Modal shift impacts on ambient PM_{10} concentration near BRT TransJakarta's corridors

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Abstract
Bus Rapid Transit (BRT) system was implemented in Jakarta City in January 2004 which gave impacts on modal shift change from private modes. These modal shift changes from car and motorcycle to BRT reduce the emission intensity of primary pollutants such as NOx, PM_{10} and CO. The objective was to evaluate the BRT system's impact on ambient concentration of PM_{10} near to BRT's corridors. By using data collected at five continuous ambient air quality monitoring stations near to BRT corridor TransJakarta in 2005, we apply structural equation model which capable to analyze cause-effects relationship among factors in determining PM_{10} concentration near to BRT lines. Major sources affecting PM_{10} concentration are likely to be related to motorcycle and diesel vehicles which measures as bus and truck fleet and local wind directions. Minor and negative influences on PM_{10} concentration come from private cars and other micro-meteorological factors. The results suggest that the park and ride motorcycle system as the access mode to BRT will improve the PM_{10} concentration near to TransJakarta BRT's lines.

Keywords: TransJakarta Bus Rapid Transit system, PM_{10}, Structural Equation Model,

1. INTRODUCTION

At the recent years, pollution standard index in Jakarta city mostly determined by PM_{10} or surface ozone (O_3). Particles in the urban atmosphere arise from combustion of fuels which may come from vehicles and other anthropogenic activities. It is considered to be one of the major environmental problems in urban and densely populated areas, as high level have been suggested to cause serious effects on human health (Furusjo, E, 2007). Particles with an aerodynamics diameter of less than 10 μm are denoted PM_{10} and are regulated in Indonesia. It was emitted directly as primary combustion particles, formed as secondary particles in the atmosphere by gas-to-particle conversion process (arising from the oxidation of SO_x, NO_x and VOC) and coarse particles (Harison, 2004). Atmospheric reaction can lead to the formation of a range of secondary particulate matter. It is supposed that modeling particles concentration should be more difficult as compared to the forecasting of common gaseous pollutants due to the complexity of the processes, which control the formation, transportation and removal of aerosol in the atmosphere (G Grivas, 2006). At urban roadside, local road traffic may be a major source of PM_{10} and the effect of local factors contributing to dispersion from source may effects the amount of PM_{10} monitored (Price, M. 2003). There are two sources categories of particles from transportation sectors: (1) exhaust emission of vehicle and (2) vehicle-related particles such as from tire, clutch and brake wear (Seinfeld, 1996). In urban atmosphere, particulate concentration (PM_{10}) measured at sites representing roadside area persistently higher compare to the background sites (Giri,D 2006). Regarding on vehicle-exhaust emission levels, diesel powered vehicles are roughly one order of magnitude higher than those for gasoline engine vehicles, most figures only consider PM_{10} emissions from diesel engines (Artinano, B, 2004). This implies neglecting the contribution of the private cars and motorcycle, which can significantly contribute to the level of particles through the atmospheric chemical interaction among gaseous pollutants. The absence of reliable and suitable emission figures from road transport in many developing countries, and uncertainties associated with road traffic conditions makes particulate matter an important issue.

Episodes of high concentration of secondary pollutants associated with slow-moving, clear skies, sunshine, and warm conditions that usually accompany high-pressure system and accelerating the atmospheric photochemical interaction. The rate of photochemical reaction increases as air temperature rises. In urban areas, paved surface, high-rise building and other constructed surfaces cause air to be higher due to the heat transfer of these surfaces. The vertical temperature profiles significantly influence to the Mixing Height value. Mixing height which represents the dispersion depth of the atmospheric boundary layer is a crucial input parameter in air pollution model *(Nath,2006)*. Wind speed in urban area is typically low. Therefore pollutants stay longer over urban areas and accumulate in the atmosphere (Rubin,2001). Light winds allow more emissions to accumulate over large area, which result in higher concentration of secondary pollutants. Wind direction is also highly related to PM_{10} level, downwind locations of precursor emission sources are strongly inclined to high concentration of PM_{10}. Precipitation which in this study expressed as relative humidity is one of PM_{10} washout or run-out mechanisms due to a wet deposition. Most tropical rain forest countries such as Indonesia have high relative humidity, especially at nighttime and wet season.

Trans Jakarta BRT System began operation the first lane on January 15, 2004, on a trial basis, beginning revenue operation on February 1 *(Ernts,2005*). This system, called the TransJakarta busway, includes the key elements of a BRT system, a designated bus lane adjacent is physically separated from mixed traffic in most of lanes, but in some other small places, it still remain mixed traffic. In the first year of operation (2004), 15.9 million passenger travelled by this system *(Susilo,2007)*. Furthermore, there is quite significant shifting, around 14%, from private car user to this BRT, and it occurs 4 months after launching date of first corridors. It is also found that there is an increase of shifting phenomenon from 14% to 15 % *(Alvinsyah,2005)*. In the first month of TransJakarta BRT operation *(Ernst,2005)*, about 20% of BRT passenger previously used private motorized vehicles for the same trip (14% shift from private car user and 6 % shift from motorcycle user). It shows a promising situation where from day to day readership of BRT increases gradually. In fact, up to mid of 2009, 8 corridors of BRT in Jakarta city already operated completely and the physical infrastructures construction of another two corridors already finished and ready to use. Since it launched in 2004, there have been some debates on the effectiveness and efficiency of BRT system in Jakarta city. Another study *(Soehodho,2007)* discussed about the traffic impact and its environmental consequences of CO and NO_X emissions intensity. Other study *(Ernst,2005)*, focus on the impacts on primary pollutants NOx and $PM_{10.}$ Based on study by Ernst, the modal shift change from car and motorcycle to bus in the first corridor of Jakarta's BRT reduce the NOx emission around 101.4 kg/day and 17.9 kg/day of PM_{10}. Most of recent studies only focus on emission reduction of primary pollutants CO, NOx and PM_{10}. There is no study about impacts of introducing new BRT corridors on the ambient air concentration.

Jakarta's traffic situation was dominated by cars, motorcycles, bus and only few of other modes. Looking at their specific emission intensity, motorcycles emit Total Hydrocarbon (THC) almost double compare to passenger car *(Nugroho,2004)* and passenger car emit 1.5 times compare to high duty truck/bus (HDT). On the other hand, HDT release NO_X more than three times compare to passenger car and it was almost 71 times compare to motorcycles *(Nugroho, 2004)*. Bus release 4.8 times NOx emission compare to passenger car and 185 times compare to motorcycles *(Ernst, 2005)*. Recent studies on Jakarta's BRT *(Ernst,2005), (Soehodho, 2007)* already mention about emission reduction of primary pollutants such as CO, THC, NO_X and PM_{10}. Modal shift change due to BRT operation not only reduces vehicle emission as mention in previous studies, but also changes secondary pollutants which might be as surface ozone and secondary particles which automatically affects on total PM_{10} concentration. The modal shift change from car and motorcycle user to BRT may possible to change VOC/NOx ratio in the atmosphere. BRT system will increase bus activities, bus traffic in particular, translates to less direct particulate matter (PM) and NOx that are an important precursors to secondary formation of PM (that absorbs sunlight in the atmosphere).

To evaluate the impacts on ambient PM_{10} concentration, first, we apply and modify our previous SEM model *(Nugroho, 2006a, 2006b)* to evaluate cause-effects relationship among traffic (as emission source), pollutants and meteorological on surface ozone concentration at the location near to BRT corridors. Based fleet composition in major road in Jakarta (Nugroho 2004), private cars and motorcycle are the major traffic. In the weekend, private cars and motorcycle use decrease significantly, but the public transports (BRT) remain stable. Therefore, we use the SEM model to analyze the role of traffic emissions from weekdays' and weekends' PM_{10} in order to assess the effect of reduces traffics on PM_{10} concentration.

2. MATERIALS AND METHOD

2.1 Study Sites

The area of Jakarta is around 664 km^2 with flat topography, closed to the Java Sea and has an average elevation 7 meters above sea level. Climate can be classified into wet season from November to March and dry season from May to September. A few weeks in April and October are transition period, respectively. Jakarta has been experiencing serious air pollution problems which are mainly contributed from automobiles. As mention in the Master plan, Jakarta will have 7 BRT Corridors by 2007 and 15 BRT corridors in 2010 *(Alvinsyh,2005)*. It was also that the Jakarta's government will develop and operate 15 buss rapid transport lines in 2010*(31)*. It will serve at the several major roads in Jakarta city. It seems to be too ambitious plan, nevertheless this reflect the local government concern in providing new public transport system. In fact, up to mid of 2009, 8 corridors of BRT in Jakarta city already operated completely (Figure 1).

Trans Jakarta BRT system began operation the first corridor on January 15, 2004, on a trial basis, beginning revenue operation on February 1. Second (Pulogadung-Harmoni) and third (Kalideres-Harmoni) corridors started to operate on January 15, 2006 and corridor 8^{th} started to serve for public since February 21, 2009. The physical infrastructure of BRT corridor 9^{th} and 10^{th} already finished the construction phase and ready to use. The primary data were collected from five mobile ambient roadside air quality monitoring stations which were installed near to BRT corridors in Jakarta (Figure 2). The monitoring stations were situated on Thamrin Road (BRT #1), Fatmawati Road (BRT #8), Perintis Kemerdekaan (BRT #2), Yos Sudarso Road (Proposed BRT #10) and Daan Mogot Road (BRT #3). The data were sampled during the weekdays and weekend on several days in April, May, September and October 2005. The monitoring stations are automatically measured CO, NO, NO_2, SO_2, PM_{10}, and O_3. In addition, in-situ meteorological data (solar radiation-SR, temperature-T, relative humidity-RH, wind speed-WS and wind direction-WD) are also recorded at the monitoring stations, which were equipped with basic meteorological sensors at 10 meter height above the ground. The measurement interval of both pollutants concentration and meteorological data are 30 minutes.

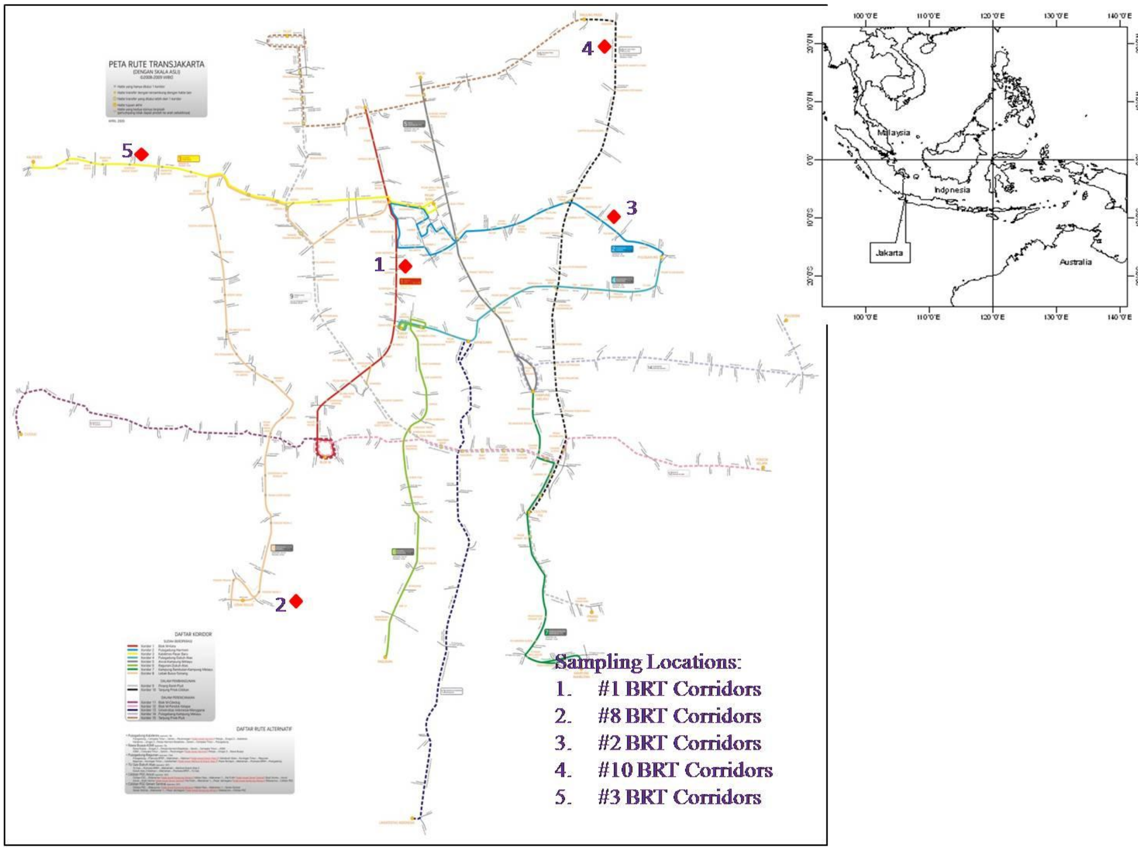

FIGURE 1 Sampling locations in Jakarta City

2.2. Structural Equation Model for PM_{10}

Structural equation model (SEM) is a modeling technique that can handle a large number of the observed endogenous and exogenous variables, as well as (unobserved) latent variables specified as linear combinations (weighted averages) of the observed variables (*Golob,2003*). The models play many roles, including simultaneous equation systems, linear causal analysis, path analysis, structural equation models, dependence analysis, and cross-legged panel correlation technique (Joreskoq, 1989). It is a confirmatory, rather than explanatory method, because the modeler is required to construct a model in term of a system of unidirectional effects of one variable on another. Advantages of SEM compared to most other linear-in-parameter statistical methods include the following capabilities: (a) treatment of both endogenous and exogenous variables as random variables with error of measurement, (b) latent variables with multiple indicators, (c) test of a model overall rather than coefficients individually, (d) modeling of mediating variables, (e) modeling of dynamic phenomena such as habit and inertia *(Rubin,2001)*.

There are 15 observed variables in the model that represent the emissions sources (Traffic volume per road capacity of Motorcycle-VCMC, Traffic volume per road capacity of Private Carss VCPC, Traffic volume per road capacity of High duty diesel vehicles-VCHDT), meteorological factors (Solar Radiation-SR, Ambient Temperature-T and Humidity-RH), wind (wind speed -WS, Sine Wind Direction and Cosine Wind Direction), primary pollutants (NO, NO_2, CO, SO_2 and PM_{10}) and the O_3. These five groups of variables respectively determine nine latent variables $\xi_1, \xi_2, \xi_3, \eta_1, \eta_2, \eta_3, \eta_4, \eta_5, \eta_6$, where ξ_1, ξ_2 indicates exogenous latent variables at time (t-1), ξ_s indicates exogenous latent variables at time (t-2), η_1, η_2, η_3 are all the endogenous latent variables at time (t-1) and η_4, η_5, η_6 are all the endogenous latent variables at time (t) (Figure 2). The latent variables, η_3, η_6 which are defined by using both O_3 and its precursor NO, are used to describe the photochemical matters at time (t-1) and at the time (t), respectively. The latent variables, η_2, η_5 which are used to defined the O_3 precursors NO, NO_2, NOx and CO which involved in the Photochemical Cycles *(Seinfeld,1998)*, at time (t-1) and at the time (t), respectively. The latent variables η_1, η_4 are used to define the non-precursors pollutants which measured at time (t-1) and at the time (t), respectively. CO, SO_2 and PM_{10} are specified in one-to-one relationships with the latent variables "Non-Precursors" (η_1 & η_4).The latent variables "Precursors" (η_2, η_5) was specified to represent gasses which give a direct effects or take part in the photochemical cycles. In this study, traffic data that was classified as traffic volume per road capacity (V/C) of Motorcycles (MC), Passenger Car (V/C PC) and High duty trucks (V/C HDT) are specified in one-to-one relationship with the latent variable of 'Vehicles Emissions' at time (t-2). To capture the non-linear relationship between some variables, several observed variables need to be properly transformed. The existing research *(Zhang,2002)* suggests that a linear function is better for O_3 and NO_2, than others. Based previous work *(Nugroho,2006)*, a natural logarithm (LN) function is applied to transform the pollutant NO, resulting in a new variable LN_NO. The state dependence correlations for each latent variable at time (t-1) and (t) in the model structure is written as β_{63}, β_{62}, β_{61}, β_{53}, β_{52}, β_{51}, β_{43}, β_{42} and β_{41} for latent variables photochemical, precursors and non-precursors respectively. Following the descriptions by Joreskog and Sorbom *(1989)*, the full model structure is summarized by the following equations:

Structural Equation Model:

$$\boldsymbol{\eta} = \boldsymbol{B\eta} + \boldsymbol{\Gamma\xi} + \boldsymbol{\zeta} \tag{5.1}$$

$$\eta_t = \mathrm{B}\,\eta_t + A_1\eta_{t-1} + A_2\eta_{t-2} + \Gamma\xi_t^{(1)} + \Gamma\xi_{t-1}^{(2)} + \zeta_t \tag{5.2}$$

Measurement Model for y:

$$y_t = \Lambda_y \eta_t + \varepsilon_t \tag{5.3}$$

Measurement Model for x:

$$x_t = \Lambda_x \xi_t + \delta_t \tag{5.4}$$

Structural equation model with multiple endogenous latent variables, model estimation becomes more challenging, and quite a few different methods have been developed (*Golob,2003*). The most commonly used estimation methods are maximum likelihood (ML), general least squares (GLS), weighted least squares (WLS), asymptotically distribution free weighted least squares (ADF or ADF-WLS) and elliptical reweighted least squares (EGLS or ELS). The most often used estimation method is ML, which maximizes the joint probabilities that the observed covariances were drawn from a population that has its variance-covariance generated by the process implied by the model, assuming a multivariate normal distribution. We used GFI and AGFI to assess our models and use AMOS-SPSS software, which has a very attractive and user-friendly interface.

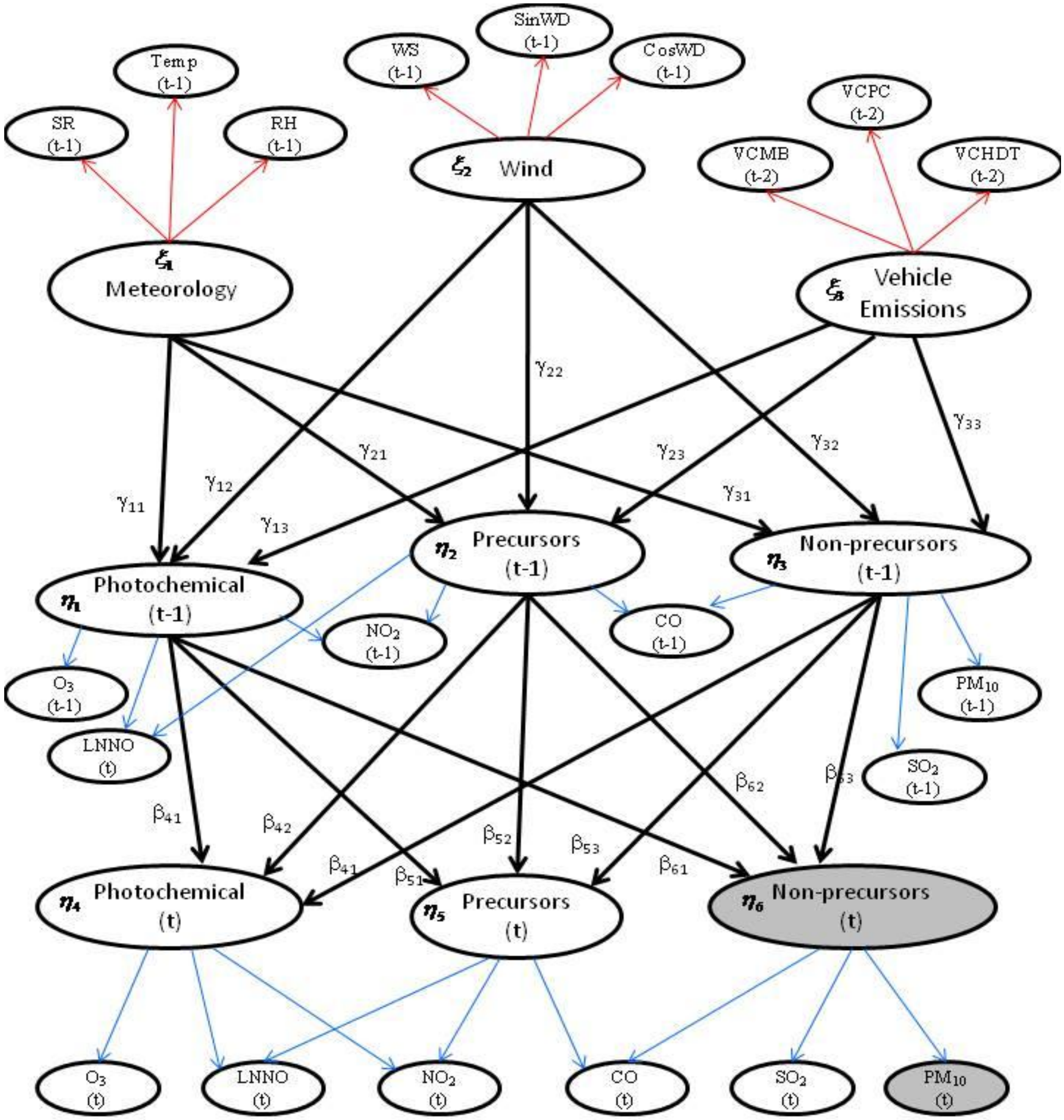

FIGURE 2 Structural equation model of ambient roadside air quality near TransJakarta BRT corridors

4. DATA

Traffic was monitored by video recording at the same locations as the monitoring stations. As an input for the SEM, the recorded vehicles were classified into 3 categories which consist of (i) motorcycle and three wheeler (MC), (ii) passenger cars (PC), and (iii) high duty trucks (HDT) that includes all diesel vehicles. The traffic data for each road was converted into the traffic volume per road capacity (V/C) ratio. In total, 715 time points were obtained from five stations, however due to sampling error only 672 time points that remained valid. Table 1 describes detail measurements results of air quality and traffic.

The highest PM_{10} concentration (Figure 3) was found at Fatmawati Road station near to the latest BRT corridor (#8) and Daan Mogot Road near to 3rd of BRT. On the contrary, the traffic volume at fatmawati road was the lowest among others (see Figure). The highest PM_{10} concentration occurs at the night which may relevant to evening peak hour traffic. It is observed that the ambient air quality standard for 24-hour PM_{10} (150 ug/m^3, Governor Decree of DKI Jakarta no 551/2001) was violated around 15.7% of samples at several stations. The violation rates increase to 19,4% in the weekdays, in contrast, it decrease to 8.48 % in the weekend days. Concretely, PM_{10} concentration remains high although traffic volume reduced in the weekend. Looking at the spatial distribution, the violation rates in West Jakarta were 38,2% and 23,6% in dry and wet season. The lowest violation rates observed at Central Jakarta at 6.3% (dry season) and 1.4% (wet season). By comparing seasonal violation rates, we found decreasing phenomena in wet season which may affected due to wet deposition.

TABLE 1 Ambient Air Quality Monitoring Data near to BRT corridors in Jakarta city, 2005

No	Locations	Measurement 2005	Pollutants												Traffic Volume		W-end/	Vehicle Speed (km/h)					
			CO (x1000) ug/m3			O3 (ug/m3)			NO2 (ug/m3)			NO (ug/m3)			Vehicle/Day		W-day	Weekday			Weekend		
			Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	W-day	W-end	Ratio	Min	Max	Avg	Min	Max	Avg
1	Bundaran HI	April 1st - 07th	0.04	8.01	2.28	6.25	133.44	18.09	6.65	276.03	68.32	17.20	741.16	215.56	174534	111780	0.64	15	30	25	20	60	40
	Central Jakarta	*(April 3rd - 5th)*	0.08	8.01	2.21	6.75	133.44	20.58	6.65	276.03	78.07	17.20	741.16	195.93									
		September 9th-15th													169902	103926	0.61	20	50	35	40	60	50
		September 11th-13th	0.40	7.60	3.32	4.80	80.90	16.96	24.40	300.40	91.12	12.70	365.60	144.99									
2	Fatmawati	April 11th - 17th	0.54	13.67	4.04	6.47	224.99	35.74	0.06	207.49	76.13	1.03	393.03	79.10	65718	61170	0.93	10	25	20	20	60	40
	South Jakarta	*(April 10th-12th)*	0.94	13.67	3.86	6.47	180.84	24.53	0.06	158.95	30.87	1.03	393.03	81.54									
		September 22nd - 29th													76380	62742	0.82	25	50	35	20	50	35
		September 25th - 27th	0.43	7.60	2.38	5.80	151.10	38.69	11.10	166.20	58.87	3.80	217.60	56.00									
3	ASMI	April 22nd- 28th	0.46	6.18	1.56	6.71	96.33	27.56	4.78	107.24	37.00	4.89	247.78	51.82	116490	142860	1.23	25	40	30	40	60	50
	East Jakarta	*(April 24th-26th)*	0.46	6.18	1.50	6.85	96.33	29.24	4.78	92.67	33.58	4.89	247.78	42.66									
		Sept 30th - October 7th													115920	144018	1.24	40	60	50	20	70	45
		October 2nd-4th	0.48	4.48	1.82	0.00	122.00	30.33	14.80	165.90	64.29	8.80	181.20	52.84									
4	Walikota Jakut	May 2nd - 8th	0.33	7.35	2.39	7.18	232.76	28.35	24.53	310.86	67.34	6.72	435.57	136.97	153630	107976	0.70	30	50	35	60	80	70
	North Jakarta	*(May8th)*	0.33	2.50	1.20	10.36	154.14	41.58	27.48	166.80	67.59	6.72	53.38	27.81									
		October 14th - 20th													135648	81498	0.60	30	50	30	40	80	50
		October 9th - 11th																					
5	HKBP Petoyo	May 11th - 17th	0.65	15.55	4.42	4.35	182.84	17.52	31.54	374.21	97.72	7.19	512.48	150.11	177480	276678	1.56	20	45	40	20	70	45
	West Jakarta	*(May 15th-16th)*	0.77	12.36	4.06	4.35	76.34	15.84	31.54	172.04	81.13	10.49	368.90	142.73									
		October 22th - Nov 8th													114660	60564	0.53	30	60	45	30	65	47
		October 23rd - 25th	0.59	9.38	3.14	5.55	97.10	17.36	16.70	203.10	76.93	3.80	261.50	100.56									

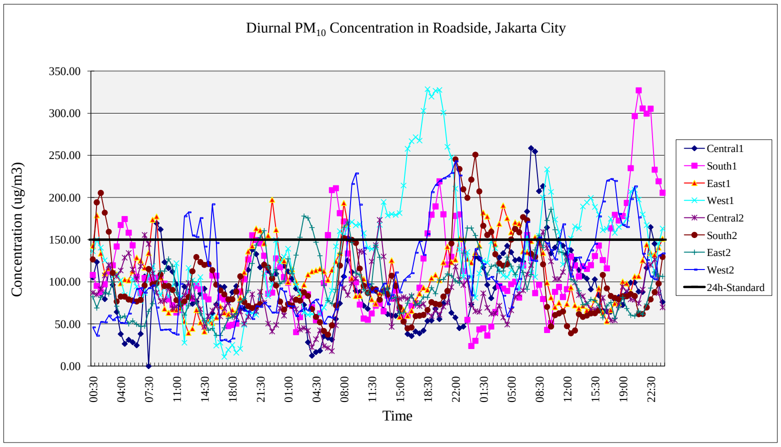

FIGURE 3 PM_{10} concentrations measured at near TransJakarta BRT corridors in 2005

5. ESTIMATION RESULTS AND DISCUSSION

First, we apply SEM model to evaluate cause-effects relationship among traffic (as emission source), pollutants and meteorological factor from onsite measurement in 2005 at the location near to BRT corridors. The GFI (AGFI) value that indicates the model accuracy are 0.658 (0.526) for all data, 0.646 (0.510) in the weekdays and 0.627(0.483) in the weekend days. Despite environmental data usually have some measurement and sampling errors *(32)* that might influence model performance, the calculated GFI and AGFI values suggest that this model is statistically acceptable.

For all of the structural equation models and measurement models, it is found that most of the parameters are statistically significant at the 1% or 5% level. This finding indicates that the postulated model structure in this study is valid. The log-transformed variable LN_NO also got statistically meaningful parameter. All the signs of the estimated parameters are intuitive and consistent with expectations. Comparing the estimation results, weekday data shows better accuracy rather than weekend data. Looking at estimated parameters of latent variables, weekday data shows better compare to weekend data in terms of significantly in statistics. The latent variable "non-precursors" at time (t-1) receives the positive influence from the latent variable "vehicle emissions" at time (t-2) (see Table 2). In contrast, Non-precursors receives negative impacts from 'Meteorology' and 'Wind'. Meteorology and Wind cause the chemical interaction among pollutants and physical dispersion of pollutants through the curbside. Looking at latent variable 'Vehicle-Emission', weekday simulations shows the influence of Motorcycle (0.914) followed by High duty diesel vehicle (0.818) and private cars (0.739). Situation was changed in the weekend, the influence of motorcycle was 0.97 followed by diesel vehicle around 0.94 and passenger car 0.93. We found the emission contribution was dominated by motorcycle in the weekdays and we couldn't found it during weekend days. It was big challenge to shift and reduce the usage of motorcycle along BRT corridors. Looking at the total effects, we could compare that the influence of Wind was bigger than compare to Meteorology. Local wind speed plays a significant role in determining latent variable 'wind'. Exposures in near source microenvironments contribute a greater fraction of total intake for rapidly decaying primary pollutants (e.g., ultrafine PM) than for non-reactive species. Because of the transport and dispersion that occurs during the interval between precursor release and secondary pollutants formation, local and microenvironment emissions will be less important for secondary pollutants that take ~0.5 h or more to form than primary pollutants. It is also confirmed that latent parameters of precursors and non-precursors pollutants at previous time (t-1) always play significant roles in determining latent parameters of non-precursors at time-t. On the other hand, photochemical concentration at time t-1 didn't give significant influences on non-precursors concentration at time-t.

TABLE 2 Estimation Results of PM_{10} Model in TransJakarta BRT Corridors

Estimated Parameters				All data		Weekdays		Weekend	
				Estimate	P	Estimate	P	Estimate	P
$Precursors_{(t-1)}$	<---	$Meteorology_{(t-1)}$	γ_{21}	0.397	***	0.269	***	0.579	***
$Precursors_{(t-1)}$	<---	$Wind_{(t-1)}$	γ_{22}	-0.622	***	-0.68	***	-0.413	*
$Precursors_{(t-1)}$	<---	$Vehicle\ Emission_{(t-2)}$	γ_{23}	0.026	0.562	0.072	0.201	0.016	0.814
$Non\text{-}Precursors_{(t-1)}$	<---	$Meteorology_{(t-1)}$	γ_{11}	-0.047	0.275	0.023	0.665	0.039	0.529
$Non\text{-}Precursors_{(t-1)}$	<---	$Wind_{(t-1)}$	γ_{12}	-0.517	***	-0.598	***	-0.138	0.234
$Non\text{-}Precursors_{(t-1)}$	<---	$Vehicle\ Emission_{(t-2)}$	γ_{13}	0.437	***	0.38	***	0.175	**
$Photochem_{(t-1)}$	<---	$Meteorology_{(t-1)}$	γ_{31}	0.675	***	0.603	***	0.786	***
$Photochem_{(t-1)}$	<---	$Wind_{(t-1)}$	γ_{32}	0.362	***	0.451	***	0.141	0.215
$Photochem_{(t-1)}$	<---	$Vehicle\ Emission_{(t-2)}$	γ_{33}	-0.228	0.259	-0.145	***	-0.082	0.189
$Precursors_{(t)}$	<---	$Precursors_{(t-1)}$	β_{52}	1.089	***	1.081	***	0.94	***
$Precursors_{(t)}$	<---	$Non\text{-}Precursors_{(t-1)}$	β_{51}	-0.078	**	-0.118	**	0.026	*
$Precursors_{(t)}$	<---	$Photochem_{(t-1)}$	β_{53}	0.053	*	0.038	0.319	0.046	**
$Non\text{-}Precursors_{(t)}$	<---	$Precursors_{(t-1)}$	β_{42}	0.082	***	0.117	***	-0.04	0.717
$Non\text{-}Precursors_{(t)}$	<---	$Non\text{-}Precursors_{(t-1)}$	β_{41}	0.982	***	0.921	***	2.091	***
$Non\text{-}Precursors_{(t)}$	<---	$Photochem_{(t-1)}$	β_{43}	-0.005	0.772	-0.006	0.764	-0.044	0.578
$Photochem_{(t)}$	<---	$Precursors_{(t-1)}$	β_{62}	-0.012	0.498	-0.026	0.254	-0.05	0.15
$Photochem_{(t)}$	<---	$Non\text{-}Precursors_{(t-1)}$	β_{61}	0.03	*	0.028	0.211	-0.017	0.302
$Photochem_{(t)}$	<---	$Photochem_{(t-1)}$	β_{63}	0.957	***	0.924	***	1.049	***
Goodness-of-fit index (GFI)				**0.658**		**0.646**		**0.627**	
Adjusted Goodness-of-fit Index (AGFI)				**0.526**		**0.51**		**0.483**	
df				167		**167**		**167**	
Estimation Method : Maximum Likelihood									
Notes : * Significant at 1 % ; ** at 5%; * at 10%**									

TABLE 3 Estimated Standardized Total Effects of PM_{10} Model in Jakarta

	Veh-emission	Wind	Meteorology	Photochem (t-1)	Precursor (t-1)	Non-Precursor (t-1)	Non-Precursor(t)
All-Data							
Photochem(t-1)	-0.1550	0.3620	0.6750	0.0000	0.0000	0.0000	0.0000
Precursor(t-1)	0.0260	-0.6220	0.3970	0.0000	0.0000	0.0000	0.0000
Non-Precursor(t-1)	0.4370	-0.5170	-0.0470	0.0000	0.0000	0.0000	0.0000
Non-Precursor(t)	0.4320	-0.5610	-0.0170	-0.0050	0.0820	0.9820	0.0000
Precursor(t)	-0.0140	-0.6190	0.4720	0.0530	1.0890	-0.0780	0.0000
Photochem(t)	-0.1350	0.3380	0.6400	0.9570	-0.0120	0.0300	0.0000
PM10(t-1)	0.4200	-0.5460	-0.0160	-0.0050	0.0800	0.9560	0.9740
PM10(t)	0.4080	-0.4840	-0.0440	0.0000	0.0000	0.9350	0.0000
Weekdays							
Photochem(t-1)	-0.1450	0.4510	0.6030	0.0000	0.0000	0.0000	0.0000
Precursor(t-1)	0.0720	-0.6800	0.2690	0.0000	0.0000	0.0000	0.0000
Non-Precursor(t-1)	0.3800	-0.5980	0.0230	0.0000	0.0000	0.0000	0.0000
Non-Precursor(t)	0.3600	-0.6330	0.0500	-0.0060	0.1170	0.9210	0.0000
Precursor(t)	0.0280	-0.6470	0.3110	0.0380	1.0810	-0.1180	0.0000
Photochem(t)	-0.1250	0.4180	0.5510	0.9240	-0.0260	0.0280	0.0000
PM10(t-1)	0.3560	-0.6260	0.0490	-0.0060	0.1160	0.9110	0.9890
PM10(t)	0.3640	-0.5720	0.0220	0.0000	0.0000	0.9580	0.0000
Weekend Days							
Photochem(t-1)	-0.0820	0.1410	0.7860	0.0000	0.0000	0.0000	0.0000
Precursor(t-1)	0.0160	-0.4130	0.5790	0.0000	0.0000	0.0000	0.0000
Non-Precursor(t-1)	0.1750	-0.1380	0.0390	0.0000	0.0000	0.0000	0.0000
Non-Precursor(t)	0.3680	-0.2780	0.0240	-0.0440	-0.0400	2.0910	0.0000
Precursor(t)	0.0150	-0.3850	0.5810	0.0460	0.9400	0.0260	0.0000
Photochem(t)	-0.0900	0.1710	0.7940	1.0490	-0.0500	-0.0170	0.0000
PM10(t-1)	0.2410	-0.1820	0.0150	-0.0280	-0.0260	1.3670	0.6540
PM10(t)	0.1000	-0.0790	0.0220	0.0000	0.0000	0.5710	0.0000

6. CONCLUSIONS AND FUTURE RESEACH ISSUES

This paper first established a structural equation model, which can endogenously incorporate various cause-effect relationships among emissions, meteorological, wind, and primary pollutants, which affect the PM_{10} concentration at the location near to BRT lines. The effectiveness of the established model is empirically confirmed and has the high value of goodness-of-fit index and adjusted goodness-of-fit index which statistically cannot be rejected. It is also confirmed that exhaust emissions emitted from vehicles at time (t-2) will give significant effects on the non-precursors concentration at time (t). The model shows that precursors and non-precursors concentration in the previous time observation (t-1) play a significant role in the PM_{10} concentrations at time-t.

Based on the estimation results through structural equation model, effect of modal share change, motorcycle emissions influence significantly and also dominant to PM_{10} concentrations. In contrast, it was not dominant during weekend days. Current traffic situation in developing countries such as Indonesia which suitable for motorcycle usage as haul-line cause a significant effects on ambient air concentration near to major road. The modal shift change due to BRT and other transport demand management will reduce and influence significantly to PM_{10}. We also could find a preliminary improvement on the PM_{10} concentration by comparing the violation rates to the ambient standard of data measured at weekdays and weekend days. Nevertheless for further analysis, the model predicts several scenarios related to Motorcycle shifting to BRT to get evidence of the side effects of BRT. In order to reduce the usage of motorcycle, it is possible to promote park and ride motorcycle system as the access mode to TransJakarta BRT system.

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