



Creating the Synergy of Land Use, Transport, Energy and Environment Elements towards Climate Change Co-benefits

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ABSTRACT

Land use, transport, energy consumption and air quality issues in a city are interconnected and therefore form a nexus. This study attempts to analyze this nexus by identifying the magnitude and quality of the links among the elements. The study was undertaken in Bandung City, Indonesia by analyzing the concentricity of land use of the city, computing traffic loads at some primary radial trunk roads towards city center, assessing transport energy and air quality in the study area. Analysis on the present linearity of the nexus was also conducted by acquiring relevant secondary data as well as information from the separate study by the first authors in the same city. A quantitative analysis was undertaken to corroborate the relationships among linear connections of the elements. The result exhibits that the interconnections among elements in the nexus do exist. It also shows that the interconnection of the nexus i.e. land use, transport, energy consumption and air quality is linear and it requires a synergistic efforts to enhance the strategies towards climate change co-benefits. By looking at the nexus as a policy arena, the study proposes prospective policy directions that could lead to synergize co-benefits of climate change and accordingly contribute to climate change adaptation of the city and the reduction of climate change impacts.

1. Introduction

The connection between land use and transport has been well researched for quite a long time as many studies have been undertaken, for example, by Newman and Kenworthy (1989), Banister and Liechfield (1995), Cervero (1996), Badoe and Miller (2000), Hickman and Banister (2007), Koomen and van Beurden (2011), Brandi et al. (2015), Wang et al. (2014). In similar manner, energy and environment relationship study has also been adequately carried out, as exhibited by Owen (1992), Brehemy (1995), Anderson et al. (1996), Ahearn (1997), Keuken (2002), Steemers (2003), Warren and Enoch (2006), Proost and van Dender (2012), and many others. In contrast, only few studies on the linear nexus of land use, transport, energy use and environment have been done. The linearity of the relationships among elements in the nexus is a multi-disciplinary research arena due to their interconnectivity, and therefore there are potential climate change co-benefits if the elements in the nexus are properly synergized.

The linear connections in the nexus can be corroborated by a common notion that land use conversions from natural environment to be built-up areas generate traffic loads at immediate collector roads as the roads serving its catchment area. Urban land use conversion from agricultural areas to be residential areas as exhibited by the process of urbanization would not only generate traffic loads but often increase the travel demand as well. The widening spatial realm associated with urbanization would create the distance between origin and destination of a travel to increase, and most of the times, beyond walking distance and thereby needs motorized transport. The separation of origin and destination beyond walking or cycling distance would lead to the use of transport energy. With the use of hydrocarbon-based fuel engine for travelling, the eventual consequence in the nexus is the presence of air pollution.

This cause-and-effect issue substantiates the linearity of land use, transport, energy consumption and air pollution nexus. In many cities, this linear nexus can be observed during the urban expansion phase of cities.

Urban expansions in cities with loose development control by the authority are usually dominated by the development of residential areas without paying adequate attention to the balance between homes and work places. Urban expansion of this type possibly creates sprawling low density residential areas and generates vehicle-dependent citizens. Further manifestation of this development is the presence of spatial isolation of residential areas from commercial or institutional areas where the work places are commonly located. Spatial segregation beyond walking or cycling distances leads to the need of motorized transport, either public or private. This situation noticeably causes higher consumption of transport energy. Although this is a chain of problems, the same offers opportunities to accrue co-benefits from integrated policy interventions in the elements of urban development, transport, energy and environment.

This study defines co-benefits as multiple benefits generated by the elements within the nexus that are accrued by implementing a policy, strategy or a measure. In other words this definition goes beyond the conventional definition of co-benefits as a win-win situation accruing two types of benefits from a single intervention (e.g., energy and environmental benefits of a policy on public transport system). A synergy of co-benefits acquired from win-win situation is therefore needed.

Interventions towards ensuing co-benefits can be undertaken by either individual or interconnected manner in each element. This opportunity can be explored by understanding the generic and specific contexts of

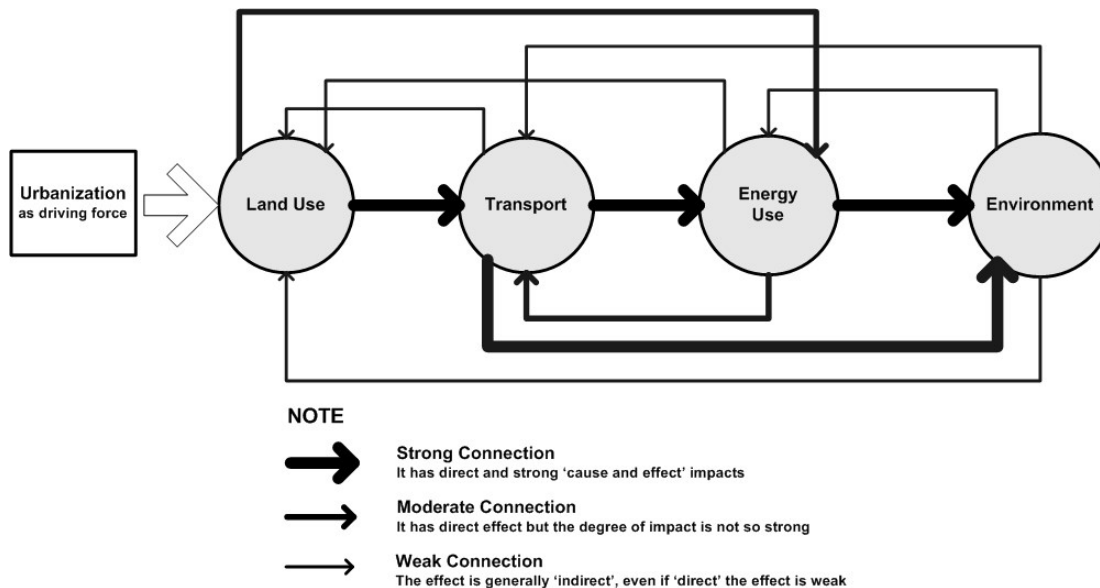


Figure 1: Linearity and Non-linearity in the Nexus' Connectivity

individual elements. The generic context is an umbrella within which all elements of the nexus are identified, such as legal and institutional framework, development plans and programs. Specific context, meanwhile, covers issues of each element such as owners, users, consumers, and other stakeholders. Specific context needs a thorough knowledge on each element of the nexus and interconnection among nexus' constituents. Generic context requires a comprehension on present legal and institutional setting in a particular urban area. For example, how present legal and institutional settings influence the implementation of land use plan. In most cities, interconnection between generic and specific contexts is absent due to uncoordinated policy design. This situation leads to various unexpected impacts, for instance, land use conflicts and asynchronous urban development. Studies on this inadequacy are not sufficiently carried out. Understanding this inadequacy may lead to discover the complexity of the nexus that may support towards coherent interventions.

The primary connectivity of land use, transport, energy consumption and environment nexus is linear with respect to the way of interconnectedness due to straightforward interconnection among the nexus with single variable. However, the nexus contains non-linearity as exhibited in Figure 1.

Even though the interconnections are strong, moderate or weak, the four elements of nexus i.e. land use - transport - energy - the environment exhibit their interconnection one another. Land use as the root element of the nexus noticeably governs transport process through transportation networks and circulation. In different way, when land use control is loosely exercised, transportation network may further govern the land use, for example, the presence of leap-frog development and urban sprawl. This issue can be easily observed when a new road network is developed and it provides first time access to a relatively non-developed area. In a relatively short period, an apparent immediate consequence is changing landscape of the surrounding areas from generally natural area to a built-up area. This simple example shows how land use and transport is mutually interconnected. This example can also show the way the nexus is interconnected in a non-linear manner. Similar situation is also present in other elements of the nexus, for instance, in the connections of transport and energy, transport and the environment or energy and the environment. Transport requires

energy while policies on energy would affect transportation performance. Each link in the interconnection has different degree of relationship i.e. strong, moderate or weak influences, and the interconnection is also very complex in nature.

Amidst the complexity and non-linearity of the nexus, an attempt to simplify the connection was made by following the only significant and strong connection among the elements of nexus. This attempt resulted in identified simpler connection which is linear rather than non-linear. The analysis towards the required policies is thereby becomes relatively simpler and easier to understand. Understanding the linearity of the nexus is an essential output of this study, since this comprehension may lead to design of new integrated policies. The expected output of this study is the development of local policies on the linearity of land use, transport, energy use, and environment nexus. The new policies will have reference to conventional management measures viz. command and control measures, economic and financial measures and moral suasion. These three types of measures are independently or collectively expected to create the co-benefits within the explored nexus, particularly with respect to transport, energy and environment. This policy arena was explored in a city in an Asian developing country.

Bandung City was selected as the study area, since this city exhibits the clear presence of linearity of land use, transport, energy and urban air quality nexus. At the same time, the relevant policies are loosely designed and implemented. The consequences of this present situation, Bandung City has experienced with leap-frog development, urban sprawl, severe traffic congestion and continuous degradation or air quality. Prior to exploring the existing policies associated with the nexus, the study attempts to substantiate the connection among elements in the nexus.

2. Interconnections among Elements in the Nexus

2.1 Land Use – Transport Connection

The study was carried out in Bandung City. The city is located on 107° East and 6°55' South at the altitude about 650-750 meter above mean sea level. The present area of the City is 16,767 hectares and

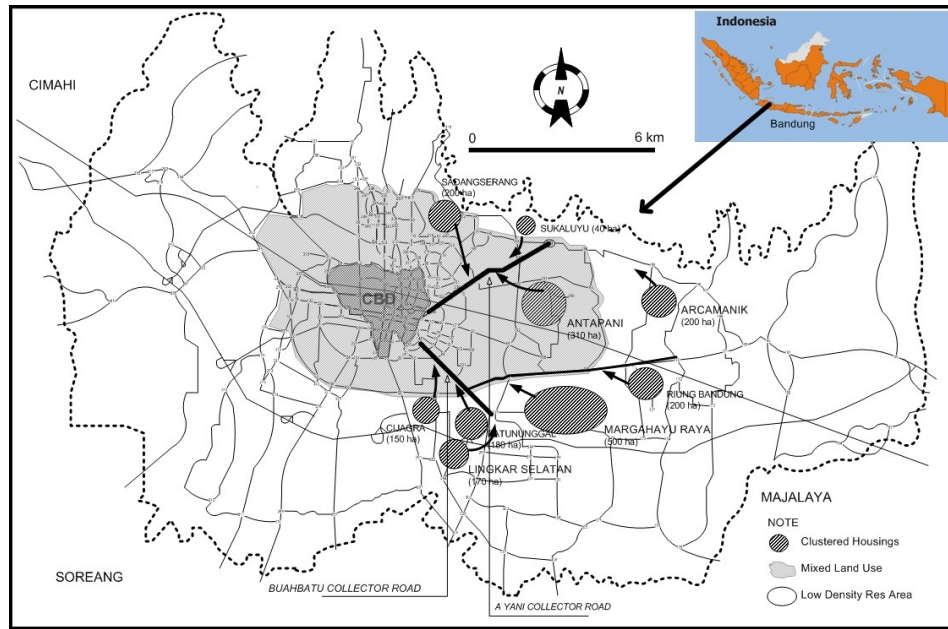


Figure 2 Bandung City, the Study Area

geographically located in the center of West Java Province as exhibited in Figure 2. Urban expansion of Bandung City has been undergoing in an inconceivable pace during the period of 1970-1980. This has created extensive leap-frog development and urban sprawl in the city.

There are various studies regarding land use and transport interconnection. Some studies used various types of urban forms to capture the effect of the land use changes on travel behavior for example by Naess (2013), Bhat and Singh (2000), and Dunphy and Fisher (1996). These studies demonstrated the use of urban density variable to describe travel behavior of the citizens. These studies also confirmed that there is a correlation between land use and mobility variables. The most observable correlation between land use change and traffic load can be examined from the proximity of origin (e.g. residential area) to destination (e.g. commercial, civic, or governmental area) as suggested by Kodialam and Orlin (1992). In case of the study area, the locations of residential areas are largely in the periphery of the city while the work places are mostly located in the urban center. Very long distance from urban center may influence the length of journeys, particularly for more discretionary journeys such as for social or entertainment purposes (Lin

and Yu, 2011; Williams et al., 2000). This shows that land use e.g. land use changes and transport is mutually interconnected.

This study attempts to correlate land use and transport elements through the connection between land use changes and traffic loads. The term “land use changes” in this study refers to alteration of category of the use of land from previously natural lands to be built-up areas. The changes are particularly manifested by the development of residential or commercial areas from previously paddy fields, fallow or urban forest or other types of natural environment. The land use changes in Bandung City that took place during the period of 1970-2010 are illustrated in Table 1. This table considers 1970 as the base year because significant land use changes have historically been started in 1970 when nationwide development program in Indonesia was commenced.

Land use of Bandung City has a purportedly concentric pattern as in other secondary cities of Indonesia. This was due to the influence of Dutch planners, since almost all of the secondary cities in Indonesia were planned by Dutch planners during the colonial era (1617 to 1945). Therefore, the influence of medieval Dutch cities in Indonesia was inescapable. This pattern, along with radial expansion of the residential areas in the peripheries, creates large numbers of commuting citizens.

Table 1 Land Use Development in Bandung City

Land Use Category	Area in 10-year Interval (hectares)									
	1970		1980		1990		2000		2010	
	Area	%	Area	%	Area	%	Area	%	Area	%
Low Residential Area	2,557	40.0	2,796	30.0	3,579	35.0	8,792	52.4	9,980	59.5
Industry	64	1.0	280	3.0	307	3.0	610	3.6	610	3.6
Mixed Use, Commercial Area	469	7.3	656	7.0	902	8.8	988	5.9	1,250	7.5
Military Area	300	4.7	300	3.2	348	3.4	348	2.1	348	2.1
Institutional Area	250	3.9	373	4.0	409	4.0	557	3.3	750	4.5
Roads and Rivers	400	6.3	450	4.8	580	5.7	933	5.6	1,294	7.7
Conserved and Reserved Area	952	14.9	3,266	35.0	3,101	30.3	3,802	22.7	2,105	12.6
Greenery	1,400	21.9	1,200	12.9	1,000	9.8	737	4.4	430	2.6
TOTAL	6,392	100.0	9,320	100.0	10,226	100	16,767	100	16,767	100

Table 1 shows considerable development of low density residential areas over time, from 2,557 ha in 1970 to 9,980 ha in 2010, or about four times for this period. Low density residential development in the periphery has created significant segregation between residential areas and job places. It is then not surprising if traffic loads in the collector roads serving their respective catchment areas increased. Based on long observations (CTSB, 2010; Permana, 2005), it seems that the residential development has brought into the substantial increase of traffic loads in some collector roads.

The relation between land use changes and traffic loads in the study area is established through the development of multivariate models of two collector roads: *Jalan A Yani* and *Jalan Buah Batu* (refer to Figure 2). These two collector roads were the receivers of catchment areas where most land use changes took place. The model assigns four independent variables and traffic load as dependent variable. All of these variables are shown in Table 2.

Multivariate analysis was done by using data from Table 2 for the catchment areas served by two collector roads. The analysis revealed that the correlation between traffic volume and land use, car ownership, length of road, and per capita income variables for the catchment area served by *Jalan A Yani* is expressed by the following equation:

$$y = 426.389 + 0.174x_1 + 4.942x_2 + 0.150x_3 + 0.028x_4$$

Similarly, for *Jalan Buah Batu* collector road, the model is expressed by:

$$y = 1582.961 + 0.009x_1 + 3.358x_2 + 0.107x_3 + 0.099x_4$$

Table 2 Data for Multivariate Models on *Jalan A Yani* and *Jalan Buah Batu*

Year	Traffic Load [PCU] (y)		Land Use Change [ha] (x1)		Per 1000 persons Car Ownership [unit/1000 person] (x2)	Length of Road [km] (x3)	Per Capita Income [USD] (x4)
	AY	BBT	AY	BBT	AY/BBT	AY/BBT	AY/BBT
1994	1,460	2,203	430	300	170	725	310
1995	1,565	2,326	450	500	184	902	368
1996	1,670	2,448	565	670	198	904	427
1997	1,695	2,497	600	870	213	904	479
1998	1,721	2,522	600	870	222	940	614
1999	1,808	2,547	750	870	223	940	646
2000	1,895	2,573	750	990	232	940	682
2001	1,991	2,598	800	1,200	248	1,050	810
2002	2,087	2,650	850	1,200	264	1,050	966
2003	2,188	2,703	850	1,250	284	1,050	1,151
2004	2,290	2,820	850	1,300	312	1,080	1,180
2005	2,406	2,915	900	1,300	328	1,080	1,300
2006	2,522	3,010	1,100	1,300	335	1,100	1,400
2007	2,638	3,105	1,300	1,400	352	1,100	1,500
2008	2,754	3,205	1,500	1,400	386	1,200	2,000
2009	2,870	3,295	1,600	1,500	388	1,200	2,500
2010	2,986	3,390	1,600	1,500	405	1,200	3,000

These two models exhibit high multivariate correlation i.e. 0.997 and 0.994 respectively. These models also corroborate strong correlation between land use and transport.

The model is useful to predict the traffic loads generated by land use changes in both collector roads. The intercept is not assigned to be zero because of the unbounded control volume, where Bandung city opens from incoming traffic from outside of the city. Although all variables (x_1 , x_2 , x_3 and x_4) are equal to zero, traffic volume (y) will not be equal to zero. The prediction of traffic volumes without land use changes in certain collector road is computed by assigning $x_1=0$ (no land use changes). The historically recorded traffic volume data at the same collector road is assigned as traffic volumes with land use changes. The comparison of traffic volumes with and without land use changes at *Jalan A Yani* (east collector road) is shown in Figure 3. The same also applies to *Jalan Buah Batu* and other collector roads. Again, this finding substantiates the correlation between land use and transport.

The first two elements of nexus i.e. land use changes and transport has been quantitatively substantiated. The connection between transportation and energy is automatically corroborated by a simple argument that is transportation needs energy to work. This argument inarguably proves a strong connection. Thus, further complex corroboration is not necessary. On the other hand, energy and environment connection can be validated through transport energy and environment relationship with an argument that transportation requires energy and emits air pollutants.

2.2 Land Use Driven Transport Energy

Transport and energy is strongly correlated with a very simple argument: transportation consumes energy, and therefore the connection between transport and energy is automatically established. However, understanding land use driven transport energy through evaluating urban form seems more interesting in a sense that urban planners might modify urban forms to minimize transport energy consumption, thus reducing impacts to the environment from urban transportation sector.

Urban form of Bandung drives the citizens towards more motorized transport dependence. The absence of pedestrian friendly environment and the remoteness of housing and jobs or commercial areas augment the dependency on motorized transport. Our survey showed that with current condition of pedestrian facilities of the city, the average distance of willingness to walk of citizen is 772 meter ($s=382$ meter), with the maximum distance of 2,000 m, minimum distance of 100 m, and mode 1,000 m. It means that beyond those distances, people tend to take motorized travel. Contribution of non-motorized travel to the total trip undertaken by the citizens within the city is almost negligible in comparison to other modes, and tends to decline over time. Most of the citizens perceived that overcrowded condition, heat (too hot), reckless traffic, street vendors, on-street parking, inadequate walkways, insufficient pedestrian facilities, and safety as the reasons why citizens are reluctant to take a walk.

The significant increase of the contribution of private cars and motorcycles over the years indicates the augmentation of motorized travel dependency of the citizens. Further consequence is that urban transport energy tends to be higher, and the city deviates further from being an energy efficient city. On the other hand, the contribution of non-motorized transport e.g. walking and biking was very low and almost negligible. This could be a sign for urban managers that something wrong has been undergoing in the city on transportation related matters.

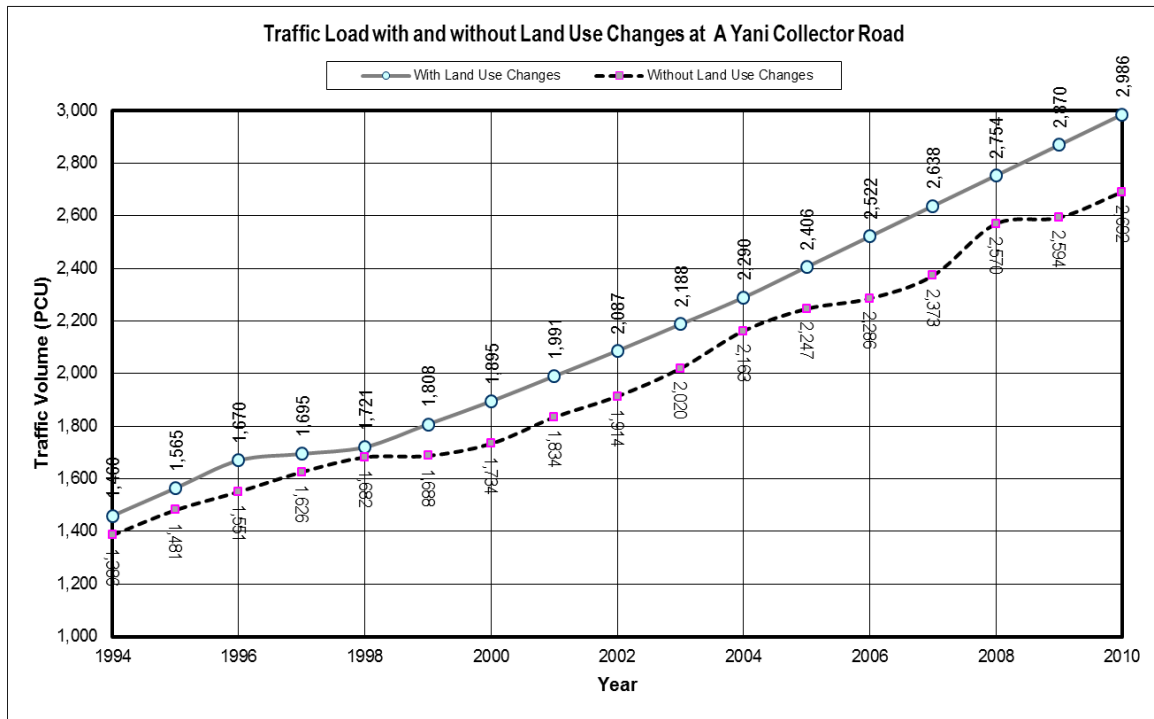


Figure 3: Traffic Load at Jalan A. Yani Collector Road

By evaluating passenger-kilometer-traveled and vehicle-kilometer-traveled, it seems that the occupancy rate¹ of private cars is low while their uses are high. It is deemed inefficient transport with respect to energy consumption. Table 3 provides a comparison on energy use of different transport modes in Bandung (West Java) and Semarang (Central Java). Both Bandung and Semarang are secondary cities. This Table indicates that private car is the costliest transport mode per kilometer per passenger, which is USD 0.0730. With about 41 percent of their contribution to the total person-kilometer traveled in 2005, the transport energy inefficiency due to this mode is tantamount to 2,671,616 GJ² per year or USD 35.5 million per year.

Above condition is also augmented by current fact of urban public transportation system in the study area is not sufficient in terms of quality of service and infrastructure. Present condition shows that willingness of the citizens to shift from private transport to public transport is only 11% (given current public transport conditions) and about 25% (given good public transport available in the city). By this condition, the annual energy saving is about 293,877 GJ per year and 667,904 GJ per year respectively. Such energy inefficiency arises due to low level of the use of public transport. This is because of the reluctance of citizens to use public transport.

Table 3: Comparison of Current Energy Efficiency of Transport Modes in Bandung City and Semarang City

Transport Modes	Fuel consumption (liter/km per passenger)	Energy Use				
		In Mega-Joule/km/ passenger		In USD/km/passenger		
		Bandung	Semarang	Bandung	Semarang	
Private Car (5 seats)	Gasoline	0.104167	3.632	2.906	0.0730	0.0584
Public Bus-AC (40 seats)	Diesel	0.008333	0.323	0.258	0.0053	0.0042
Van (10 seats)	Gasoline	0.208334	0.726	0.872	0.0146	0.0175
Train (480 seats)	Diesel	0.003333	0.129	0.129	0.0021	0.0021
Public Bus Non-AC (40 seats)	Diesel	0.006667	0.258	0.258	0.0042	0.0042
Taxi (5 seats)	Gasoline	0.056818	1.981	1.550	0.0398	0.0312
Motorcycle (2 seats)	Gasoline	0.022727	0.792	0.726	0.0159	0.0146

Note: Gasoline price: USD 0.70/liter, Diesel price: USD 0.63/liter, USD 1 = IDR 12,000 as of November 2014
Source: Author Analysis, Semarang Dalam Angka for various Years [Semarang: Facts and Figures]

¹Occupancy rate is defined as the number of passengers (including the driver) of moving vehicles from origins to destinations.

²807,378.797 VKT*(3.632-0.323) MJ per km per passenger

2.3 Transportation and Air Quality Connection

The relationship between transport and air quality in Bandung City was established by connecting traffic loads and air quality at selected monitoring points. Air quality data were monitored and acquired by means of mobile air quality monitoring laboratory (MAQML) at ten monitoring points. The measurement was undertaken by parking the MAQML at the road-side, and then MAQML observed the air quality. Simultaneously, traffic loads at corresponding points were computed and analyzed. This straight forward procedure was undertaken to understand the connection transport i.e. traffic volume, and environment i.e. air quality. This connection could also reflect the

presence of the nexus in study area. Air quality data acquired by MAQML at selected monitoring points are shown in Table 4. A Four-year air quality monitoring was acquired.

In this study, data sets as shown in Table 4 were analyzed by employing regression analysis. Regression analysis was carried out on two principal air pollutants to confirm the correlation between traffic loads and the quantity of air pollutants. Linear regression shows moderate to low determination factors, which are 0.71 and 0.45 for SO₂ and HC respectively. The correlation can be directly established since traffic is the only dominating source of air pollution in the study area.

Table 4 Air Quality at Selected Monitoring Points in Bandung [Figures are in ppm]

Monitoring Point	Year	Traffic Load (PCU)	SO ₂	CO	NOx	O ₃	HC	PM
Leuwipanjang	2002	1,974	0.040	2.067	0.047	0.033	1.409	112.00
	2003	3,835	0.048	3.000	0.091	0.030	1.940	139.60
	2005	5,696	0.057	3.933	0.119	0.025	2.471	167.20
	2007	7,557	0.065	4.866	0.149	0.035	3.002	194.80
Cicaheum	2002	2,730	0.043	2.670	0.075	0.031	1.600	120.00
	2003	3,471	0.054	3.601	0.080	0.030	1.970	121.60
	2005	4,212	0.065	4.532	0.085	0.029	2.340	123.20
	2007	4,953	0.077	5.063	0.090	0.027	2.710	124.80
Elang Raya, Cibeureum	2002	1,266	0.034	1.960	0.047	0.040	1.240	98.67
	2003	3,430	0.046	2.400	0.059	0.038	1.302	128.80
	2005	5,594	0.058	2.840	0.071	0.030	1.364	158.93
	2007	7,758	0.070	4.280	0.083	0.020	1.426	189.06
Margahayu Raya	2002	458	0.027	1.059	0.013	0.054	0.980	60.53
	2003	610	0.023	1.400	0.043	0.042	1.130	91.00
	2005	962	0.019	1.741	0.059	0.030	1.280	121.47
	2007	1,314	0.015	2.082	0.070	0.024	1.430	151.94
Sarijadi	2002	650	0.024	1.670	0.043	0.048	0.820	96.50
	2003	1,460	0.036	2.060	0.075	0.039	1.350	99.60
	2005	2,270	0.048	2.450	0.090	0.030	1.880	102.70
	2007	3,080	0.061	2.840	0.104	0.020	2.410	105.80
Buah Batu	2002	2,542	0.022	2.450	0.067	0.038	1.850	120.00
	2003	3,891	0.043	3.680	0.075	0.037	2.060	129.40
	2005	5,240	0.065	4.910	0.083	0.036	2.270	138.80
Cibiru	2002	1,431	0.039	1.618	0.059	0.036	1.000	106.70
	2003	2,310	0.042	2.400	0.063	0.031	1.480	112.00
	2005	3,189	0.045	3.182	0.067	0.026	1.960	117.30
	2007	4,068	0.048	3.964	0.071	0.021	2.440	122.60
Ujunr Berung, Rumah Sakit	2002	1,575	0.032	1.230	0.043	0.039	0.670	76.90
	2003	1,733	0.033	2.054	0.052	0.033	1.353	88.60
	2005	1,891	0.034	2.878	0.061	0.026	2.036	100.30
	2007	2,049	0.036	3.702	0.070	0.019	2.719	112.00
Ahmad Yani, Persib	2003	4,950	0.052	3.450	0.072	0.020	1.880	116.50

Source: Office of Environmental Impacts Management Agency of Bandung (EIMA, 2010)

Relation between SO₂ and Traffic Load: A longer data record is certainly required for a reliable establishment of the correlation. It is acknowledged that the quantity of SO₂ is positively associated with traffic volume. The correlation is shown in Figure 4.

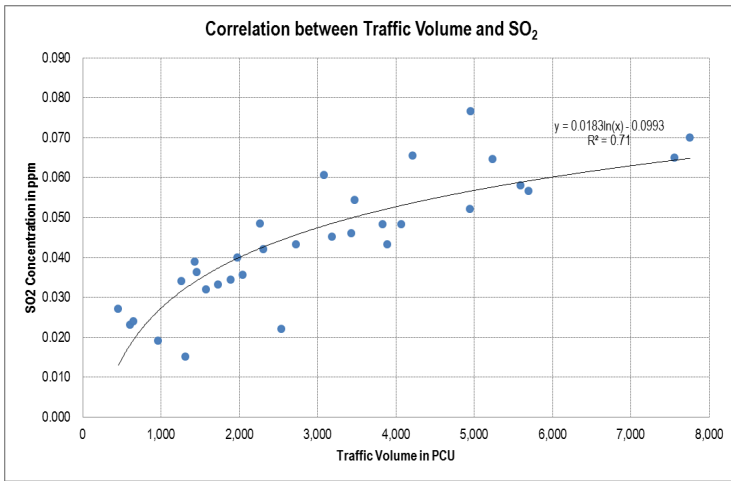


Figure 4: Traffic Load and SO₂ Concentration

Another important pollutant in the study area is Hydrocarbons (HC), particularly benzene (C₆H₆), and the correlation between HC and traffic volume is discussed below.

Relation between Hydrocarbons (HC) and Traffic Load: In the study area, hydrocarbon is the only pollutant, in which the concentration exceeds national standard since a long time ago. With similar data sets used, relationship between concentration of hydrocarbon and volume of traffic is exhibited in Figure 5.

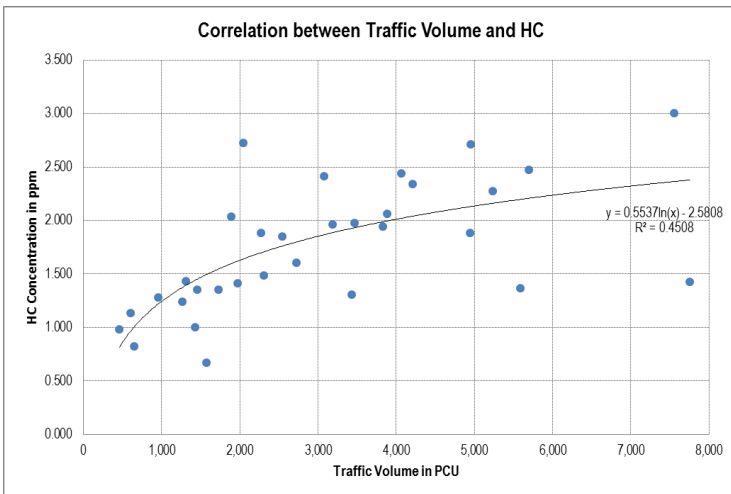


Figure 5: Traffic Load and HC Concentration

The tendency of the concentration of these two air pollutants is increasing over time as traffic loads increase. This exhibits the need of suitable coping strategies to deal with the degradation of air quality in the study area. The strategies, derived from the analysis, can be strongly considered along with presently suitable coping strategies. It is easy to propose strategies dealing with the interconnection between land use, transportation, energy consumption and air quality. In contrast, it is uneasy to implement the strategies as various barriers would impede the

implementation.

3. Primary Barriers that Impede Co-benefits

The primary barriers encountered by Bandung City to implement the strategies to cope with the issues within the nexus of land use – transportation – energy – air quality are presently stemming from two possible sources, namely inadequate policies and strategies at both city and national levels, and lack of awareness of both policy makers and citizens on the importance of co-benefits accrued from the existing nexus. Presently, urban land use plan of Bandung is based on *Rencana Tata Ruang Bandung 2003-2013* (Bandung Spatial Plan 2003-2013). This plan does not provide clear reference to the interconnection among the realms of the nexus. This condition, among others, leads to current urban development which is predominantly denoted by urban sprawl which, from energy and environment viewpoints, is not favorable. Concurrently, there is no transport policy and/or instruments at local level which enables to develop efficient urban transportation systems. Urban public transportation system is seemingly designed without adequate attention on energy and environment. These are general condition of pertinent legal settings in the study area.

Any policies, instruments or measures require legal and institutional supports in the implementation. Meanwhile, there is no clear policy statement in Bandung City regarding the nexus of land use, transport, energy use and environment. Present measures in the city are characterized by loose connections. Furthermore, there are no written or unwritten national policies which explicitly address the link between land use, transportation and the environment. Present policy on national development is too broad and more a philosophy than a clear direction. The way how city’s stakeholders carry out their respective roles and responsibilities, with respect to the nexus, is mainly based on present regulations. Meanwhile, the features of regulations and policy instruments, as explained earlier, lead to ineffective roles and coordination among departments and eventually results in present condition of the nexus in Bandung City.

The existing policy instruments, those directly or indirectly associated with the nexus of land use or land management, traffic or transportation, and air quality were identified and gathered as secondary information. These instruments were distinguished from their level of directives, either national level or city level. There are three policy instruments in the national level of directive that relate to land use-transportation-air pollution nexus. Those instruments are Law on Spatial Plan and Management (Law No. 26/2007), Law on Traffic Management and Overland Transport (Law No. 22/2009) that is the replacement of former Law 14/1992, and Law on Environment Protection and Management (Law No. 32/2009) as the substitute of Law 23/1997. These policy instruments usually need further regulations to be implementable. The lower level regulations may only be effective for certain kind of issues or certain regions.

The “imbalance” of the policy instruments creates numerous gaps and barriers in both national and city level. These barriers should be adequately addressed in the future policies or instruments pertaining to the nexus of land use, transport, energy and environment. The future policies of land use should be given emphasis in this particular issue because of its nature of upstream in the process. Any single policy in land use affects the downstream of the nexus. In addition to that, the present national level instruments on the environmental matters are more completed in comparison to land use and transportation instruments. Despite ineffective implementation, the existing policies and instruments can be considered as one of the potential means in

addressing key barriers which are presently faced by Bandung City if the improvements of implementation are made.

4. Potential Coping Strategies through Existing Instruments

Policy instruments are appropriate tools to achieve the advantage of accruing co-benefits in land use, transport, energy consumption, and environment. The existing instruments in Bandung City are therefore seen as a potential coping strategy to achieve this purpose. Discussion on the analysis of pertinent policy instruments on the nexus is given below.

4.1 Spatial Planning Instruments

National government has promulgated Law on Spatial Plan and Management (Law 26/2007) as the replacement of Law 24/1992. The goals of Law 26/2007 are summarized as itemized below:

- To accomplish a high quality space utilization towards the achievement of national welfare, efficient use of natural and artificial resources, and prevent negative impacts of the land utilization on the environment.
- To accomplish an environmentally sound space utilization based on “Holistic unity system of Indonesia” (*Wawasan Nusantara*) and National Defense System (*Ketahanan Nasional*).
- To accomplish an effective control on space utilization for both land conservation and cultivation purposes.

There are three kinds of spatial plans which are addressed in this instrument. Those are National Spatial Plan, Provincial Spatial Plan and City or District Spatial Plan. National Plan provides general guidelines on the Provincial Plans, while Provincial Plan provides guidelines on the City or District Plan. National Plan also provides guidelines on the designation of conservation and cultivation areas, and uncategorized area in terms of use. Criteria on the space utilization are also guided in broad manner. Guidelines to control the space utilization are also addressed. However, this Law has not specifically addressed the implementation method of the guidelines and criteria. The time-frame of National Spatial Plan is 25 year. This is also a reference time-frame for spatial plan in provincial and city level.

The primary reference of spatial plan in the City of Bandung is City Regulation on *Rencana Tata Ruang Bandung 2011-2031* (Bandung Spatial Plan 2013-2031) based on City Regulation No. 18/2011. This is a revised version of the City Regulation No. 02/2004 to appropriately keep up with the promulgation of Law 26/2007 on National Spatial Plan. The objectives of the plan are to guide the development of the Bandung City towards a Metropolitan city, and to achieve a spatially equitable condition by preventing concentrated development. For the purpose of implementation, this General Plan is broken down to specific detailed plans. Both general and detailed plans addressed the development of each sector including transportation and land use. However, the guidelines are still too broad for practical implementation. Further break-down of the plan is required for the effectiveness of the policy implementation. Adequate coordination with other instruments such as transport-related instruments as well as institutions is also required to ensure that the effective countermeasure is undertaken.

4.2 Transport Regulatory Instruments

Transportation system in Indonesia including Bandung is mainly based

on Law on Traffic and Overland Transportation, LTOT (Law No. 22/2009) as an instrument towards the achievement of the policy on land transport. The policy aims to achieve safe, free flow, comfortable, efficient, orderly and regulated transportation system. There is no specific regulation at the city level regarding traffic management and transportation in Bandung. In the absence of city regulation, the national law (LTOT) is the main regulation to guide transportation issues in Bandung. This law is uniformly valid all over the country. A transportation system which is able to integrate all transport modes and support the growth and distribution of development is the main objective of this law.

There must be sets of guidelines to achieve the objectives, particularly those associated with transportation management. Transportation management should actually improve the traffic flow, reduce emissions per vehicle-kilometer traveled while enhance urban mobility. Transportation management, in principle, consists of traffic supply management and traffic demand management. On the supply side, traffic management is intended to increase speed of existing traffic without modifying it, while demand side desires on the improvement of speed by reducing traffic volume and therefore reducing impacts on environment as well.

4.3 Instruments on Traffic-associated Environment

Present policies and instruments on environment provide sufficient guidance towards better air quality. However, implementation of the measures is not insufficient, since law enforcement is the weakest link in the environmental management process. With insufficient law enforcement, the environmental degradation is steadily intensifying over time. This deficiency is reflected in the present urban air quality in the study area. In addition, some measures do not clearly guide towards the objectives of improving urban air quality and environmental condition in general. Presently, the highest level of direction on environment is Law on Environmental Protection and Management (Law No. 32/2009). The overall objectives of this law are to support the accomplishment of sustainable development by undertaking appropriate and proportionate environmental management.

The law generally addresses issues on traffic associated environment, while addressing the needs of further regulation for specific purposes. To complement the law, some complementary regulations have been promulgated. These regulations are mainly in the form of ministerial decree e.g., Minister of Environment's Decrees. Ambient level of vehicles emissions, emission standards, blue sky policy, air pollution standard index and guidelines on the control of air pollution have been introduced as management instruments so far.

Policy instruments on urban air quality seem adequate with respect to the extent of guidance. Sources of air pollution are sufficiently addressed. However, the instrument does not cover all sectors that have strong connections with urban air quality. For example, the policy instrument does not address urban planning and transportation issues at all. The contents are heavily focused on natural and anthropogenic relationships, because this is a significant issue in Indonesia. Emission control is addressed but more focused on end-of-pipe strategies rather than addressing root-cause of problems. Again, this is because of the initiator of the instrument, the Ministry of Environment, did it without adequate consultation with other sectors such as urban planning and transportation authorities. This inadequate connection must be appropriately solved, and it must be reflected in a comprehensive strategy in order to improve urban air quality.

5. Implemented and Prospective Policies to Address the Issues

Existing policies and instruments are seemingly inadequate to accommodate the issues and synergize the co-benefits derived from the nexus. Some potential policies and instruments are still required to strengthen the existing instruments to effectively synergize the co-benefits. The identification of possible policies and instruments attempts to explore all possibilities related to land use, transportation and its associations for the purpose of improvement of urban air quality in Bandung City. The ultimate goal of these interventions is to synergize the possible co-benefits of the nexus so as to improve urban environmental condition in Bandung City by reducing emissions stem from transport sector.

5.1 “Do the Doable” and First Phase Interventions

Based on the issues within the nexus of land use – transport – energy consumption – environment and present weakness of the existing policies, all potential coping strategies are identified. The strategies may not be doable today but otherwise the other days. The doable strategies today are recommended for implementation.

The recommended strategies or plans are intended for immediate actions, although step-wise implementation according to designated

time-frame is possible. This immediate action should provide adequate foundation and therefore would be able to pave the way towards further longer term interventions. Some policies created a dilemma due to their complexity in the implementation, for example the use of *becaks* (human-powered tricycle transport) in Bandung City. Amid its contribution to the improvement of urban air quality because of its nature of operation, the use of *Becak* in many respect, is opposed by human right activists, as they argue that *becak* is indecent and exploitative transport mode. However, *becak* riders think differently as they are not at all exploited. Riding *becak* is considered as easiest jobs for unskilled labors within limited job opportunities in the City. The policy on this issue is debatable among, local government, non-governmental organizations and *becak* riders themselves. Non-motorized transport of *becak* has been in place for couples of decade or so.

Among the strategies as shown in Table 5, some strategies have already been implemented. Emission control attached to vehicle’s licensing system has been undertaken for a quite long time. However, no evaluation is undertaken so far. *Rukan* (office-housing) and *Ruko* (shop-housing) developments are getting popular among the real-estate developers as well as customers. A study in Bandung shows that this concept is able to reduce transport energy consumption for working activities of the people living in *Rukan* or *Ruko* to zero in comparison to people living in peri-urban areas for the same level of household income.

Table 5 Implemented and Proposed/Recommended Plans and Policy Instruments (First Phase)

Level of Directive	Corresponding element of Nexus	Nature of the Proposed Strategies	Objectives	Present Status	Possible Co-benefits
City	Air Pollution	Emission control attached to car licensing	To improve urban air quality by enforcing vehicle to comply with the	Implemented	Air Quality improvement and reducing the possible causes of climate change
	Transportation Management	MLRT Public Transport	To discourage people to use private car	At planning stage	Efficient transport, efficient use of transport energy, air quality improvement and reducing the possi-
		<i>Kancil</i> small wheeled transport	To provide low emission small public transport	Implemented but cancelled due to strong	Reducing the use of transport energy, air quality improvement and reducing the possible cause of
		<i>Becak</i> , tricycle transport	To reduce air pollution within residential area	Implemented but cancelled due to inappro-	Reducing the use of transport energy, air quality improvement and climate change
		Park and ride system	Support MLRT and reduce number of vehicles operating within the city	At planning stage in line with MLRT	Provide support in reducing transport energy use, improving air quality and reducing the possi-
	Land Use and Urban Planning	<i>Rukan</i> (Office-house) development	To accomplish proximity between housing premise and job places	Implemented and getting popular	Reducing transport energy consumption, improving air quality and reducing the possible cause of
		<i>Ruko</i> (Shop-house) development	To obtain proximity between housing and jobs (for commercial people)	Implemented and getting popular	Reducing transport energy consumption, improving air quality and reducing the possible cause of
		<i>Masyarakat Jalan Kaki, Majaka</i> (Walking society)	To create pedestrian people by providing pedestrian friendly environment	Implemented intermittently during car-free day.	Reducing transport energy consumption, improving air quality and reducing the possible cause of climate change

5.2 Second Phase Interventions

Implementation of the prospective policy instruments or plans cannot be undertaken at once. By keeping and maintaining the momentum of simultaneous and continuous actions towards the improvement of urban air quality and at the same time creates the other co-benefits in Bandung, the subsequent phases can be planned. In every phase of intervention, step-wise objectives leading to the achievement of livable and sustainable cities should be addressed. Certain milestone should be achieved at each phase of the development. It requires strong connection and consistent implementation among the phases.

At the second phase, similar consideration with the first phase is undertaken. The synergizing co-benefits are more generic in nature since the policies look into longer terms in comparison to the first phase. Preceded by the first phase, in the next phase, more comprehensive and progressive policy instruments or plans are recommended. The implementation is undertaken according to given time-frame.

At the second phase, various necessary interventions particularly related to primary elements of the nexus which are land use, traffic and air pollution are recommended. Policy on energy use is quite unique in Indonesia, since the policy on energy will affect every single aspects of the life of Indonesian. Government is continuously reducing the subsidy of petrol and diesel. The November 2014 price hike aims at diverting the subsidy for more productive works i.e. infrastructure development, while reducing unnecessary travel demand and therefore improving air quality. The interventions which are addressed by the conclusion must be reflected in the recommendation. With this consideration, in the second phase, the recommended plans or policy instruments as resulted by the comprehensive and progressive scenario are presented in Table 6.

As it can be observed that proposed strategies are all within the co-linearity of the nexus in a sense that a policy on particular issue (in an element of the nexus) will directly lead to the creation of co-benefits in another element of the nexus. The co-benefits are therefore created and synergized within the line of nexus. The strategies are expected to continuously create and synergize co-benefits towards the betterment of

Table 6 Prospective Comprehensive and Progressive Plans and Policy Interventions (Second Phase)

Level of Directive	Corresponding Elements of the Nexus	Nature of the Policy/ Instrument/Plan	Present Status	Possible Co-benefits	
National	Air Pollution	Standard of compliance of vehicle emission	Implemented	Air quality improvement	
	Energy	Energy price by reducing government subsidy on energy.	Implemented	Getting fresh money for infrastructure development while improving air quality.	
City	Air Pollution	Economic incentives and disincentives	Partially implemented	Air quality improvement	
		The Use of low emission fuels (CNG, LPG)	In a pilot project phase	Air quality improvement	
	Transportation (TDM)	Temporary command and control on the implementation of the existing regulation	Partly implemented	Air quality improvement	
		Application of Area Licensing Fee	Not implemented	Efficient transport, efficient use of transport energy and improvement of air quality	
		Application of Vehicle Quota System	Not implemented	Efficient transport, efficient use of transport energy and improvement of air quality	
		Guidelines on Appropriate Traffic Management	At planning stage	Efficient transport, efficient use of transport energy and improvement of air quality	
	Transportation (TSM)	Provision of traffic infrastructures	Implemented according to plan	Efficient transport but sometimes encourage more traffic	
		Guidelines on appropriate parking system	Not implemented	Support comfort transit system	
		Provision of appropriate mass rapid transportation system	At planning stage	Efficient transport, efficient use of transport energy and improvement of air quality	
		Land Use and Urban Planning	Redevelopment and Revitalization of the CBD	At planning stage	Improve urban management, create economic opportunities
			Promotion of Mixed-Use development and high density residential	Implemented according to city plan	Improve urban management, create economic opportunities, reduce transport energy, improve air quality and contribute to the reduction of climate change
			Redevelopment of Bandung Sub-center and urban containment	At planning stage	Improve urban management, create economic opportunities
Promotion of the neighborhood type development	Partially implemented according to city plan		Improve urban management, reduce transport energy, improve air quality and contribute to the reduction of climate change possibility		
Development Incentives and Disincentives	Development Incentives and Disincentives	Not implemented	Improve urban management		
	Command and Control	Partially implemented	Improve urban management		

urban environmental conditions of Bandung City on the way to livable city and sustainable city.

6. Co-benefits in Bandung City: the Way Forward

Despite ineffectiveness of the policy implementation that prevents the City to accrue and synergize the co-benefits derived from the nexus of land use, transport, energy use and environment, a possibility of synergizing the co-benefits is potentially there with a precondition that the political will of the policy makers, adequate policies and effective implementation of the policies or plans are present. However, external stimulants such as national and international supports to create such a favorable condition are required towards synergistic efforts with available local solutions.

While the government reform has been taking place for more than fifteen years now, persistent bureaucratic state of local government, lack of coordination among the agencies and insufficient policies implementation are seen as major barriers to gain and synergize the co-benefits. Bureaucratic reform has actually been taking place since 1998. However, no fundamental changes are seemingly undergoing. The present government's jargon on 'mental revolution' has been declared by the present administration under President Joko Widodo. In the past, the decentralization of administration has even created ubiquitous corruptions by head of districts, mayors, governors or members of local parliament. These barriers should be appropriately removed by using available local capacities. However, external supports may also be required. National and international supports may be necessary.

Political and financial supports from national government are the most crucial aspects towards the achievement of co-benefits. *Dana Alokasi Khusus* (a special allocation fund), which is a specific budget allocated by the central government to the local government may perhaps be a good medium of national support from financial viewpoint. Sometimes, the difference of political orientation between central and local governments prevents cities to move forward. This constraint should not come into picture in the future for the success of the program, particularly when international supports are required.

Technological know-how which is not always locally available may be required to push the co-benefits related program forward. International pressures, along with international aids, are sometimes workable to encourage particular program to roll out. Cooperation among cities from different countries can also be models of international supports. Exchange studies on successful policies among cities are also possible.

7. Concluding Remarks

Identification of possible policies within the nexus of land use, transport, energy consumption and air pollution is expected to provide Bandung City with a wide variety of policy options at different phase of development. Bandung City is obviously in need of appropriate tools and policy instruments to cope with current energy issues and urban environmental problems. The identification of required policies pertaining to land use, transport, energy use and air quality, to synergize co-benefits, and in broader context, towards the betterment of urban environment, can also be exercised for application in other Asian cities with similar development stage and administration system. Structural and technical adjustment to the policies will be required to ensure the applicability as well as the achievability of the policies towards the objectives. Simultaneous achievement of the betterment of urban environment in Asian cities towards livable cities will make Asian cities

approaching the same level of development with their counterpart cities in developed countries such as North American and European countries.

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