147: Urban forms, Life-style, and Energy Consumption: A Case of Bangkok Metropolis.

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Abstract

This study investigated the impact of urban form on the extent of energy consumption in the city. The research hypothesized that distinctiveness of land use pattern, density, and occupancy size were factors determining differentiated patterns of journey to work, fuel consumption, and living conditions. It applied a case study approach to compare three communities with three different spatial arrangements—inner, mid, and outer Bangkok – to reveal the pattern of daily travelling distance, mode of transportation, amount of household floor area per capita, and household electricity consumption as indicators differentiating the level of energy consumption. The study found a significant relationship between living density and the length of journey to employment and to obtain daily supply. The mixed-use physical settings of inner city with the availability of goods and services in proximity could reduce both travelling distance and frequency. Despite the fact that dwellers in the densely populated areas are willing to travel on foot, bicycles and mass transportation, the unavailability of bike-lane and inefficient public transportation were factors barring them to do so. The study also found two contradictory facts which complicated the energy conservation schemes in cities of developing countries—the energy sufficient high density living condition versus the dwellers' desires for a better quality of life. Dwellers in settlements of low density at the suburban areas tended to travel longer distance on automobiles, while the costly urban land in city centre mandated the settlement to grow vertically, and fostered a higher density living condition, which made residences in urban centre, consumed less energy than dwellers in outskirt. Populations with higher income, however, opted to live in a lower density community located in greater distance from their job and services in favour of higher quality of life. Frequent long journeys during weekends and long holidays toward vacation spots in outer provinces have been a norm.

Keywords: urban form, mobility, transportation, energy consumption.

1. Introduction

Living conditions and lifestyle of urbanites fostered by the pattern of urban settings have long been regarded as factors affecting energy consumptions, especially fossil fuel. This research investigated the extent of energy consumption vis-à-vis living density and occupancy types, hypothesizing that densely populated and compact nature of cities tended to reduce the extent of automobile utilization, and therefore, the cities' energy consumption. The ultimate goals of this study were to synthesize the findings in order to suggest an optimal planning policy from which energy and urban environment can preserved.

2. Previous Research and Study Framework

Mobility in the urban area depended much upon the spatial settings of the city. Land use planning, and spatial configuration of socioeconomic activities governed the pattern of road network and transit system [1]. Urban dynamic has been a key factor transforming the pattern of land use in most cities since industrial revolution as early as 1850 [2]. The automobile era started in the 1950s, where most cities transform the urban setting to accommodate the increasing number of private cars, instigated the excessive usage of automobile worldwide.

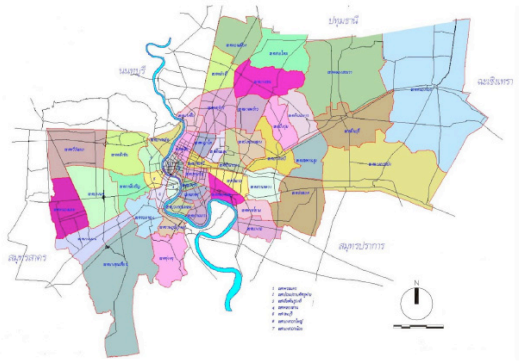
Unavoidably, urban form together with the pattern of intra-urban mobility has a close relation with energy consumption in the city [3,4]. A web of interrelated variables was also found important to explain the extent of energy consumption. For instance, the linear travel distance was found correlated with the distance and amount of time one spent on traveling. Travelling distance was, however, determined by travelers' income, living density, distance from CBD, job housing balance, family structure, and automobile ownership [5,6]. In other words, living density was considered a

composite variable correlate with travelling distance and car ownership, and therefore the consumption of energy [7,8]. The spatial setting of city, especially living density, was in turn determined by energy cost and the affordability of residents. It was a constraint determining the mobility behaviour of residents to move closer to work place to reduce travelling cost, in so far as the spatial setting of the high density area was able to sustain all the family members' needs. The concept of mixed land use and compact city size also support the idea of minimizing travelling distance and time.

Another segment of factors shaping the decision to live in a particular area has been the availability of services such as schools, shopping centres, entertainment centres, public parks, and post offices. Availability of services within walking distance also encourages people to travel by foot or bicycle instead of by automobile [9,10]. It was the residents' perception and attitude toward the preference of housing types together with the expectation of healthier built environment [11]. The amount of floor space per capita differed according to the location, land cost, and housing type chosen by the residents. In this light, the amount of floor area also determine the size of air-conditioning—in the case of tropical housing—and the amount of area to be lit, all of which determined the extent of residential energy consumption. Population attribute, such as income, and family structure thus played an important role on the residents' decision making in terms of affordability and life style.

3. Research methodology

The research attempted to investigate the impact of urban settings on the residents' life style and the utilization of energy. Three sample communities were randomly drawn from three different urban groups of setting to represent the inner city, mid city, and suburban settings. Figure 1 shows the zoning of Bangkok (BKK) Metropolis categorized by population density in the year 2000—inner city, mid city, and suburban area—and distance from the CBD in kilometre. Three sample communities to be studied were drawn from the three different city areas of Bangkok; they were Polis Spa, Nirrun Villa, and Wat Lanbun, representing Bangkok's inner city, mid Bangkok, and outer Bangkok respectively. A physical survey was conducted to obtain information regarding population density, land-use activities, building types, and physical conditions in the three study areas. The differentiation of spatial settings under studied included neighbourhood size, shape, density, pattern of network connectivity, land-use type, and open spaces. The conceptual model derived from literature review and previous research (Fig.2) was applied as the basis of research design, to inquire information concerning population attributes, travelling behaviour, decision on choosing housing type, attitude toward quality of life, accessibility to urban services, and the extent of energy consumption. Energy consumption was measured by means of distance and time of daily travel, mode of transportation, size of dwelling, and monthly energy cost. Quality of life, on the other hand, was measured by means of environmental awareness and preference to live in a particular area. Statistical linkages were used as a mean to proof the validity of the proposed model toward urban policy implication.



Source: Bangkok Information Center

Figure 1 Administrative districts of Bangkok

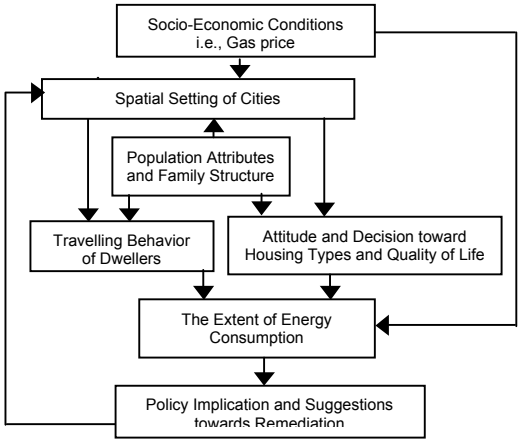


Figure 2 Conceptual framework of the Study

4. Study areas

The three study areas—Plis Spa, Nirrun Villa, and Wat Lanbun—located in different urban settings were chosen to represent different types of density, pattern of travelling, occupancy, and availability of urban services (Fig.3). Distinctive housing types were also found among the three study areas, whereby, shop house, town house, and detached house constitute the largest number in inner, middle, and outer Bangkok respectively. Urban functions from physical survey were also found differed among study areas. Commercial activities, for example, were more likely to be found in inner city, while residential were more prominent in both inner city and mid BKK. Outer BKK was, however, more eminent in both residential and mixed use (Table 1 and 2).

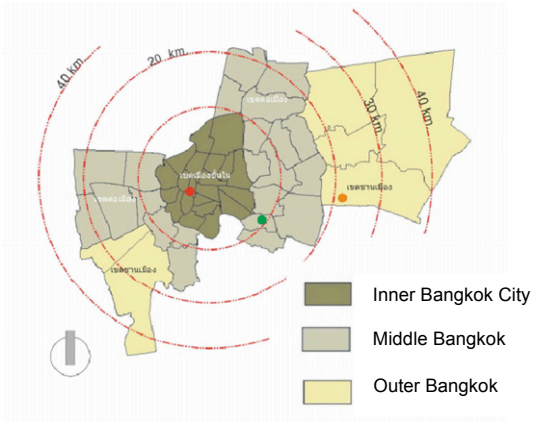


Figure 3 Inner- Middle- and Outer-Bangkok

Table 1: Building Type in the Three Study Areas.

Study areas	Building Type (%)			
	Detached House	Town House	Row House	Shop House
Polis Spa (inner BKK)	5 (6.4%)	6 (7.7%)	19 (24.4%)	48 (61.5%)
Nirrun Villa (middle BKK)	14 (6.5%)	223 (89.9%)	4 (1.6%)	7 (2.8%)
Wat Lanbun (outer BKK)	63 (85.1%)	18 (24.3%)	0 (0%)	7 (9.5%)
Total	82 (20.5%)	233 (58.3%)	23 (5.8%)	62 (15.5%)

χ^2 Sig. < 0.001

Table 2: Building Usage in the Three Study Areas.

Study areas	Building Usage(%)		
	Residential	Commercial	Mixed Use
Polis Spa (inner BKK)	53 (67.9%)	13 (16.7%)	12 (15.4%)
Nirrun Villa (middle BKK)	187 (75.4%)	21 (8.5%)	40 (16.1%)
Wat Lanbun (outer BKK)	41 (55.4%)	4 (5.4%)	29 (39.2%)
Total	281 (70.3%)	38 (9.5%)	81 (20.3%)

χ^2 Sig. < 0.001

These occurrences were hypothesized to have an impact on the respective lot size, population density, and per-capita occupancy space of dwellers, and therefore, affecting the extent of energy consumption—i.e., need for cooling. Explanation of the phenomenon will be the centre of discussion in the later part of the article. While city centre had the highest population and housing density, suburban area had more ample open space, average lot size, per capita occupancy, and building size (Table 3). Affordability was found correlated with land cost, since city dwellers compete with each other to occupy the location of their choice—detailed discussion of this aspect has been discussed elsewhere. Income was proof among the influential factors explaining the spatial distribution of population. Wealthier residences were more likely to succeed to obtain land of their choice in the sub-urban area.

Figure 4, 5, and 6 show the spatial and environmental settings of the areas under studied, in terms of living density, street width, building height, and building conditions. Among the aforementioned attributes, building height and street width were most distinctive features among the three study areas, while the spatial configuration of the communities also played an important role determining the orderliness and appearance of the communities.

Table 3: Comparison of Residential Attributes in the Three Study Areas.

Attributes	Polis Spa (inner BKK)	Nirrun Villa (Mid BKK)	Wat Lanbun (Outer BKK)
# of Residences / people	1330	4000	789
# of Households	289	800	240
Pop Density Person/hectare	506	443	106
Housing Density Unit / hectare	112	93	31
Open Space Sq. meters / HH	28	76	204
Aver. Plot Size Sq. meters / HH	51	63	98
Aver. Building Size Sq. meters / HH	153	107	187
Aver. Occupancy space Sq. meters / person	33	21	57
Aver. Household Size person/HH	4.6	5	3.3
F.A.R. (B.C.R)	2.72 (62%)	1.71(56%)	1.90(30%)

Source: Calculated from the 2000 census

5. Finding of the study

5.1 Pattern of Population Distribution

The study found three factors determining the pattern of residential decision making, namely, public transport, land price, and monthly family income. Availability of public transportation of the three study areas differs in accordance with the urban location and settings. Better public transport facilities tended to be more available in the inner city than the mid- and outer-Bangkok. Land value was usually the factor allocating the population in accordance with their ability to pay. The study found that land value in the three study areas differed substantially, whereby; land value in the inner city was almost ten times that of the mid-city, while land value in the mid-city was twice that of the outer Bangkok (Table 4). Urban residences tended to locate themselves by trading off the availability of urban transportation with land value, which explained the low percentage of owner occupiers in the inner city (only 47% in Polis Spa). Family income in the three study areas also explicated the pattern of residential location decision making. Dwellers in the inner city had the lowest average monthly income (22,709 Baht), while mid city and outer Bangkok had moderate and the highest income level respectively—29,357 baht and 46,435 baht. Poorer families chose to live in the more expensive inner city by renting instead of buying their dwelling units to save travelling cost. The wealthier households tended to live farther away from the city centre with relatively less public

transport owning to their affordability to pay for higher travelling and energy cost.

Figure 4 Wat Lan Bun community representing outer Bangkok setting

Figure 5 Nirrun Villa representing middle Bangkok community

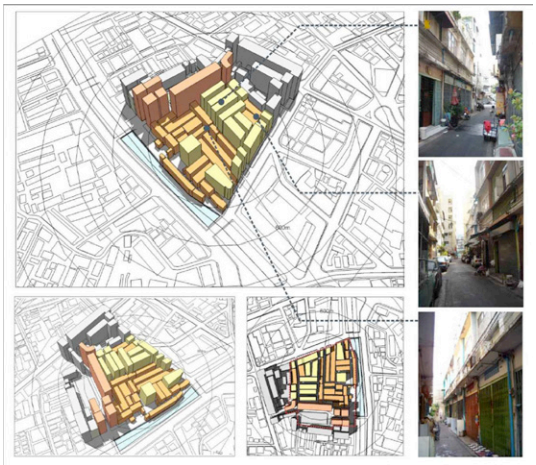


Figure 6 Police Sapa Community representing Inner Bangkok

Table 4: Availability of Public Transportation, Income, Home Ownership, and Land Value

	Study Areas		
	Polis Spa (inner BKK)	Nirrun Villa (Mid BKK)	Wat Lanbun (Outer BKK)
Public Transport Facilities: Average Distance			
Bus Stop	193 meters	250 meters	500 meters
Sky Train Station	3 Km.	4 Km.	14 Km.
Subway Station	400 meters	10 Km.	20 Km.
Train Station	400 meters	6 Km.	400 meters
Mini Bus Routes	400 meters	200 meters	500 meters
Passenger Boat Dock	400 meters	2.7 Km.	12 Km.
Land Price	235,000 Baht / square Wah*	27,500 Baht / square Wah*	13,000 Baht / square Wah*
Avg. Monthly income	22,709 Baht	29,357 Baht	46,435 Baht
% of owner occupiers	47%	79%	74.3%

*1 square Wah = 4 square meters

5.2Trip generation and mode of transportation

The availability of urban services has an impact on the age structure of the family. Since prestigious schools and universities were concentrated in the inner city, a large number of wealthy families tended to move their children into the city centre in order to attend schools / universities justifiably. A large portion of working population also concentrated in the city centre to enjoy the convenience of access to work place. Aged population and the retired group, on the other hand, tended to remain in the sub-urban areas to enjoy a better living environment. Beside the impact of city form, such pattern of family structure, therefore, played an important role in determining the need for mobility as well. However, the total number of trips generated by population in the three study areas differed significantly—inner city had the fewest average number of trips (5.10) while outer Bangkok had the largest average number (5.28). Table 5 shows the average number of trips and average distance among inner- mid- and outer-Bangkok that inner Bangkok, which indicated that inner Bangkok constituted the fewest number of trip with shortest average distance to other areas while outer-Bangkok travel the longest distance (17.02 km). The phenomenon might be attributed to the diverse pattern of urban form—the compactness of the inner city and the dispersion of outer Bangkok.

Detailed analysis on the objectives of mobility also showed that average distance per trip by purposes from the three study areas differed significantly (at the 0.05 level). Almost all the trip categories—to school, to employment, to shopping centre, and to other destination—generated in the outer Bangkok area had the longest distance, while trip generated from the inner city had the shortest. As mentioned earlier, family structure and proximity to urban services in the urban centre were factors that had a direct

impact on the shorter distance of travelling on most purposes (Table 6).

Table 5: Average Trip Distance between Areas

Study area	Average Trip Distance (Km) / Trip and Destination			Total Average Distance (Km)**
	To Inner BKK (Km)**	To Mid BKK (Km)**	To Outer BKK (Km)**	
Polis Spa (inner BKK)	7.75	20.10	26.67	10.62
Nirrun Villa (middle BKK)	15.38	9.37	30.53	13.68
Wat Lanbun (outer BKK)	27.39	14.56	11.13	17.02
Total	14.34	10.68	19.09	13.70

**Sig. F at 0.05 Level

Table 6: Average Trip Distance, Frequency, and Objectives

Study area	Average distance (Km) / Trip and Trip Objective				Total
	Trip to Schools	Trip to Employ-ment	Trip to Shopping Centres	Trip to Other Destination	
Polis Spa (inner BKK)	7.47	14.71	5.25	10.00	10.62
Nirrun Villa (middle BKK)	16.16	13.53	9.13	19.06	13.68
Wat Lanbun (outer BKK)	15.20	19.69	11.21	20.00	17.02
Total	13.28	14.77	8.90	17.03	13.70

** Sig. F at 0.05 Level.

Modes of transportation and their extent of energy usage were factors indicating the energy consumption in different urban settings. The study found that percentage of trip by mode of transportation in the three study areas also differed significantly (Chi-square significant at 0.006 level). Survey results showed that outer Bangkok had the highest percentage of private car usage, followed by mid-Bangkok, while inner-Bangkok used private car only 44.9%. Utilization of public transport also associates with the availability and proximity of services in the more concentrated urban settings (Table 7). Usage of non-energy mode—such as walking and bicycling—were also found higher in the more concentrated inner Bangkok, all of which support the notion of energy

The pattern of familial vehicle ownership not only explained the need for mobility in the three study areas, but it was also governed by the accessibility to mass transit system. While mid Bangkok had the lowest mean cars per family (1.30) it also had the lowest percentage of households without car (19.0%) (Table 8). The availability of mini-bus route together with decent proximity to urban services tended to ease the necessity of private car in the mid-Bangkok community. The number of car per house hold in inner city was fewer than that of outer-Bangkok due to its relatively shorter distance to employment and the availability of mass transit system.

Table 7: Trip to Employment and Energy Requirement Conservation in compact city.

Study area	Daily Trip to Employment and energy requirement				
	Require Energy			Not Require Energy	other
	Private Cars	Bus	Mass transit rail	Walk / Bicycling	
Polis Spa (inner BKK)	35 (44.9%)	24 (30.8%)	3 (3.8%)	8 (10.3%)	7 (9.0%)
Nirrun Villa (middle BKK)	137 (55.2%)	83 (33.5%)	8 (3.2%)	8 (3.2%)	12 (4.8%)
Wat Lanbun (outer BKK)	47 (63.5%)	17 (23%)	0 (0%)	4 (5.4%)	3 (4.1%)
Total	219 (54.8%)	124 (31%)	11 (2.8%)	20 (5.0%)	29 (7.3%)

χ^2 Sig. =0.006

Table 8: Vehicle Ownership

Study area	Number of Familial Vehicle Ownership				Mean
	None	1 car	2 cars	3 & more	
Polis Spa (inner BKK)	17 (21.8%)	26 (33.3%)	21 (26.9%)	14 (17.9%)	1.46
Nirrun Villa (middle BKK)	47 (19.0%)	117 (47.2%)	57 (23%)	27 (10.9%)	1.30
Wat Lanbun (outer BKK)	16 (21.6%)	23 (31.1%)	18 (24.3%)	17 (23.0%)	1.61
Total	80 (20.0%)	116 (41.5%)	96 (24.0%)	58 (14.5%)	1.39

χ^2 Sig. = 0.60, Sig. F= .106

5.3 The extent of energy consumption resulting from urban mobility

Shorter distance to other urban functions in Inner city tended to reduce travel distance in all mode of transportation, which entailed reduction of energy requirement (Table 9). Car ownership was found a function of trip frequency and therefore determining the extent of energy consumption which was indicated by the amount of monthly gas expenditure (Table 10). Both indicators confirmed the reduction of energy consumption in more densely populated urban settings.

Table 9: Average Distance Trip Frequency and Mode of Transportation

Study area	Average distance (Km) / Trip and Mode of Transportation				
	Require Energy		Non Energy	Other mode of transporta-tion**	Total
Mode of Transpiration	Private cars**	Bus**	Walk / Bicycle**		Total Distance**
Polis Spa (inner BKK)	13.67	10.34	0.63	7.86	10.62
Nirrun Villa (middle BKK)	15.88	11.09	1.36	16.50	13.68
Wat Lanbun (outer BKK)	17.97	18.40	6.13	17.02	17.02
Total	15.98	11.99	2.03	12.50	13.70

** Sig. F at 0.05 Level

The extent of petroleum consumption depended much upon the vehicle's velocity. The estimated amount of energy consumption in Table 11 was calculated by converting distance and number of trip per-capita in Table 10 using a formula devised by the Board of Land Traffic System Management (BLTSM). The BLTSM estimated

that rate of petroleum consumption was 0.598 litre / km. at 10 km. / hour, and 0.299 litre / km. at 40 km. / hour. Table 11 demonstrated that the extent of petroleum consumption in inner Bangkok was relatively more economical than that of mid- and outer-Bangkok for all mode of transportation.

Table 10: Mean Familial Monthly Gas Expense by Study Areas

Study areas	Familial monthly expenditure on Gas (Baht / month)		
	N	Mean	Std. Dev
Polis Spa (inner BKK)	52	3239.42	3732.32
Nirrun Villa (middle BKK)	178	3662.92	3252.71
Wat Lanbun (outer BKK)	57	4122.81	3092.27
Total	287	3677.53	3321.81

Table 11: Estimated Petroleum Consumption by Urban Setting

Study area	Estimated Energy Consumption (Liter / Km) and Mode of Transportation					
Mode of Transpiration	Private cars		Bus 40 persons		Other modes	
Velocity	V = 40	V = 10	V = 40	V = 10	V = 40	V = 10
Polis Spa (inner BKK)	21.57	43.14	48.08	110.12	9.10	18.20
Nirrun Villa (middle BKK)	26.15	52.30	48.58	111.26	23.51	47.02
Wat Lanbun (outer BKK)	29.00	58.00	82.14	188.12	27.21	54.42
Total	26.03	52.06	81.80	122.07	17.06	34.12

5.4 Living environment, residential preference, and city form

Most urban theories hypothesized that housing preference were in accordance with the availability of urban services, adjacent to employment, convenience to commute, and decent environment. Questionnaire survey from the three study areas confirmed the validity of these variables. Those who chose to live in inner city tended to realize the significance of urban services and convenience to commute, while mid- and outer Bangkok were in favour of good environment (Table 12). The finding could partly explain the complicated relations shown in the study framework. While economic factors assisted dwellers to compete for the location of their choice, life style and personal value judgment governed their decision. Average occupancy size, for instance, tended to govern the amount of per capita energy consumption—for air conditioning and artificial lighting—in different living density. Detailed discussion regarding energy consumption was discussed elsewhere (see table 3).

Table 12: Respondents' Reasons on Residential Preference

Study areas	Urban Services	Adjacent To Employment	Convenience to Commute	Decent Environment	Others
Polis Spa (inner BKK)	22 (28.2%)	8 (10.3%)	25 (32.1%)	20 (25.6%)	3 (3.8%)
Nirrun Villa (middle BKK)	49 (19.8%)	44 (17.7%)	50 (20.2%)	87 (35.1%)	18 (7.3%)
Wat Lanbun (outer BKK)	8 (10.8%)	0 (0%)	7 (9.5%)	56 (75.7%)	3 (4.1%)
Total	79 (19.8%)	52 (13.0%)	82 (20.5%)	163 (40.8%)	24 (6.0%)

χ^2 Sig. < 0.001

Personal attributes such as income and education level, life style, and family structure tended to direct their environmental needs, which in turn, partly explain the dwellers' spatial needs. The study found differences in environmental needs among the three study areas. While the three most significant environmental concerns for inner city dwellers were parking space, traffic congestions and exhaust fume, dwellers in outer Bangkok perceived that poor road surface, dust, and noise were the three most important environmental apprehensions (Table 13). Obviously, inner city dwellers valued what they were lacking, while sub-urban dwellers cherished what they were yearning for. In other words, urban settings which promoted energy conservation would compromise the quality of life of dwellers.

Table 13: Respondents' Environmental Needs

Respondents' attitude toward the ranking of environmental needs (N=400)		
Average of the Three study areas Ranking of problem priority	Mean score	Sig. F *
1.Traffic congestion	.51	.000*
2. Dust	.44	.000*
3. Street lighting	.42	.000*
4.Poor traffic surface	.40	.000*
5. Lack of parking space	.40	.000*
6. Noise	.39	.015*
7. Unsafe environment	.22	.210
8. Smell from waste water	.19	.813
9. Building deterioration	.18	.000*
10. Lack of waste disposal space	.18	.000*
11. Automobile exhaust	.17	.000*
12. Flood	.17	.071
13. Lack of recreational space	.17	.198
14. Poor public telephone service	.08	.001*

6. Discussion

Empirical fact from the three study areas confirmed that spatial setting of city was important factor governing the pattern of urban mobility. Higher living density in city centre tended to reduce travelling distance and the energy consumption. Location and housing choice were in fact complicated by personal socioeconomic and familial factors. The differentiation of income and life style among the

three study areas make housing location more a constraint than a choice.

In this light, lower land value was found the prime factor determining larger distance between residential areas and other activities in the sub-urban area, and therefore, greater travel demand. Despite of the fact that higher land value in the inner city fostered vertical growth and enhanced the need of elevator usage, the higher living density and smaller per-capita living space helped reduce energy consumption of dwellers comparing to those living in the outer Bangkok. Smaller per-capita living space optimized the cooling and lighting needs. Congestion and urban pollution, on the other hand, had driven the wealthier families to compete for land in the sub-urban areas for the sake of a better quality of life. Such competition, in turn, tended to heighten the sub-urban land value and drove the urban poor to live in the inner city to save travelling cost and enjoy the availability of public transportation. The abundant of urban amenity also a major factor attracting dwellers from the suburban areas while sacrificing their own living condition. Education was one example cited by respondents as among the most important reason to keep them in the inner city. Most prestigious high schools were located in the CBD. Most dwellers in the inner city voiced their concern regarding bad living condition such as congestion, lack of parking space, and noise. Inner city dwellers thus favour traffic control and areal tax for vehicle entering the inner city from the sub-urban areas. For inner city dwellers, travelling to rural areas during the weekend to get away from the unfavourable environment required a large portion of energy, while suburban dwellers travel more during week days to their employment. Empirical fact still showed a relatively greater potential to save energy for high density area comparing to the dispersing nature of the sup-urban areas.

7. Conclusion and suggestions

The study found a complicated relationship among a group of intertwining factors—urban settings, dwellers' personal attributes, family structure, life style, and mode of transportation. Urban settings in a more compact form tended to promote energy conservation much more than a dispersed setting. Quality of life was, however, was compromised in a more compact urban form, which made wealthier dwellers seek to live in more ample sub-urban areas. The study thus suggested that urban policies should take into account the optimal size and appropriate density of settlement, regulating and controlling spontaneous growth and sprawl. Location of employment should be balanced with the number of housing by means of urban revitalizing measures in high density areas. A 'transit-oriented development' (TOD) with mixed-use approach, equipped with pedestrian way and bike lanes, connecting residential areas with urban transit, should be encouraged. Urban development personals must also consider the dweller' quality of life among its foremost priorities, in order to maintain a well balanced social policy towards an equitable living condition and energy sufficient way of life in the city.

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