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Monitoring CO_2 Emission in Indonesian Planned Housing Complexes and Designing Alternative Future Images

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インドネシアの計画的住宅地における二酸化炭素排出量の調査と、将来像代替案の検討

小林　英之＊

Monitoring CO_2 Emission in Indonesian Planned Housing Complexes And Designing Alternative Future Image

Hideyuki Kobayashi ＊

概要

環境省予算により、2004～2006 年度に行なった、インドネシアの計画的住宅地から排出される CO_2 の実態調査結果と、これに基づく排出量を増やさない住宅地将来像の検討結果である。インドネシア公共事業省人間居住研究所の協力を得て、光熱消費、交通のためのガソリン消費、建材消費を訪問調査すると共に、衛星画像解析により緑被率、地形を分析した。これに基づき、現地の建築家・都市計画家の参加を得て、２地区に関して将来像代替案を設計し、地元居住者も招いて討論を行なった。

キーワード：二酸化炭素、住宅、交通、計画、材料

Synopsis

This book reports the result of monitoring current CO_2 emission from planned housing complexes in Indonesia, and the resulting future image of housing which will not increase emissions. Through cooperation with the Indonesia Research Institute for Humane Settlements, Ministry of Public Works, the consumption of domestic energy and fuel for transportation and building materials were monitored through a field survey, while analysis of satellite images of the same place clarified the green coverage and detailed land shape. Based on these, architects and city planners designed several alternative future plans for 2 model districts, which were presented and discussed with inhabitants of the districts.

Keywords: CO_2, Housing, Transportation, Planning, Material

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What is occurring in tropical large cities in developing countries：

Population increase causes horizontal urban expansion, reducing surrounding greenery and increasing risk of floods.
Mass transportation is poor and traffic jams are caused by rapidly increasing vehicles, especially motor bicycles.
Higher incomes boosts the consumption of electricity. A/C is installed in houses without thermal design.
Houses with shorter service lives consume materials causing destruction of forests and consumption of fossil fuels.
Solutions can be sought through invention and socialization of images of new utopia, before inflation of fossil fuels' price. Tropical traditional houses that have coexisted with nature offer many suggestions for future, through their design and usage of materials.

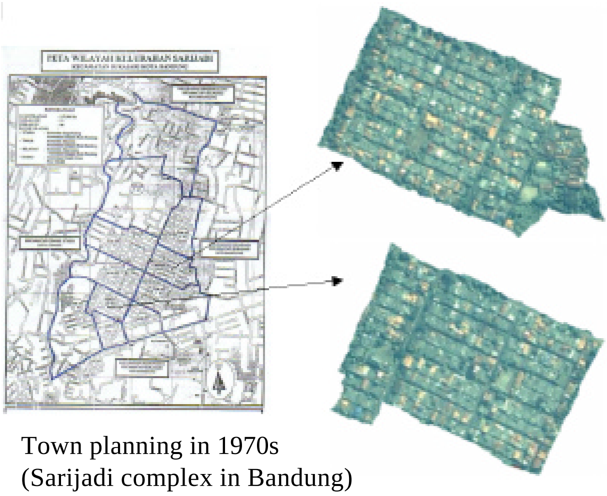
1. Analysis of satellite images to grasp existing conditions

(1) Identification of houses supports field survey activities

Bandung: IKONOS(1m), Cirebon and Malang:Quick Bird（0.6m)

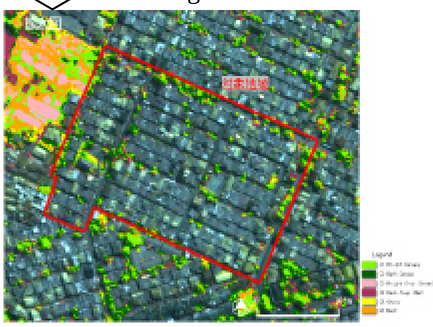
Initial form of houses

Extended houses



Town planning in 1970s
(Sarijadi complex in Bandung)

Analysis of 4 bands identifies area of canopy of trees, covering 11 % of total area.



(2) 「ALOS」(2.5m): Acquisition of DEM from stereo pair image
→Identification of Low wet coastal zone and slope area.

Table 4 Optimal parameters for matching

Area	Area for searching (pixels)		Size of matching window (pixels)		Lower limit of coefficient
	X	Y	X	Y	
Bandung	31	3	3	3	0.5
Cirebon	11	3	7	7	0.5

More detailed DEM was obtained from satellite images (left) than that from geographical map1:25,000 (right).

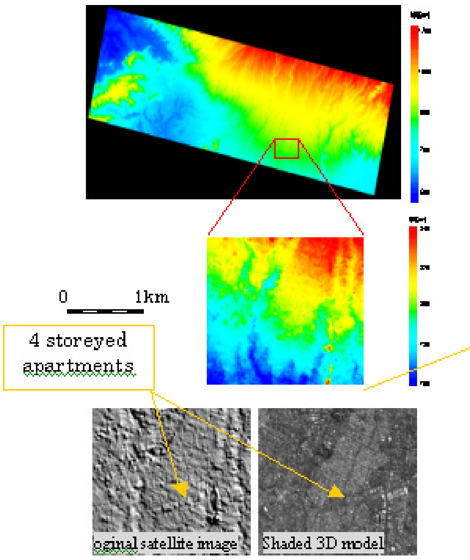


Fig. 2 The obtained DEM data for Bandung

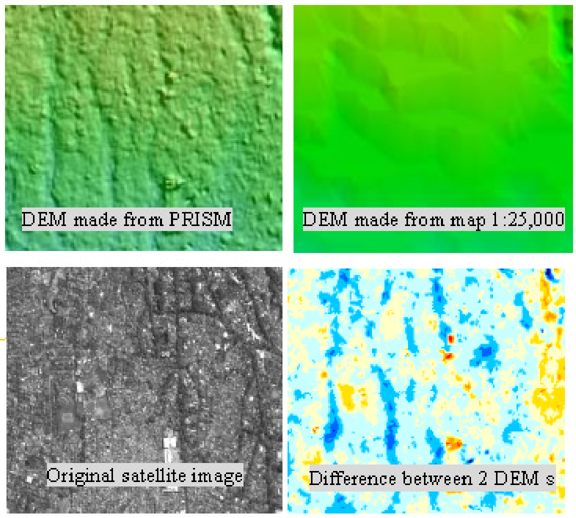
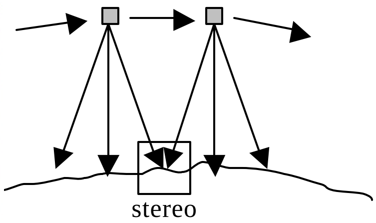


Fig. 3 Comparison of DEM from PRISM & Geographical Map 1:25,000



Satellite "DAICHI" (ALOS)
Sensor：PRISM

Analysis of stereo pair images taken from different angles provides 7.5m DEM with 1m resolution of altitude, corresponding to the height of roofs, green canopies and vacant land.

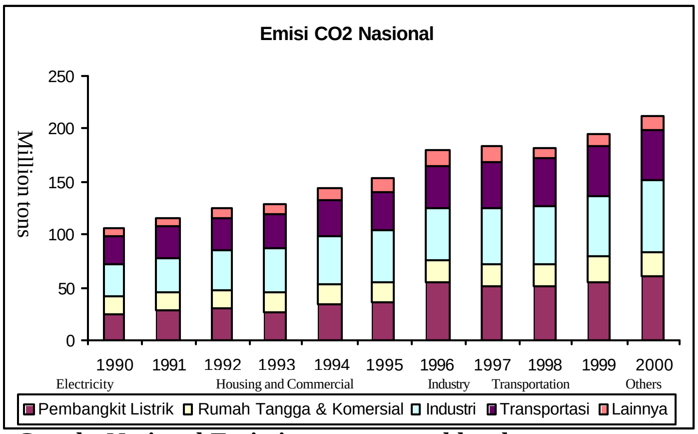
2. Field Survey of Life

Under supervision of the Research Center for Human Settlements Ministry of Public Works, a questionnaire survey was performed of 900 sample households from 13 planned housing complexes in 7 Indonesian Cities. Most were masonry houses made by greatly expanding the original houses. Domestic consumption of energy and of fuels for transportation and usage of building materials were monitored. Building material factories were also surveyed to identify the life cycle emission of each material occurring outside of the complexes. The length of life of houses was c.a. 15 years, to calculate annual emission through building materials compared to that of domestic energy and vehicle fuels.

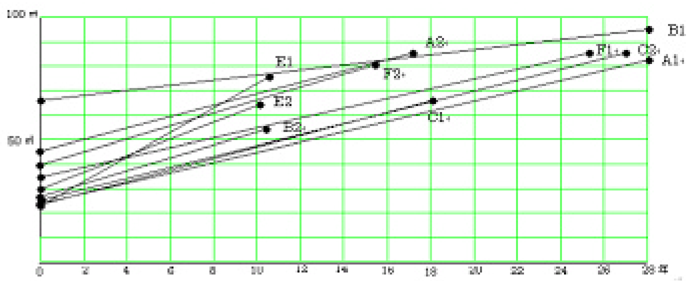
Fig: Cities surveyed

Table: Housing complexes surveyed

A.Bandung city	A1 :Sarijadi Complex (public)
	A2 :Antapani Complex (public)
B.Cirebon city	B1 :Hardjamukti Complex (public)
	B2 :Gulia Sunyaragi Permai Complex (private)
C.Semarang city	C1 :Banyumanik complex (public)
	C2 :Peramongan Indah complex (private)
D.Malang city	D1 :Sawojajar complex (public)
E.Mataram city	E1 :Seweta Indah complex(public)
	E2 :Bakudan Permai(private)
F.Makassar city	F1 :Banakukan complex(public)
	F2 :Bumi Tamalanrea Permai complex(private)
G.Banjarmasin city	G1 :Buruntung complex(public)
	G2 : HKSN complex(private)



Graph: National Emission, announced by the government



Graph: Average floor area of houses, original and current
(Big increase, however still under 100m²)

·In spite of a monetary crisis(1997), constantly increasing, doubling every 10 years

·Contribution of electricity is large. It is highly dependent on income according to the survey finding.

·In this research, evaluation is not confined to "housing" sector, but also include the indirect emissions that are classified in other sectors in this graph.

Table: Total annual emission of household (kg-CO_2/Year/Household)

cities	Samples	Domestic	Transportation	B. material	Total
Bandung	200	2,390	1,455	108	3,868
Cirebon	200	1,891	751	76	2,708
Makassar	100	2.262	821	75	3,159
Banjarmasin	100	2,120	1,322	81	3,502
Semarang	100	1.976	1,092	72	3,199
Mataram	100	1,870	1,223	99	3,192
Malang	100	2,087	1,179	85	3,350

Table: Emission coefficient used

·Electricity:0.684KgCO_2／kWh
(Diesel generators are popular in local cities.)

·Kerosene 1 liter emits 2.54kg-CO_2
Weight0.8136Kg/L Carbon weight 85%

·City gas 1m3 emits 2.031kg-CO_2
Weight0.677Kg/m3 Carbon weight 81.8%

·LPG 1Kg emits 2.999kg-CO_2
Carbon weight0.818kg/L

One average household emits 3-4 tons of CO_2 in one year.

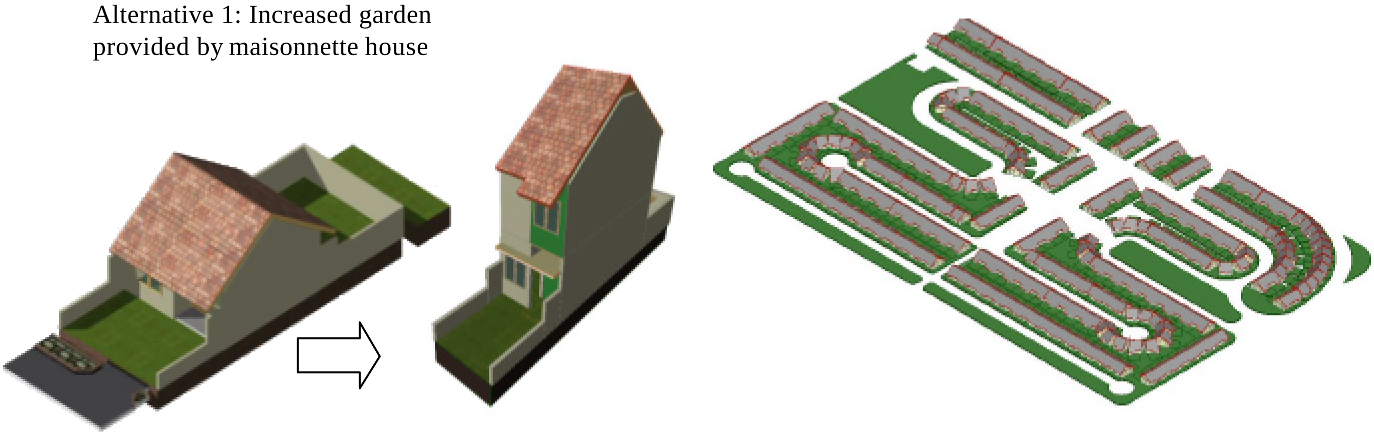
National total emission is 200 million tons per year, therefore one ton per person per year, and the survey result is comparative to this. The survey targets are urban planned housing areas, and the average emission per year is probably relatively larger than national average of whole houses including rural settlements.

3. Planning alternative futures

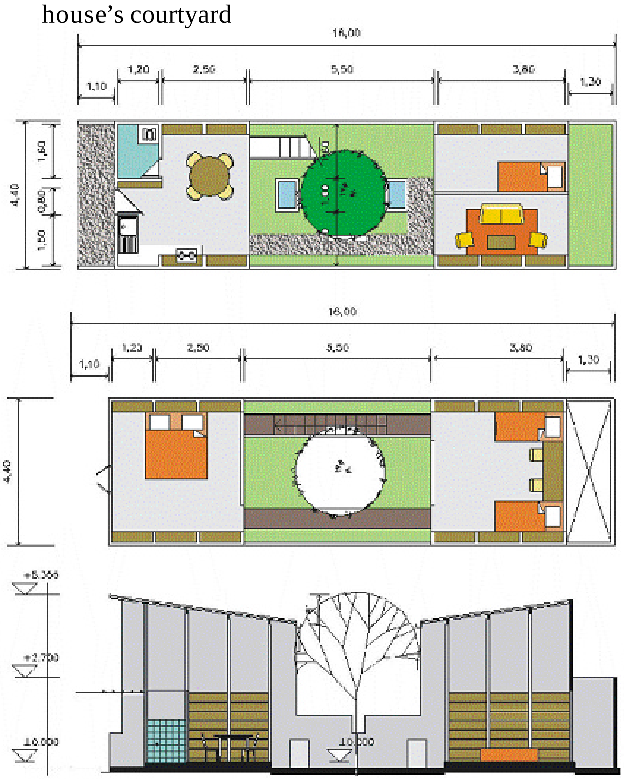
With the participation of Indonesian architects and city planners, alternative plans were elaborated for two actual districts in Bandung and Cirebon cities, considering the “emission”, instead of usual “cost”. Before starting the design, a workshop was held in Bandung (March 2006) in order to discuss the basic concepts, including the understanding of system boundary, saving energy and electricity, LCE (life cycle emission) of building materials and carbon stock effect, evaluation of greenery (absorption of CO_2 and exterior heat), natural ventilation, and transportation trip of vehicles. Several new solar cells, building greenery, high-rise building and low house combination, etc. were proposed.

Elaborated alternative plans were presented in the form of three dimensional data, with explanations of concepts and reduction of CO_2 emission, at the workshop, held with invited non-engineer resource persons and citizens in the target areas (March 2007).

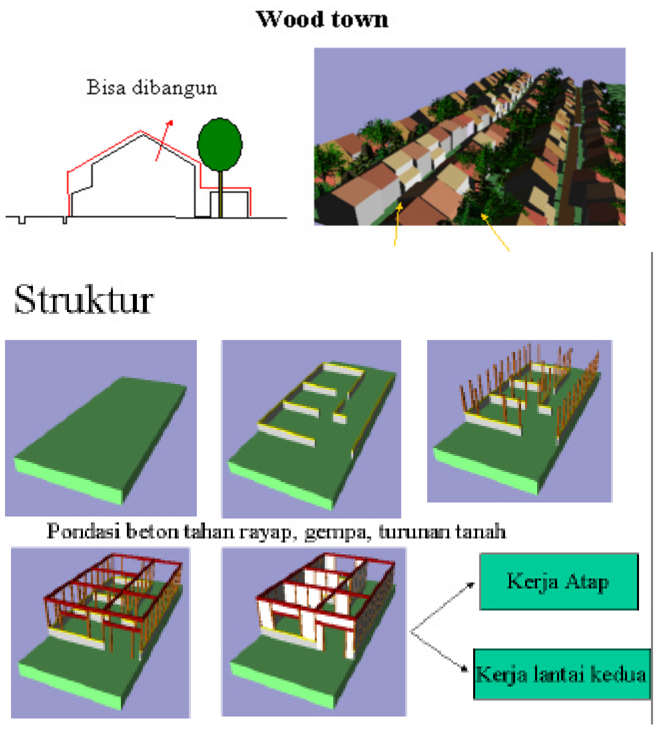
Alternative 1: Increased garden provided by maisonnette house



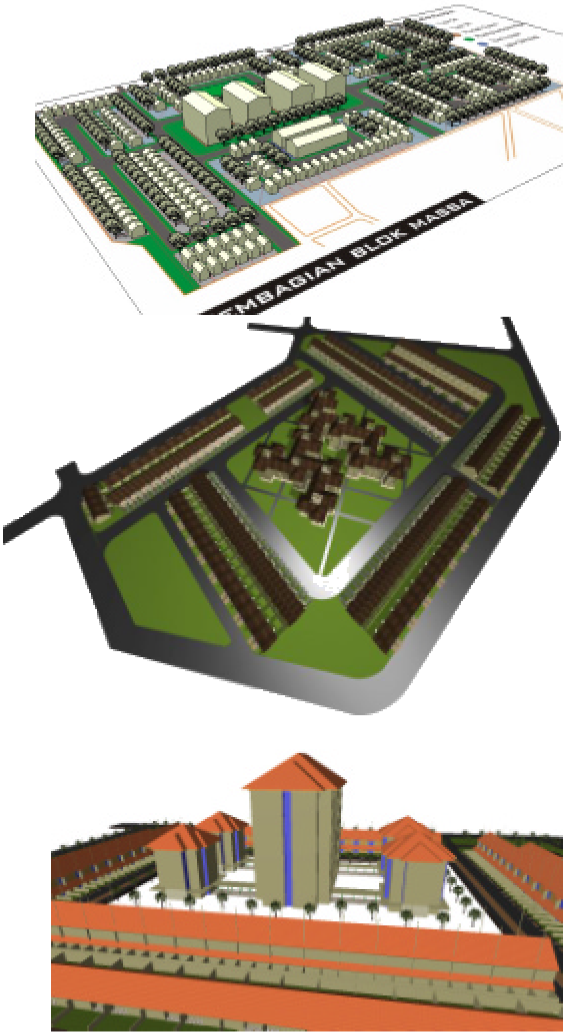
Alternative 2: Planting a tree in every house’s courtyard



Alternative 3: Carbon stock in fire-proof timber houses



Alternative 4,5,6:Creation of greenery by apartment



Alternative 7: Greenery on roofs and walls of apartment

Alternative 8: Artificial land, with greenery on top

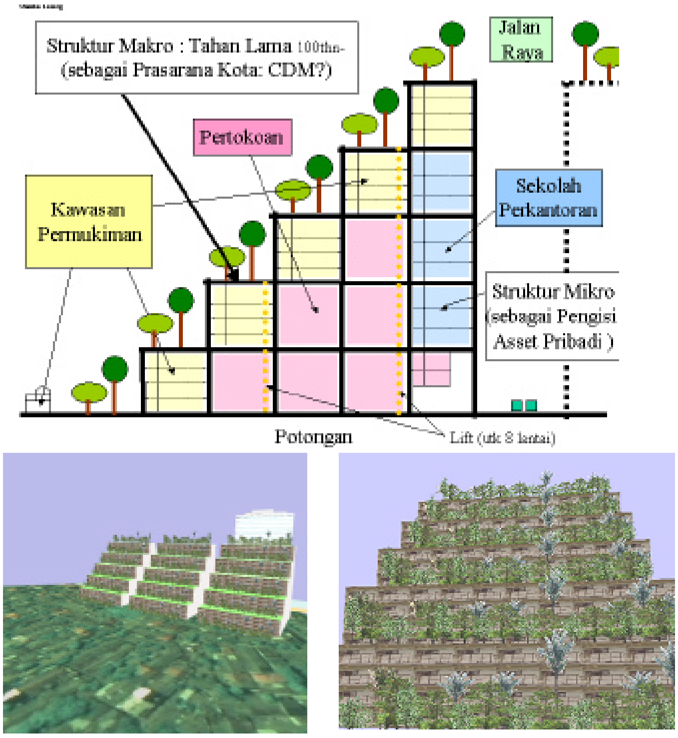


Table: Summary & evaluation of alternatives (Cirebon)

Items	Existing	Plan 1	Plan 2	Plan 3	Plan 4	Unit
Land area	54,700[*]	54,700	54,700	54,700	54,700	m²
Total units	324	364	924	578	344	Units
Population	1,090	1,457	3,737	2,312	1,376	Persons
Total floor area	39,056	40,616	136,836	35,616	25,420	m²
Housing	28,836	32,396	72,036	27,396	17,200	m²
Non-housing	8,220	8,220	64,800	8,220	8,220	m²
CO_2 emission/Year/Unit	2.710	5.419	2.382	4.168	4.226	T-CO_2
Building Material LCE	369	15,809	13,488.6	13,369	8,394	T-CO_2
B. material LCE/unit	1.140	43.4	14.6	23.1	24.4	T-CO_2
Expected length of life	15	15	60	15	15	Years
B.Material LCE/Year	24.624	1,054	224.8	891	560	T-CO_2
LCE/Unit/Year	0.076	2.8	0.243	1.54	1.63	T-CO_2
LCE/m² of floor/Year	0.00085	0.033	0.0031	0.033	0.033	T-CO_2
Domestic energy/Year/Unit	1.891	1.891	1.891	1.891	1.891	T-CO_2
Transportation/Year/Unit	0.751	0.751	0.263[*]	0.751	0.751	T-CO_2
Tree cap coverage	4,814	15,614	25,130	14,944	29,994	m²
Absorption/year[*]	-5.1	-16.6	-26.6	-15.8	-31.8	T-CO_2
Absorption/Year/Unit	-0.008	-0.023	-0.015	-0.014	-0.046	T-CO_2
Carbon Stock in Building	324	364	0	0	0	Ton-C

Absorption of CO_2 by trees is calculated using IPCC default value of 2.9 ton-C/Year), however this must be larger in tropical zones, and it is now studied through forestry researches.
Carbon stock is related to the amount of timber as a building material.

Photo: discussion and evaluation workshop (2007.3.6-7)

The evaluation of a housing complex still does not reflect its location of in an overall city, therefore the whole city is not evaluated. In the next step, evaluation of the total city must be done by comparing new town development in the fringe of city vs. urban renewal in the inner city area.

P r e f a c e

Last year, the IPCC (Intergovernmental Panel for Climate Change) released its fourth report, which clarified that CO_2 emissions resulting from human activities are the major cause of global warming. "Climate change", both mitigating and adapting to this phenomenon, is now an important issue in managing national land. In spite of successful efforts to reduce the CO_2 emission in many industries, emission from households and offices is still increasing, and growing electricity demand in the hottest hours in summer is a critical issue in Japan.

In the near future, these will be phenomena common to tropical cities where modernization is rapidly changing the shapes of cities and urban life styles. However, planting trees to provide shade from the sun is a cultural tradition in the hot climates of tropical cities. Traditional and colonial houses also feature a variety of passive adaptations to the hot and humid climate: adaptations which offer suggestions for the design of future houses.

Human settlements have traditionally been local issues, however, borderless interaction is occurring through GHGs, and the international trade of materials is influencing local market prices. Therefore, we have to consider global impacts even when designing details of human settlements.

If instead of locking the barn door after the horses have escaped, we find sustainable solutions related to housing and the structures of cities before the price of fossil fuels soars and damage caused by emissions imposes heavy costs, , citizens of the future will enjoy happier lives. Architects, engineers and city planners can also contribute to the creation of an image of future human settlements that will be sustainable in the face of climate change: a challenge unknown to creators of utopias in the past centuries. New technologies for saving material and energy arenow being developed rapidly and might soon be available at reasonable costs.

This book is a report on the results of research titled "Supporting Strategy for Urban Development and Housing Construction in Developing Countries Related to Global Climate Change" undertaken between fiscal years 2004-2006. This work was supported by the Global Environment Research Fund (04-10) of the Ministry of the Environment, Japan.

Cities studied were selected in Indonesia, and the field research was carried out by a research team organized by the Research Center for Human Settlement, Ministry of Public Works, Indonesia, with the participation of many invited resource persons and experts, while the NILIM of Japan analyzed the satellite images . The research concluded with the proposal of eight alternative future plans related to climate change for two model districts. They were presented in the form of 3D data so they are easily comprehended by non-engineers. Emission from each plan was also evaluated based on data obtained from the field surveys of existing housing complexes. This is the first such endeavour undertaken for the above-mentioned purposes.

In addition to the research and planning activities, 4 seminars/workshops were held to report the findings. Howeverthe results have still not been sufficiently disseminated. Therefore, this book is being released to publicize our findings and proposals and to trigger wider discussions regarding human settlements and climate change. One such effort is an international symposium to be held in Bali, March 2008.

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Field surveys of housing complexes were undertaken in cooperation with following universities:

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Winaya Mukti University (UNWIM), Bandung (Prof. Asep, et-al.)

Semarang University, Semarang (Prof.Ayu, et -al.)

Politeknik, Cirebon (Prof. Yoyon, et -al.)

Hassanudin University (UNHAS), Makassar

Mataram University, Mataram (Prof. Rini, et-al.)

Politeknik, Banjarmasin (Prof. Johan, et -al.)

Analysis of Satellite Image was undertaken by:

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Mr. Akihiro Nakazawa (Ajiko, DEM of Bandung and Cirebon cities)

Improvement of software handling 3D data was undertaken by:

Mr. Hiroshi Nakajima (Softprime)

Alternative Plans of model districts were elaborated by:

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Mr. Sigit (DHIKA)
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1. Introduction

Since the enactment of the "Kyoto Protocol" in 1997, global warming has become a more important issue even in fields of housing and city planning throughout the world including developing countries.

In fiscal year 1999, the Building Research Institute (BRI), Ministry of Construction, Tsukuba-Japan proposed a feasibility study (FS), the "Global Environmental Impact Study of Housing and Urban Development in Indonesia", and year 1 of the FS was funded by the Ministry of Environment of Japan and undertaken cooperatively by the BRI and the Research Institute for Human Settlements (RIHS), Ministry of Public Works, in Bandung-Indonesia [7) 8)]. This FS was a study of both the Impact of Global Warming on Human Settlements, and Impact of Developing Human Settlements on Global Warming.

The total length of the coastline of Indonesia has been estimated as 80,000km, however, previous research results, data related to climate change and human settlements etc. were very limited.

Based on this FS, research titled "Impact of Sea Level Rising on Coastal Cities" was conducted between 2000-2002 in 8 Indonesian cities through BRI-RIHS cooperation. Due to a governmental re-organization in Japan, the Ministry of Construction was replaced by the Ministry of Land, Infrastructure and Transport, the National Institute for Land and Infrastructure Management (NILIM) was newly established in 2001, and this research was taken over by the NILIM.

The results were published by the NILIM in August 2004[12)].

Another aspect of the FS, namely, CO_2 emission from human settlements, was studied between 2004-2006 as a research on "Supporting Strategies for Urban Development and Housing Construction in Developing Countries Regarding Global Climate Change", funded by Ministry of Environment, Japan. This report is based mainly on the results of various studies undertaken through this research.

The Ministry of Construction of Japan supported another project to construct an eco-house in Surabaya through the Infrastructure Development Institute between 1998-2000, and undertook several monitoring activities up to 2002[14)].

During those years, some symptoms of global warming also appeared in Indonesia, including irregular rainy seasons and frequent floods, apparently enhancing social consciousness of global warming.

(1) Objective

a. Target Areas – Tropical Coastal Cities and Inland Cities

The rapid increase of CO_2 emissions in developing countries is predicted. In human settlements in tropical regions, even though the current level of CO_2 emission seems to be still low, (1) increasing domestic consumption of energy (e.g. usage of air conditioning), (2) increasing consumption of fuels for transportation (horizontal expansion of cities without provision of public transportation), and (3) consumption of building materials (scrap-and build type construction of houses with short service lives). The future rising cost of energy will restrict our ability to improve the shapes of cities and revise housing styles, however, it will take a long time to re-model existing urban districts. Therefore, starting to develop ideal prototypes and models of housing complexes that will save energy and materials (therefore emission of CO_2) is an effective way to ensure a happier future for the cities of the future. .

This research targeted areas selected from Indonesian coastal and inland cities. The risks of the negative impact of global warming and sea level rising have already been estimated and the needs for adaptation through alternative approaches (spatial planning and provision of infrastructure) have already been recognized through previous research (2000-2002). And in addition, basic data of the cities studied (geographical and demographic data) can also be utilized for studies of CO_2 emissions.

One point that promises potential benefits is that Indonesian cities are rich in “greenery” along their streets, in their public open spaces and in individual house lots. This will absorb CO_2 from atmosphere and emit O_2. This urban greenery also helps prevent the heat island phenomena and reduce the air temperature, lowering energy consumed by air conditioning. Traditional and colonial houses have provided abundant shady and comfortable spaces, principles that can provide good lessons applicable to future houses.

Till now, we have sought the ideal form of urban settlement from the viewpoint of “Safety”, “Health” and “Comfort”, but we have still not formed new models and images of future human settlements in response to the challenge of climate change. We must treat climate change as a new condition, while not ignoring previous issues in the planning and design process.

Finally, we also included urban greenery (absorption of CO_2 or negative value of emission), and carbon stock in the form of organic building materials.

b. Goals to be achieved

As part of this research, we monitored the current level of CO_2 emissions through a field survey of housing areas and the flow of building materials, which are the basic units for the evaluation. These units (e.g. life cycle emission per unit of material) will be applied to evaluate alternative future plans . Mathematically, this evaluation will be similar to a cost estimation. We will use “kg- CO_2, instead of price or “Rupiah”.

The alternative future plans and designs were elaborated by Indonesian architects, city planners and engineers, and were discussed and evaluated by citizens and policy makers (non-engineers) from the viewpoint of social and cultural applicability/appropriateness.

(2) Method

a. System Boundary of Housing and Urban Development

In order to evaluate the current situation and future plans from the viewpoint of CO_2 emissions, we have to grasp not only direct emissions that take place in a region, but also indirect emissions that accompany activities in theregion. If we consider only direct emissions, a life style which consumes huge amounts of electricity (causing emissions from power plants) and usage of exclusively prefabricated materials (causing emissions in factories) will gain the highest score (lowest emission). Obviously this is not a fair way to select better solutions to reduce “total emissions”. Therefore, we defined the system boundary for building materials and domestic energy to include indirect emissions.

It is difficult to measure fuels burnt to transport goods if we try to separate the portion that is consumed only within housing complexes. For this technical reason, we monitored the consumption of fuels by vehicles owned by the inhabitants of theregion while neglecting emissions by vehicles passing through theregion. The monitored consumption would reflect the location of studied site in the averall city, therefore the whole spatial structure of the city, rather than spatial arrangement within the complex. However, assumption of dominant transportation mode in the initial plan (e.g. provision of parking space) might have guided the lifestyle of inhabitants.

b. Time Scale and Change of Stock

To consider the life cycle, we have to start with the empty land before development, and study construction, operation and maintenance, alteration and reconstruction, and finally demolition. Emissions by building materials should also be considered during the entire life cycle ending with demolition. Annual emissions will be calculated by dividing life cycle emissions by the lifetime:

Annual Emissions = Life Cycle Emissions / Lifetime

If we try to choose materials with short LCE and long lifetime, the annual emissions will below.

However, this is appropriate only with a constant total amount of stock. In reality, the total number (or total floor area) of houses increases continually in developing countries, and major materials (formerly traditional timber) are replaced by bricks and concrete.

Simplifying the process obtains the following 3 stock models:

Model 1: Case of Lime

(1) Construction Phase: Emission

Limestone ($CaCO_3$) is obtained underground at the development site. Timber obtained from trees at the site is burnt to produce CaO used for constructing houses ($Ca(OH)_2$). CO_2 is emitted to the atmosphere by the chemical process:

$CaCO_3 \rightarrow CaO + CO_2$

(2) Maintenance Phase: Absorption

Lime slowly absorbs CO_2 from the atmosphere. $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

(3) Demolition Phase: Absorption

Disposed lime continues to absorb CO_2

The total amount of CO_2 in the atmosphere remains the same, but increases while the houses exist.

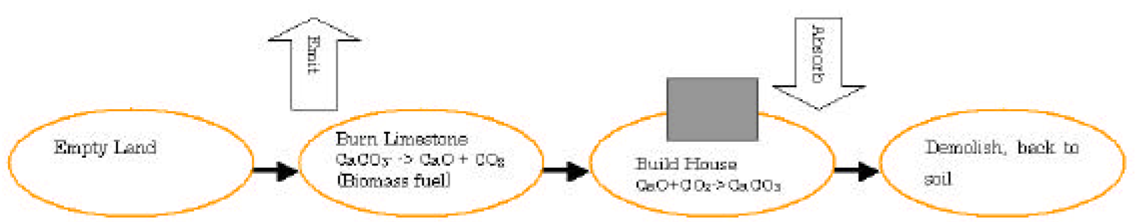


Fig.1: An Example of Negative Stock, with Zero Emission

Model 2: Case of Brick

(1) Construction Phase: Nothing
Clay is obtained from the soil at the development site. Rice husks are burnt to produce bricks.

(2) Maintenance Phase: Nothing
No chemical reaction takes place.

(3) Demolition Phase: Nothing
The house is demolished and the brick is broken and goes back to the soil.

The whole process is neutral in terms of CO_2 emissions.

Model 3: Case of Timber

(1) Construction Phase: Absorption
Young trees are planted on the development site. They are grown and cut and the timber is obtained. The timber is used for constructing houses.

(2) Maintenance Phase: Nothing
Ideally, no chemical reaction occurs.

(3) Demolition Phase: Emission
The houses are demolished and burnt. The carbon contained in the timber material returns to the atmosphere in the form of CO_2.

The whole process causes no emissions, however, the houses stock a certain amount of CO_2 from the atmosphere while it is in use.

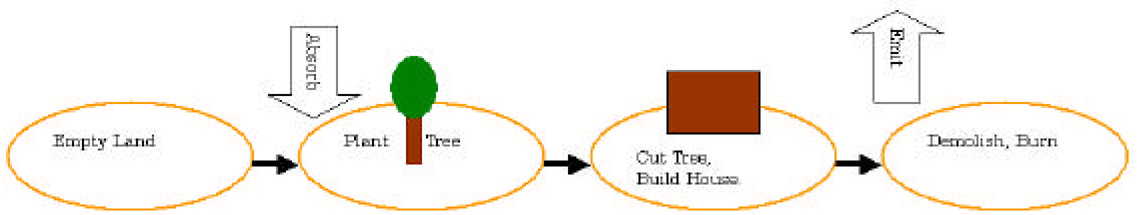


Fig.2: An example of Positive Stock Effect, with Zero Emission

In order to see this, we have to evaluate the carbon stock contained in the house unit, and also evaluate the change of total stock.

In Indonesia, this impact is large, because huge numbers of existing timber houses have been demolished and replaced with brick houses as described later. In short, several hundred million tons of CO_2 is emitted to the atmosphere from this process.

c. Data Source and Analysis

Statistical data on housing is available at the Central Bureau of Statistics (Biro Pusat Statistik) in Jakarta. Geographical maps and related digital data are available at the National Coordinating Agency for Surveys and Mapping (BAKOSURTANAL) in Bogor.

All satellite images were available in Japan. IKONOS, Quick Bird and ALOS images were utilized in this research. The NILIM analyzed green coverage and acquired DEM.

Field surveys of existing housing complexes were organized by the RCHS and undertaken by local universities. A common questionnaire including domestic energy consumption, transportation and building material usage was prepared, and was used to survey c.a. 900 samples in 13 planned housing complexes in 7 cities. The tabulation and analysis were mainly undertaken by the RCHS, with the cooperation of the Research Center for Road and Bridge in Bandung.

d. Design and Evaluation

Two districts in Cirebon and Bandung cities were selected for model planning. Indonesian architects and city planners were invited to discuss the basic concepts for future design regarding lowering CO_2 emissions, and to elaborate various alternative plans. Emissions which would result from each alternative plan were evaluated by comparing them to existing conditions in the target region. Alternative plans were presented and discussed in the final workshop to which local people and resource persons in various fields were invited to participate.

The whole process is shown in the flow chart (Fig.3).

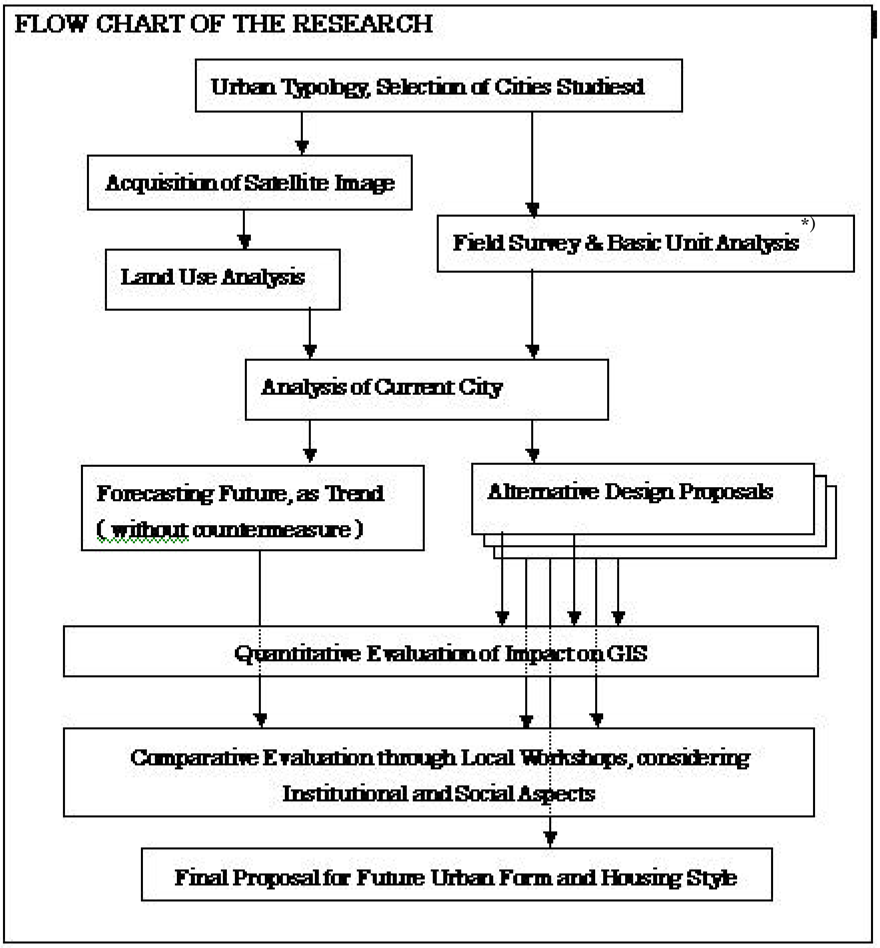


Fig.3: Flow Chart of the Research

*) Field surveys of housing complexes, building materials factories, etc. are done to clarify the various basic units such as CO_2 emissions by producing one piece of roof tile, the average number of roof tiles used per square meter of roof, average area of the roofs of houses, etc., which will be utilized to evaluate future plans.

2. Historical Overview of Indonesian Housing and Urban Development

(1) From Timber to Brick

The total land area of Indonesia is 1.92 million km^2, and 1.44 million km^2 of this land is forested[1). Traditional houses were made of timber, with each region showing unique characteristics differentiating it from other regions. Especially in regions where earthquakes occur, it is possible to identify countermeasures learned through experience of these earthquakes . For example, an earthquake struck Sumatra on Dec.26, 2004 (M9.0) and another struck Nias Island on Mar. 28(M8.8). In Nias Island, 12,010 houses were totally destroyed, 32,454 houses were severely damaged and 39,437 houses were partially damaged. Most of those damaged were made of brick, while large traditional timber houses were not damaged [2)]. In the mountain regions of Sumatra and Sulawesi islands, old traditional houses that were constructed before independence (1945) are still inhabited. In most of the coastal settlements and urban districts on the other hand, timber houses are made of smaller and slender members (posts and beams), are smaller in floor area, and are influenced by western structures (king posts etc.).

Just after 1968, when Soeharto became president, the natural forests became national forests, exploitation rights (HPH) were given to the commercial sector and the military, and they began to export timber abroad (including Japan) to boost the national income. Raw timber was exported until the end of the 70's when it was prohibited, and since the 80's, cut timber and plywood have been exp orted instead to enhance profits. According to APKINDO statistics for 1999, 55.59 million m^3 of timber was cut, 19.39 million m^3 of plywood was produced, and of this, 2.77 million m^3 was exported to Japan, a quantity that accounted for 58% of plywood imp orted to Japan. After exporting began, the domestic market price of timber was established and went up along with the international market price.

In place of the traditional timber material, brick became the dominant cheap building material for popular houses. These bricks are produced in small scale factories burning rice husks or firewood at low temperature. Their structural strength is comparatively low, but sold at very low prices, they have become increasingly popular.

(2) Toward Permanent Houses

Cement was imported from independence (1945) until 1975 when the domestic production of cement started[4)]. The houses provided by the public sector were low cost houses and walk-up flats made of RC frames filled with concrete block. The houses provided by the private sector or constructed individually were made of bricks, while public housing adopted concrete blocks as in-fill.

After 1997, when an economic crisis struck several Asian countries, lower domestic demand of cement and lower exchange value of the Rupiah encouraged the export of cement. In 1996, total annual cement exports were 0.2 million tons. This rapidly increased, reaching 8.455 million tons in 2000, when total national production was c.a. 30 million tons. That amount was the second largest in the world[5)].

The government took action to encourage builders to increase the quantity of cement added to mix concrete in order to increase the structural strength of houses, however on construction sites, saving expensive cement is a condition to raise profits, so it is difficult to obtain accurate information about the cement usage rate..

(3) Housing Policy and Statistics

Also in the 1970s, the National Housing Corporation (Perum Perumnas) was established and started to develop housing complexes. At the same time, the National Saving Bank (BTN) was also established and started offering housing loans to developers that develop housing complexes. Publicly provided houses are made of concrete blocks strengthened with frames of reinforced concrete. The initial building structures that are handed over to inhabitants are well designed in compliance with the technical standard supported by a formal building permission procedure.

Since the 1980's, so-called "core house" were introduced to provide low income groups with affordable housing,. The National Housing Corporation delivers only minimum houses, designed to be expanded by their occupants to reach the designed full scale house after occupation. Usually the expansion process takes place without building permission or technical inspections, and without sufficient reinforcement. And even vertical expansion (adding an upper floor) has become popular. The expanded part is usually made of cheap bricks.

In urban and rural areas, the "image" of an urban masonry house became popular, encouraging people to imitate them by using cheap bricks finished with beautiful plaster, but without enough strengthening, as a result of the technical level of the region, low cement content in the concrete, or insufficient reinforcement bars. These resulted in vulnerability to earthquake damage. These "imitated" houses had neither empirical knowledge nor modern engineering to resist against shaking.

Housing statistics widely applied the classifications, "permanent", "semi permanent" and "temporary", with brick houses of the lowest quality deemed to be "permanent" houses, while timber houses with good quality (including traditional ones) were classified as "temporary". Although recently. the definition has been modified to reflect the lifetime of each house, the results of field surveys remain confusing.

Thus, a nation-wide shift from timber houses to masonry houses has occurred, as shown by housing statistics.

The 1961 Population Census of the Republic of Indonesia did not survey materials of various parts of houses., but houses were classified as shown in table 1. This perception and classification is quite different from that in Japan, where "fire-proof" or "not fire-proof" is considered very important.

Table 1: Classification of Houses in Population Census (1961)

Classification	Urban	Rural	Total
Permanent	18.6 %	3.8	5.8
Semi Permanent I	16.8	6.5	7.9
Semi Permanent II	42.7	53.2	51.9
Temporary	20.9	36.5	34.4

Source: Population Census, Republic of Indonesia 1961

In 1992, the National Social-Economical Survey started. It identified kinds of building materials of each part (floor, wall, roof etc), and the results for walls shows the main structural systems of the surveyed houses. However since 2000, the tabulation has ceased to classify brick walls and timber walls, with only bamboo and others tabulated to indicate low-quality housing.

In 1992 in particular, when this survey started, tabulation was performed separately for urban and rural areas (table 2).

Table 2: Building Material for Walls (1992)

Major Material	Brick	Timber	Bamboo	Others
Urban	65.31	21.43	11.89	1.37
Rural	31.17	34.49	31.90	2.44
Total	41.67	30.47	25.75	2.11

Source: National Social-Economical Survey 1992 (Unit: %)

Brick houses are usually classified as "permanent", so we can conclude that the major material for walls drastically changed between 1961-1992. And in urban areas in particular,, it increased from 18.6%(1961) to 65.31%(1992) i.e. accounting for more than half of all houses.

Changeng after 1992 is shown in table 3.

Table 3: Macro Change of National Housing Stock after 1992

Year	Brick	Timber	Bamboo etc.
1992	41.67	30.47	27.86
1993	-	-	-
1994	47.69	29.19	23.12
1995	47.69	28.79	23.52
1996	51.19	27.81	21.00
1997	53.40	27.67	18.91
1998	54.25	27.78	18.10
1999	55.79	26.92	17.29
2000			15.98
2001			16.89
2002			15.71
2003			14.21
2004			12.86

Source: National Social-Economical Survey 1992-2004

This table shows that houses made of cheap and simple wall material, i.e. "bamboo etc." are rapidly decreasing, while brick houses are increasing. Houses with "timber walls", are slowly but continually decreasing.

Since 2000, tabulation tables that identify brick or timber have disappeared from the annual report, and recently, “usage of ceiling” has been added to the tabulation items.

Definition of “permanent” houses is changing from the simple classification of material to a performance-oriented approach that considers the lifetime of houses, however, understanding in the field is still confusing. Village leaders still keep data on the total number of permanent, semi permanent and temporary houses of the villages available for these reports.

However, changes of the way tabulation is done to prepare annual statistics that are published widely seem to reflect a changing perception of the quality of houses.

3. Survey of Existing Planned Housing Complexes

In the first year of this research (2004), field surveys of 900 households in 13 housing complexes in 7 cities were undertaken (Fig.3, Table 4).

The cities surveyed were selected, reflecting the opinions of Indonesian resource persons, and to include both coastal cities with flat land and hot climate and inland cities with sloping land and cooler climate. The National Housing Corporation and private developers developed the surveyed complexes of detached houses since the 1970's. The sample areas were chosen, houses in those areas were measured, and surveyors who visited the houses had households fill in questionnaires .

Fig.4: Surveyed 7 Cities

Table 4: List of Complexes surveyed

#	Name of city	Code	Developer	Name of complex
A	Bandung	A1	NHC	Sariiadi
		A2	NHC	Antapani
B	Cirebon	B1	private	Hardjamukti
		B2w	NHC	Gurya Sunyaragi Permai
C	Semarang	C1	NHC	Banyumanik
		C2	private	Plamongan Indah
D	Malang	D1	NHC	Sawojajar
E	Mataram	E1	NHC	Sweta Indah
		E2	private	Pagutan Permai
F	Makassar	F1	NHC	Panakkukang
		F2	private	Bumi Tamalanrea Permai
G	Banjarmasin	G1	NHC	Beruntung Jaya
		G2	private	HKSN

Finally, the average amounts of CO_2 emissions (kg-CO_2 per household per year) caused by domestic energy usage, transportation and building material consumption were summarized in table 5. Emissions caused by domestic energy usage are now larger than that from other sources. Emissions caused by consumption, which was calculated by summing up the total amount of each building material multiplied by the unit amount of its emissions, and total life cycle emissions is subdivided by the lifetimes of houses. This value is relatively low, because the two major materials, timber and brick, are biomass based.

Table 5: Summary of Emission from Households in Each City Surveyed

City	Samples	Domestic	Transportation	Building Material	Total
Bandung	200	2,390	1,455	108	3,868
Cirebon	200	1,891	751	76	2,708
Makassar	100	2,262	821	75	3,159
Banjarmasin	100	2,120	1,322	61	3,502
Semarang	100	1,976	1,092	72	3,139
Mataram	100	1,870	1,223	99	3,192
Malang	100	2,087	1,179	85	3,350

Unit: kg-CO_2/year/household

Details of 4 complexes in Bandung and Cirebon cities (tabulation of 399 effective responses to the questionnaires) are described in (1)-(4). Results of surveys of building material factories are also integrated in (4). (5) and (6) describe the results of analysis of satellite images elaborated in Japan of Bandung and Cirebon cities, covering Sarijadi Complex (A1) in Bandung City and Harjamukti Complex (including Gunung district, B1) in Cirebon City. These two districts were further studied to plan models in the latter half of this research.

(1) Basic Attributes of Respondents

In Bandung city, Sarijadi complex (A1), a high percentage is on pensions, while in Antapani complex (A2), the enterprise owner rate is high. Both complexes were developed by the National Housing Corporation. In Cirebon city, Harjamukti complex (B1) was developed by the Corporation, while the Gurya Sunyaragi Permai complex (B2) was developed by a private developer.

Table 6: Occupation of Respondents (Unit: %)

Occupation	A1	A2	B1	B2
Professor	1.0	1.0	2.0	2.0
Teacher	1.0	0.0	3.0	3.9
Housewife	1.0	3.0	4.0	2.9
Salaried employee	15.2	16.2	42.4	25.5
Student	1.0	0.0	0.0	1.0
Pension	37.4	13.1	11.1	11.8
Official	18.2	24.2	25.3	17.6
Military/Police	0.0	0.0	2.0	2.0
Owner of firm	16.2	41.4	10.1	31.4
Others	9.1	1.0	0.0	2.0
Total	100.0	100.0	100.0	100.0

Table 7: Average Monthly Income of Households

Complex	Maximum	Minimum	Average
A1	90,000	3,000,000	1,168,757
A2	500,000	15,000,000	2,193,917
B1	350,000	4,000,000	1,597,556
B2	200,000	5,000,000	1,303,535

(Unit: Rupiah)

Table 8: Number of Family Members

Complex	Maximum	Minimum	Average
A1	1	10	3.9
A2	2	7	4.0
B1	2	8	4.1
B2	1	8	3.5

(Unit: person/households)

(2) Transportation

Table 9-10 show the numbers of vehicles owned. In Antapani where many owners of private firms live, the highest average, 0.72 automobile/household, was identified, while relatively fewer motor bicycles were owned compared with other complexes.

Table 9: Number of Automobile Owned (4 Wheels)

Complex	Minimum	Maximum	Average
A1	0	1	0.15
A2	0	2	0.72
B1	0	1	0.24
B2	0	1	0.18

(Unit: vehicles/household)

Table 10: Number of Motor Bicycle Owned (2 Wheels)

Complex	Minimum	Maximum	Average
A1	0	6	0.89
A2	0	3	0.74
B1	0	3	0.83
B2	0	3	0.64

(Unit: vehicles/household)

Table 11: Choice of Transportation within Complex

Transportation	A1	A2	B1	B2
Vehicle (4 wheels, 2 wheels)	4.4	9.1	38.7	7.4
City Bus	60.3	4.5	0.0	1.1
Ojek (rear seat of motor bicycle)	7.4	27.3	3.3	0.0
Becak(manpowered service)	0.0	46.6	16.7	25.3
On foot	27.9	12.5	43.3	66.3
Total	100.0	100.0	100.0	100.0

(Unit: %)

The questionnaire asked about frequency, distance and method for travel for each purpose. Choice of transportation depends not only on income, but also the spatial arrangement of each complex (site plan) and bus lines. "Ojek" is a service that transports passengers on the rear seats of motor bicycle for a fee.

Table 12: Choice of Transportation for Each Purpose

Method / Destination	Job	School	Market	Supermarket	Shops
4 wheel vehicle	3.11	1.3	9.9	9.8	19.5
2 wheel vehicle	46.2	5.0	28.3	17.5	19.5
Urban bus	19.7	0.4	48.3	42.2	47.2
Ojek (rear seat of 2w)	0.0	0.0	0.4	0.4	0.5
Becak (manpower)	0.7	0.0	0.4	2.8	4.6
On foot	1.7	93.3	11.2	26.7	8.7
Others	0.7	0.0	0.9	0.8	0.0
Total	100.0	100.0	100.0	100.0	100.0

(Unit: %)

Automobiles are used mainly for commuting to workplaces, while buses are utilized for shopping.

Table 13: Consumption of Fuel for Transportation

Complex	Number	Maximum	Minimum	Average
A1	20	2	120	39.35
A2	32	11	200	61.11
B1	71	0	180	32.15
B2	32	10	120	32.47

(Unit: Liters per month)

Number of answers (N) shows families that own an automobile and/or a motorized bicycle. In Antapani complex (A2) where the number of automobiles owned is high, a household consumes 61 liter of fuel per month, causing the emission of 150kg-CO_2 per month. This amount is comparative to the emission caused by consumption of electricity by high-income families as described later.

(3) Domestic Consumption of Fuels and Energy

a. Electricity

In Indonesia, total consumption of electricity is, as shown in table 14, rapidly increasing. Usage of lamps and televisions, and air-conditioning of houses largely contribute to this increase. The emission occurs in power plants (indirect emission), however, it depends on the city plan and the design of its houses.

Table 14: National Consumption of Electricity, by Sectors

Sector	1997	1998	1999	2000	2001	2002	2003
House	22,739	24.866	26,884	30,563	33,340	35,836	37,775
Office	7,250	8,667	9,330	10,575	11,395	11,845	13,224
Factory	30.709	27.985	31,336	34,013	35,593	36,831	36,497
Others	3,554	3,743	3,780	4,012	4,192	2,575	2,945
Total	64.252	65,262	71,332	79,164	84,520	87,088	90,441

(Source: National Power Corporation, Unit: GWh)

Air-conditioning will be a major issue and a choice in the near future. One option is to retain natural ventilation and enhance the heat isolation of roofs, ceilings and walls. Other options are to make houses more air tight, by introducing aluminumsashes etc., or to enhance the efficiency of air conditioning.

As for lighting, the wider use of “energy saving lamps” is being promoted, and a CDM project is being studied. The reduction of power plant emissions s is also being as potential CDM projects.

CO_2 emission from power plants and their efficiency between 1990-2000 are shown in table 15.

Table 15: National Demand for Electricity and CO_2 Emissions

Year	Generation (GWh)	CO_2 Emissions (Million Ton-CO_2	Emission coefficient (kg-CO_2/kWh)
1990	32,293.2	24.20	0.749
1991	37,290.5	28.04	0.752
1992	39,422.6	30.05	0.762
1993	38,608.0	26.52	0.687
1994	44,668.5	34.21	0.766
1995	52,832.4	35.34	0.669
1996	57,523.5	54.69	0.951
1997	68,924.4	51.10	0.741
1998	74,461.0	50.92	0.684
1999	80,023.8	55.32	0.691
2000	83,503.5	60.07	0.719

(Source: National Electric Power Corporation, Min. of ESDM)

Electricity consumed by a household largely depends on its income, and is tabulated as table 16 for Bandung.

Table 16: Income and Consumption of Electricity

Monthly Income (Rp.)	Significant Answer	Monthly Expenditure for Electricity (Rp)	Monthly Consumption of Electricity (kWh)	Estimated CO_2 emission (kg-CO_2 per month)
2,000,000<	30	105,600	196	142.36
1,000,000 - 2,000,000	81	87,938	170	122.23
500,000 - 1,000,000	57	64,066	126	92.03
0 - 500,000	23	57,957	124	89.16

b. Fuels

Average monthly consumption of fuels has been tabulated in table 17.

Table 17: Types of Fuels and Related Emissions (Bandung and Cirebon Cities)

Type of fuel	Monthly consumption	CO_2 emission coefficient:	CO_2 emission (kg-CO_2/household/month)
Gas (piped supply)	26.3 m^3 / household	2.031kg-CO_2 / m^3	53.54
LPG (tank)	15.9kg / household	2.999 kg-CO_2 / kg	47.74
Kerosene	30.9 Liter / household	2.54kg-CO_2 / Liter	78.49
LPG + Kerosene	(Composite)	(For each)	94.84

Heating in the cold season is unnecessary and electric lamps are already popular. Therefore, domestic consumption of fuels is mainly done for cooking. There are 4 types, namely (1) urban gas service, (2) LPG, (3) kerosene and (4) mixed use of kerosene & LPG

The amount of fuels consumed for cooking does not depend on the income of each household or its total floor area, but on the kinds of fuels it uses.

Emission by production of electricity consumed exceeds emission by fuels, and the higher the income of a household, the larger the emission caused by production of electricity. This trend indicates the future of the domestic consumption of energy.

(4) Building Materials

Many discussions must be conducted to gain a common understanding of the system boundary applied to evaluate emissions through the consumption of building materials. An evaluation considers the total life cycle of each material. A large part of such emissions takes place outside of housing complexes, and are, therefore, indirect emissions. However, if only direct emissions in the complex are considered, materials that cause overall larger emissions through their life cycles will be mistakenly selected. Therefore, to consider the evaluation of alternative plans and designs, the introduction of the concept of life life cycle analysis was attempted.

a. Method

Secondary data is not available in Indonesia. Therefore two approaches, namely a field survey of houses, and a survey of production processes and transportation of building materials, were undertaken.

a-1. Building Material Factories to Identify Basic Unit

Conventional units used to measur amounts of materials (area, volume, weight, number) were used for each kind of building material to evaluate the specific amount of CO_2 each emits. These emissions occur through both chemical processes during production and supplying heat for production. Efficiency of production processes and treatment of waste from production processes must be monitored.

Building materials remain as part of every house for a certain period (lifetime). After demolition, it is recycled, disposed of, or treated. Life cycle emission means the total emission through this process. In Japan, a database of life cycle emissions of building materials is being elaborated.

a-2. Amount of Materials Used in Houses

A field survey of houses was done to measure the amount of each kind of material used to build a house. The measurements were done by measuring and summarizing the kinds and amounts of material applied to each part of a house. After occupation, houses are usually expanded and altered. In most of the surveyed areas, completed houses (not empty land prepared for construction of housing) were handed over (sold) to the inhabitants. Therefore, the results of the field survey were tabulated to separately identify the amounts of the materials of original parts and of materials of the expanded parts. Usually, original houses were similar (one type or a few types), and the design drawings are often available. However, after they are occupied, they are expanded in different ways, so it is easy to distinguish the original part and extended part.

a-3. Lifetime of a House

No secondary data comparable to real-estate taxation data in Japan are available. Therefore, years of construction and years of expansion were obtained by the questionnaire survey. However, the number of cases of total renewal is nothigh; partial demolition and replacement/expansion are more popular. We estimated the lifetime as c.a. 15 years.

$$E = \Sigma (M_i \times U_i) / Y$$

E: Emission per year M_i: Amount of material i

U_i: Unit emission of material i Y: Service life (years)

The calculated E (averaged annual emission) has the same dimension with annual emissions by domestic energy consumption or transportation, so it is possible compare or sum up with those emissions.

b. Results of the Survey

To study the major building materials, factories were surveyed to identify the production process and the fuels, energy and raw materials consumed to produce one unit of final product. In general, it was easier to gain access to small factories producing red bricks, roof tiles and lime, but more difficult to approach large industrialized factories producing cement, steel etc. to request the disclosure of information.

b-1. Production Process

1) Cement

In order to produce 1 ton of cement, a producer uses 1.1 ton of limestone ($CaCO_3$), 0.2 ton of clay and 0.1-0.2 ton of other materials. In Japan, to produce 1 ton of cement, 0.449 ton of CO_2 is generated by the chemical process and 0.334 ton of CO_2 by burning fossil fuels. In developing countries, the figures are almostidentical, however, due to their lower efficiency, emission of c.a. 0.9 ton of CO_2 is estimated as necessary to produce 1 ton of cement [5)].

250kg of cement is contained in 1 m^3 of concrete.

2) Red brick

Ways of producing red brick are different among regions.

In Jawa Island, wet clay is pressed in boxes, then dried and logged under a thatched roof. The porous logs are filled with rice husk i then burnt. At the 8 factories surveyed in Nagrek and Sapan, 20,000-30,000 pieces of brick are produced by each burning. To do this, 300-400 sacks of rice husk (6,000-8,000kg) are burnt. Experiments in the laboratory of a ceramic factory have shown that burning 1g of rice husk emits 0.24g of CO_2. Therefore, production of 1 piece of brick emits 70g of CO_2. Rice husk is a biomass fuel, and it is usually disposed if it is not used to produce brick. Therefore, this can be exempted from the evaluation.

The size of the red bricks is 60×120×230mm and their weight is c.a. 1,200g. Usually a brick wall is a single layer that is 120 mm thick. 1 sq-m of brick wall contains c.a. 80 pieces of brick with bonding mortar.

In Sumatra, stoves burning fire wood are widely used.

3) Roof tiles

Wet clay is pressed, dried and burnt to produce roof tiles: a process basically similar to brick production. Roof tiles are popular in Jawa Island, while corrugated zinc plates that are easier than roof tiles to transport are more popular in other islands. All 8 of the factories surveyed in Jatiwangi in West Jawa Province burn firewood. To produce 1 piece of roof tile, 0.0014m^3 of firewood is burnt, emitting 183 grams of CO_2. This is deemed to be biomass based fuel.

4) Tiles

Tiles are widely used for floors. Fossil fuel is burnt to produce them. Surveyed factories burn 0.6 liters of kerosene to produce a piece of tile with dimensions of 300*300*6mm, emitting 1.61kg of CO_2.

5) Timber

Generally, 1 ton of dry timber contains c.a. 0.5 ton of carbon, that is equivalent to 1.8 tons of CO_2. Amounts are usually counted in terms of cubic meters, however the weight per unit volume varies widely between different kinds of trees. Both local light cheap timber (e.g. Albasia Farcata) and heavy strong timber transported from Kalimantan (Borneo) are used. Different kinds of wood suited to specific parts of a house are used. It is difficult to identify the average emission caused by the cutting and transportation of the timber.

6) Steel bars

Steel bars used for the concrete frames of brick houses are mostly made of second hand steel produced by informal methods in corners of large factories that mainly produce new materials. It was difficult to get data for this process.

b-2. Survey of Houses

Floor plans of surveyed houses were sketched, and dimensions of each room and major materials used for each part of the room (floor, wall, ceiling and roof) were noted. In the tabulation, usage, floor area and material for each part were coded for each room. The usages classified include terrace, paved open space, fence, guest room, living room, dining room, bedroom, kitchen, bathroom, storage, garage, pond etc.

Table 18-20 show the major materials for floors, walls and roofs. The percentage of e.g. brick for walls means the percentage of rooms whose dominant wall material is brick.

Table 18: Share of Building Materials for Floors

Material	Bandung	Cirebon
Ceramic Tile	1006	1171
Cement Tile	222	93
Cement Tile + PC Tile	17	8

(Unit: Number of rooms)

Table 19: Share of Building Materials for Walls

Material	Bandung	Cirebon
Brick	1533	1242
Concrete Block	132	301
Concrete / Concrete Block	22	30
Timber	8	75
Brick / Hard Board	8	1

(Unit: Number of rooms)

Table 20: Share of Buildi ng Materials for Roofs

Material	Bandung	Cirebon
Roof tile	652	705
Asbestos	363	1,240
Zinc plate	10	5

(Unit: Number of rooms below)

c. Stock Effect

The present average total floor area of surveyed houses is far larger than their initial floor areas when they were sold andoccupied, due to the their subsequent expansion by their occupants. Fig. 4 shows the increase of the average floor area between the initial development and present time. The Y-axis shows the average total floor area, while the X-axis show the years since construction. The increase of the average floor area in each complex is shown by two dots bound by a line.

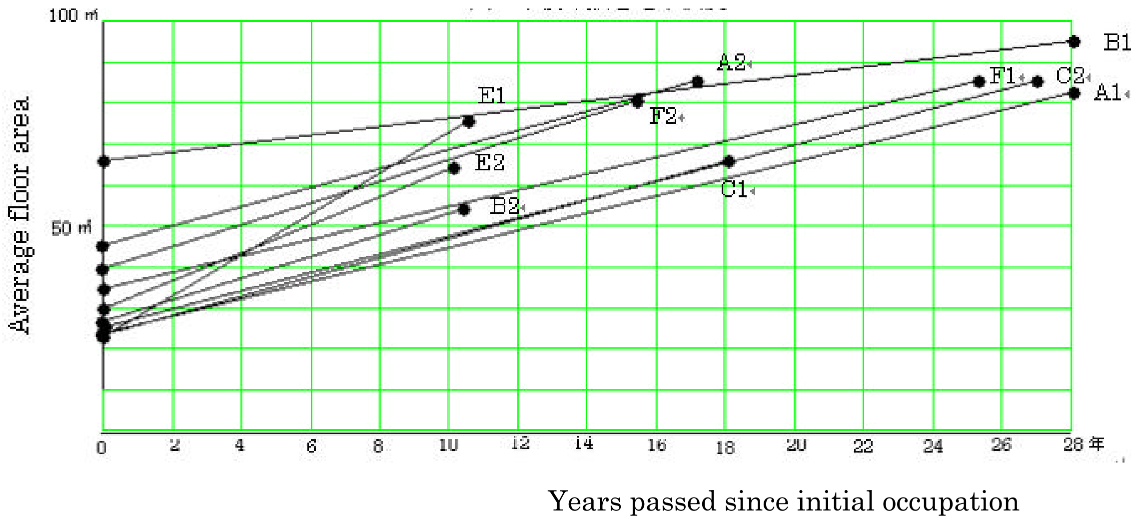


Fig.5: Original Average Floor Area and Current Average Floor Area

In general, the older a complex, the larger the increase of its average floor area, because the individual occupants expand them whenever necessary. However, no averages exceed 100 m2. This can be considered to design an image of future housing.

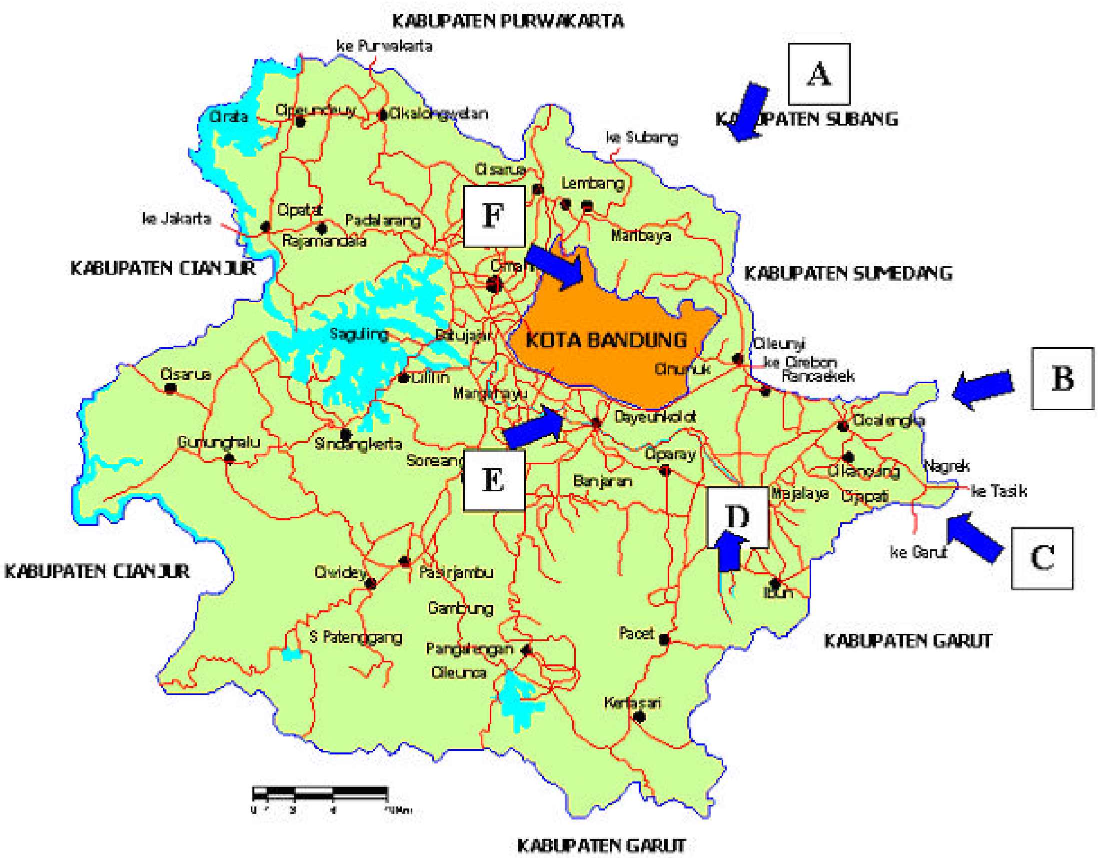
Also, expanded parts have larger area than the original part, and consequently bricks, the dominant material of walls of expanded part, are the most popular material of walls of overall houses. Bricks have neutral stock effect, while concrete blocks that dominate the original part have negative carbon stock effect.

It is technically difficult to precisely measure the amounts of applied materiala by a field survey. Fortunately, the materials used to build the original part are precisely recorded in the design documents for standardized types. Based on the material table for Type-36 (36 sq-m), 21kg of timber (roof structure and sash), 48kg of cement (31kg for structural member and 17kg for finishing) are applied for each 1 m2 of floor area. This principle can be also be applied to roughly estimate extended parts.

The estimated stock effect of a house with 90m2 floor area is +3.4Ton-CO_2 due to the timbers applied, and –1.9Ton-CO_2 due to the cement applied.

d. Survey of Distribution Routes of Building Materials

Transportation also causes emissions, mainly due to the fuels for trucks. Spatial distribution of factories of building materials, and transportation distances were surveyed in Bandung and Cirebon cities.



Explanation of codes（A～F show main roads connecting Bandung city to surrounding region）
A：From Northern (Subang) ＝Timber, bamboo and volcanic ash
B：From Eastern (Cirebon, Sumedan)＝Sand, timber, brick, roof tile and cement
C：From Eastern (Garut, Tasik)＝Sand, brick and timber
D：From Southern(Ciwidai)＝Brick, timber, bamboo, ready mixed concrete
E：From Western(Batujajar)＝Precast concrete, concrete block, cement roof tile, sand, PC-tile
F：From Western(Jakarta, Tangerang, Bekasi)＝Lime, cement, steel, marble, roof tile, asbestos, paint etc.

Fig.6: Distribution Routes of Major Building Materials in Bandung City

A：Retail shops（0～1 km）
B：Wholesale shops（1～5 km）
C：Factories（Cement、Brick、Roof tile）、Excavation Site sand and stones、Timber factories（5～2 5 km）

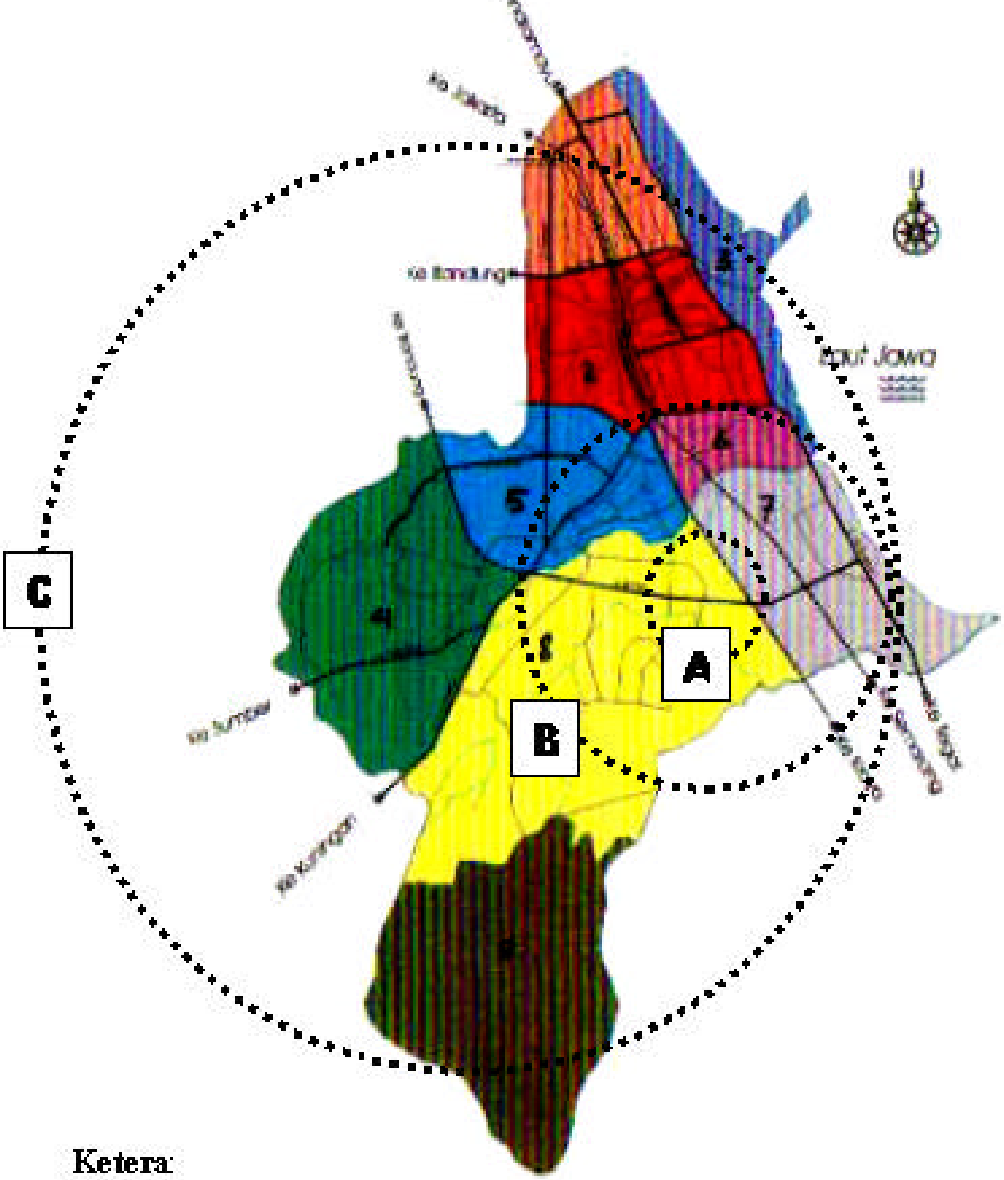
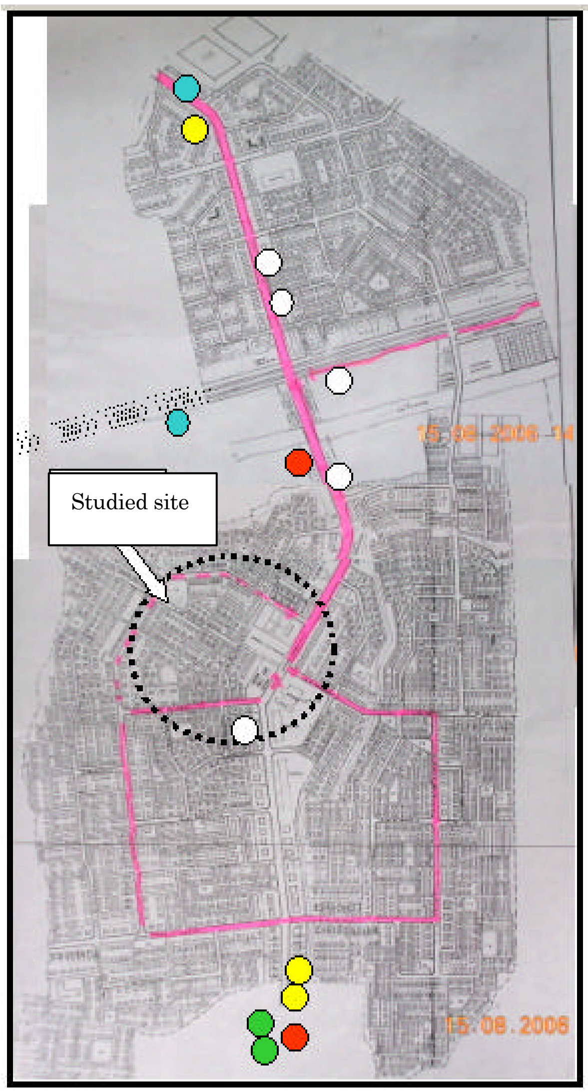


Fig.7: Distribution Routes of Major Building Materials in Cirebon City



White：Building material in general

Blue：Timber

Yellow：Sash

Green：Steel

Red：Sand and rocks

Fig.8: Building Material Shops nearby Surveyed Complex in Cirebon City

However, further studies are needed to identify the quantity of emissions caused by transportation of materials

.

(5) Green Coverage Ratio

Urban greenery, which creates comfortable shaded space along the streets and within individual house lots, is an important characteristic of tropical cities. It also plays a role as a carbon sink, which is proportional to the green coverage (canopy). According to IPCC (2002), 2.9Ton-C / hectare of canopy / year is the default value for an urban area in a temperate Zone*). Field surveys can easily quantify the trees (kinds and size, that are related to the stock of carbon) in the districts, but it is more difficult to measure the canopy area. However, recent multi-band satellite images with high resolution (1m by IKONOS, 0.6m by Quick Bird) now permit measurement of the green coverage ratio. It is still difficult to distinguish the canopy of high trees from other greenery like bushes, agricultural fields, or open grass-covered space.

We attempted this measurement in the "Sarijadi" housing complex in Bandung city, where we conducted a field survey to estimate the current CO_2 emission and also planned and designed alternative forms of future human settlements. We used IKONOS Pansharpen data (4 band) (Fig.1), with resolution of 1.0m that was taken in May 6, 2001, 03:13 GMT.

*) "Good Practice Guidance" by IPCC, Chapter III, D. Nowak 2002.

a. Land Use Classification

At first we separated the greenery from other land use (roof, water etc.) by applying NDVI**), and classified the greenery into 6 categories: <C1>Bright Tree <C2>Dark Tree <C3>Bright Crop <C4>Dark Crop <C5>Grass <C6>Bush, and chose 56 obvious cases from a wider area in the image to obtain the teacher data.

**) Normalized Difference Vegetation Index
NDVI = (Band4 – Band3) / (Band4 + Band3) where Band 4: Infra Red, Band 3: Red

b. Analysis of Teacher Data

The spectrum of each category C1-C6 was statistically calculated as shown in Table 21.

Table 21: Statistic of each Category of Greenery

Category	Average (standard deviation)			
	Band 1 (blue)	Band 2 (green)	Band 3 (red)	Band 4 (ultra red)
C1 Bright Tree	346.5(25.0)	358.2(37.6)	251.0(43.0)	541.7(94.8)
C2 Dark Tree	319.7(23.7)	316.8(34.1)	204.7(36.5)	382.0(76.3)
C3 Bright Crop	347.5(13.4)	371.3(20.7)	258.9(23.5)	682.2(39.4)
C4 Dark Crop	325.8(12.1)	332.7(17.1)	233.1(18.0)	389.0(58.6)
C5 Grass	364.6(11.8)	404.9(20.2)	302.5(24.1)	634.8(62.6)
C6 Bush	346.5(25.0)	358.2(37.6)	251.0(43.0)	541.7(94.8)

The value of each band: 0-2047 (11 bit)

c. Judgement of Each Dot in the Target Area

Each pixel that had been identified as greenery within the target area was classified into the six categories (C1-C6) through maximum likelihood estimation. A pixel identified as C1 or C2 was deemed to be the canopy of trees. A total of 5,771 pixels were classified as C1 or C2from among the total of 52,028 pixels that formed the target area. Therefore, 11.1% of the total area was classified as canopy of trees. This is much larger than the open space on the site, which has been decreased by the expansion of occupied houses, as identified by a field survey performed in 2005 by RCHS. That means that trees on the very limited open space spread their canopies over the roofs, creating shade and absorbing CO_2,even in the densely inhabited area.

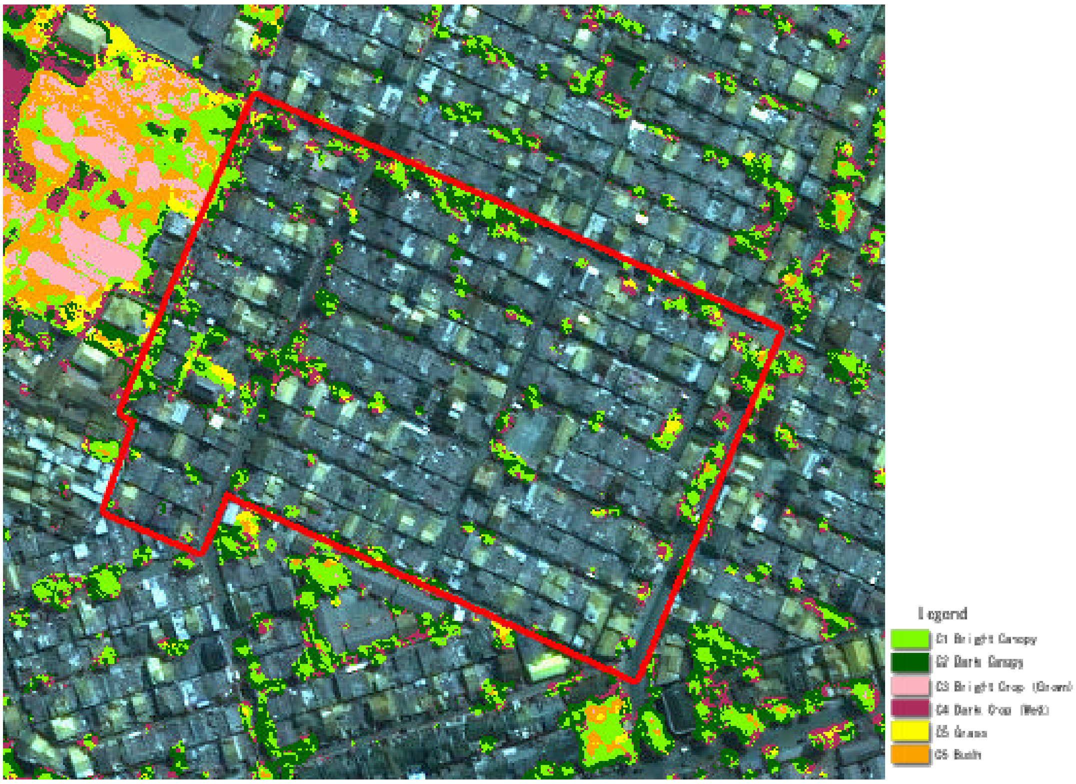


Fig.9: Identification of 6 Categories of Greenery in the Target Area (Bandung -Sarijadi)

d. Comparison with the Results of Visual Identification

In order to check and evaluate the accuracy of the classification, we also had an operator try to perform a visual classification. This method, which considers not only the color, but also the texture of each land use, requires greater skill and man-power. This method identified 5,176 pixels (9.9%) as the canopy of trees. The result is quite similar to that obtained by classifying each dot. We also tried to judge the teacher data used to determine the parameters. The result is shown in table 22. For example 8.3% of the teacher of C1 is misjudged as C3 and 5.4% of the teacher of C4 is misjudged as C2. The similarity of the spectra of the different categories is probably the cause of the errors.

Table 22: Errors of Classification of the Teacher Data

(%)

		Teacher						
		Other	C1 Bright Canopy	C2 Dark Canopy	C3 Bright Crop (Grown)	C4 Dark Crop (Wet)	C5 Grass	C6 Bush
Maximum Likelyhood Classification	Other	55.4%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%
	C1 Bright Canopy	10.4%	63.6%	13.0%	2.0%	5.4%	2.9%	5.3%
	C2 Dark Canopy	13.2%	14.4%	72.8%	0.0%	4.0%	0.7%	0.1%
	C3 Bright Crop (Grown)	1.1%	8.3%	0.0%	83.8%	0.0%	6.1%	17.3%
	C4 Dark Crop (Wet)	11.2%	2.9%	10.5%	0.0%	89.4%	1.5%	0.3%
	C5 Grass	6.3%	2.7%	0.6%	4.4%	0.1%	77.9%	3.4%
	C6 Bush	2.3%	8.2%	3.0%	9.8%	1.1%	10.8%	73.8%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

(6) Land Shape

Land shape is another indicator important in the consideration of climate change. Considering the impact of sea level rise, the detailed contour or altitude of an area is an important factor in planning for the future. On hilltops, slopes eliminate transportation modes . At first, we tried to obtain the contour from a digital map from BAKOSURTANAL, however it was too rough for district planning (12.5m pitch of contour lines, or 50m mesh of DEM).

Direct measurement performed for this kind of study (not an actual urban development) is also quite disturbing to the inhabitants. Fortunately, satellite images obtained from the ALOS-PRISM sensor provide images from with three different camera angles, namely front view, straight view and back view, all available in the library images.

Analysis of normal stereo air-photos is one established photogrametry technology. Since the 1990s pattern-matching of one stereo pair is performed automatically by computers. However, working on stereoscopic satellite images is a somewhat new field developed since ALOS-PRISM data became available in 2006. The most important feature of the PRISM sensor is its ability to shift the scanning angle forward (+23.8 degree) and backward (-23.8 degree). That means that one point on the earth is portrayed from three different angles (positions of satellites), enabling three pairs for stereoscopic viewing (front-straight, straight-back, front-back). The altitude of the orbit is 691.65km. We analyzed the monochrome (single band) images with level of processing IB2R (geo reference), provided in the form of Geo-TIFF format. We used an image of Cirebon city taken in 2006/07/04, and an image of Bandung city taken in 2006/08/07.

We used "Leica Photogrammetry Suite 9.1" software for the analysis, using the function (sensor model) of "Generic Pushbroom".

a. Control Points and Tie Points

In order to identify the coordinates, we chose the control points randomly from the straight image and identified the x and y coordinates obtained from the attribute data of the image, while obtaining their altitudes from the 90m mesh DEM data from SRTM (Shuttle Radar Topography Mission, with mesh by 90m).

We also automatically selected tie points from the images needed for image matching (Table 3).

Table 23: Number of Control Points and Tie Points

Area	Number of control points	Number of tie points	Total
Bandung	24	19	43
Cirebon	25	23	48

b. Image Matching

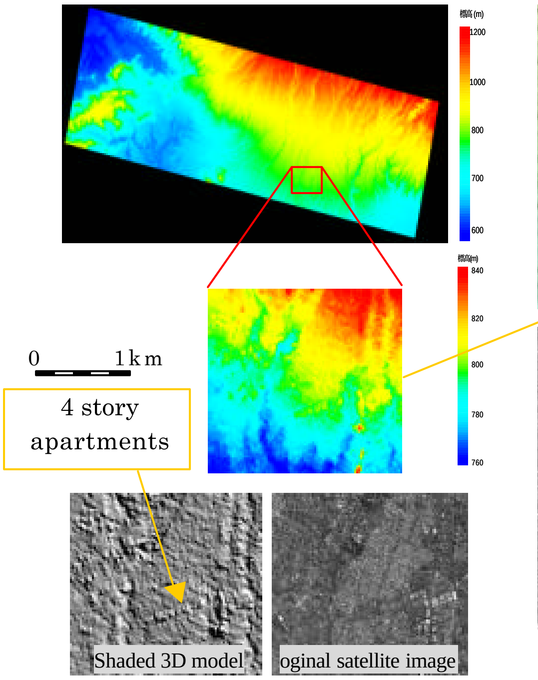
DEM was obtained through image matching between each pair from three images, and we chose the altitude data from one of three pairs that resulted in the least error at each dot.

The three important parameters for this matching are <a> the area for searching <b> the windows size for matching, and <c> lower threshold of correlation coefficient. Through several trials, we came to the conclusion that the following parameters gave the best result (Table 4).

Table 24: Optimal Parameters for Matching

Area	Area for searching (pixels)		Size of matching window (pixels)		Lower limit of coefficient
	X	Y	X	Y	
Bandung	31	3	3	3	0.5
Cirebon	11	3	7	7	0.5

At first, we obtained 7.5m mesh DEM of, and re -arranged it to 10m mesh for convenient usage.



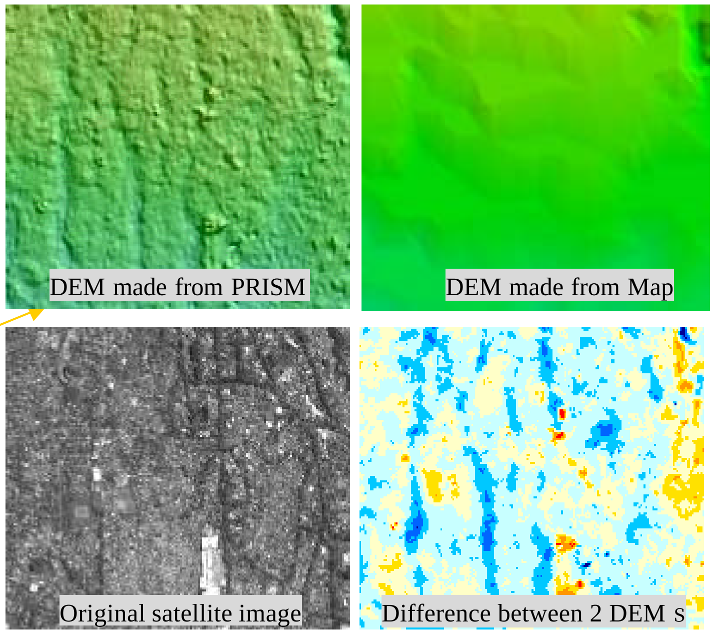


Fig.11: Comparison of DEM from PRISM & Geographical Map 1:25,000

Fig.10: The DEM Data obtained for Bandung

The figure 10 shows that the land shape obtained from PRISM data is far more detailed than that obtained from the map (1:25,000) and more useful for urban planning activities (Fig. 11-12).

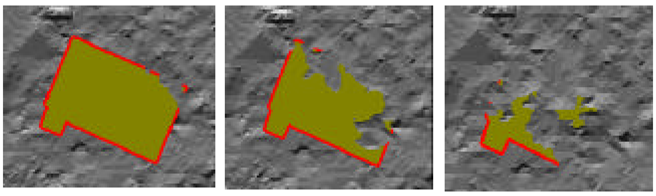


Fig.12: DEM around Target Area

Fig. 13: Photo of the Target Area

A similar analysis was also undertaken in Cirebon (Figure.6)

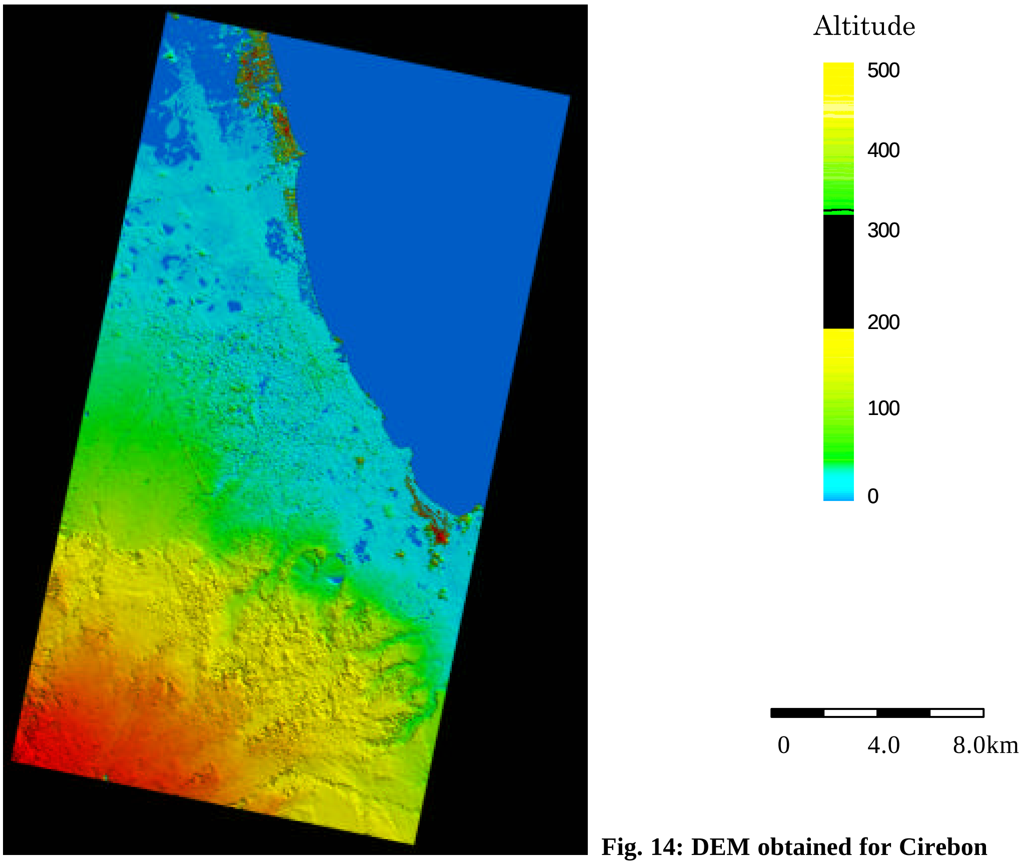


Fig. 14: DEM obtained for Cirebon

The data clarified the altitude of the target area for planning and design, and it was adequately high and free from the impact of the forecasted rise of the sea level.

4. Planning Alternative Future

Two previously surveyed model districts within housing complexes in Cirebon and Bandung Cities were selected. . Cirebon is a coastal city with low and flat land and a hot climate. Bandung is an inland city with high and sloping land conditions (altitude is 700-800m above average sea level) and cooler climate.

(1) "Gunung" District in Cirebon City

a. Existing Condition of the District

The target area is selected from Gunung Complex, a subdivided part of Harjamukti Complex developed by the National Housing Corporation. The area includes two communities coded RW-08 and RW-09. This site is located on the inland side of the inner part of Cirebon City. The 18m wide main street runs north-south in the eastern side of the district. A market, local government office, and schools are located along this street. The western part of this district is a housing complex surrounded by an 11m wide access road served by public buses.

The National Housing Corporation invited a Dutch architect to plan this area where houses were constructed in 1979.

Existing conditions in the district are described in Table 29. The two communities occupy a total of 5.47 ha, and the target area (for model planning) is 4.1 ha with 1,090 inhabitants and 273 houses.

Table 25: Existing Condition of the District including the Target Area for Model Planning

RW	RT	Population	Households	Houses		
				Total	Occupied	Empty
08	4	529	128	221	209	12
09	7	808	221	202	191	11

The results of analysis of ALOS stereo satellite images show that the altitude of this district is between 8-16m above average sea level, higher in south-west part, and lower in north-east part. When people walk in this district, they obviously do not sense this slope (less than 2%).

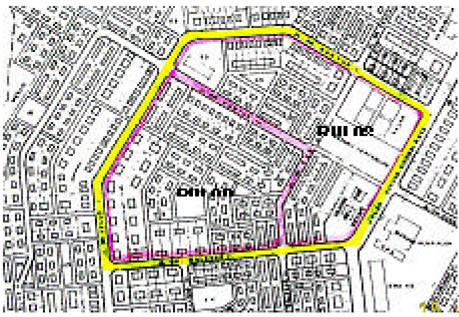


Fig 15: Site Plan of Existing Area

b. Alternative Planning for the Future

Four alternative plans were prepared as 3D data, to be used to give a presentation from the viewpoint of social-cultural aspects at the workshop attended by non-engineer discussants and resource persons.

The four alternative plans for the study area in Cirebon are summarized as follows:

Table 26: Concept of Planning Each Alternative for Gunung District in Cirebon City

Designer	Concept	Site Plan	House Unit
1. Arief	High Rise + Low Rise + Open Space	Renewal to High Rise in Center and Low Rise in Fringe	Maisonette
2. HK	High Rise Artificial Land	Preserve Housing Area Renewal Business Area along Street	High Rise Complex Flat House & Business
3. Aswin	One Tree for Each House	Preserve Existing Lot	Two storied, with center court
4. Sigit	One Tree for Each House	Renewal to Grid Plan	Two storied, with center court

Alternative 1: Existing house lots are rearranged, plotting core type apartment houses in the center and maisonette-units in the fringe. Apartments can create open space on the ground. Maisonettes also achieve more intensive land use than exiting single storied houses by increasing open space. The open space this creates will be covered with greenery. This plan does not involve changing the existing business areas along the street.

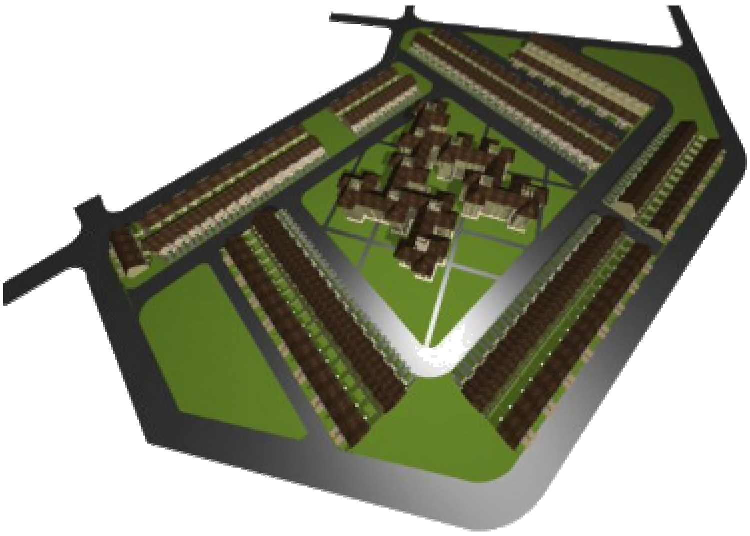


Fig.16: Site Plan

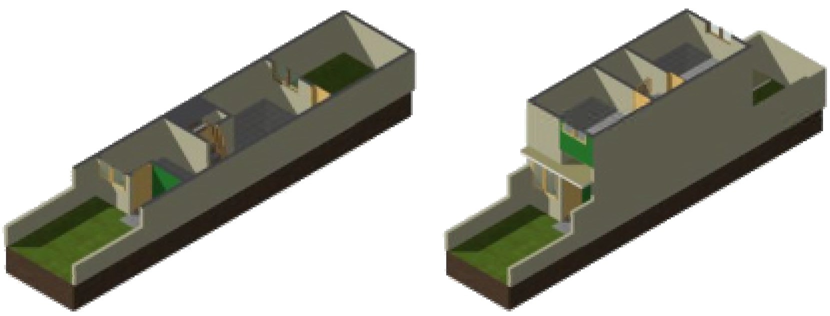


Fig. 17, 18: Dwelling Unit of Maisonette

Fig.19: Apartments in the Center

Fig.20: Landscape from the Ground

Alternative 2: Considering the future decrease of land in the coastal zone caused by the rising sea level, this plan provides high-rise artificial land for both housing and business purposes through the redevelopment of existing business areas along the street while preserving the low rise housing area. The new artificial land also provides greenery on its top. The steel superstructure will last a very long time (ideally forever), while in-fill substructures (for housing and business use) can be altered to adapt to changing social needs. After all the main streets are redeveloped, the new landscape will resemble low-rise housing areas surrounded by green hills. This intense and mixed land use will prevent an increase of trips that will result from the horizontal expansion of cities that is now occurring.

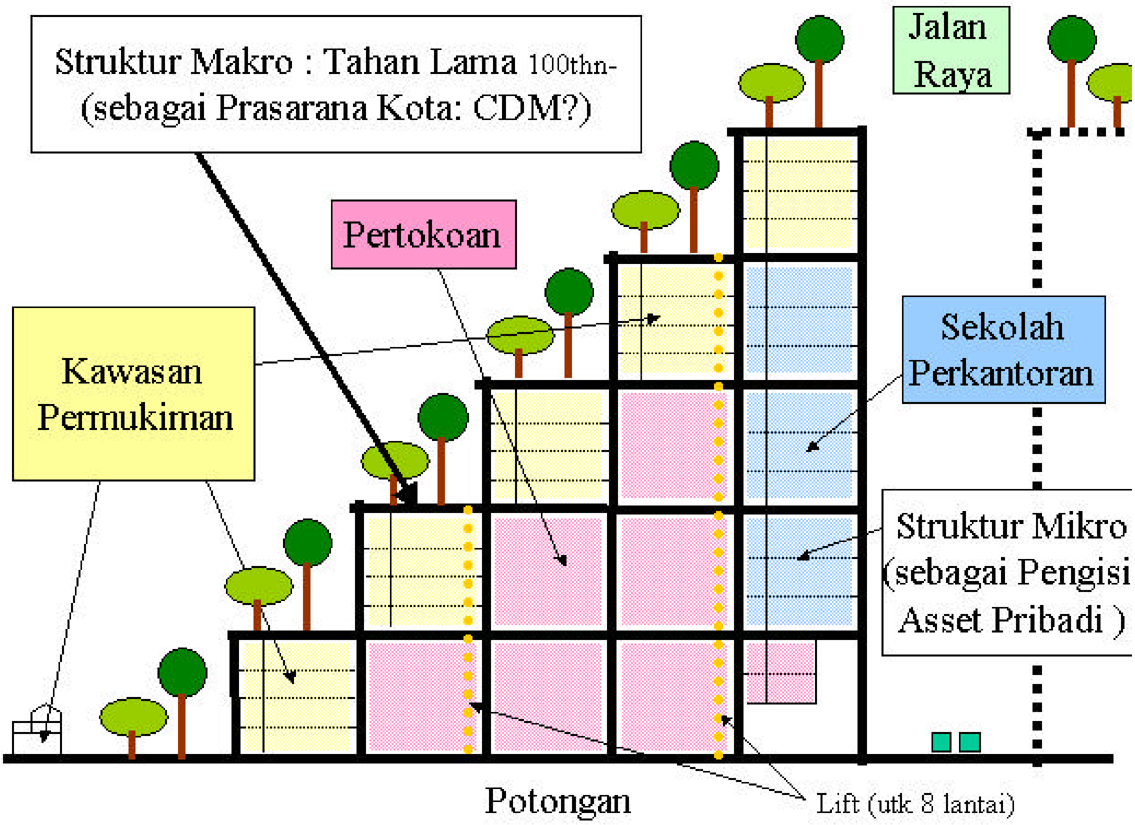


Fig.21: Cross Section showing the Concept

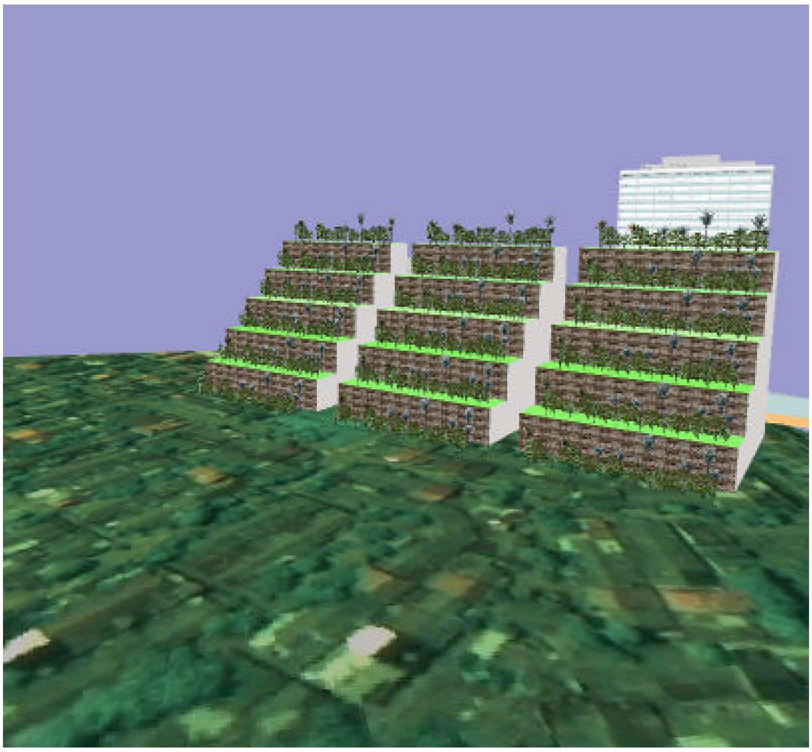


Fig.22: Birds Eye View

Fig.23: Landscape from Street, showing the Greenery on the Top

Alternative 3: A two-storied courthouse is proposed in this plan. It promotes a very simple and clear concept of planting a family tree in the central court. It will also promote a public movement to plant trees in entire urban areas.

Fig.24: Description of the Concept

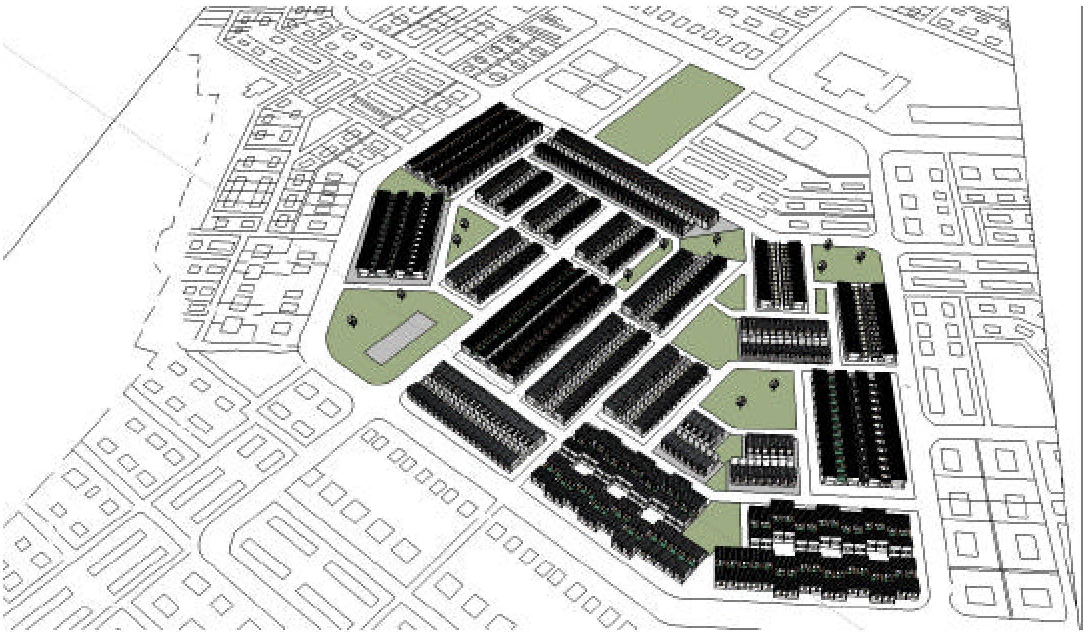


Fig.25: Birds Eye View

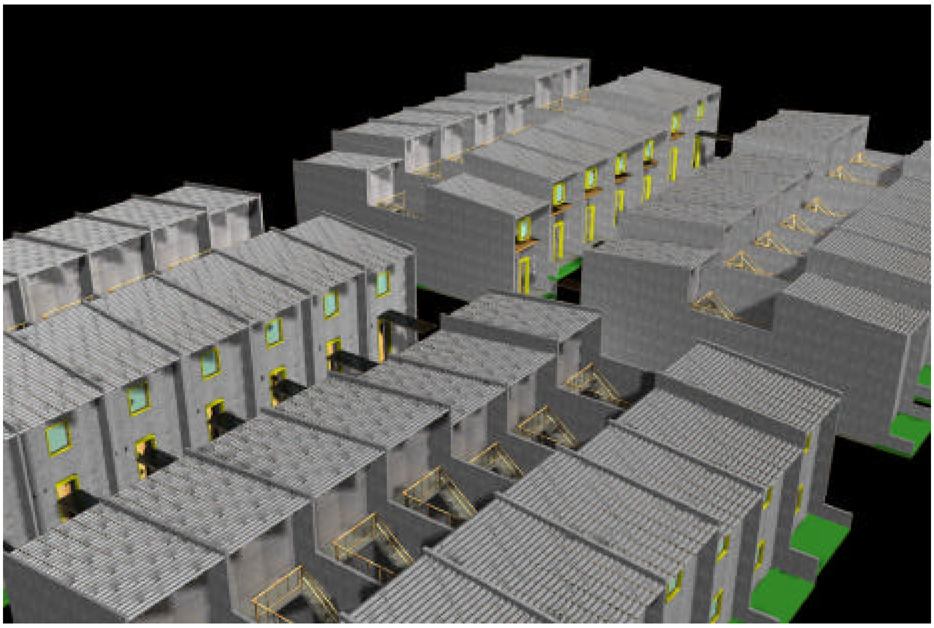


Fig. 26: 3D Images of the Environment

Fig. 27: Landscape

Alternative 4: This plan, which is a further development from (b-3), rearranges the spatial order from the existing order to strict grid planning. The grid planning will more efficiently use natural wind for ventilation, and shorten the average trip distance from each house to destinations.

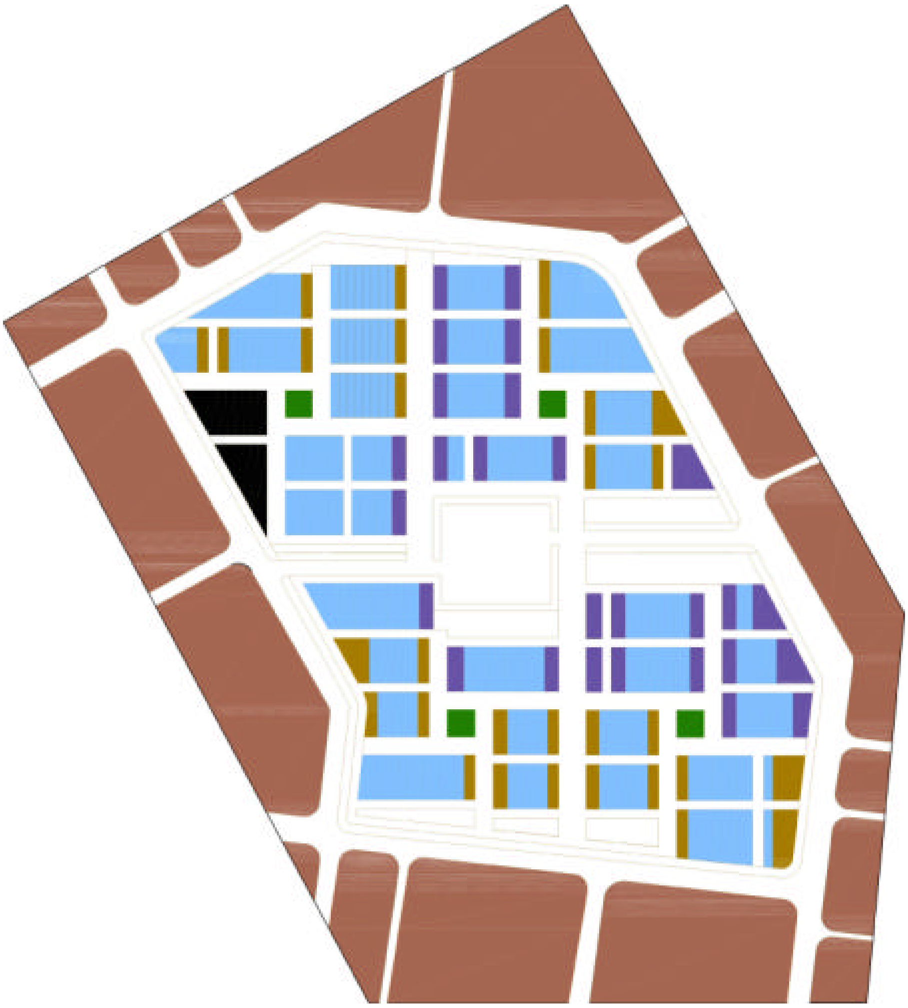


Fig.28: Rearrangement of the Site Plan

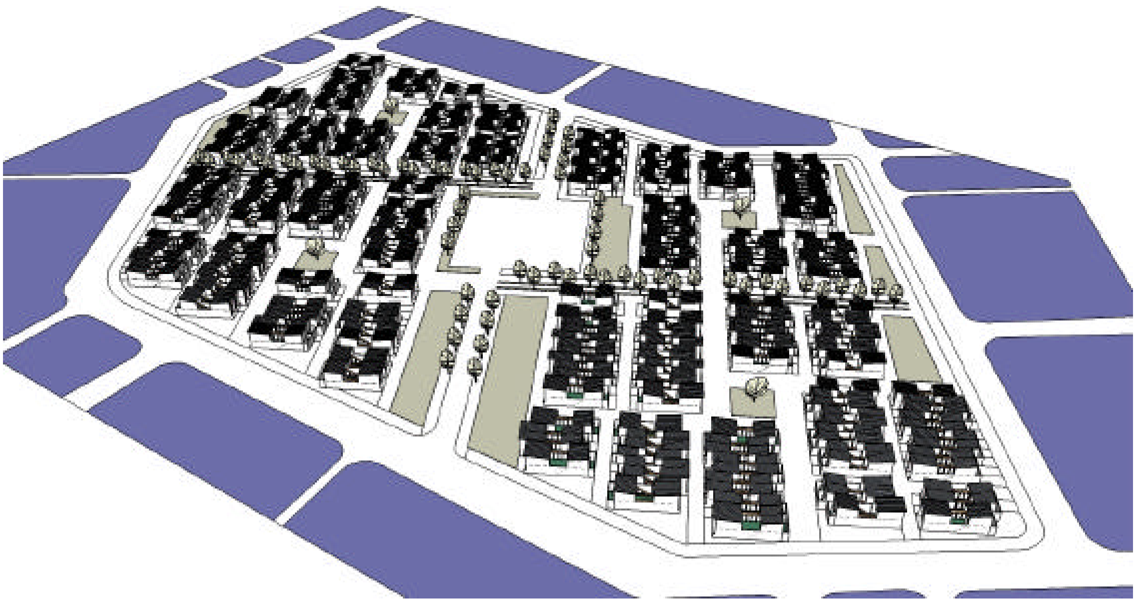


Fig.29: Birds Eye View of the Plan

c. Estimation of CO_2 Emissions

Table 27: Estimation of CO_2 Emissions for each Alternative Plan, Gunung District in Cirebon City

Items	Existing	Plan 1	Plan 2	Plan 3	Plan 4	Unit
Land area	54,700[1)]	54,700	54,700	54,700	54,700	m²
Total units	324	364	924	578	344	Units
Population	1,090	1,457	3,737	2,312	1,376	Persons
Total floor area	39,056	40,616	136,836	35,616	25,420	m²
Housing	28,836	32,396	72,036	27,396	17,200	m²
Non-housing	8,220	8,220	64,800	8,220	8,220	m²
CO_2 emission/Year/Unit	2.710	5.419	2.382	4,168	4.226	T-CO_2
Building Material LCE	369	15,809	13,488.6	13,369	8.394	T-CO_2
B. material LCE/unit	1.140	43.4	14.6	23.1	24.4	T-CO_2
Expected length of life	15	15	60	15	15	Years
B. Material LCE/Year	24.624	1,054	224.8	891	560	T-CO_2
LCE/Unit/Year	0.076	2.8	0.243	1.54	1.63	T-CO_2
LCE/$m^2$of floor/Year	0.00085	0.033	0.0031	0.033	0.033	T-CO_2
Domestic energy/Year/Unit[4)]	1.891	1.891	1.891	1,891	1,891	T-CO_2
Transportation/Year/Unit	0.751	0.751	0.263[2)]	0.751	0.751	T-CO_2
Tree cap coverage	4,814	15,614	25,150	14.944	29,994	m²
Absorption/year[3)]	-5.1	-16.6	-26.6.	-15.8	-31.8	T-CO_2
Absorption/Year/Unit	-0.008	-0.023	-0.015	-0.014	-0.046	T-CO_2
Carbon Stock in Building	324	364	0	0	0	Ton-C

1) Of the total area of 54,700m², street side business areas occupy 13,700m², and housing areas behind them cover 41,000m². Plan 1, 2 and 4 will rearrange the housing area, and Plan 3 will rearrange the business area.

2) Plan 2 assumes that the newly created high-rise complex will not create additional demand for trip distance, because offices, commercial areas, governmental offices and schools accessible only by foot are included.

3) In order to calculate absorption by greenery, 2.9 Ton-C/Ha/Yr (namely, 5.32 Ton-CO_2/Ha/Yr) was applied as a default value as proposed by IPCC. In a tropical humid climate, the actual value, that will be far larger than this, is now being investigated by forestry research institutes. In addition to the direct absorption of CO_2, the cooling effects of greenery will reduce the outdoor temperature and therefore the load of air conditioning and related consumption of electricity.

4) Domestic energy consumption will presumably be kept at its present level.

5) Materials for multi-storey buildings are evaluated using Japanese data for 1990, as follows: SRC: 156 kg-C/m², RC: 133 kg-C/m², S: 85kg-C/m² and W: 59 kg-C/m² reported in literature 9).

(2) Sarijadi complex in Bandung City

a. Existing condition of the area

Sarijadi complex is located in the western part of Bandung City at an altitude near 800m above average sea level. The area is sloped and lower in its southern part. The target area for the model design is exactly equivalent to the community coded RW-07. The spatial order of this area is clear grid planning, and the size of house lots is almost standardized at 6.5m (frontage) and 15m (depth) in satellite images. The main street runs in the eastern part of the area, and there is a row of shop houses along this street that is part of the target area. The total area of the district measured based on satellite images is 5.2 hectares, which is a little different from that in documentary records of the initial development.

Streets are not only those in front of the house lots, but include narrow footpaths connecting the backyards of houses. Their width is less than 1m, but residents can use them to escape in emergencies. Providing footpaths in backyards is a custom in planned housing areas in Bandung region, but not common in other Indonesian provinces.

The National Housing Corporation developed the area in 1980. To construct the initial houses, the RIHS (which undertook the field survey of this area in this study, and was then called LPMB) developed building materials .

Only 13 houses were constructed as complete model houses ($54m^2$) while another 335 units were constructed as "core houses" to be expanded by inhabitants following the final design shown by the model houses. Therefore, as their families grew and children matured, , occupants actively expanded their houses. Now the average total floor area is $82.16m^2$ and almost all house lots are covered by roofs. Open space in each house lot has almost disappeared. However, trees planted in narrow open space spread their leaves over the roofs so that the area of green caps measured in satellite images (11%) is larger than the actual rate of open space at ground level.

Nowadays, many who were children at that time have already married and moved to new housesourside this complex so it has , become rather a silent area where many residents have already retired from their jobs.

The land shape is sloped: higher in the east and lower in the west. Streets running from northwest to southeast are steeper in the eastern half, and rather flat in the western half.

Fig.30: Site Map of the Area from Design Drawing

b. Alternative Planning for the Future

Four alternative plans were prepared in the form of 3D datato be used for presentations from social-cultural perspectives at a workshop attended by non-engineer discussants and resource persons.

The four alternative plans for the study area in Bandung are summarized as follows:

Table 28: Basic Concepts of Each Alternative Plan for Sarijadi District in Bandung City

	Concept	Site Plan	House Unit
1. Arvi	Enhance Open Space for Greenery	Renewal to Cul-de-sac pattern	Maisonette
2. HK	Wood town	Preserving existing house lot Individual Renewal following three dimensional regulation of shape	Fire-proof timber houses, with enough natural ventilation and sunlight
3. Doni	Land re-adjustment for creating open space	Rearrangement to Cul-de-sac pattern	Two storied, partially apartment
4. Kukuh	Greenery on building	Rearrangement for apartment complex	Apartment

Alternative 1: Site plan is re-arranged in a Cul-de-sac pattern, and more intensive land use is achieved through maisonette type dwelling units, enhancing the open space with greenery.

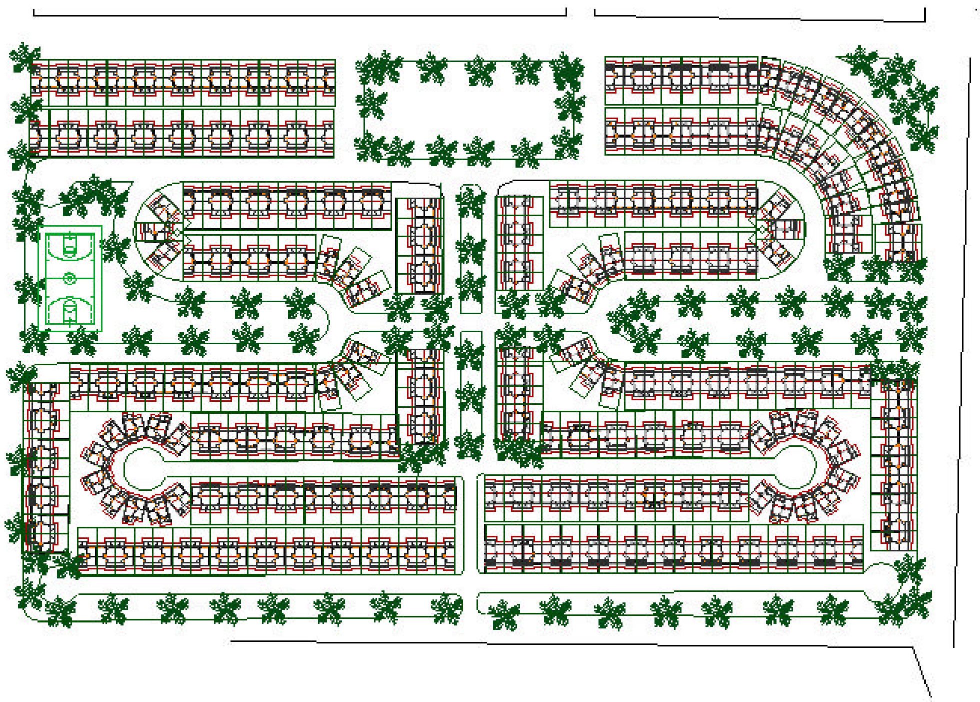


Fig.31: Site Plan

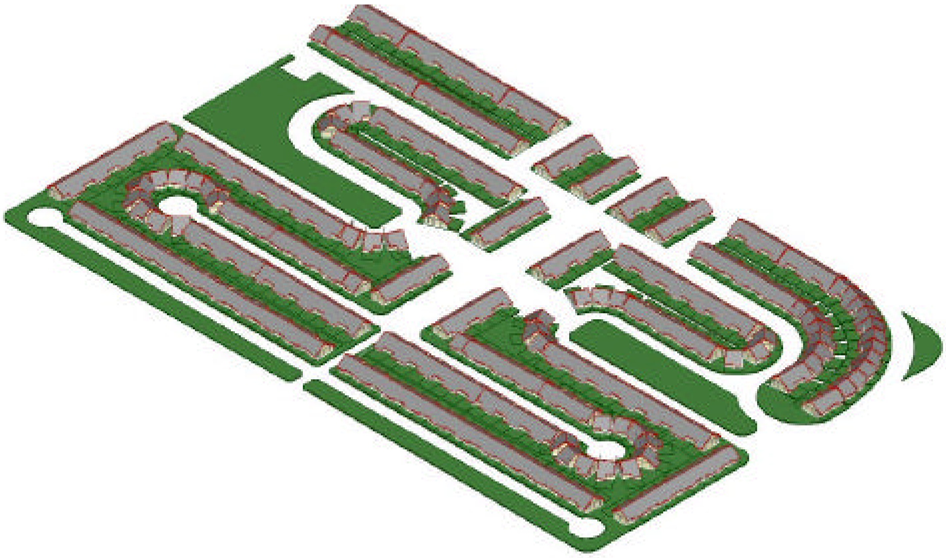


Fig.32: Birds Eye View

Fig.33: Dwelling Unit that was Originally Planned for Existing Complex

Fig.34: Maisonette Type Dwelling Unit proposed

Alternative 2: The altitude of Bandung city is 700-800m above sea level, and its temperature is cool (4.5 degrees (daytime) and 6 degrees (nighttime) cooler than Jakarta). These conditions improve the use of organic materials (by prolonging their lifetimes) and simplify the provision of comfortable indoor environments without artificial air conditioning. This plan is not intended to change the existing lot-subdivision pattern, because it introduces three-dimensional regulations to maintain good ventilation and natural lighting in the whole area. Houses will be re-constructed individually in line with this three dimensional regulation, utilizing timber material supplied by sustainable forestry that will be established in the nearby mountains and, hopefully, combined with the urban housing area maintenance . C.a. 18 m^3 of timber is needed to construct one house. Planting trees on c.a. $500m^2$ of empty land in the mountains can provide enough timber material to reconstruct this house every 40 years. Fire-proof materials will be applied to walls of the timber houses.

Garis Sempadan Kubus

Konsep2:

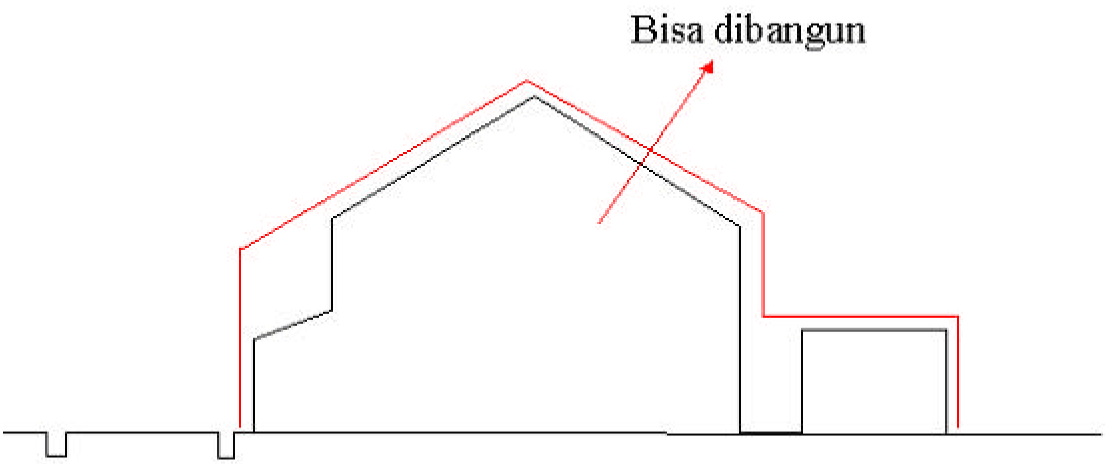


Fig.35: Three Dimensional Regulation of Land Use

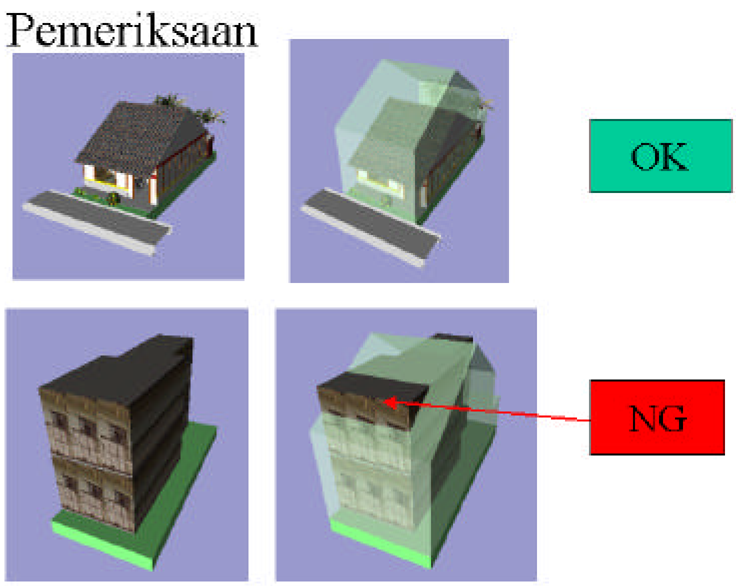


Fig.36: Shape of Houses Under the Regulation (Envelope)

Pemeriharaan lingkungan yang tidak perlu pasangan AC

Satu unit ruang RT Lingkungan

Fig.37: Townscape that will be created by the Regulation

Contoh lantai dasar

Luas lantai dasar : 65 m2 + kamar mandi 3m2
Lantai kedua : untuk anak (max 65m2) : jumlah sekitar 140 m2

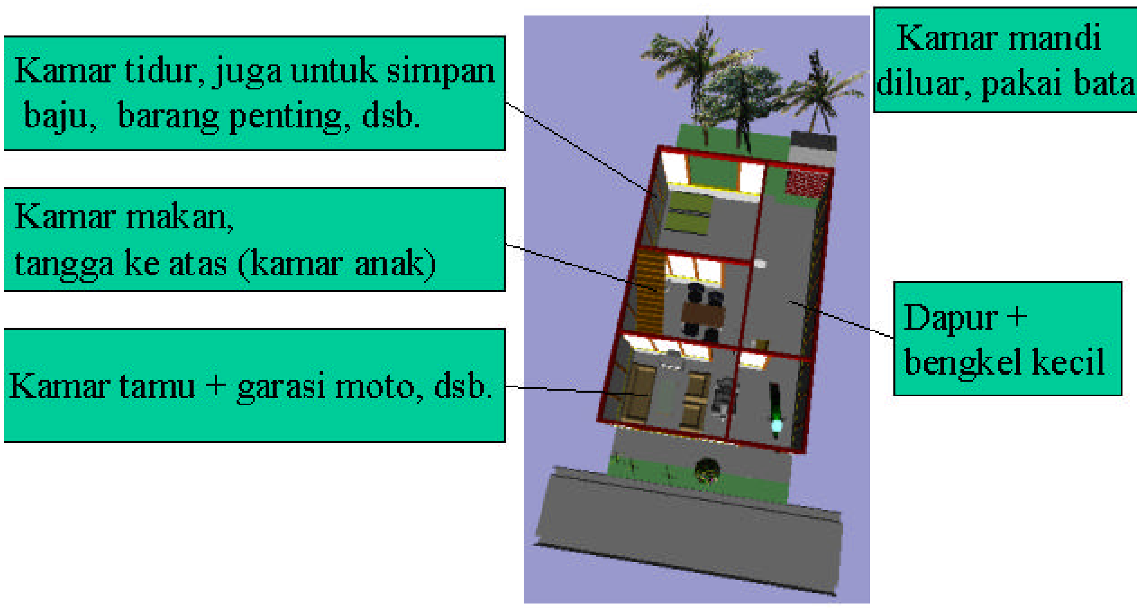


Fig.38: Example of dwelling unit

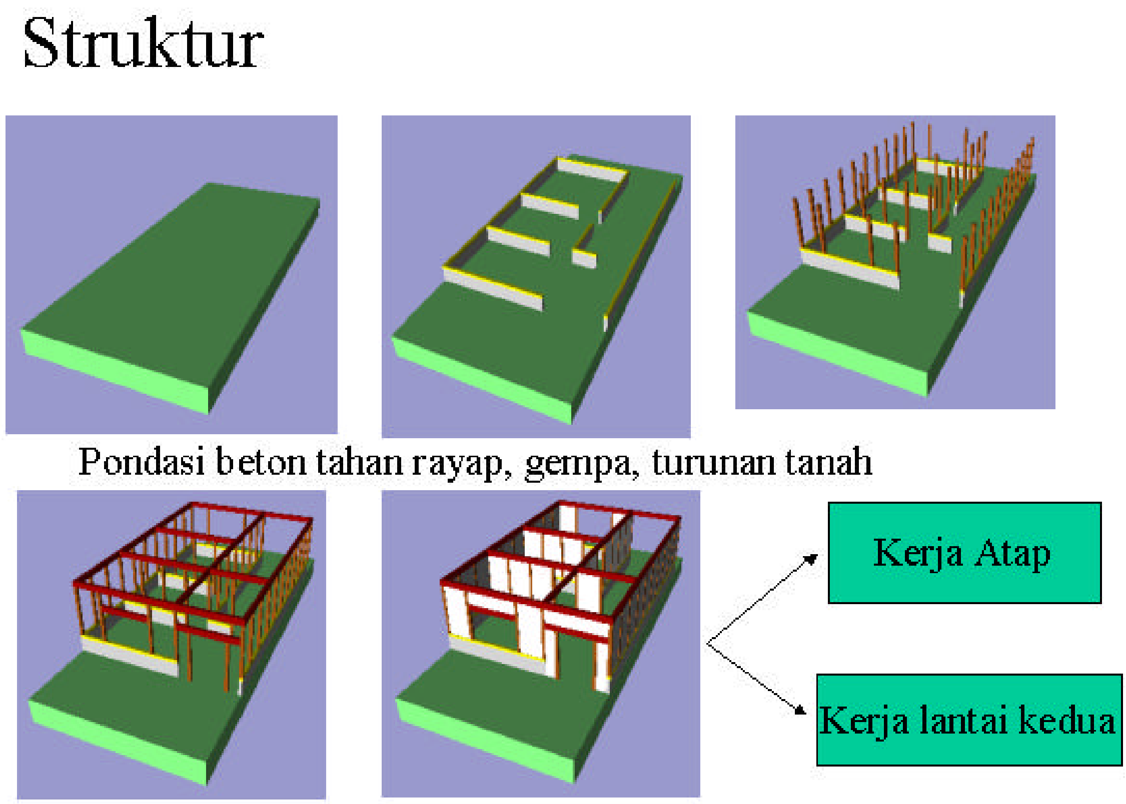


Fig.39: Timber Structure

Alternative 3: Existing crowded environment will be re-arranged through land-readjustment, creating open space.

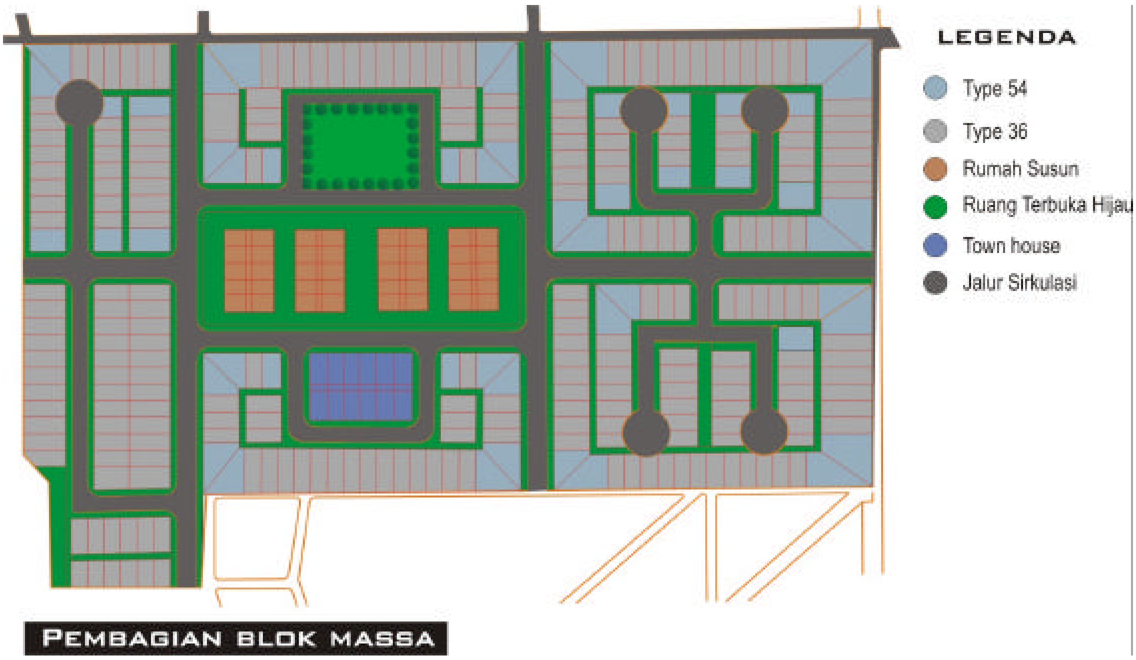


Fig.40: Site Plan

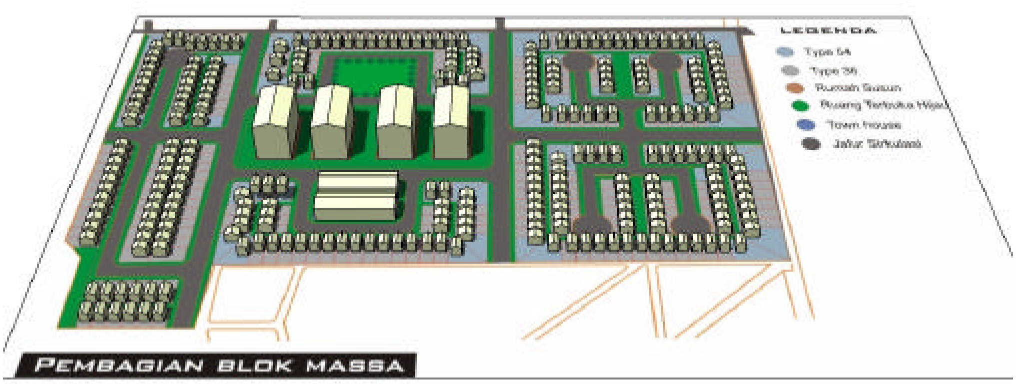


Fig.41: Birds Eye View

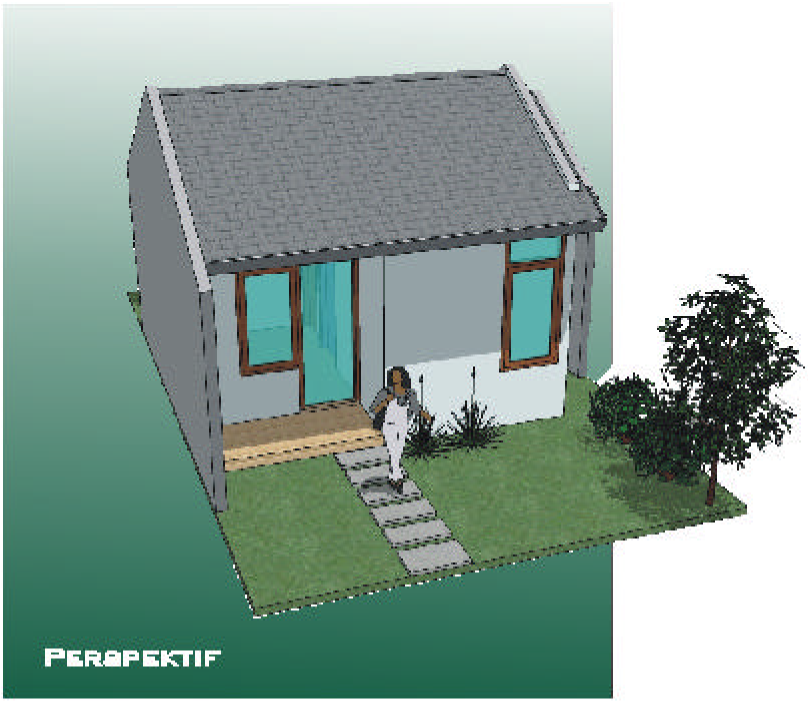


Fig.42: Dwelling Unit

Alternative 4: Urban renewal will change the existing crowded environment to apartment houses with greenery on the top and walls, in addition to the open green space created at ground level.

Fig.43: Site Plan

Fig.44: Birds Eye View

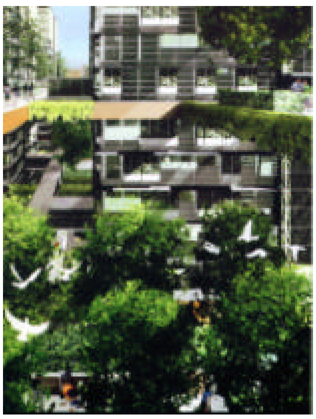


Fig.45: Image of Greenery on the Buildings

c. Estimation of CO_2 Emissions

Table 29: Estimation of CO_2 Emission for Each Alternative Plan, Sarijadi District in Bandung City

Items	Existing	Plan 1	Plan 2	Plan 3	Plan 4	Unit
Land area	52,028	52,028	52,028	52,028	52,028	㎡
Total units	343	343	343	343	343	Units
Population	1,570	1,212	1,372	1,372	1,372	Persons
Total floor area	29,400	32,870	29,400	32,870	32,870	㎡
Housing	27,400	30,870	27,400	30,870	30,870	㎡
Non-housing	2,000	2,000	2,000	2,000	2,000	㎡
CO_2 emission/year/unit	3.648	3.613	3.517	3.535	3.513	T-CO_2
Building material LCE	555	555	0	900	900	T-CO_2
B. Material LCE/unit	1.6	1.6	0	2.6	2.6	T-CO_2
Expected length of life	15	15	20	60	60	Years
LCE/Year	37	37	0	15	15	T-CO_2
LCE/Unit/Year	0.108	0.108	0	0.044	0.044	T-CO_2
LCE/ ㎡ of floor/Year	1.35	1.20	0	0.49	0.49	T-CO_2
Domestic energ/Year/Unit [1)]	2.390	2.390	2.390	2.390	2.390	T-CO_2
Transportation/Year/Unit [2)]	1.159	1.159	1.159	1.159	1.159	T-CO_2
Tree cap coverage	5,700	28,149	20,811	37,532	46,915	㎡
Absorption/Year	-3.0	-15.0	-11.1	-20.0	-25.0	T-CO_2
Absorption/Year/Unit	-0.009	-0.044	-0.032	-0.058	-0.080	T-CO_2
Barbon Stock in Building	68.6	68.6	987.8	34.3	34.3	Ton-C

[1)] Technical proposals for domestic energy consumption (solar cells, electric devices etc.) were discussed, however they were not included in the plan.

[2)] Fuel consumption did not differ significantly between the different spatial arrangements. In order to evaluate the total fuel consumption, urban scale spatial arrangement (including planning compact cities through vertical expansion) and provision of mass transportation were considered. That will be the next major topic of research. However, differential analysis by comparing an additional unit within the complex with additional development in the urban fringe could be attempted using the data on hand.

[3)] Materials for multi-storey buildings are evaluated using Japanese data for 1990, as follows: SRC: 156 kg-C/m^2, RC: 133 kg-C/m^2, S: 85kg-C/m^2 and W: 59 kg-C/m^2 reported in literaturen 9).

5. Evaluation and Discussions through Workshops

We held the final workshops on March 6-7, 2007 in Bandung to present, discuss, and evaluate the alternative plans. On the first day, a general explanation of global environmental issues and the purpose and result of this research in Indonesia, were followed by the presentation of the 4 alternative plans for Gunung district in Cirebon city. On the second day, reports on the approaches taken in Malaysia, Singapore and Thailand, were followed by presentations and discussions of the 4 alternative plans for Sarijadi district in Bandung city, then by wider more general discussions.

Representatives of the study areas and officials of the two local governments attended the workshops. Also, in addition to the resource persons in the building and city planning fields, representatives of forestry participated in the workshop.

(1) Presentation and Discussion

After a general explanation of global warming issues and a survey of housing complexes, architects and city planners who designed the alternative plans presented them to the workshop. They were requested to explain the concept of the plans, and then, the contents of their design in three-dimensional presentations so that non-engineers could understand them.

Usually planning and designing is undertaken in preparation for actual development and construction. However this presentation, which dealt with rather conceptual works for the distant future, utilized 2 districts as examples of model plans. The participants seemed quite confused at first, however they finally understood and appreciated the real meaning of this research.

They accepted and supported the greenery aspects of the plans. The natural wind and ventilation were also accepted. However discussions of quantities (degree of emissions reductions) appeared to still be difficult, due to the lack of data and established methods. Research activities on thermal comfort, that is classified in “building science” in this country is still in its infancy. Various thematic researches on thermal environments around human settlements must be undertaken to permit quantitative discussions.

Opinions on building materials are very diverse. Many participants view theusage of timber as an evil which destroys natural forests. Some forestry experts are promoting artificial sustainable forestry as a new business that requires a timber market and needs industries to produce durable timber products to absorb and fix CO_2 from the atmosphere faster than natural forests. However, it is also recognized that there is a risk of fire or rapid deterioration of timber in tropical climates. Even though traditional houses in all provinces are all made of timber, governmental promotion of permanent houses since the 1970s has made masonry houses a part of the culture of the Indonesian people.

High-rise and dense apartments, still a new life style in this country, are promoted by some architects as a way to provide greater open space for more urban greenery and to make cities more compact. However, not enough comparisons of alternatives within complex have been made to discuss this issue, but larger scale studies covering the total spatial plan of a city including its mass transportation infrastructure will be needed.

Opinions and questions from the floor were contributed as follows:

a. On Overall Activities

- The two planned target areas provide examples of simulation and optimization, but do not hypothesize actual development projects. Simulation means the systematic calculation of values (CO_2 emission, in this case). Optimization is a method of selecting and deciding one solution from among plural alternatives.
- The purpose of this research is to obtain an appropriate prototype.
- The target fields are city, district, housing environment and buildings.
- This research focuses on building materials, transportation and everyday life.
- Limits of indexes can be clarified.
- After the limit to every index has been set, analysis can be performed at the house, district, area and city scales.

b. On the Design

- Orientation of buildings should be north to south.
- Trees should be planted on the west side of buildings to block the heat from sunshine
- A roof garden effectively blocks the heat from sunshine: a principle also applicable to the side walls.
- Cul-de-sac type site planning is not efficient for pedestrians, causing more distant approaches. Also, they restrict access by public transportation. Supplementary short-cut footpaths (passages) should be provided.
- Grid-type site planning is more efficient, however it is more difficult to recognize its orientation. Introduction of a hierarchy of streets can aid orientation. Minor modifications can be added through parking spaces and greenery created by flowerpots along the streets (case of Sarijadi district in Bandung).
- Planners should consider the dominant direction of the wind. Even though the velocity of wind is low in a tropical climate,it can be effective.
- If we consider the eco-system, self-sufficient design is impossible, because physical conditions, land conditions and landscapesvary.
- On the urban scale, houses and housing areas are diverse, so approaches taken will not be stereotypical.
- Planning should account for such aspects as:

>Cultural landscape

>Participatory design

>Economic capacity of the government and citizens

>Feasibility of high-rise buildings considering earthquakes

-The explanation of concepts should cover aspects such as:

>Changes from current common understanding

>Provision of guidelines

>Ideas from small communities like Kampung Naga

>Introduction of regulations for achievement

- It is difficult to introduce new basic thinking of ways to enhance the amount of timber used, as a replacement for the conventional philosophy,“keep and preserve forests, reducing the usage of timbers”. A wood town is difficult in Indonesia.

- Quality-based designs are presented, and further calculations of quantitative indexes should be carried out.

- Needs of the inhabitants that should be consideredare:

>Safety and security from criminals and animals etc.

>Comfort

>Accessibility and mobility

- Housing districts can be classified from the following perspectives:

>Geographical conditions (flat, ocean, coast, hill, mountain)

>Local infrastructure and facilities (market, medical) that relate to the inhabitants

>Culture etc.

- Population increase will increase the consumption of building materials. Open green space should be enhanced through vertical development. Apartment houses of the kind now constructed are not appropriate.

- Direction of wind was not analyzed through this research.

- Greenery functions as sunshade and umbrellas.

- How to reduce poisonous gases?

- What is the purpose of urban renewal? Is town planning also included?

- Is this research intended to disturb environment plan 1996 (Holler)?

- Garden city by Howard has a park in the center.

- Designs lack landmarks, nodes, and a maintenance concept .

- In a normal development, profit is considered. How about cost and benefits?

- Does the reduction of CO_2 emissions lead to reasonable prices?

- To what degree will the reduction of CO_2 emission be achieved through each alternative model?

- Is it easy move between stories in the designed apartments?

- It seems to be assumed that land will be provided for the development plan. What about districts where individual landowners already exist?

- In Bandung, housing area is dense, so it is difficult to find new land for housing development.

- In general, land for new development is inadequate, and not appropriate for selection as a development site.

c. Open Green Space (RTH: Ruang Terbuka Hijau)

- Designing RTH should be included in house unit and district plans.

- Designing RTH should be based on types, structure and form of the city and its cultural landscape.

- Regulations stipulating the optimal % of RTH will be needed.

- Trees will reduce the risk of landslide, and also they are related to CDM. They, therefore, enhance the value of houses.

- Planning should consider not only building coverage ratio (KDB), but also the green coverage ratio (KDH). Local governments should urge citizens to plant trees.

- CO_2 also comes from oceans, therefore the system is not closed.

- Not only RTH, but the kinds of trees are also related to the reduction of CO_2 emissions. Considering the rate of absorption per hectare per year, Acacia Mangis shows very high performance.

- It is difficult to measure the actual amount of CO_2 in the field, however it is possible to apply an estimation formula. If dynamic informatics is established, it can be used for this calculation.

- A forestry research institute in Bogor is measuring the amount of CO_2 absorbed by 50 kinds of trees. It measures the amount absorbed by sample leaves and twigs during 10 hour periods.

- There is software to estimate the consumption of gas by the population.

- Trees that emit poisonous gases are harmful. Research on short useful kinds of trees is needed.

- Greenery on the top of buildings effectively isolates heat from sunshine.

- Local governments should establish adequate regulations. In Indonesia, trees are being grown and cut without clear reasons.

- Research on the total amount of absorption of CO_2 by unit area of forest should be undertaken. Trees absorb CO_2 during the daytime, but emit CO_2 at night.

- Is the absorption of CO_2 by RTH in urban areas significant? How about the mechanism? How about in cities with different characteristics?

- Planting trees is cheap and effective. Therefore, it is promoted.

- RTH plays significant roles in reducing CO_2 emission, catching and holding surface water, and contributing to beautiful landscapes.

- The concept of “one tree for each house” is easy to understand.

d. Building Materials

- Timber fixes carbon. On the global scale, construction of timber houses will be effective. The production of timber should be done in forests on mountains.

- Bamboo grows everywhere in Indonesia where it isutilized for buildings. However, the absorption of CO_2 by bamboo has not been evaluated. Bamboo is deemed effective for protection from strong winds and from earthquakes (by strengthening soil).

- It has long been known that bamboo grows rapidly. It is utilized as cheap building material. In order to enhance its value, new related technologies must be developed.

- Bamboo houses with performance better than brick houses must be designed.

- The concept of “Wood Town” will help reduce CO_2 emissions. Timber houses and bamboo houses can be developed in Indonesia, however, we must consider the fact that they are not still not sufficiently safe from fire.

- The price of timber is high. It is now difficult for people to build timber houses. However, if the price of cement goes up and cement-related products become more expensive, market demand will shift to timber.
- It is impossible to immediately popularize timber and bamboo. Technologies, energy and funds are needed to develop and produce cheap timber and bamboo members and components ready to be assembled at construction sites. Research on optimal safety is needed, hence, "value engineering".
- To what degree can bamboo absorb CO_2? For engineering reasons, it is important to make RTH well balanced between house lot and district planning, to establish housing areas as green belts.
- Brick houses are already part of the culture of Indonesia.
- It is important to develop prototypes of housing areas.
- From the architectural perspective, it is important to enhance the lifetime of timber buildings and to make them more beautiful. In principle consumers seek lower prices.
- Bamboo can be utilized for either primary structures or as additional finishing.
- The question is "how to make it possible to use teak trees that are 8 years old or younger,".
- Constructing high-rise buildings using timber is now limited to a maximum of 3 stories.
- Discussions of applicable technologiesshould consider the locality. For example, local building materials are easier to purchase, and using them will contribute to the local economy.

e. Social and legal aspects

- Populariization activities are needed to arouse consciousness of citizens.
- In order to put new concepts into practice, local governments should take the lead to stimulate the desires of the the wider society. However, the difficulty in Indonesia lies in the weakness and lack of continuity of local governments.
- In order to reflect strategies in regulations, management budgets should be clear.
- In order to manage building regulations, rules must come from the community level and be strictly enforced.
- Media must help spread rules in society.
- Mailing lists are useful tools to start networking.
- The results of this research seem to be fruitful, however, will actions to put them into practice be taken continuously?
- At this moment, results of research and development are abundant. However, popularization is still insufficient, and they have not been put into practice.
- Are the results of this research "proposed models" and "evaluation of impact"? Are the outputs technical guidelines?
- Popularization of life styles led at multiple levels in three-dimensional cities will be needed.
- It is also significant to popularize organic building materials (timber), natural wind (direction), and

greenery on the top and side of buildings.

- Proposals are difficult to execute, and concepts should be clearer.
- In order to popularize socialize the result of the workshops, and promote their realization, concerned authorities must cooperate.
- It is difficult to spread local consciousness to large cities or some districts in large cities where ethnic groups vary. We have to translate our local consciousness into more logical language.
- The ways that Indonesians think should be changed.
- Special local regulations are needed to establish the legal foundations within societies.
- Proposals and planning are valuable. Efficiently providing quantitative indexes will result in the establishmenbt of technical guidelines.

f. Transportation

- Research on mass-transportation will help reduce CO_2 emissions. What about the efficiency of fuels (km / liter)? This index is still low in Indonesia.
- What are the shares of emissions by transportation by domestic energy consumption?
- “Walking on foot” must be encouraged.
- How can a living environment whose inhabitants desire to walk on foot be created? How to socialize this among urban governments?
- Motorcycles contribute 73% of air pollution in Bandung.
- Transportation contributing to CO_2 emissions consists of not only local public buses and individual vehicles, but also vehicles that pass through the Sarijadi district to visit Lemban (mountain resort) and Cimahi (a western satellite city next to Bandung).

(2) Evaluation by Non-engineer Participants

Questionnaires were provided to workshop participants. They asked participants about the presentation and contents of each alternative plan, elaborated for two districts in Cirebon and Bandung cities.

Because presenting this kind of questionnaire at seminars and workshops is not usual in this country, the questions were simple and the choice of answer was also only “yes or no”.

The educational backgrounds of participants in this workshop was high, and most of the participants already knew about “Global Warming”.

Presentation of alternative plans using 3D models seems to be effective, and most of the participants could understand the contents of design.

For both districts in the two cities, in general, the most support was given to maisonette type (two storied) houses for many reasons. .

a. “Gunung” District in Cirebon City

a-1. Attributes of Respondents

Table 30: Address

NA (No Answer)	Bandung city	Cirebon city	Others
1	16	5	5

Table 31: Sex

NA	Male	Female
1	20	6

Table 32: Age

NA	-29	30-39	40-49	50-59	60-
1	2	5	11	7	1

Table 33: Education

NA	High School	University	Master	Doctor
1	3	9	10	4

a-2. Evaluation of Each Alternative Plan

Table 34: Presentation

	NA	Clear	Insufficient
Plan 1	2	24	1
Plan 2	7	18	2
Plan 3	8	19	0
Plan 4	11	15	1

Table 35: Explanation of Concept

	NA	Clear	Insufficient
Plan 1	3	23	1
Plan 2	8	15	4
Plan 3	9	16	2
Plan 4	12	12	3

Table 36: Explanation of Design

	NA	Clear	Insufficient
Plan 1	6	17	3
Plan 2	10	13	4
Plan 3	8	18	1
Plan 4	11	14	2

Table 37: Transportation

	NA	Good	Insufficient
Plan 1	4	17	6
Plan 2	7	9	11
Plan 3	8	15	4
Plan 4	11	12	4

Table 38: Domestic Energy Consumption

	NA	Good	Insufficient
Plan 1	3	14	10
Plan 2	7	11	9
Plan 3	8	13	6
Plan 4	10	9	7

Table 39: Building Material

	NA	Good	Insufficient
Plan 1	4	18	5
Plan 2	7	15	5
Plan 3	9	12	6
Plan 4	11	8	8

Table 40: Greenery

	NA	Good	Insufficient
Plan 1	5	14	8
Plan 2	6	14	7
Plan 3	8	14	4
Plan 4	12	12	3

Table 41: Daily Life

	NA	Good	Insufficient
Plan 1	6	20	1
Plan 2	7	15	5
Plan 3	10	16	1
Plan 4	14	13	0

Table 42: Feasibility

	NA	Good	Insufficient
Plan 1	4	21	2
Plan 2	7	15	5
Plan 3	11	15	1
Plan 4	13	14	0

Table 43: Free Comments

	NA	Answered
Plan 1	18	9
Plan 2	18	9
Plan 3	21	6
Plan 4	21	6

Table 44: Understanding of Global Warming

NA	I knew.	I newly learned now.
10	14	3

b. "Sarijadi" District in Bandung City

b-1. Attributes of Respondents

Table 45: Address

NA	Bandung city	Cirebon city	Others
2	14	6	2

Table 46: Sex

NA	Male	Female
4	18	2

Table 47: Age

NA	-29	30-39	40-49	50-59	60-
3	1	4	9	6	1

Table 48: Education

NA	High School	University	Master	Doctor
4	4	9	4	3

b-2. Evaluation of Each Alternative Plan

Table 49: Presentation

	NA	Clear	Insufficient
Plan 1	0	24	0
Plan 2	2	19	3
Plan 3	2	21	1
Plan 4	10	14	0

Table 50: Explanation of Concept

	NA	Clear	Insufficient
Plan 1	1	23	0
Plan 2	3	21	0
Plan 3	3	21	0
Plan 4	11	13	0

Table 51: Explanation of Design

	NA	Clear	Insufficient
Plan 1	4	20	0
Plan 2	6	18	0
Plan 3	5	19	0
Plan 4	15	9	0

Table 52: Transportation

	NA	Good	Insufficient
Plan 1	1	18	5
Plan 2	3	16	5
Plan 3	2	17	5
Plan 4	10	11	3

Table 53: Domestic Energy Consumption

	NA	Good	Insufficient
Plan 1	1	18	5
Plan 2	3	16	5
Plan 3	2	19	3
Plan 4	10	10	4

Table 54: Building Material

	NA	Good	Insufficient
Plan 1	1	14	9
Plan 2	2	16	6
Plan 3	2	16	6
Plan 4	10	11	3

Table 55: Greenery

	NA	Good	Insufficient
Plan 1	1	19	4
Plan 2	3	19	2
Plan 3	2	19	3
Plan 4	10	12	2

Table 56: Daily Life

	NA	Good	Insufficient
Plan 1	2	21	1
Plan 2	3	20	1
Plan 3	3	19	2
Plan 4	10	13	1

Table 57: Feasibility

	NA	Good	Insufficient
Plan 1	2	22	0
Plan 2	2	20	2
Plan 3	3	19	2
Plan 4	10	13	1

Table 58: Free Comments

	NA	Answered
Plan 1	14	10
Plan 2	17	7
Plan 3	16	8
Plan 4	23	1

Table 59: Understanding of Global Warming

NA	I knew.	I newly learned now
12	12	0

6. Conclusion

(1) Summary

The first half of this research was a survey of existing conditions at planned housing complexes and building material factories related to CO_2 performed in order to establish the foundations for future evaluations. In order to evaluate plans intended to lower total emission while also considering indirect emissions caused by activities in the housing complex the system boundary was defined. Thus, data concerning building material factories and power plants were also surveyed and collected.

An average household in the surveyed housing complexes emits a total of 3-4 Tons of CO_2 every year. This value is comparable to the total national emissions of c.a. 200 million tons per year by the entire population of Indonesia that is c.a. 200 million persons.

A comparison of (1) domestic energy consumption, (2) transportation and (3) consumption of building materials shows that the largest emissions are caused by domestic energy consumption. Among various kinds of energy consumption,, the usage of electricity is rapidly increasing, suggesting that in the future, conditions in this country that will be similar to those during the summer in developed countries.

Emissions by transportation are related to the location of each housing complex and related availability of facilities (market etc.). It is also strongly related to the distance to job opportunities and the popularization of private cars. This aspect should be discussed within the scope of an entire urban structure and the provision of mass transportation.

Emissions by the consumption of building material are relatively low, because even though the lifetime of houses is short, the major material is red brick produced by burning biomass-based rice husks,.

Greenery in the housing complexes which were studied was measured both through field surveys and the through analysis of satellite images. Field surveys listed the kinds of greenery within house lots and neighborhoods, while satellite images permitted the measurement of the total area of green caps of trees. These were compared to grasp the quantitative effect of greenery.

The second half elaborated, 4 alternative plans for each of the 2 districts selected in Cirebon and Bandung cities. Most architects and city planners that participated considered the vertical expansion of the housing complex by providing multi-story houses (maisonettes and apartments). The main purpose was to restore the greenery on the ground that has tended to be decreased by the unexpected private and unplanned expansion of rooms beyond the regulated maximum building coverage rate.

However, a relatively small amount of CO_2 is absorbed by trees within a complex, in comparison with the increase of emissions by the use of cement and steel: materials whose production emits huge amounts. However extending the expected lifetime of building structures will relieve this situation. The contribution of greenery to the reduction of the outdoor temperature, which is very important in developed countries where air conditioning is popular, could not be surveyed quantitatively,; rather it was considered from the viewpoint of good behaviour, experienced comfort or feelings of co-existence with nature. In the future, the measurement of outdoor environments, now simplified by the development and popularization of thermal sensors and related equipment will be carried out.

Fixing carbon by using organic components with long lifetimes in buildings will require lengthy consideration, exploiting timber has been considered to be bad behavior that destroys natural forests, and also lowers the quality of houses(shortening their lifetimes). However, some resource persons from the forestry field have started to gain benefits by promoting artificial productive forests and improving the domestic sustainable timber materials market of. They are studying and testing several kinds of trees that grow very rapidly.

During the period when this research was undertaken, the public's interest in global environmental issues seemed to grow in Indonesia. This is partially a result of extraordinary weather, including the large-scale flood that struck Jakarta in February 2007. The concept of the compact city, especially through the development of high-rise apartments, was presented by the government to the people, as an approach, that will slow the development of fringe areas of large cities: a cause of the destruction of forests and agricultural fields that retain rainwater.

(2) Outputs

The overall results have been reported to the Ministry of Environment and published in three annual reports in the Japanese language with short summaries in English.

As part of the activities related to this research, seminars or workshops were held in Bandung. Papers based on this research and also papers by related resource persons weresubmitted to these events. These can now be seen at the NILIM web site :

http://sim.nilim.go.jp/GE

A paper based on the results of the field survey of existing planned housing complexes waspresented to the City Planning Institute of Japan. in 2005 (Okinawa).

Four pages of posters were presented at the Technical Conference of Ministry of Land, Infrastructure and Transport during November 2007 in Tokyo.

An international symposium based on findings of this research on "Climate Change and Human Settlements" is scheduled for March 18-19, 2008 in Bali, Indonesia.

Literature

1. Sources of data on each table are noted under the table. Other tables without such notes are based on result of the surveys undertaken in this research.

2. Literatures quoted with numbers n) are as follows:

1) Ministry of Environment Japan: "Report on evaluation method for tree planting", 2002 (in Japanese)

2) Subandono: "Tsunami", 2006.2 (pp.120-123, in Indonesian)

3) Japan Plywood Manufacturers' Association (JMPA): "Monthly report on statistics related to plywood" (monthly, in Japanese)

4) Jiro Takagi: "Technology Transfer in Indonesia", 13th Workshop on Asian Business, 2003.7.11, Graduate School for Creative Cities, Osaka City University (in Japanese)

5) Research Institute of National Economy: "Report on Cost-rationalization for Material Industries, from viewpoint of Domestic Marine Transport" 2003 (Part IV Cement, in Japanese)

6) Kenji Sakai et-al, "Carbon Dioxide Emissions During Producing Construction Materials in 1985 and 1990 and It's Influence on the Civil Works", '*Environmental System Research Vol.25*', Oct.1997 pp.525-533, Japan Society of Civil Engineering (in Japanese)

3. Result activities preceding this research in the same context are reported as follows:

7) FS-1. (Feasibility Study) "Global Environmental Impact Study of Urban Development and Housing Construction in Indonesia", pp.259-260 in '*Global Environment research of Japan in 1999*', Research and Information Office, Global Environment Department, Environment Agency, Government of Japan

8) Final Report: "Survey of Availability of Basic Data and Study of Research Methods for Global Environmental Impact Study of Urban Development and Housing Construction in Indonesia", Bandung, August 2000, by Research Institute for Settlements Technology, Agency for Research and Development of Settlements and Regional Development, Department of Settlements and Regional Development, Government of Indonesia

9) "Studies on Comprehensive Assessment of Impacts of Sea-level Rise and Adaptation (2000-2002)", 117p in Japanese, Global Research Fund, Ministry of Environment, Japan

10) "Studies on Comprehensive Assessment of Impacts of Sea-level Rise and Adaptation (Abstract of Interim Report)", pp.99-112 in '*Summary Report of Research Results*', Global Environment Research Fund in FY 2002, Research and Information Office, Global Environment Bureau, Ministry of the Environment, Government of Japan

11) Hideyuki Kobayashi: "Impact Evaluation of Sea Level Rise on Indonesian Coastal Cities – Micro Approach through Field Survey and Macro Approach through Satellite Image Analysis", pp.65-76, '*Journal of Global environment Engineering*', Vol.10, Aug.2004, Japan Society of Civil Engineering

12) Hideyuki Kobayashi and Zubaidah Kurdi: "Impact of Sea Level Rising on Coastal Cities -Case Studies in Indonesia-", 287p, *Technical Note of National Institute for Land and Infrastructure Management No.194*, Aug. 2004, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport, Government of Japan

13) Hideyuki Kobayashi, "CO_2 Emission from Planned Housing Complexes in Indonesia -Basic Data Acquisition for Planning Future Housing and Town Planning-", pp.869-874 in Japanese, *City Planning Bulletine 41*, Oct.2006, City Planning Institute of Japan (in Japanese)

14) Ministry of Construction, Infrastructure Development Institute, "Report on Projects for Promoting Technology-Development for Construction in Developing Countries -Passive Solar System-", Mar. 2001 (in Japanese)

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