ARCHITECTURAL \ TECHNICAL RESEARCH PAPER

TRA-DIGITAL HYBRID
Using digital fabrications to create a hybrid design for developing countries
ACKNOWLEDGEMENTS

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A. RESEARCH ARCHITECTURE BANDUNG

+ VALUES KAMPUNG
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+ RESEARCH INCOME SHOPS KAMPUNG
+ ELABORATION HOUSE B
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  - Roofs
  - Floors
  - Stairs
  - Facades
  - Windows
+ LOCATION /ARCHITECTURAL INTEGRATION
  - Site
  - Housing matrix
PROBLEMS \ VALUES KAMPUNG

// PRIORITIZED ACCORDING TO THE DIGITAL RESEARCH

It is quite easy to pick out obvious problems in the kampung, overcrowding and poor quality were the first problems that came to mind when navigating the kampungs. What took slightly longer was to find the strengths of these areas. It requires a very different mind-set to realise there is great value in these area’s compared to the western ways of building.

The kampung are a great source of economic activity and know a very tight knit community. They are more than just housing areas. This is very important to take into account when designing for these areas.

Fig A1. Visualisation problems Indonesian kampungs (own ill.)
Fig A2. Visualisation most important values Indonesia (own ill.)
ECONOMIC ACTIVITIES
- Workshops
- Hairdressers
- etc.

FOOD STALL COMPLEX

FOOD STALLS ATTACHED TO THE HOUSE

COMMUNITY MEETING SPACE
- Corridor as a place to Go, Sit, Meet

Fig A1.
PRIVACY ZONING

// PRIVACY ZONING AND EXPANSION IMPLICATIONS

The Indonesians know quite a specific zoning system with regards to privacy. During our time in Indonesia it became clear that once you step into the kampung it is similar to stepping into someone’s backyard. The very small kampung streets are considered private property. People use this space not only as social meeting space, but also to expand their houses and shops. Almost all houses have some sort of partially covered outside space to hang their laundry, sit with neighbors or be outside when the monsoon hits. The first room in the house is usual the family room with utility spaces further in the back. Bedrooms are either at perpendicular to the living room, when the house is sufficiently broad, but usual the more private rooms like the bedrooms are situated in the back of the house.

Fig A3. Visualisation privacy zoning kampung Indonesia (own ill.)
1. Bedrooms
2. Family room
3. Reception room
4. Porch/Balcony
5. Semi-private-public inbetween space
6. Street/Walkway
7. Kampung Entrance
INCREMENTAL EXPANSION

// ARGUMENTATION EXPANSION, VERTICAL & HORIZONTAL

During our time in the kampung it was clear most of the space available was build upon. The Indonesian population had two ways of expanding, vertically and horizontally. The research as visualized on the right is based on the article ´Considerations on Typology of Kampung House (red..)´ by Shuji Funo. What was most important for my research was the realization that local building knowledge was often not sufficient for building over two storeys high. The expansion was therefore halted at this level while in the kampung much more building space is needed. This is one of the key elements in my final building system design.

Fig A4. Visualisation incremental expansion methods kampung Indonesia (own ill. based on data from Considerations on Typology of Kampung House (red..) by Shuji Funo)
1: FAMILY EXPANSION

A-1
- BACK GARDEN OR TERRACE TRANSFORMED INTO KITCHEN
- ADDITION OF WASHING ROOM
- ADDITION OF TOILETS / SHOWER
- EXPANSION OF THE HOUSE WITH EXTRA BEDROOMS INSIDE AND UTILITY SPACES PLACED FURTHER IN THE BACK

B-1
- EXTRA FLOOR BUILD OFTEN OF WOODEN CONSTRUCTION
- USED FOR:
  - EXTRA BEDROOMS
  - STORAGE
  - LIVING AREA
  - BALCONY

C-1
- EXTENSION OF GUEST AREA
- EXTRA BEDROOMS
- EXTRA DINING ROOM

2: BUSINESS VENTURES

A-2
FRONT EXPANSION:
- WARUNG/TOKO/WARTEL
- HAIRDRESSER
- WORKSHOP
- GARAGE
- STORAGE SPACE

BACK EXPANSION
- RENTAL TOILETS
- RENTAL ROOMS

B-2
- RENTAL ROOMS UPSTAIRS
- PLACEMENT OF BEDROOMS UPSTAIRS AND NEW SHOP STORE DOWNSTAIRS

C-2
- RENTAL ROOMS BOTH UPSTAIRS
- TOILETS AND BATHROOMS

3: BOTH BUSINESS AS FAMILY EXPANSION

A-3
GROUND FLOOR:
- DINING ROOM
- BEDROOMS
- MORE UTILITY SPACES

1ST FLOOR
- RENTAL ROOMS
- RENTAL TOILETS

B-3
- RENTAL ROOMS UPSTAIRS, SEPERATE STAIRCASE VIA OUTSIDE
- EXTRA FAMILY BEDROOMS UPSTAIRS

C-3
- RENTAL ROOMS BOTH UPSTAIRS AND DOWNSTAIRS
- RENTAL TOILETS IN THE BACK
- WASHING SPACES
- RENTAL HOUSING

C-1
GROUND FLOOR:
- DINING ROOM
- BEDROOMS
- MORE UTILITY SPACES
- TOILETS AND BATHROOM RENTALS

1ST FLOOR
- RENTAL ROOMS
Both from research in Indonesia, as from articles like that of Shuji Funo: "Considerations on Typology of Kampung House (red.)" and "Typology of the Kampung house and its transformations (red.)" a composition of existing typologies of the Indonesian Kampung was drafted:
- Type A - Apartment blocks with one room, no kitchen or private bathroom. Service areas are shared.
- Type B - Apartment blocks with private service blocks
- Type C - Privately owned housing with only one room and kitchen, service areas like toilets and washing spaces are communal in the kampung
- Type D - Privately owned housing with own kitchen and washing areas, often long and narrow.
- Type E - Family housing with both wide and long floor plans, bedrooms often situated in the side of the house.

Fig A5. Visualisation typology kampung housing Indonesia [own ill.]
RESEARCH INCOME SHOP OWNERS

// EIGHT SHOP OWNERS INTERVIEWED

For the local community a safer way of building is not high on the list of priorities. It is therefore essential to find a different argumentation to convince them of using a different building system. In my system there are two reasons why they should use this system to (re)build their houses. The first being an emotional one: when build up over two stories high, there is more room for the family, children will not have to be sent away to live in a different kampung, as is now often the case. The second reason is an econimical one; when there is more space, more money can be earned with the house by turning the ground floor into a shop, workshop or to use the top floors to rent out rooms. The extension of the house would be paid from the revenues of the economic activities. To calculate how long the repayment period would be it was essential to research how big the revenues from shops were.

Fig A6.  Photo warung shop Kampung Dago Pojok (own ill.)
Fig A7.  Photo’s shops & shop owners. kampung Cigondewah & Dago Pojok (own ill.)
TRUNTUT RAWUT SAYUDAN JAGA LEMBUR BABARENGAN YOGUR
WATER SHOP  
Kampung Dago Pojok  
Ibu Dian (32 y/o)  
Family owns water shop  
Sells water bottles / gas stoves  
Does not live next to the shop  
Monthly income from shop IDR 3,000,000

GROCERY SHOP  
Kampung Cigondewah  
Ibu Ai (54 y/o)  
She is a widow who inherited the shop from her husband. She supports 6 children + grandchildren with the shop and also rents out rooms  
Monthly income from shop IDR 1,500,000

BIRDS SHOP  
Kampung Dago Pojok  
Pak Pakedi (35 y/o)  
The house was abandoned, his family fixed it up and has been selling birds there ever since. The family is eight people, two brothers and their family.  
Monthly income from shop IDR 700,000

GROCERY SHOP  
Kampung Cigondewah  
Ibu Tia (32 y/o)  
Family owns grocery store  
Lives behind the shop with her husband and two children.  
Monthly income from shop IDR 1,500,000
ANIMAL STORE
Kampung Cigondewah
Pak Ayep (32 y/o)
Rents the shop and does not live there. Has been renting it for 2 years, is supporting his family of four.
Monthly income from shop IDR 2.000.000

GROCERY SHOP
Kampung Dago Pojok
Ibu Masran (42 y/o)
Owns the house, lives with her family in the back, one husband, wife and four children. House was bought for 40.000.000
Monthly income from shop IDR 2.000.000

GROCERIES SHOP
Kampung Cigondewah
Pak Sanjaya (38 y/o)
Family owns grocery store. He has a side business of renting out cars [revenue 1.000.000 p/m]
Monthly income from shop IDR 2 / 3.000.000

MATERIALS SHOP
Kampung Dago Pojok
Pak Nagreh (32 y/o)
Family owns materials store
Monthly income from shop IDR 4.000.000
ELABORATION HOUSE B

// EXPLODED VIEW HOUSE DURING PHASES

In the visuals on the right the economic revenues gained by applying the researched building system are combined with a spatial organisation. As seen in Fig. A16, the first year gains no extra revenues, the house is simply torn down and replaced by a similar size building, which will serve as foundation for the upper floor to be build upon. In the second year more space is made by adding an extra floor, so a shop can be realised on the ground floor. Revenues made by this shop can be put aside to save up for one extra floor, or if required, two extra floors. If in total four floors are realised, the total term of repayment will be 10 years. This is taking into account only the revenues earned by the shop and rented spaces in the house. The house will therefore in a sense ‘pay for itself’.

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**Fig. A14**

PHASE I // 1st FLOOR - ‘THE RESIDENTIAL’

I.1 Outside living space
I.2 Guest room + Living room
I.3 Bedroom no. 1 (4 m²)
I.4 Bedroom no. 2 (4 m²)
I.5 Service area (kitchen + bathroom)

**Fig. A15**

PHASE II // 2nd FLOOR - ‘THE SHOP’

II.1 Semi public/private space
II.2 Porch for shop
II.3 Food shop: revenues IDR 2.000.000 p/m
II.4 Living room/guest area + stairs
II.5 Service area (kitchen + bathroom)
II.6 Private open space - laundry room
II.7 Bedroom no. 1 (12 m²)
II.8 Bedroom no. 2 (7 m²)

**Fig. A16.**

PHASE III // 3rd FLOOR - ‘THE RENTAL’

III.1 Private entrance rental rooms
III.2 Kitchen area rental rooms
III.3 Rental room no. 1 (7 m²)
III.4 Rental room no. 2 (7 m²)
III.5 Rental room no. 3 (9 m²)
Revenues: 1.750.000 p/m
CATALOGUE EXTERNAL ELEMENTS

// INTEGRATION EXTERNAL ELEMENTS TO BUILDING SYSTEM

In this research a building system for purely the frame of the building was researched. The reasoning here was when there is a very sound frame, the construction imediately becomes more safe. There are however of course other building elements that make up a house. Facades, roofs, floors and stairs are not always easy to construct. While this is not completely part of the scope of this research, I made a catalogue of possible elements that could be sold within the CNC hub. As seen in Fig. A8 there is one hub in the city of Bandung where the system is rented out. The building system could be made in such a way it would fit perfectly with current roofing systems, facade materials and floor widths. Stairs could also be poored in CNC milled moulds and both windows and doors could be made by CNC milling.

Fig A8.  How does it work? (own ill.)
Fig A9.  External elements building system (own ill.)
Fig A10.  Create your own house recepy (own ill.)
Construction System Renting

**BASE CONCRETE FRAME**

- **Give In Plot Size**
- **Calculate Construction**

**Concrete Frame**

- Rent CNC Beam: 400,000 IDR (€ 28.00)
- Rent CNC Column: 300,000 IDR (€ 21.00)
- Rent Scaffolding: 15,000 IDR (€ 1.00) per month/pc
- Reinforcement: Buy per m³: 30,000 IDR (€ 1.75)

**Design Roofs**

- Light Steel: IDR 150,000 (€ 10.50)/m²
- Wooden Roof System: IDR 225,000 (€ 15.75)/m²
- Do It Yourself: IDR ? (€ ?)/m²

**Find Floors**

- Chicken Wire: IDR 27,000 (€ 2.00)/m²
- Steel Sheets (2.10x0.80): IDR 55,000 (€ 3.85)/sheet
- Wooden Floor, Kamper Banjah Wood: IDR 6,500,000 (€ 455)/m³
- Wooden Stairs: IDR 350,000 (€ 24.50)/m²
- Do It Yourself: IDR ? (€ ?)/m²

**Pick Stairs**

- Concrete Formwork: IDR 250,000 (€ 17.50)/m²
- Wooden Stairs: IDR 350,000 (€ 24.50)/m²
- Do It Yourself: IDR ? (€ ?)/m²

**Choose Facades**

- Bamboo: IDR 150,000 (€ 10.50)/m²
- Concrete Frame: IDR 250,000 (€ 17.50)/m²
- Wooden Facade: IDR 350,000 (€ 24.50)/m²
- Do It Yourself: IDR ? (€ ?)

**Doors & Windows**

- Windows & Doors: IDR 1,000,000 (€ 69.00)

**Create Your Own House**

- External Elements System
- Base Concrete Frame
- Design Roofs
- Foundation
- Renting

**Materials**

- Use the hub for detailing connections, also for steel U-shoes for the wooden floors
- Use the hub for CNC Milling of doors/windows or connect with second hand stores
- Use the hub for detailing, possibly formwork for creative bricks

**Light Steel**

- IDR 150,000 (€ 10.50)/m²

**Bamboo**

- IDR 30,000 (€ 1.75)/m³

**Concrete Formwork**

- IDR 250,000 (€ 17.50)/m²

**Steel Sheets (2.10x0.80)**

- IDR 55,000 (€ 3.85)/sheet

**Kamper Banjah Wood**

- IDR 6,500,000 (€ 455)/m³

**Concrete Frame**

- IDR 150,000 (€ 10.50)/m²

**Do It Yourself**

- IDR ? (€ ?)

**Wooden Roof System**

- IDR 225,000 (€ 15.75)/m²

**Wooden Floor**

- IDR 6,500,000 (€ 455)/m³

**Wooden Stairs**

- IDR 350,000 (€ 24.50)/m²

**Wooden Facade**

- IDR 350,000 (€ 24.50)/m²

**Do It Yourself**

- IDR ? (€ ?)

**Concrete Beam**

- IDR 400,000 (€ 28.00)

**Concrete Column**

- IDR 300,000 (€ 21.00)

**Scaffolding**

- IDR 15,000 (€ 1.00) per month/pc

**Reinforcement**

- Buy per m³: 30,000 IDR (€ 1.75)
LOCATION/ARCHITECTURAL INTEGRATION

// RESEARCH INTO MOST USED TYPOLOGIES

The integration of the building system in the local architecture could be done in any place in Bandung. Since the kampung Cigondewah was already chosen by the group of students researching Bandung this was also my chosen location. Within Cigondewah a location was chosen next to the municipal road. Here, five houses were chosen, at random, to analyse. In the housing matrix is shown how much the houses change over time. Each phase of the incremental way of building is shown in the matrix, also the building costs, revenues made by in-house shops and rented rooms, and the calculated repayment period.

Fig A11. Chosen location: Java - Bandung - Cigondewah (own ill.)
Fig A12. Chosen site - Chosen site transformed by building system (own ill.)
Fig A13. Housing matrix (own ill.)
Cigondewah City

Chan Ged situ

Site

Java

Max

imum 2 storey height

Grading and Dual Density
Fig A12.
CHANGED SITUATION

Fig A12.
ASSORTED HOUSING KAMPUNG

1ST PHASE

ORIGINAL

2ND PHASE

3RD PHASE

4TH PHASE

HOUSE A

HOUSE B

HOUSE C

HOUSE D

HOUSE E

REVENUES VS REPAYMENTS

Fig A13.
**1ST PHASE**

- **ORIGINAL**

**2ND PHASE**

- **HOUSE 2 FAMILIES**
  - PLOT SIZE 81.6 M
  - 13.5 X 6 M
  - 2 STOREYS HIGH

**SPACE:** + 200% MORE SPACE (162 M²)

**COST CONSTRUCTION:** (324 M²) ≈ IDR 648 M (€45,000)

**REVENUES RENT/MONTH:**
  - 3RD STORY (55 M²) ≈ 1,925,000 IDR (€135)
  - 4TH STORY (59 M²) ≈ 2,065,000 IDR (€145)

**TOTAL** ≈ 4,000,000 (€280) / MONTH
  ≈ 48,000,000 (€3,360) / YEAR

**TOTAL TERM REPAYMENT** ≈ 15 YEARS

**3RD PHASE**

- **HOUSE 1 FAMILY**
  - PLOT SIZE 74.0 M
  - 10.6 X 4 M
  - 1 STOREY HIGH

**SPACE:** + 300% MORE SPACE (126 M²)

**COST CONSTRUCTION:** (168 M²) ≈ IDR 336 M (€23,500)

**REVENUES RENT/MONTH:**
  - 3RD STORY (30 M²) ≈ 1,050,000 IDR (€74)
  - 4TH STORY (30 M²) ≈ 1,050,000 IDR (€74)

**TOTAL** ≈ 2,100,000 (€147) / MONTH
  ≈ 25,200,000 (€1,764) / YEAR

**TOTAL TERM REPAYMENT** ≈ 15 YEARS

**4TH PHASE**

- **HOUSE 1 FAMILY**
  - PLOT SIZE 91 M²
  - 9.8 X 3.2 M
  - 1 STOREY HIGH

**SPACE:** + 200% MORE SPACE (44 M²)

**COST CONSTRUCTION:** (66 M²) ≈ IDR 132 M (€9,240)

**REVENUES RENT/MONTH:**
  - 3RD STORY (45 M²) ≈ 1,570,000 IDR (€110)
  - SHOP ≈ 1,500,000 IDR (€105)

**TOTAL** ≈ 3,070,000 (€215) / MONTH
  ≈ 36,840,000 (€2,579) / YEAR

**TOTAL TERM REPAYMENT** ≈ 10 YEARS

**ASSOCIATED HOUSING KAMPUNGS**

**REVENUES VS REPAYMENTS**

- **COST CONSTRUCTION** (40.5 M²) ≈ IDR 81 M (€5,670)

- **REVENUES GROCERY STORE:** ≈ 1,500,000 (€105) / MONTH
  ≈ 36,000,000 (€2,520) / YEAR

- **TOTAL TERM REPAYMENT** ≈ 6 YEARS

- **COST CONSTRUCTION** (66 M²) ≈ IDR 132 M (€9,240)

- **REVENUES PET STORE:** ≈ 1,800,000 (€126) / MONTH
  ≈ 21,600,000 (€1,512) / YEAR

- **TOTAL TERM REPAYMENT** ≈ 6 YEARS

- **COST CONSTRUCTION** (44 M²) ≈ IDR 132 M (€9,240)

- **REVENUES GROCERY STORE:** ≈ 1,500,000 (€105) / MONTH
  ≈ 36,000,000 (€2,520) / YEAR

- **TOTAL TERM REPAYMENT** ≈ 6 YEARS

- **COST CONSTRUCTION** (66 M²) ≈ IDR 132 M (€9,240)

- **REVENUES PET STORE:** ≈ 1,800,000 (€126) / MONTH
  ≈ 21,600,000 (€1,512) / YEAR

- **TOTAL TERM REPAYMENT** ≈ 6 YEARS
B. RESEARCH INCREMENTAL BUILDING SYSTEM

+ INTERVIEWS CONSTRUCTION TEAMS KAMPUNG
+ COST CALCULATION SYSTEM FORMWORK
+ DESIGN SYSTEM FORMWORK
  - How does it work
  - CNC milled elements
  - Cost calculation matrix
INTERVIEWS CONSTRUCTION TEAMS

// PROFESSIONAL / SEMI-PROFESSIONAL / INFORMAL

For the second research trip to Indonesia the goal was to visit as much construction sites as possible to assess not only local building knowledge, but also research specific questions like: how to transport material in the kampung, what is the structure of a building team, what are the prices of building cost per m², are there any kind of roof systems in the kampung, prices of building material and so forth.

Many of these questions were answered in interviews with construction leaders like Pak Nana, but also by interviewing Pak Apep, the foremen of local architect Ramalis Sobandi. With him I discussed specifically my building system and incorporated his tips and worries into my final design.
// Pak Iwan (32 y/o) Carpenter (one of three)
// Construction site Kampung Dago Pojok
// Project Extension house (2 floors)

# SEMI - PROFESSIONAL CONSTRUCTION SITE

GROUND FLOOR:
- DINING ROOM
- BEDROOMS
- MORE UTILITY SPACES

1ST FLOOR
- RENTAL ROOMS
- RENTAL TOILETS
- RENTAL ROOMS

UPSTAIRS, SEPERATE STAIRCASE VIA OUTSIDE
- EXTRA FAMILY BEDROOMS UPSTAIRS
Pak Thito (18 y/o) Son of owner
Construction site Kampung Dago Pojok
Project Extention house

TYPE A - HORIZONTAL EXPANSION
1: FAMILY EXPANSION
2: BUSINESS VENTURES

TYPE B - VERTICAL EXPANSION

TYPE C - COMBINATION
- BACK GARDEN OR TERRACE TRANSFORMED INTO KITCHEN
- ADDITION OF WASHING ROOM
- ADDITION OF TOILETS / SHOWER
- EXPANSION OF THE HOUSE WITH EXTRA BEDROOMS INSIDE AND UTILITY SPACES PLACED FURTHER IN THE BACK
- EXTRA FLOOR BUILD OFTEN OF WOODEN CONSTRUCTION
- USED FOR: EXTRA BEDROOMS STORAGE LIVING AREA BALCONY

FRONT EXPANSION:
- WARUNG/TOKO/WARTEL
- HAIRDRESSER
- WORKSHOP
- GARAGE

BACK EXPANSION
- RENTAL TOILETS
- RENTAL ROOMS
- RENTAL ROOMS UPSTAIRS
- PLACEMENT OF BEDROOMS UPSTAIRS AND NEW SHOP STORE DOWNSTAIRS
- RENTAL ROOMS BOTH UPSTAIRS AND DOWNSTAIRS
- RENTAL TOILETS IN THE BACK
- WASHING SPACES

INFORMAL CONSTRUCTION SITE
// Pak Isun (56 y/o) Construction worker (one of 3)
// Construction site Cigondewah
// Project Build new house behind existing house

# SEMI-PROFESSIONAL CONSTRUCTION SITE
INFORMAL CONSTRUCTION SITE

Pak Mamat (45 y/o) Brother of owner (bank clerk)
Construction site Kampung Cigondewah
Project Extention house to two floors

INFORMAL CONSTRUCTION SITE

Type A - Horizontal Expansion
A-1
B-1
C-1
- Family Expansion
- Business Ventures

Type B - Vertical Expansion
- Back Garden or Terrace transform into kitchen
- Addition of washing room
- Addition of toilets/shower
- Expansion of the house with extra bedrooms inside and utility spaces placed further in the back
- Extra floor built often of wooden construction
- Used for: extra bedrooms, storage, living area, balcony, extension of guest area, extra bedrooms, extra dining room

Type C - Combination
- Front Expansion:
  - Warung/Toko/Wartel
  - Hairdresser
  - Workshop
  - Garage
- Back Expansion
  - Rental toilets
  - Rental rooms
  - Rental rooms upstairs
  - Placement of bedrooms upstairs and new shop store downstairs
  - Rental rooms both upstairs and downstairs
  - Rental toilets in the back
  - Washing spaces rental housing
Pak Omar (43 y/o)  Construction leader [foreman]
Construction site: Kampung Braga
Project: Extension house to two floors

# SEMI-PROFESSIONAL CONSTRUCTION SITE

- Type A - Horizontal Expansion
  - A-1
  - A-2

- Type B - Vertical Expansion
  - B-1
  - B-2

- Type C - Combination
  - C-1
  - C-2

Front Expansion:
- Warung/Toko/Wartel
- Hairdresser
- Workshop
- Garage
- Storage space

Back Expansion:
- Rental toilets
- Rental rooms
- Rental rooms upstairs
- Placement of bedrooms upstairs and new shop store downstairs
- Rental rooms both upstairs and downstairs
- Rental toilets in the back
- Washing spaces

Rental Housing
The cost calculation for the formwork consists of the sum of the following factors:
- Material cost formwork
- Maintenance cost CNC mill
- Costs milling (electricity + labour)
- Rent CNC hub
- Labour workers CNC hub

Because certain factors are unsure I had to make a rough estimation for some of these factors and make some assumptions for the other. For the startup of the CNC hub I assume some government help is given by funding the labour costs, maintenance of the CNC mill and overhead costs of the CNC hub. This leaves the costs for the material to be paid in terms by renting out the CNC milled formwork to possible house owners. Current building practice in Indonesia is to use Albasia wood, also known as Kaso. This wood is the cheapest option in Indonesia, after use it is sold to garbage companies to be burned. Slightly better wood: Dolken is used for crossbracing the scaffolding of the formwork. When in good condition this wood is sold to furniture makers, or when in bad conditions it is sold together with the Albasia to be burned.

A quick comparison of the three materials available for milling the system-formwork shows that cocosboard (by Goodhout) is the best option. Not only is it very sustainable; it uses local cocos husk waste material to press high quality board material, but it can also compete price-wise. Betonplex is very strong and has a surface suited for multiple usage but can not compete price-wise. Moso Bamboo boards is a very sustainable material, but has a rather porous surface and is therefore less suited for multiple usage, unless it is coated thoroughly.
ALBASIA / KASO
Local Indonesian formwork
Unknown Kn/m²
€ 210,- per m³
15.000 IDR/m³ (5 mm board)
Reusability = 1 times, burned after

COCONUT HUSK BOARD (CHB)
+/- 5.000 Kn/m²
€ 10,- per plaat (1.2 x 2.4 x 0.05 m)
50.000 IDR/M²
Boards of 1.20 x 2.40 m
Reusability = 5 times

BETONPLEX
+/- 4.500 Kn/m²
€ 39,- per plaat (1.2 x 2.4 x 0.18 m)
190.000 IDR/m²
Boards of 1.20 x 2.40 m
Reusability = 3-5 times

MOSO BAMBOO
unknown Kn/m²
€ 39,- per plaat (1.2 x 2.4 x 0.18 m)
190.000 IDR/m²
Boards of 1.20 x 2.40 m
Reusability = 3-5 times

FORMWORK COLUMN
3,8 m² needed + 5% lost material
= 4 m² material needed
4 m² x 50.000 = 200.000 IDR
The column can be reused five times so the cost per column per time rented is:
200.000 / 5 = 40.000 IDR
Material for a similar sized column using Albasia wood is 60.000 IDR.

FORMWORK BEAM (3 M GRID)
5 m² needed + 5% lost material = 5,3 m² material needed
5.3 m² x 50.000 = 265.000 IDR/beam
The 3 m beam can be reused five times so the cost per beam per time rented is:
265.000 / 5 = 53.000 IDR
Material for a similar sized beam using Albasia wood is 80.000 IDR.
The formwork system was designed in a way that it could provide for most orthogonal floorplan shapes of the kampung. While the columns were always 2.5 m, the length of the beams varies from 2.5 until 4.5. When a longer beam is needed, for example 5 meters long, an extra column is placed in between and two shorter beams are combined. As seen in Fig. B2 the columns determine what kind of corner is poured in concrete, L, T and + shaped corners could provide for all connections necessary. On the next page is shown not only the exploded view of the CNC milled beams and columns, but also the recipe for the milled elements to send to the CNC mill. Everything in grey is necessary for the milled element, everything in white can be considered extra stock.

**Fig B1.** Variable length beams formwork system (own ill.)
**Fig B2.** Variable shapes columns formwork system, depending on corner shape (own ill.)
**Fig B3.** Shape formwork system, 3 x 3 x 2.5 measured (own ill.)
Fig B4. Exploded view assembly column formwork system (own ill.)
Fig B5. Exploded view assembly corner formwork system (own ill.)
Fig B6. Exploded view assembly beam formwork system (own ill.)
Fig B7. CNC recepy column formwork system (own ill.)
Fig B8. CNC recepy beam formwork system (own ill.)
Fig B9. Housing matrix construction + costs calculations (own ill.)
Fig B7.

Fig B8.
Construction Building System Cost Renting Building System

House A  House B  House C  House D  House E

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<th>RENT PER PHASE</th>
<th>TOTAL RENT COSTS</th>
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Fig B9.
C. MODEL MAKING

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C1. 1:50 // Travel model

C2. 1:7 // Building system 1.0
C3. 1:7 // Building system

C4. 1:7 // Building system - poored result

C5. 1:100 // Location model kampung Cigondewah

C6. 1:1 // Building system - corner detail on
Using digital fabrications to create a hybrid design for developing countries