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Supplementary Materials:

Near Real-Time Spatial and Temporal Distribution of Traffic Emission in Bangkok Using Google Maps Application Program Interface

Supiya Naiudomthum [1], Ekbordin Winijkul [1,*] and Sunicha Sirisubtawee [2]

[1] Environmental Engineering and Management, Asian Institute of Technology, Pathum Thani 12120, Thailand
[2] Health Department, Bangkok Metropolitan Administration, Bangkok 10400, Thailand
* Correspondence: ekbordinw@ait.asia; Tel.: +66-2-524-5648

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Emission Factors

Emission factors used in this study are separated by vehicle type, engine technology and vehicle speed on the road. Eight vehicle types include light-duty vehicles (PC, van, pick-up, taxi, MC and tuk-tuk) and heavy-duty vehicles (truck and bus). Engine technologies include Pre-Euro to Euro IV for light-duty vehicles and Pre-Euro to Euro III for heavy duty vehicles. In this study, PC, taxi, tuk-tuk and MC were assumed to be gasoline vehicles while van, pick up, bus and truck were assumed to be diesel vehicles. It was assumed that there was no PM emission from gasoline vehicles (PC, taxi, tuk-tuk and MC). The Equations of emission factors with speeds of vehicles on the road are summarized in Table S1-S8.

Table S1. Equations for estimating CO emission factor from vehicle speed for light-duty vehicles.

Vehicle Type	Emission Control Technology				
	Pre-Euro	**Euro I**	**Euro II**	**Euro III**	**Euro IV**
PC	$y = 12.88x^{-0.144}$	$y = 10.874x^{-0.223}$	$y = 9.9629x^{-0.505}$	$y = 0.2592x^{-0.226}$	$y = 0.4715x^{-0.756}$
Van	$y = 3.20\ x^{-0.349}$	$y = 3.38x^{-0.417}$	$y = 1.33x^{-0.417}$	$y = 0.082x^{-0.417}$	$y = 0.0732x^{-0.417}$
Pick-up	$y = 5.65x^{-0.452}$	$y = 7.32x^{-0.625}$	$y = 12.453x^{-1.034}$	$y = 4.9706x^{-0.787}$	$y = 1.9009x^{-0.787}$
Taxi	$y = 5.097x^{-0.128}$	$y = 3.1996x^{-0.128}$	$y = 2.8335x^{-0.161}$	$y = 2.8797x^{-0.507}$	$y = 1.2463x^{-0.507}$
MC	$y = 38.47x^{-0.283}$	$y = 41.614x^{-0.429}$	$y = 39.597x^{-0.419}$	$y = 2.368x^{0.0513}$	
Tuk-tuk			$y=76.82x^{-1.009}$		

Note: x is any vehicle speed, y is EFs depend on any speed.

Table S2. Equations for estimating CO emission factor from vehicle speed for heavy-duty vehicles.

Emission Control Technology	Vehicle Type	
	Bus	**Truck**
Pre-Euro	$y = 4E{-}07x^4 - 7E{-}05x^3 + 0.0055x^2 - 0.2513x + 19.404$	$y = 5E{-}07x^4 - 0.0001x^3 + 0.0109x^2 - 0.5106x + 17.195$
Euro I	$y = -1E{-}06x^4 + 0.0002x^3 - 0.0076x^2 - 0.2225x + 21.274$	$y = 1E{-}07x^4 - 3E{-}05x^3 + 0.003x^2 - 0.1408x + 5.3667$
Euro II	$y = 6E{-}07x^4 - 0.0001x^3 + 0.013x^2 - 0.543x + 10.569$	$y = 4E{-}07x^4 - 9E{-}05x^3 + 0.0081x^2 - 0.3521x + 8.1644$
Euro III	$y = 4E{-}07x^4 - 0.0001x^3 + 0.0093x^2 - 0.3879x + 7.5492$	$y = 1E{-}07x^4 - 3E{-}05x^3 + 0.0024x^2 - 0.1156x + 4.4055$

Note: x is any vehicle speed, y is EFs depend on any speed.

Table S3. Equations for estimating HC emission factor from vehicle speed for light-duty vehicles.

Vehicle Type	Emission Control Technology				
	Pre-Euro	**Euro I**	**Euro II**	**Euro III**	**Euro IV**
PC	$y = 2.7363x^{-0.453}$	$y = 4.1799x^{-0.716}$	$y = 1.0327x^{-0.681}$	$y = 0.2504x^{-0.577}$	$y = 0.0395x^{-0.577}$
Van	$y = 0.414x^{-0.262}$	$y = 0.4538x^{-0.446}$	$y = 0.9698x^{-0.888}$	$y = 3.4971x^{-1.343}$	$y = 2.0574x^{-1.343}$
Pick-up	$y=1.3735x^{-0.411}$	$y = 2.0924x^{-0.693}$	$y = 0.3738x^{-0.533}$	$y = 0.2973x^{-0.64}$	$y = 1.2279x^{-1.308}$
Taxi	$y = 4.5661x^{-0.421}$	$y = 2.5795x^{-0.421}$	$y = 3.7876x^{-0.542}$	$y = 5.2247x^{-0.724}$	$y = 0.5336x^{-0.724}$
MC	$y = 26.866x^{-0.531}$	$y = 33.56x^{-0.663}$	$y = 4.7529x^{-0.527}$	$y = 0.7483x^{-0.406}$	
Tuk-tuk	$y = 315.31x^{-1.408}$				
Bus	$y = 35.689x^{-0.527}$	$y = 71.657x^{-0.896}$	$y = 23.933x^{-0.657}$	$y = 16.681x^{-0.657}$	

Note: x is any vehicle speed, y is EFs depend on any speed.

Table S4. Equations for estimating HC emission factor from vehicle speed for heavy-duty vehicles.

Emission Control Technology	Truck & Bus
Pre-Euro	$y = 1E{-}07x^4 - 3E{-}05x^3 + 0.0027x^2 - 0.1195x + 2.8889$
Euro I	$y = 1E{-}07x^4 - 3E{-}05x^3 + 0.0027x^2 - 0.1195x + 2.7672$
Euro II	$y = 6E{-}08x^4 - 1E{-}05x^3 + 0.0013x^2 - 0.056x + 1.27$
Euro III	$y = 6E{-}08x^4 - 1E{-}05x^3 + 0.0013x^2 - 0.056x + 1.27$

Note: x is any vehicle speed, y is EFs depend on any speed.

Table S5. Equations for estimating NOx emission factor from vehicle speed for light-duty vehicles.

Vehicle Type	Emission Control Technology				
	Pre-Euro	**Euro I**	**Euro II**	**Euro III**	**Euro IV**
PC	$y = 2.2524x^{-0.138}$	$y = 1.9723x^{-0.184}$	$y = 1.2302x^{-0.09}$	$y = 0.2122x^{-0.607}$	$y = 0.0251x^{-0.607}$
Van	$y = 6.5627x^{-0.303}$	$y = 7.6062x^{-0.487}$	$y = 0.4761x^{-0.103}$	$y = 0.4227x^{-0.588}$	$y = 0.1768x^{-0.588}$
Pick-up	$y = 8.4285x^{-0.325}$	$y = 8.975x^{-0.417}$	$y = 4.414x^{-0.526}$	$y = 3.6624x^{-0.487}$	$y = 17.949x^{-1.041}$
Taxi	$y = 6.3709x^{-0.031}$	$y = 5.5789x^{-0.077}$	$y = 4.3587x^{-0.11}$	$y = 3.1403x^{-0.23}$	$y = 0.1776x^{-0.23}$
MC	$y = 0.6281x^{0.1258}$	$y = 0.2301x^{0.2344}$	$y = 0.0605x^{0.4376}$	$y = 0.0466x^{0.3363}$	
Tuk-tuk	$y = 1.8886x^{-0.491}$				

Note: x is any vehicle speed, y is EFs depend on any speed.

Table S6. Equations for estimating NOx emission factor from vehicle speed for heavy-duty vehicles.

Emission Control Technology	Vehicle Type	
	Bus	**Truck**

Pre-Euro	$y = 2E{-}06x^4 - 0.0005x^3 + 0.0421x^2 - 1.7545x + 34.692$	$y = 9E{-}07x^4 - 0.0002x^3 + 0.02x^2 - 0.8871x + 22.537$
Euro I	$y = 2E{-}06x^4 - 0.0004x^3 + 0.037x^2 - 1.5613x + 31.829$	$y = 9E{-}07x^4 - 0.0002x^3 + 0.02x^2 - 0.8871x + 22.011$
Euro II	$y = 8E{-}07x^4 - 0.0002x^3 + 0.0175x^2 - 0.7791x + 19.644$	$y = 1E{-}06x^4 - 0.0002x^3 + 0.0227x^2 - 0.9922x + 22.854$
Euro III	$y = 5E{-}07x^4 - 0.0001x^3 + 0.0123x^2 - 0.5454x + 13.751$	$y = 6E{-}07x^4 - 0.0002x^3 + 0.014x^2 - 0.613x + 14.12$

Note: x is any vehicle speed, y is EFs depend on any speed.

Table S7. Equations for estimating PM emission factor from vehicle speed for light-duty vehicles.

Vehicle Type	**Emission Control Technology**				
	Pre-Euro	**Euro I**	**Euro II**	**Euro III**	**Euro IV**
Van	$y = 0.4385x^{-0.24}$	$y = 0.4305x^{-0.299}$	$y = 0.1322x^{-0.299}$	$y = 0.0778x^{-0.299}$	$y = 0.0467x^{-0.299}$
Pick-up	$y = 0.438x^{-0.128}$	$y = 0.3363x^{-0.272}$	$y = 0.305x^{-0.33}$	$y = 0.1254x^{-0.21}$	$y = 0.1205x^{-0.254}$

Note: x is any vehicle speed, y is EFs depend on any speed.

Table S8. Equations for estimating PM emission factor from vehicle speed for heavy-duty vehicles.

Emission Control Technology	**Vehicle Type**	
	Bus	**Truck**
Pre-Euro	$y = 4E{-}08x^4 - 8E{-}06x^3 + 0.0007x^2 - 0.0306x + 2.1734$	$y = 6E{-}08x^4 - 1E{-}05x^3 + 0.0013x^2 - 0.0601x + 2.1673$
Euro I	$y = 3E{-}08x^4 - 6E{-}06x^3 + 0.0005x^2 - 0.0243x + 1.7113$	$y = 7E{-}08x^4 - 2E{-}05x^3 + 0.0015x^2 - 0.0682x + 1.8229$
Euro II	$y = 3E{-}08x^4 - 6E{-}06x^3 + 0.0005x^2 - 0.0243x + 1.3115$	$y = 1E{-}08x^4 - 2E{-}06x^3 + 0.0002x^2 - 0.007x + 0.5038$
Euro III	$y = 6E{-}09x^4 - 1E{-}06x^3 + 0.0001x^2 - 0.0049x + 0.2623$	$y = 1E{-}08x^4 - 2E{-}06x^3 + 0.0001x^2 - 0.0067x + 0.4812$

Note: x is any vehicle speed, y is EFs depend on any speed.