INTERNATIONAL JOURNAL OF BUILT ENVIRONMENT AND SUSTAINABILITY
Published by Faculty of Built Environment, Universiti Teknologi Malaysia
Website: http://www.ijbes.utm.my
IJBES 2(3)/2015, 158-167

Three Sustainability Advantages of Urban Densification in a Concentric Urban Form: Evidence from Bandung City, Indonesia

Ariva Sugandi Permana[1*], Erianto[2], Norsiah A. Aziz[3], Chin Siong Ho[4]

[1]Centre for Innovative Planning and Development (CiPD), Faculty of Built Environment, Universiti Teknologi Malaysia
[2]Faculty of Forestry, Tanjungpura University, Indonesia
[3]Department of Urban and Regional Planning, Faculty of Built Environment, Universiti Teknologi Malaysia
[4]Faculty of Built Environment, Universiti Teknologi Malaysia
*Email: ariva@utm.my

History:
Received: 10 August 2015
Accepted: 09 September 2015
Available Online: 30 September 2015

Keywords:
Concentric City, Environmental Consequences, Sustainable City, Transport Energy, Urban Flood

Contact Number:
+60-75537382 (Ariva)

ABSTRACT

Amid limited land resource in Bandung city, pressure on the needs of lands continuously exists. Urban densification may create high density spaces and minimizes trip length by exploiting vertical growth. In contrary, sprawling city expands horizontally and creates low density spaces. Sprawling cities in most cases are motorized transport dependent cities. The study was carried out by analyzing the present form of Bandung City. Bandung City in Indonesia, a pronounced concentric-cum-sprawling city of a developing country, was selected as study area. The analysis covers three most determinative environment-related issues that lead to sustainability advantages of the city, since appropriately addressing the issues would likely contribute to sustainability of the city. These three issues are transport energy, flood, and groundwater depletion. Analysis on transport energy consumption in three urban development forms was carried out. The study result reveals that urban densification may lead to lower transport energy consumption as reflected in the mixed use areas compared to the other two urban development forms. The study also confirms that urban densification enables groundwater depletion to be minimized amid significant abstraction in the city and at the same time reducing flooding problems.

1. Introduction

Urban densification, in most cases, is associated with compact city because of similar goal of these two overlapping entities in optimizing limited land resources. Thus, this study borrows an understanding that urban densification leads to compact city as the ultimate goal of the process. The increase of urban land demand in the city has led to persistent pressure to the sustainability of city. In a city with loose development control like in the study area, this pressure is translated into the appearance of sprawling city. One approach to reduce the impact of increasing demand of lands is to minimize the spatial extent of urban areas by developing more compact city forms (Tratalos et al., 2007). However, heated debate on compact city has been undergoing since long time ago before the issue of sustainable development was launched by the Brundtland's Report on Our Common Future in 1987. While the compact city and sustainable development issues are presently being a hot topic in international environmental agenda, pros and cons are underway on whether or not compact city leads to sustainable city, the way that city should be developed in the future amid continuous depletion and degradation of natural resources and environment. Inarguably, cities contribute to environmental degradation according to the extent of their ecological footprint as asserted by Rees (1992) and Wackernagel & Rees (1996).

The continuous enlargement of ecological footprint of cities as they are growing has confirmed the parasitic attribute of cities, as plainly depicted by Douglas (1983) who argues that great cities are biologically parasites in their use of vital resources such as air, water and food in urban system. With the emerging sustainability issue, this attribute confronts diametrically the sustainable urban development concept which requires equilibrium state among three important aspects of economic growth, social development and ecology (UN, 2001). This challenge has long been pondered by prominent urban planners, Dantzig and Saaty (1973) for instance, proposes a compact city concept with the main objective is to enhance the quality of urban life by creating more exciting city for personal interactions in today's fast moving world. The proposal of compact city implicitly disputes the organically grown sprawling cities which ubiquitously exist in developing countries, though in some instances, the quality of compact and sprawling cities is co-exist in a city.

While Hong Kong and Singapore characterize Asian compact cities and have undergone extensive urban densification as disputably argued by Lau and Chiu (2004), Bangkok, Jakarta and Manila undeniably exhibit the characters of Asian sprawling cities, as urban agglomeration exists in these three major cities. The different characters of compact and sprawling cities inscribe in these five Asian cities, would likely display dissimilar performance in many respects. It would also constantly invite debate between their respective proponents and opponents. Although the debate on compact city may continually go on, it can be expected to enrich the knowledge of decision makers, academicians and practitioners towards better understanding on sustainable urban development. Above all, reaching optimal solutions regarding the future form of cities, which would likely encounter more problems, receive more pressures and challenges with limited resources, are more important. Today's decisions would determine tomorrow's conditions. The future of sustainable urban development would therefore be determined by today's debate. Within this framework, this study is undertaken.

The study analyses and assesses the performance of an existing concentric-cum-sprawling city from the perspective of urban densification concept. The analysis and assessment were particularly carried out with environment-related issues as the basis, since this subject matter is the most physically distinguishable aspect of urban densification within the quality of sprawling cities. There are three environment-related issues included in this study, namely transport energy, aggravating flood problems, and groundwater depletion. The choice of these issues is based on the fact that the issues are also the most excruciating problems which frequently suffer the city and bring significant socio-economic losses and destruct environmental sustainability. The study is undertaken in Bandung City of Indonesia, a pronounced concentric-cum-sprawling city.

2 Compact Cities, Sprawling Cities and their Environmental Consequences

Compact cities and sprawling cities are two most spatially distinguishable models of cities. Compact cities are generally characterized by high-density, mixed-use urban areas, efficient public transport system, and the environment that encourage walking and cycling (Burton, 2000). Sprawling cities, on the other hand, grow in a horizontally dispersed way which is characterized by low density (Kasanko et al., 2006; Anas and Pines, 2008), and also wasteful land (Anas and Pines, 2008). Compact city is one way of reducing travel distance (Jenks et al., 1996). It offers opportunities for efficient modes of transport such as walking, cycling and public transport (Williams, 1999). Similarly, Thomas and Cousins (1996) recap the advantages of compact city as less car dependency, low emissions, reduced energy consumption, better public transport services, increased overall accessibility, the reuse of infrastructure and previously developed land, and the preservation of green space and a milieu for enhanced business and trading activities. Gusdorfa and Hallegatte (2007) argue that over a timescale, spread-out cities are more vulnerable than compact cities when confronted with an abrupt increase in their transportation costs. The compactness of compact city provides possibilities to reduce transport energy, and thus curb adverse environmental impacts such as global warming (Jenks et al., 1996). Newman and Kenworthy (1989) support this row by arguing that unplanned and low density features of peri-urban areas have possibly greater energy consumption contrasting the facts that city with high density has lower transport energy. Smith and Raemaekers (1998) also argue that higher density brings trip-end closer together and thus reduce trip length and subsequently reduce transport energy. Similarly, Saunders et al. (2008) demonstrate that sub -urban development has created further spatial separation of activities. As a result, increase in travel distances required to access the activities which entails an increase in transport energy consumption (da Silva et al., 2001).

Higher transport energy consumption of sprawling cities, as demonstrated by many studies, is not singularly isolated issue, rather complicated and multifaceted one. The increase of CO_2 emissions is one of the considerable aftermaths of the issue as demonstrated by Paravantis and Georgakellos (2006), Lund and Munster (2006) and Al-Hinti et al. (2007). According to them, sprawling cities has impending feature to aggravate air quality and other aftermaths such as global warming and climate change. This linear cause-and-effect relationship might indirectly show the prominence of compact city as an alternate urban sphere in comparison to naturally grown sprawling cities. The sprawling cities are the most pronounced development found in many major cities in Asian developing countries. Despite disputable, we argued that the main causes of this phenomenon is due to the inferiority of planning practice with business-as-usual approach undertaken in many urban management practices in Asian developing cities, particularly in relation with land resources management.

One most noticeable advantage of compact city is the efficient use of limited urban land as reflected in its urban densification process as main feature of the compact city. For the same number of population, compact city requires smaller urban land coverage than sprawling city. The unused urban land can then be used for various appropriate purposes of cities, such as greenery. With more greenery landscape than hardscape, a compact city would be able to reduce flood magnitude through the reduction of runoff coefficient since overland runoff is directly proportion to run-off coefficient (Chow et al., 1988; Molina et al., 2007; Podwojewski et al., 2008). With similar nature of the environment, for instance, soil type, slope and land use, the compact city would likely exhibit less vulnerable environment to flooding problems for its natural ability to reduce the flood magnitude in comparison to sprawling city. McCuen (2004) confirms that flat lands with hard surface such as in industrial, commercial and parking areas have 10 to 25 times higher overland flow, means 10 to 25 times higher flood magnitude, than forest and open spaces for the same rainfall intensity. This view assumes that the city is contained within a single hydrological entity. This fact substantiates the notion that naturally grown sprawling cities could devastate environment. This perception is also supported by Fang et al. (2004) who assert that urban sprawl can cause very large changes in environmental conditions, more than other land use changes.

Any changes in land use would subsequently alter the capacity of the land to absorb surface runoff and accordingly change infiltration to groundwater (Podwojewski et al., 2008; Welderufael et al., 2008). The infiltration could either be increased or decreased depending on the type of land surfaces, as briefly explained in previous paragraph. By using a simple common water balance at land surface derived from Mitsch and Gosselink (2000), the amount of rainfall would be equal to surface runoff + evapotranspiration + infiltration. This simple equation reveals that for unchanged amount of rainfall and evapotranspiration, the total amount of surface runoff and infiltration are constant. As the amount of infiltration decreases, the amount of surface runoff is consequently increases or vice versa.

In the case of naturally grown sprawling cities with predominant built-up areas, the increase of surface runoff along with simultaneous decrease of recharge to groundwater is therefore present. This phenomenon has long been observed in the study area. There is a simultaneous propensity of the expansion of flood inundation and the fall of groundwater table in the study area. The continuous declining water table has resulted in severe water scarcity in the city, since most of the citizens depend greatly on shallow groundwater to meet their water needs.

Present feature of the study area has caused the continuous increase of transport energy, floods vulnerability and water scarcity. The situation has also led to considerable economic losses and intense distress and thus deteriorating quality of life of the citizens. With this rationale, the study

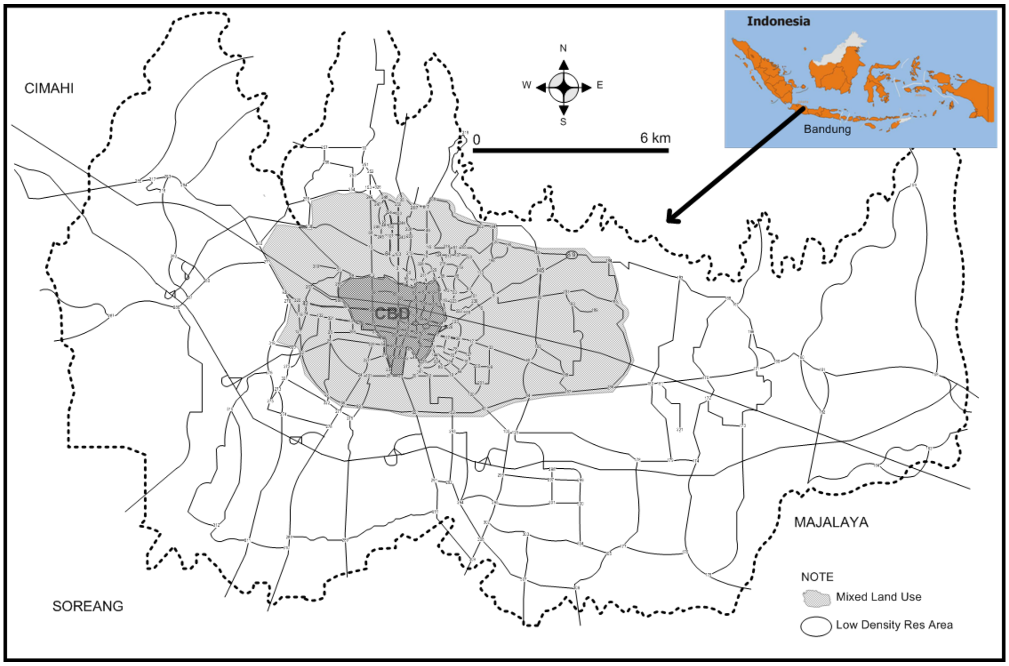


Figure 1 *Bandung City, Indonesia*

concentrates on these three environment-related issues that have potential contribution to urban sustainability. The study was conducted by employing questionnaire survey and direct observation and also supported by secondary information.

3. Methods of Study

The study was undertaken in Bandung City in Indonesia, an obvious concentric-cum-sprawling city (Figure 1), a city with 2.3 million people living inside.

The city has gone through a continuous horizontal expansion of low density residential areas since 1970s. The expansion was particularly significant during 1990s because of government's policy that encouraged property development to flourish with the presence of soft loan for the property developers. At the demand side, the considerable expansion of property development also took place due to high demand on housing, although this opportunity was totally impeded by 1998 economic crisis in Indonesia and other Southeast Asian countries.

Study in Bandung City employed questionnaire-based household survey. About 750 questionnaires distributed to randomly selected respondents by considering proportional distribution among existing township. Out of 750 distributed questionnaires, 389 responses were received. Different questionnaire was also distributed to citizens living in commercial-cum-residential area with the expectation to represent a compact city. The questionnaire-based surveys were specially employed to understand transport energy at household level. To understand the other two issues, flood and groundwater recession, a direct observation on water table of some citizen's wells was carried out. Interview with the citizens living in flood vulnerable areas supported by secondary information, to understand the extent of flood, was also carried out. Secondary information on land use, particularly built-up and non-built up areas, was gathered to estimate surface runoff and groundwater recharge. This method is expected to discover the facts on three environment-related issues which can lead to the achievement of objectives of study.

4 Three Sustainability Advantages of Urban Densification in the Study Area

Horizontal expansion of Bandung City is mainly signified by the development of low density residential areas, particularly to east direction since this path is the most possible way to expand. This shows the true quality of Bandung as a sprawling city. While expansion to the north is constrained by mountainous areas, expansion to the south is hampered by frequent flood. Urban expansion to the west is definitely unlikely because there is another city. This expansion has made the span of Bandung City is about 20 km in east-west, and 9 km in north-south directions. This wide span, along with the concentricity of the city, creates numerous commuters which require higher transport energy. It is further aggravated by the absence of adequate public transport.

4.1 Transport Energy

The concentric pattern of Bandung City drives citizens towards motorized transport dependent. The absence of mass rapid transit system, distinct segregation of housing and job places or commercial areas with not-within-walking-distance quality, as well as unavailability of pedestrian friendly environment augment this dependency. Survey shows that with present condition of public transport and pedestrian friendly facilities, the average distance of willing to walk is 771 meter (2000 m maximum, 100 m minimum, and 1000 m mode). It means that beyond this span, people tend to make a travel by motorized modes. However, if good and adequate public transport and pedestrian friendly environment were available, 292 respondents (75%) prefer to walk and/or use public transport, 61 respondents (16%) will use bicycle, and the remaining 36 (9%) respondents will keep using car. With current city span and concentric pattern of the city, this fact substantiates the validity of motorized transport dependent citizens of Bandung. The significant increase of private car and motorcycle users on total passenger-kilometer travelled by various transport modes, over the years, indicates the augmentation of motorized travel dependency of the

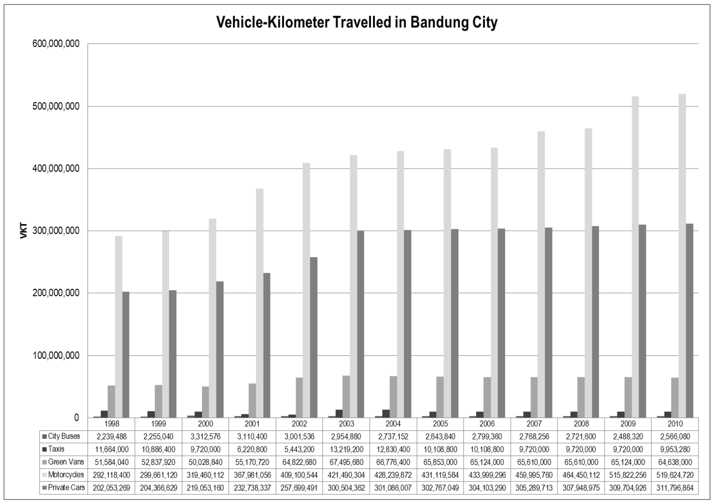


Figure 2 *Vehicle-kilometer Travelled*

citizens of Bandung. This also is validated by higher consumption or transport energy of the citizens. One of the indicators on inefficient transport energy can be observed from the vehicle-kilometer travelled, as exhibited by Figure 2.

Vehicle-kilometer travelled during the period of 1998-2010 in the study area showed significant contribution of private transport over total VKT in the city, which is 91.5%. Moreover, the occupancy rate of private cars is low while their uses are high. It is deemed inefficient transport energy consumed. By this condition, the transport energy inefficiency due to the use of private cars is tantamount to 2.6 million GJ per year in 2010.

Transport energy consumption was analyzed from the responses of 389 respondents upon questionnaire distributed to 750 households. Transport energy, in this study, includes transport within the city for different purposes and intercity land transport. The analysis reveals that the average household's transport energy consumption in the study area is 5195 ± 1128 MJ/Month. Transport energy contributes 72 per cent of the total household's energy consumption that consists of energy uses for transport, cooking, lighting, thermal comfort and electrical appliances. The substantial contribution of transport energy on total energy consumption of the citizens reflects the notorious organically grown sprawling cities as characterized by the study area.

For a comparison, a survey on transport energy consumption in commercial-cum-residential area in the study area was also undertaken. The commercial-cum-residential area is assumed to symbolize the final form of urban densifications for its similar character of the compactness. Households located in mixed commercial-cum-residential area have a precondition to consume lower energy for transport because of the nature of proximity between home and job places. Sample area, where controlled commercial-cum-residential area located, was selected within the central business district (CBD) of Bandung City. Most of samples of the building in the residential-cum-commercial area are two-story shop-houses, and few of them were three-story shop-houses. In these shop-houses, residents manage their businesses while living in there.

Survey involved 140 respondents who live in controlled commercial-cum-residential area. This area represents the quality of compact city. The survey result reveals that household's transport energy for working, studying, shopping and social purposes, despite higher monthly income, much lower than the average transport energy consumption in the city, which is 1432 ± 959 MJ/Month. The average monthly household income in controlled commercial-cum-residential area is 938 ± 281 USD, while average income in the city is 375 ± 131 USD (Table 1).

For the whole city, which represents the sprawling nature of the city (Figure 2), the average transport energy consumption is almost four times greater than the consumption in commercial-cum-residential area, which impersonates the compact city. By almost three times higher of average household's income in comparison to the average income in the whole city, the households in commercial-cum residential area spend only less than 2 per cent of their total income for transport energy expenditure. In different manner, households in the whole city spend more than one-third of their total monthly income. This big gap shows the advantage of compact city over sprawling city in terms of transport energy consumption. The advantages of mixed commercial-cum-residential area can be further explored to attain lower consumption of transport energy, along with other quality of a compact city.

The real condition of study area as a sprawling city has also brought to other environment-related problems which are severely suffered by citizens in this city. One of these substantial problems is flood. The flooding problem is particularly aggravated by intensive development of built-up area and disadvantage topographical condition of the city,

Table 1 *Average Transport Energy Consumption at two different Household's Locations*

Location of Household	Monthly Transport Energy Consumption (MJ/HH/Month)	Household's Income (USD/HH/Month)	Transport Energy Consumption per Unit Household's Income (MJ/USD)	Percentage of Transport Energy Expenditure from Total Expenditure (%)
Commercial-cum-residential Area* (n=140)	1432± 959	938± 281	1.53	1.97± 1.17
Whole City** (n=389)	5195±1128	375± 131	13.85	32.90±11.79

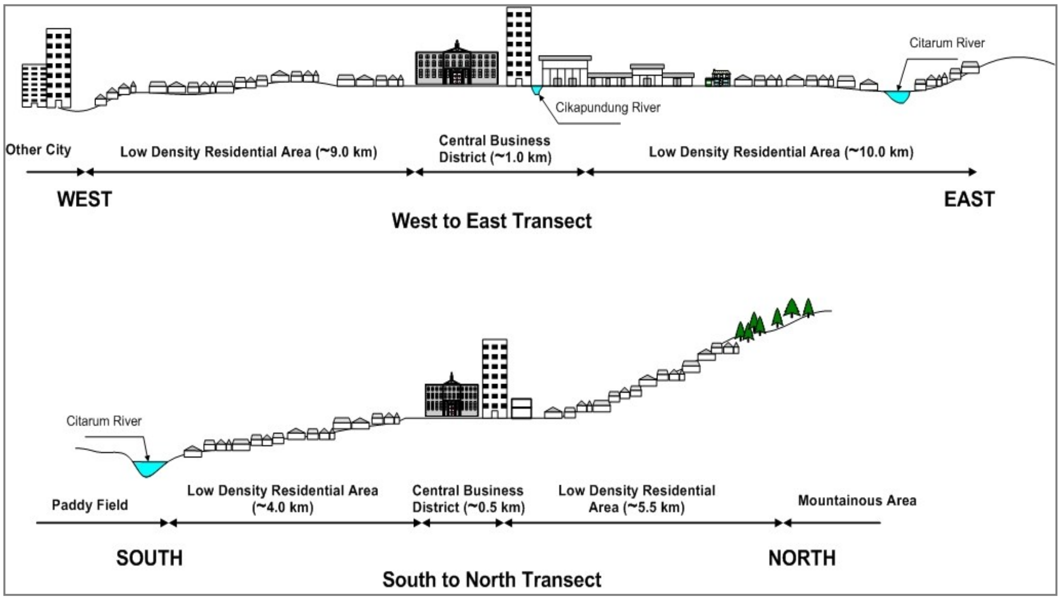


Figure 2 *Transect Diagram of Bandung City (Not to Scale)*

especially in the southern part. In the southern part, upper *Citarum* River basin, a largest river in West Java Province, stretches out. The river flows gently with a mild slope that generates slow velocity of water flow. Due to constant reduction of river section because of frequent sedimentation, the capacity of upper *Citarum* River has reduced significantly. The improvement of river carrying capacity has been undertaken though. The not-to-scale West-East and South-North transects is shown in Figure 2.

4.2 Flooding Problems and Urban Densification

Flood is generated by overland flow which can be determined by rational formula Q=CIA (Chow et al., 1988). This formula shows that discharge (Q) directly proportionate to runoff coefficient (C), rainfall intensity (I) and catchment area (A). While C and A are deterministic variables in nature, I is probabilistic variable that cannot be determined or controlled. Urban expansion in Bandung City, which is signified by the alteration of natural areas to be built-up areas, directly changes the value of C to become higher. The increase of C value is not independently underway rather interconnected with the changes of other urban parameters as urban development undergoes. This complex interconnection can be observed from the alteration of urban land use and environmental parameters along with recorded consequences as shown in Table 2.

Bandung City has been expanding horizontally towards radial direction with very few vertical growing in the central business district. The rapid horizontal expansion of built-up areas in Bandung City is seemingly stimulated by the following situations: (1) existing spatial policies that are not clearly spelled particularly with respect to building's height, thus it creates development is it goes. (2) No adequate economic instruments exist to encourage the development with more efficient use of land. (3) Relatively low land price in the peripheral areas that does not generate higher floor area to plot ratio in the urban center. (4) Vertical development is presently more costly than horizontal development. (5) As part of their culture, citizens of Bandung prefer detached house to apartment. These situations have also provoked the urbanizing process in eastern peripheral areas of Bandung City as denoted by low density residential areas. The constant process of this development increases built-up areas and subsequently decreases non built-up areas in the city. This development is also believed aggravating flooding problems in the city, since the record shows that flood inundation area is constantly increasing over the years.

The form, type and topography of the land surfaces would significantly affect the quantity of flood flow through variety of runoff coefficient. The more impermeable land surfaces the greater overland flow generated by rainfall. This is a matter of changing non built-up to built -up areas. In contrast, urban densification followed by land conversion from built-up to natural areas in compact city development process would create more natural environment regularly or intermittently within urban built-up area. Natural environment has larger infiltration capacity than built-up areas and therefore reduce overland flow and flood. This is possible since the changes of form and type of land surface from asphaltic surface or concrete bloc, for instance, to be urban forest or any greenery areas would automatically increase the absorption capacity of the ground surface and thus reduce flood.

Urban densification reduces flood and simultaneously increases infiltration to groundwater. Infiltration rate is generally promoted by natural vegetation, flat topography, permeable soils, deep water table, and the absence of confining beds and climatic factors (Canora et al., 2008, Kollet and Maxwell, 2006). Infiltration rate depends on the storage capacity of the land, though not that simple but it is generally acceptable that infiltration leads to groundwater replenishment. It would be greater in the condition where land surface is permeable like natural environment. In contrary, it would be lesser in a built-up environment.

Simulation on surface runoff reduction was done with three scenarios, namely: existing condition, concentric land use with 1000% densification at the city center i.e. mixed use development, and gradual decrease of densification towards periphery by various levels from 0 i.e. converted existing land use to be completely natural landscape. The simulation employs rational method of Q=CIA where

Table 2 Interconnection among Urban Parameters for Different Periods

Urban Parameters	1970	1980	1990	2000	2010
Built-up Area (ha)	4,040	4,854	6,125	12,228	14,232
Non built-up Area (ha)	2,352	4,466	4,101	4,539	2,535
TOTAL (ha)	6,392	9,320	10,226	16,767	16,767
Estimated Runoff Coefficient (C) for the whole area of the city	0.48	0.45	0.48	0.51	0.55
Estimated Relative Urban Drainage Capacity (1970=100%)	1.00	0.78	0.56	0.51	0.30
Recorded Flood Inundation Area in the city and periphery (ha)	250	350	800	900	1,500

Q: overland flow, C: runoff coefficient, I: rainfall intensity and A: catchment area. The design rainfall intensity was based on statistical analysis of 25-year return period, which is 75 mm/hour. The simulation result is shown in Table 3.

The densification of urban areas is principally carried out by applying higher density at the center and decrease at the periphery, and keeping present central business district at the center for both concentric and polycentric land use scenarios. For the existing condition, no urban densification is applied. Urban densification for simulation purpose is shown in Figure 3.

Figure 3 shows densification simulation with concentric land use. *Sumur Bandung* Township as present central business district is condensed by at least ten times of current population density of the City. This scenario keeps built-up area only 5,531 hectares (33%) and leaves most urban area (67%) becomes natural environment. This condition is able to reduce 36% flood in comparison to "existing condition" scenario.

Figure 4 shows densification of scenario 3 where two central business districts i.e. *Sumur Bandung* and *Cicadas* Townships were assigned. These two towns were proposed as sub-centers in the Bandung City Plan 2011 -2031. Thus the scenario is in line with the city authority plan. This scenario maintains built-up area and natural area in balance. The built-up area accounts for 8,672 ha (51%) and natural environment of 8,095 ha (49%), and is able to reduce 23% of flood magnitude. Up to this point, the urban densification offers advantages on sustainability in comparison to present form of Bandung City as organically grown sprawling city. This is reflected in its ability to reduce flood magnitude, which is crucial to cope with current persistent flooding problem in the city.

With urban densification in Bandung City implemented, significant flood reduction, environmental quality improvement and energy conservation would take place. Considerable flood reduction would also improve urban environment and reduce economic losses. According to a report, total annual economic losses due to Bandung's flood are about USD 30 million (Media Centre, 2007).

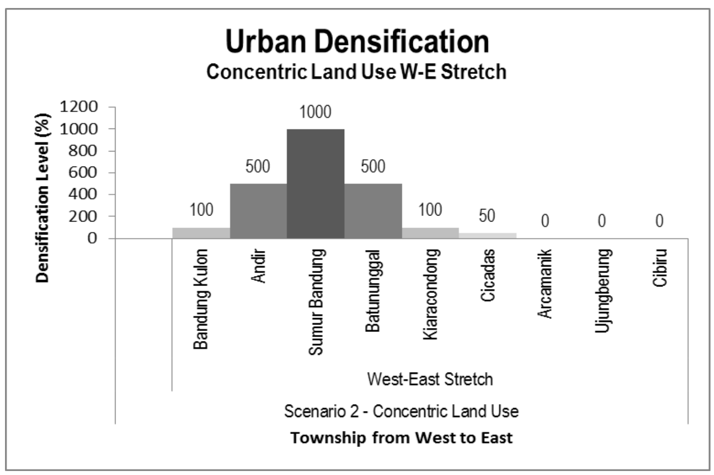


Figure 3 *Urban Densification for Scenario 2*

Table 3 *Simulation of Total Runoff and Estimated Flood Reductions due to Urban Densification in Bandung City*

Scenario	Urban Area (ha)		Urban Densification[1]	Total Population accommodated by urban service	Total Runoff (m3/sec)[2]	Estimated Flood Reduction (m3/sec)
	Built-up Area	Natural Area				
Existing condition	14,232	2,535	None	2,300,000	2,532	0 (0%)
Concentric land use with densification on current CBD by 1000%	5,531	11,236	1000% at city center and decrease towards periphery	3,450,000	1,625	907(36%)
Polycentric land use with two urban centers. Densification level at the centers is 1000%	8,672	8,095	1000% at two urban centers and decrease towards periphery	3,490,000	1,953	579(23%)

[1]Refer to Figure 3 and 4
[2]For design rainfall I=75 mm/hour, C built-up: 0.8, C natural area: 0.3

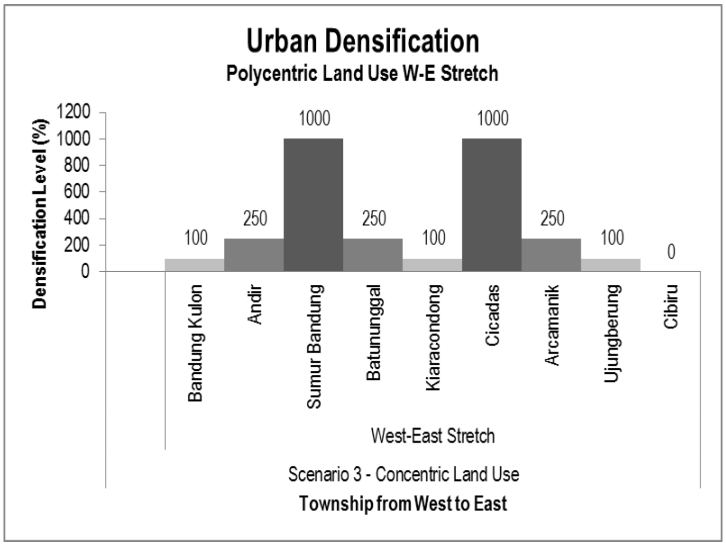


Figure 4 *Urban Densification for Scenario 3*

Another essential issue in Bandung City is continuous fall of groundwater table. The only water supply company in Bandung City served 40% of the population (Perpamsi, 2008) and does not change up until today. The remaining 60% of city population is largely depending on groundwater lifted by manual device or electric pump and other lifting device. This situation has brought to the continuous fall of groundwater, while recharge to groundwater is almost none because it is hampered by urban development on the above ground part. The development prevents rainfall to infiltrate and percolate further towards shallow groundwater reserve.

4.3 Groundwater Replenishment and Urban Densification

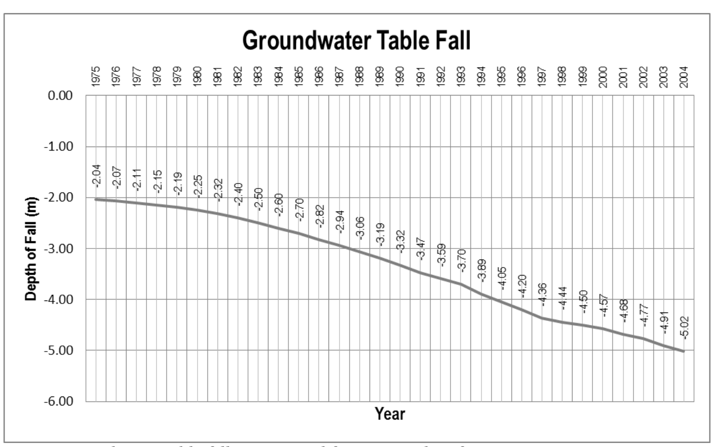
By far, 60% of the citizens satisfy their need of drinking water from the groundwater through pumped shallow-wells or dug-wells. It is equivalent to about 67,650,000 m3 groundwater extractions annually. Some industries and hotels also extracted groundwater for their needs, however no data available on this matter. With more than 67 million m3 of groundwater were lifted from the Bandung's earth, and in order to maintain the elevation of water table at certain level, the same amount of recharge to groundwater must be present. The only source of recharge, in this case, is infiltration and percolation of rainfall to groundwater aquifer, while present condition shows that about 55% (Table 2) are being overland flow that generates flooding problems. Monthly observations on water table were carried out in some observation wells, however only 30-year observation data were available. Figure 5 shows the average fall of groundwater table in the city. The figure exhibits the propensity of constant fall of groundwater table in the study area.

The trend of groundwater table fall confirms the constant increase of groundwater abstraction along with the decrease of groundwater recharge. These two causes are unarguably due to steady expansion of built-up areas in the city. The space that allows overland flow to infiltrate to the ground is steadily reducing. At the same time, groundwater abstraction, due to unmet demand of water of the citizens from present drinking water supply provider, is increasing. Such an undesirable environmental problem would not take place if any one or both of the causes were appropriately addressed. One possible solution is by undertaking urban densification, which is a principle of compact city along with the application of low impact development principles.

By using same three scenarios, a simulation of urban densification shows that the fall of groundwater table can be prevented if more urban spaces, which allow more infiltration, exist. Figure 6 shows the tendency of groundwater recharge. The figure shows that a jumping magnitude of recharge was taking place in 1999-2000. This was because of the administrative expansion of the city boundary. In 2000, the city area was enlarged to 16,767 hectares from previously 10,226 hectares in 1999. The expansion of city administrative boundary was mainly to eastern and southern directions, because of a number of constraints in other directions.

Amid gradual trends, the continuous increase of groundwater abstraction in the city is alarming. Extensive groundwater abstraction in Jakarta, Indonesia has led to two frightening impacts: land subsidence in some places and sea water intrusion. The impact is obviously harmful to the environment. Similar incident should not take place in Bandung City. A fundamental approach towards compact city is essential while meeting the water demand by surface water through water supply providers.

Figure 6 shows continuous drop of groundwater recharge under existing condition of the city. At the same time, two compact city scenarios are able to maintain the recharge since these two scenarios keep natural landscape with high infiltration capacity constant. The



Note: Groundwater table fall is measured from ground surface as 0.0 meter.

Figure 5 *Groundwater Table Fall in Bandung City*

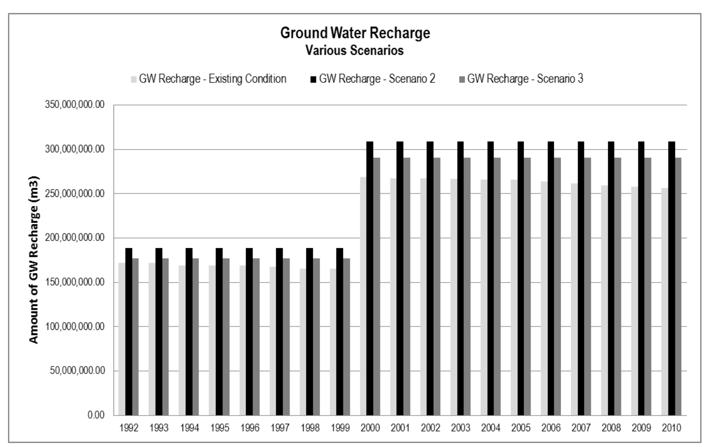


Figure 6 Groundwater Recharge at Three Scenarios

Table 5 Effect of Urban Densification on Groundwater Resources in Bandung City

Year	Existing Condition – Scenario 1			Scenario 2		Scenario 3	
	Water Demand (10^3 m3/y)	Water Supply (10^3 m3/y)	Estimated Groundwater (GW) Abstraction (10^3 m3/y)	Estimated GW Recharge (10^3 m3/y)	Water Surplus/ Deficit (10^3 m3/y)	Estimated GW Recharge (10^3 m3/y)	Water Surplus/ Deficit (10^3 m3/y)
1992	79,417	26,472	52,945	188,362	135,417	177,318	124,373
1993	79,687	26,562	53,125	188,362	135,237	177,318	124,193
1994	80,416	26,805	53,611	188,362	134,751	177,318	123,707
1995	81,030	27,010	54,020	188,362	134,342	177,318	123,298
1996	81,993	27,331	54,662	188,362	133,700	177,318	122,656
1997	83,220	27,740	55,480	188,362	132,882	177,318	121,838
1998	85,278	28,426	56,852	188,362	131,510	177,318	120,466
1999	88,476	29,492	58,984	188,362	129,378	177,318	118,334
2000	92,549	30,849	61,699	308,848	247,148	290,739	229,040
2001	93,568	31,189	62,378	308,848	246,469	290,739	228,360
2002	94,223	31,407	62,815	308,848	246,032	290,739	227,924
2003	94,882	31,627	63,255	308,848	245,593	290,739	227,484
2004	97,788	32,596	65,192	308,848	243,655	290,739	225,547
2005	99,468	33,156	66,312	308,848	242,535	290,739	224,427
2006	100,601	33,533	67,067	308,848	241,780	290,739	223,671
2007	102,050	34,016	68,033	308,848	240,814	290,739	222,705
2008	103,989	34,663	69,326	308,848	239,521	290,739	221,413
2009	105,877	35,292	70,584	308,848	238,263	290,739	220,154
2010	104,895	34,965	69,930	308,848	238,917	290,739	220,809

scenarios allow only vertical development in a confined designated urban area. Groundwater abstraction keeps increasing as the population increases while the capacity of water supply provided by a company does not increase without revolutionary improvement, which is impossible for today's situation.

Table 5 confirms that groundwater supply would be surplus at scenarios 2 and 3 of urban densification. Thus groundwater table may not fall as at current rate if urban densification exists. By maintaining level of groundwater table, the future problem on land subsidence in Bandung City can be avoided.

Analysis on three environment-related issues i.e. transport energy, flooding problem, and groundwater depletion, shows two different extreme conditions of concentric-cum-sprawling city and compact city. On one hand, an organically sprawled city, as exhibited by the study area, retains a "time-bomb" which potentially explodes if carrying capacity of the city were exceeded. Higher transport energy with its subsequent impacts such as air pollution, increasing flooding problems and considerable decrease of groundwater resource are possible adverse environmental consequences that would likely take place. On the other hand, urban densification, as a very first step of the alteration of an organically grown sprawling city towards compact city, is able to lessen these three problems. This fact brings lucid messages on the needs of adequate space-related policies in a naturally grown sprawling city. These policies should be able to solve the present problems simultaneously while provide sufficient basis towards more sustainable urban development.

5. Implications on City Policies

Three environment-related problems as discussed above are presently the most fundamental issues which are easily encountered in Bandung City. Present policies on urban space in this city do not adequately guide urban development towards environmental sustainability. There is a city's spatial plan in place, which was promulgated as City Bylaw of 2004 and then revised in 2010, but it does not provide clear guidance rather its wishes to achieve short-term socio-economic goals while ignoring environmental aspect. No specific explanation in this bylaw on sustainable city, yet how to optimize land and other urban resources to achieve higher efficiency in the resources use is not clearly spelled. The ambiguity cum too generic spatial policies has led Bandung City towards current urban situation that contains numerous problems. While debate on sustainable city and compact city still underway, the authors personally believe that urban densification, to some extent, better than naturally grown urban sprawl. This belief is also supported by the findings of this study, although densification is not an isolated issue. Urban densification should be accompanied by the improvement of urban environment quality. Putting only people in dense residential areas without compensating their sacrifices would not be workable. Betterment of their living environmental quality is deemed necessary along with urban densification process.

The study found that urban densification would theoretically be able to lessen, if not totally solve, the three environment-related issues. Policy on urban densification should be imposed as very first step towards more comprehensive policies. In the case of Bandung City, a step-wise policy would be better than leap-frog policy which might lead to total failure. This is by considering the socio-cultural condition of the citizens. Urban densification policies can be simultaneously accompanied by land development or land consolidation processes. The latter is intended to pave the way towards higher urban population density. This is possible with a condition that win-win solution should always be offered by urban authorities. Citizens must be provided by clear implementation programs and goals which differ with current practice for implementing any government projects. However, a constraint on the absence of political will of the government along with insufficient government budget to implement the program can be a serious constriction on the way to a comprehensive urban policy.

A comprehensive policy which addresses three pillars of sustainable development, namely social, economic and environmental aspects could be the next step of the policy development. With sufficient policies that support sustainable urban development, a way towards sustainable development is therefore smoother.

References

Al-Hinti,_I., A. Al-Ghandoor, B. Akash, E. Abu-Nada (2007). Energy Saving and CO2 Mitigation through Restructuring Jordan's Transportation Sector: The Diesel Passenger Cars Scenario. Energy Policy 35, pp. 5003-5011.

Anas, A., Pines, D. (2008). Anti-sprawl policies in a system of congested cities, Regional Science and Urban Economics, doi:10.1016/ j.regsciurbeco.2008.05.001

Canora, F., M. D. Fidelibus, A. Sciortino, G. Spilotro (2008). Variation of infiltration rate through karstic surfaces due to land use changes: A case study in Murgia (SE-Italy). Engineering Geology 99, pp. 210-227.

Chow, V.T., D.R. Maidment, L.W. Mays (1988). Applied Hydrology. McGraw-Hill Science, First Edition.

Dantzig, G. B. and T.L. Saaty (1973). Compact City: A Plan for Livable Urban Environment. W.H. Freeman and Company, San Francisco.

da Silva, A.N.R., Brondino, N.C.M., Avalos, M.S., Costa, G.C.F. (2001). Urban Sprawl and Energy Use for Transportation in the Largest Brazilian Cities. Proceedings of Computers in Urban Planning and Urban Management: An Urban Space Odyssey (CUPUM), July 18–21, 2001 Hawaii.

Douglas, I. (1983). The Urban Environment, Edward Arnold, London.

Fang, S., G.Z. Gertnera, Z. Sun, A.A. Anderson (2004). The Impact of Interactions in Spatial Simulation of the Dynamics of Urban Sprawl. Landscape and Urban Planning 73, pp. 294-306

Gusdorfa, F. and S. Hallegatte (2007). Compact or Spread-out Cities: Urban Planning, Taxation, and the Vulnerability to Transportation Shocks. Energy Policy 35, pp. 4826–4838.

Jenks, M., E. Burton and K. Williams eds. (1996). The Compact City: A Sustainable Urban Form?. E&FN Spon, Routledge, London and New York.

Kasanko, M., J.I. Barredo, C. Lavalle, N. McCormick, L. Demicheli, V. Sagris, and A. Brezger (2006). Are European Cities becoming Dispersed? A Comparative Analysis of 15 European Urban Areas. Landscape and Urban Planning 77, pp. 111–130

Kollet, S.J., R.M. Maxwell (2006). Integrated Surface- Groundwater Flow Modeling: A

Free-surface Overland Flow Boundary Condition in a Parallel Groundwater Flow Model. Advances in Water Resources 29, pp. 945-958

Lau, J.C.Y., and C.C.H. Chiu (2004). Accessibility of workers in a compact city: the case of Hong Kong. Habitat International 28, pp. 89-102.

Lund, H., and E. Munster (2006). Integrated Transportation and Energy Sector CO2 Emission Control Strategies. Transport Policy 13, pp. 426-433

McCuen, R.H. (2004). Hydrologic Analysis and Design. Prentice Hall, Upper Saddle River, New Jersey, 07458, 3rd edition.

Mitsch, W.J., and J.G. Gosselink, (2000). Wetlands, John Wiley and Sons, NY, 3rd Edition.

Molina, A., G. Govers, V. Vanacker, J. Poesen, E. Zeelmaekers, F. Cisneros (2007). Runoff generation in a degraded Andean ecosystem: Interaction of vegetation cover and land use, Catena 71, pp. 357–370

Newman, Peter W.G., and J. Kenworthy (1989). Cities and Automobile Dependence: A Sourcebook. Gower Technical, Aldershot, England.

Paravantis, J.A., D.A. Georgakellos (2007). Trends in Energy Consumption and Carbon Dioxide Emissions of Passenger Cars and Buses. Technological Forecasting & Social Change 74, pp. 682-707.

Podwojewski, P., D. Orange, P. Jouquet, C. Valentin, V.T. Nguyen, J.L. Janeau, D.T. Tran (2008). Land-use Impacts on Surface Runoff and Soil Detachment within Agricultural Sloping Lands in Northern Vietnam. Catena 74, pp. 109-118

Rees, W.E. (1992). Ecological footprints and appropriated carrying capacity: what urban economics leaves out. Environment and Urbanization 4(2), pp. 121-130.

Saunders, M. J., T. Kuhnimhof, B. Chlond, A.N.R. da Silva (2008). Incorporating Transport Energy into Urban Planning. Transportation Research Part A, 42, pp. 874-882

Smith, H., J. Raemaekers (1998). Land Use Pattern and Transport in Curitiba. Land Use Policy, 15(3), pp. 233-251.

Thomas L., W. Cousins (1996). The Compact City: A Successful, Desirable and Achievable Urban Form? In M. Jenks, E. Burton and K. Williams (eds). The Compact City: A Sustainable Urban Form? E&FN Spon, London, pp. 101-113.

Tratalos, Jamie, Richard A. Fuller, Philip H. Warren, Richard G. Davies, Kevin J. Gaston (2007). Urban form, Biodiversity Potential and Ecosystem Services. *Landscape and Urban Planning,* 83(4), pp. 308-317

UN (2001). Sustainable Urban Development: A Regional Perspective on Good Urban Governance. Economic and Social Commission for Western Asia. New York.

Wackernagel, M. and W. Rees (1996), Our Ecological Footprint, Chapter 2, Footprints and Sustainability: New Society Publishers, pp. 31-47.

Welderufael,W.A., P.A.L. Le Roux , M. Hensleyet (2008). Quantifying Rainfall-Runoff Relationships on the Dera Calcic Fluvic Regosol Ecotope in Ethiopia. Agricultural. Water Management, doi:10.1016/j.agwat.2008.04.007

Williams, K. (1999). Urban Intensification Policies in England: Problems and Contradictions", *Land Use Policy*, 16(3), pp.167-178.

Internet Source:

Media Center (2007). Pusat Informasi Bencana di Indonesia (Indonesia Center for Disaster Information). http://www.mediacenter.or.id. Retrieved on 14 July 2008.

Perpamsi (2008). The Association of Water Supply Corporations of Indonesia. http://www.perpamsi.org Retrieved on 14 July 2008.