendly public transport. *"Improve"* means increasing the energy efficiency of vehicle technology.

Furthermore, the Indonesian government has realized the importance of reducing the GHG emissions. Recently, the Indonesian government encourages the concept of a *low carbon society*. There are three main strategies for reducing the GHG emissions, which are listed and described in Table 8. Generally, a *low carbon society* can be achieved through the integration of public transport. As shown in the simulation results, the growth of GHG emissions can be reduced by reducing private vehicle ownership. One of the options is the integration of transportation systems such as train and bus modes. Furthermore, a light-rail transit system, Bus Rapid Transit, and non-motorized transport should be integrated with land-use and urban planning.

Table 7 National Action Plan for Reducing Emissions of Greenhouse Gases (RAN-GRK)

No	Action Plans	Key point (s)	Location
1	Reformation of Bus Rapid Transit (BRT) system	- Implementation of mass transit - Road based using buses which uses a special line.	12 cities in Indonesia: Medan, **Padang**, Pekanbaru, Palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
2	Renew of public transportation vehicles	- Evaluation of public transportation vehicles - Emission inspection - Vehicle life expectancy - Change with new vehicles	12 cities in Indonesia: Medan, **Padang**, Pekanbaru, Palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
3	Installation of "converter kits" for public vehicles	- Installation of "converter kits" for public vehicles to replace oil fuel use with natural gas. - Reduce CO2 emission to 20%	nine cities in Indonesia: Medan, Palembang, Jabodetabek, Cilegon, Cirebon, Surabaya, Denpasar, Balikpapan and Sengkang
4	Socialization and training of smart driving	Teaching and training the environmentally friendly driving to save fuel and to reduce air pollution.	12 cities in Indonesia: Medan, **Padang**, Pekanbaru, Palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
5	Non motorized transport development	- Increasing pedestrian and bicycle paths - Integrated with public transport planning and air quality planning	12 cities in Indonesia: Medan, **Padang**, Pekanbaru, Palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
6	Intelligent transport system development	• Improving the communication and information system in the public transport ➢ Travel routes ➢ Cut travel time • Decrease GHG emissions	13 cities in Indonesia: Medan, **Padang**, Pekanbaru, Palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan, Banjarmasin and Jabodetabek (Jakarta, Bogor, Depok, Tanggerang and Bekasi)
7	Implementation of Traffic Impact Control (TIC)	• Land use and transport planning • Travel demand management • Integrated public transport	12 cities in Indonesia: Medan, **Padang**, Pekanbaru, Palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
8	Parking Management Application	• Anti idling regulation • Transport demand management (TDM)	12 cities in Indonesia: Medan, **Padang**, Pekanbaru, Palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
9	Implementation of Congestion Charging and Road Pricing	• Decrease the private vehicles on the road • Integrate with mass transportation	two cities in Indonesia: Jakarta and Surabaya

Table 8 Strategies to achieve a *low carbon society*

Strategy	Measure	Opportunity	Stakeholders
Reducing per kilometer emissions	Improvement of emissions standards for new vehicle technology	- Adopted Euro 3 emissions standard - Can be promoted by using cleaner fuel such as natural gas, CNG, and biofuel - Combined with Bus Rapid Transit	- National Government agencies: MEMR, MoE, MoI, MoT - Automotive industry
	Improvement of land use and transport planning	- Integration of transportation planning and air quality - A significant political will is necessary	- Local government - Urban planners
Reducing per unit transport vehicle emissions	Enforcement of routine inspection of vehicle emissions	- Requires a regulation mechanism - Enforcement to prevent corruption	- Local government and policy makers - Traffic agencies - Vehicle owners
	Enforcement of mass transport (buses or trains)	- Integration of transportation planning and private sectors - Non-motorized transport development	- National Government; MEMR, MoE, MoI, and MoT - Local government - Private sector
Reducing travel distance	- Travel demand management - Non-motorized transport - Land use and transportation planning	- Changing the behavior of society - Significant regulation necessary - Integration of public transportation and urban planning	- Urban planner - National Government; MoE, MoI, and MoT - Local government - Policy makers

Sources : [14]
MEMR Ministry of Energy and Mineral Resource, *MoE* Ministry of Environment, *MoI* Ministry of Industry, *MoT* Ministry of Transportation

Conclusion

In order to project fuel consumption and emission from the road sector in Padang from 2013 to 2050, an integrated system dynamics model was developed under three different scenarios. Although it is a basic model with various limitations as mentioned above, it provides to capture energy consumption and emission trends. The results show that Padang, in the small scope, will be confronted with a heavy burden of fuel consumption and emissions, which will need serious attention in the future. Particularly, with the existing vehicle growth rate, the total fuel consumption and emissions only from road transportation is predicted to be 65 times higher than that of 2013. Emission reveals that motorcycles contribute higher CO_2 and other pollutant compounds in the year of 2050 (CO_2: 53.8%, CH_4: 91.4%, CO: 90.8%, HC: 98.7%, NOx: 85%, PM: 93.3%, SO_2: 65%) compared to other road vehicles such as buses, microbuses, taxi and cars. From the overall results it was found that having a split mode of 70:30 between private and public transportation provided a good result in terms of fuel consumption and emissions.

Regarding the forcast of fuel consumption and emission levels, there are several strategies that have been taken by government reduce fuel consumption and emission from road transport. The critical factors that should be prioritized in the future context are to reduce private vehicle usage and encourage people to move to public transportation. Reformation of Bus Rapid Transit (BRT) system, Installation of "converter kits" for public vehicles and Improvement of emissions standards for new vehicle technology are the policy option that can be adopted in Padang. Nevertheless, a policy evaluation should be performed to identify whether such policies provide a significant impact to decreasing fuel consumption and emission level.

Abbreviations

ADO, automotive diesel oil; BOE, barrel of oil equivalent; BRT, bus rapid transit; CH_4, nitrous oxide; CO, carbon oxide; CO_2, carbon diocide; FO, fuel oil; GHG, greenhouse gases; HC, hydrocarboon; IDO, Industrial Diesel Oil; MEMR, Ministry of Energy and Mineral Resource; MoE, Ministry of Environment; MoT, Ministry of Transportation; PM, particulate matter; RAN-GRK, Rencana aksi nasional-Gas rumah kaca (In Indonesia) or National action plan for reduction emissions of greenhouses gases; SO_2, sulfure dioxide; TIC, traffic impact control; UNFCCC, United Nations Framework Convention on Climate Change

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Authors' contributions

IS, HM and LS contribute to data collection and verification. IS and HM participated in design of the case report and drafting the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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