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.

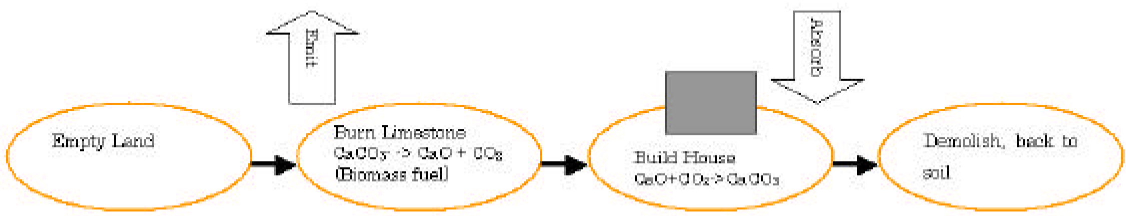

Fig.1: An Example of Negative Stock, with Zero Emission

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.

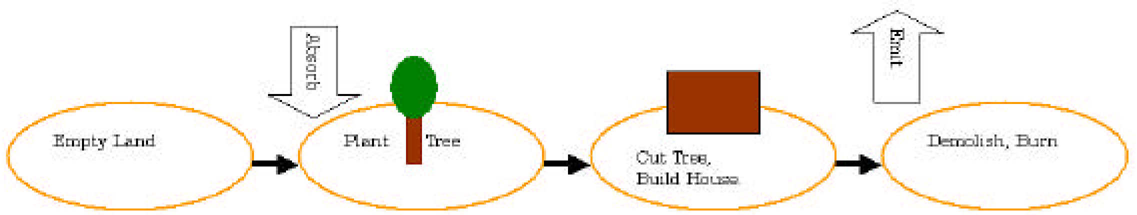

Fig.2: An example of Positive Stock Effect, with Zero Emission

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).

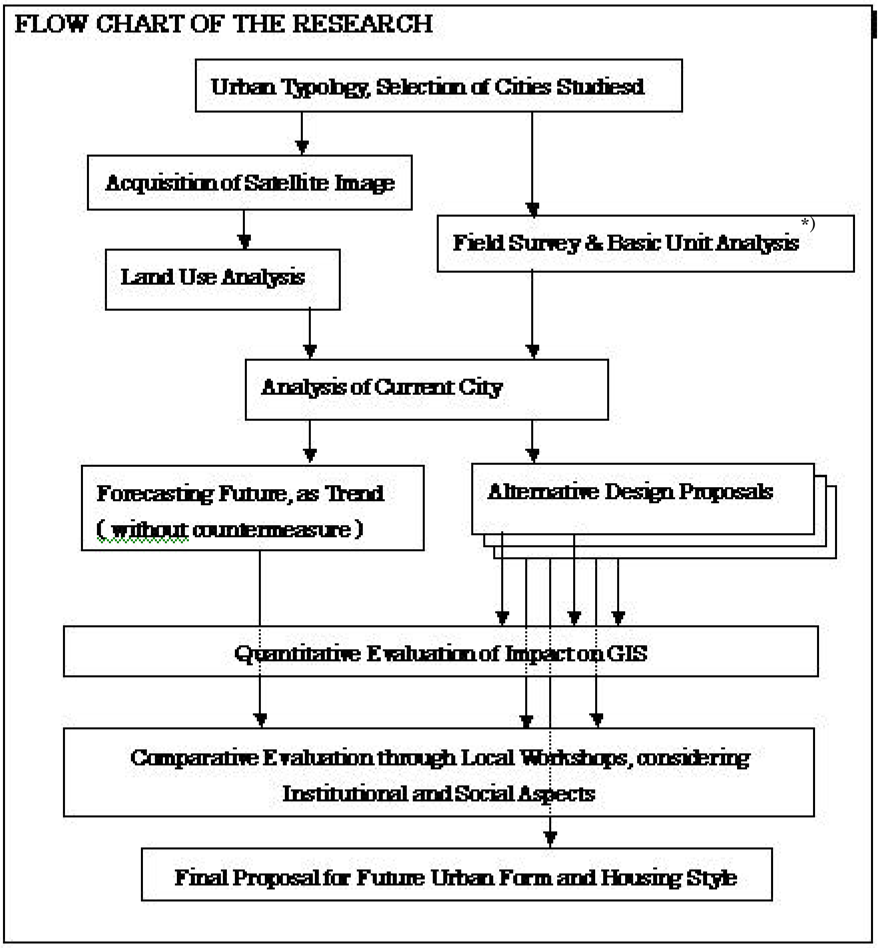

Fig.3: Flow Chart of the Research

*) 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 km², and 1.44 million km² 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 exported instead to enhance profits. According to APKINDO statistics for 1999, 55.59 million m³ of timber was cut, 19.39 million m³ of plywood was produced, and of this, 2.77 million m³ was exported to Japan, a quantity that accounted for 58% of plywood imported 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.