### 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 Building 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.

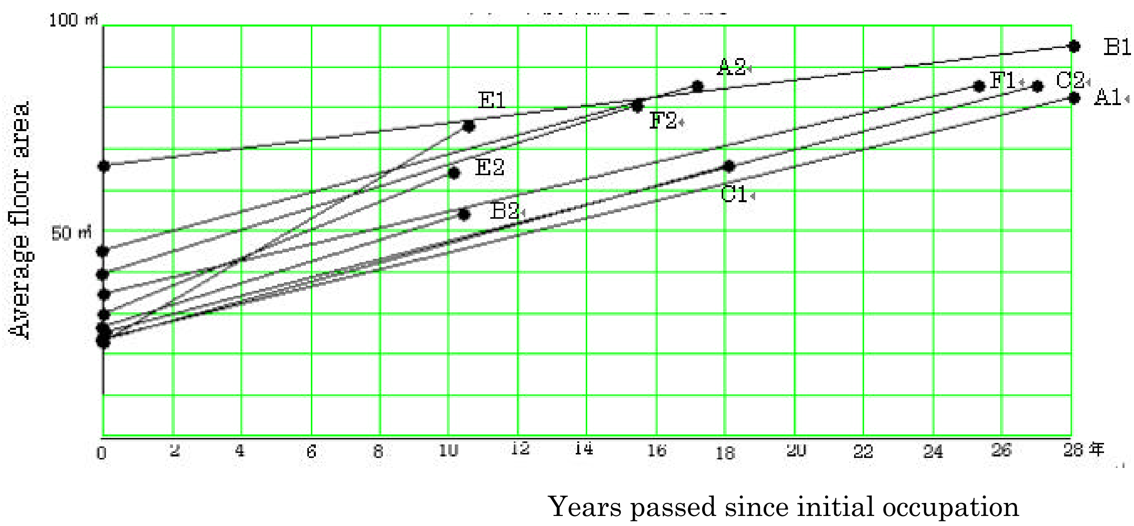



**Fig.5: Original Average Floor Area and Current Average Floor Area**

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.

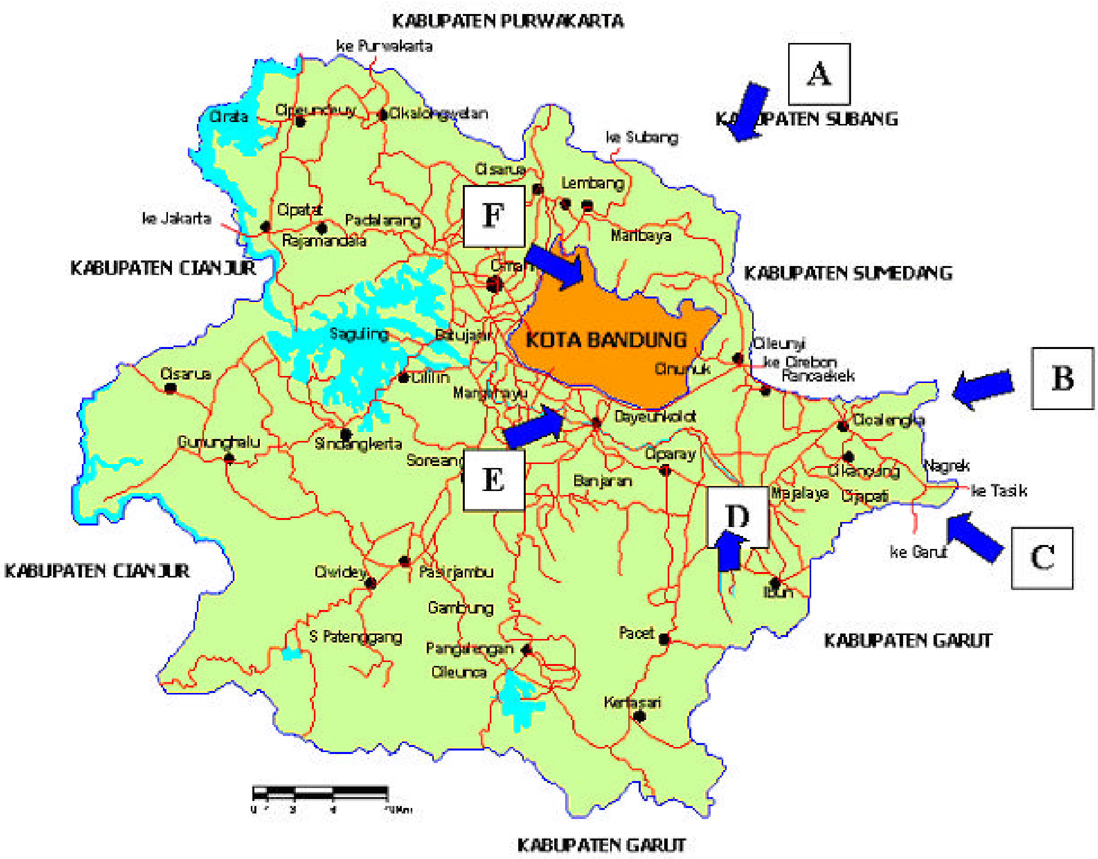
Also, expanded parts have larger area than the original part, and consequently bricks, the dominant material of walls of expanded part, are the most popular material of walls of overall houses. Bricks have neutral stock effect, while concrete blocks that dominate the original part have negative carbon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

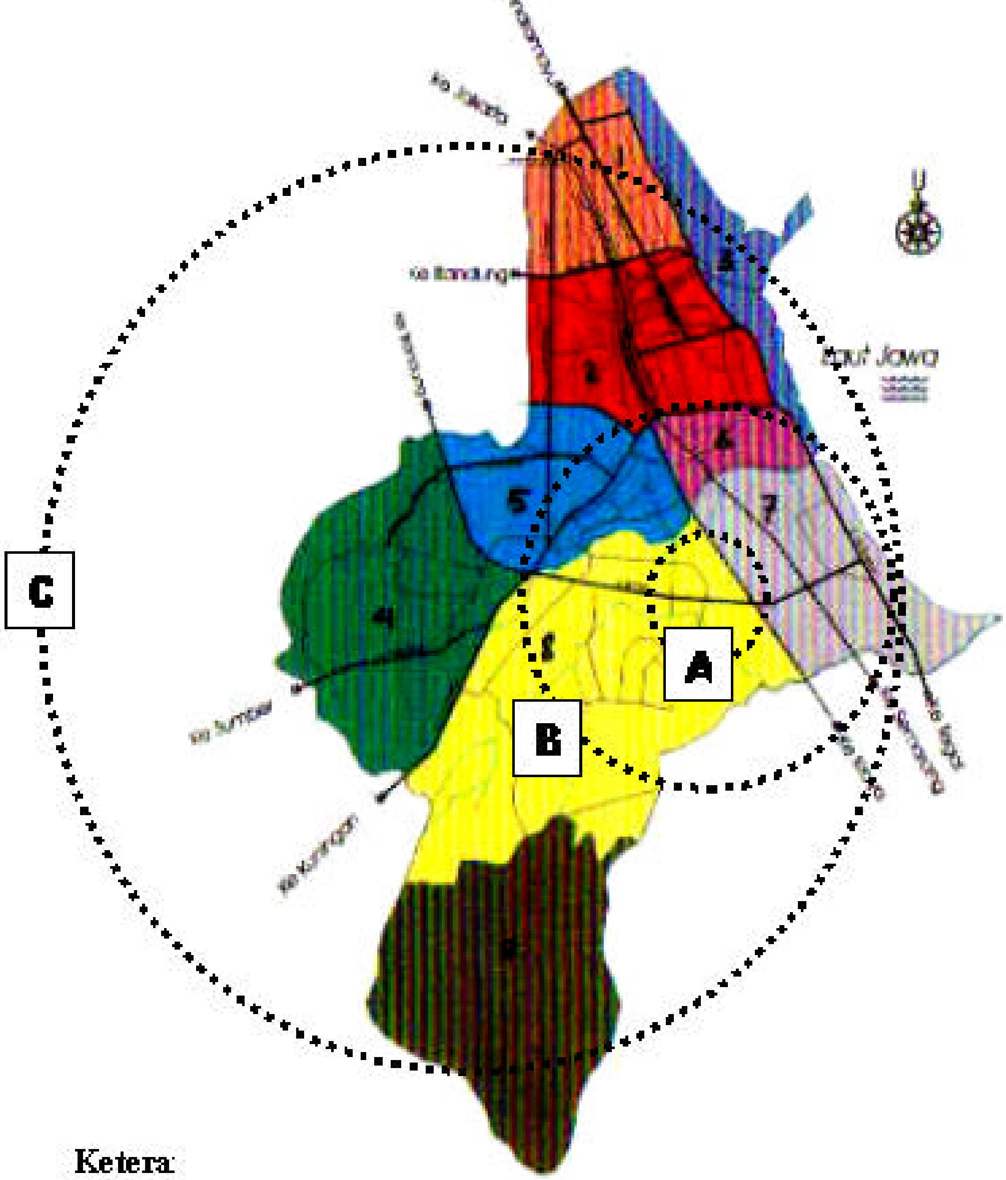
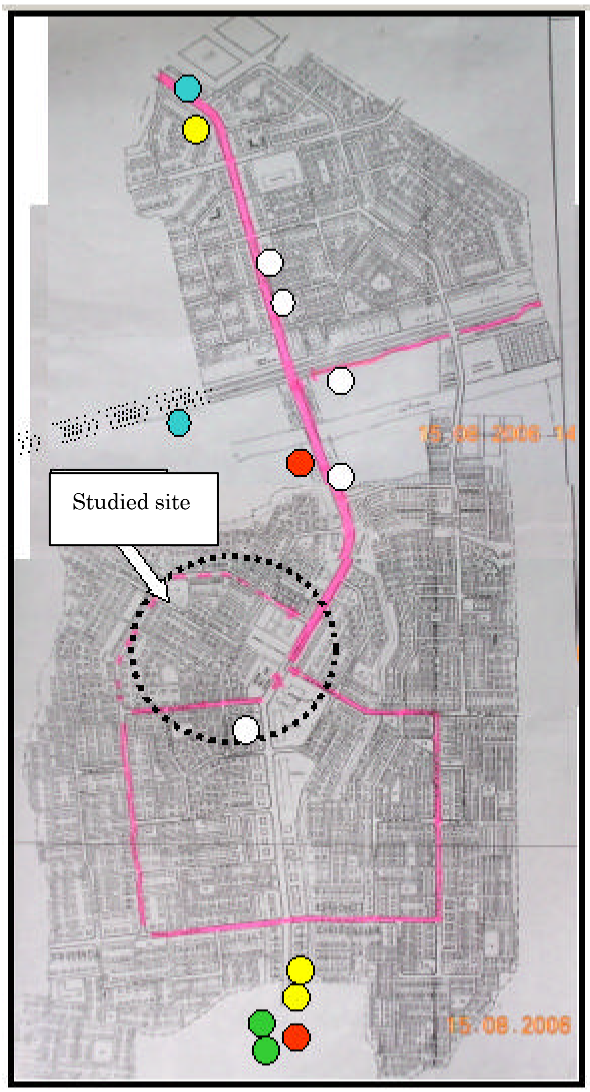



**Fig.7: Distribution Routes of Major Building Materials in Cirebon City**




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

.