

Building material reuse and upcycle strategies in Bandung, Indonesia

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Abstract

In this research paper the current building materials for low-income self build dwellings in Bandung, Indonesia are analysed. Additionally local re-use and upcycling opportunities of materials are investigated by site analysis and the use of case studies. A concluding strategy allows designers to make educated decisions concerning building materials that provide a future focus regarding re-use and upcycling of materials.

Keywords: Bandung, Indonesia, Building materials, Reuse, Upcycling, Circular economy

1. Introduction

Bandung is the third largest city in Indonesia with approximately 2.5 million inhabitants in 2018. The current scale of the city of Bandung has a strong relation with Indonesia's history of Dutch colonialism. The Dutch advertised Bandung as new capital of Indonesia mostly because of the more comfortable and healthier climate. After Dutch rule ended in 1949 Indonesia was struggling with finding its own identity which led to times of big instability within the government.

This instability combined with massive globalisation lead to a big influx of people moving to the city and building informal dwellings on abandoned or unoccupied land area.

Informal dwellings are defined as: dwellings that are self-built or have no formal contractor and instead make use of local entrepreneurs.

These urban dwelling area's also known as kampungs and should not be mistaken with rural kampungs which are in fact just small villages.

The focus of this research is on the central area of the city: Kampung Braga. This area is particularly interesting because of the big amount of informal dwellings that are present here.

The kampung structure is a very dense structure consisting of narrow streets which are not uncommon to be found with a width of just 1.2 metres. The population of kampung Braga is about 2.368 people with a high density of 0.12 people/m²¹. Cars are not able to enter the kampung so main transportation is done by foot, grobaks (handcarts) or scooters. The community of both the kampungs can be depicted as tight knit communities.

This is due to many big family structures all living within the same kampung. The relative small scale allows everyone to be familiar with each other.

The kampung contains a diverse mixture of incomes. These different types of income work complimentary.

Much of the infrastructure is provided by the community through a system of mutual cooperation - Gotong Royong². Every inhabitant of the kampung contributes to the Gotong Royong according to their means. For example for building a new mosque a bigger contribution is provided by people with a higher income. The lower income group provides other tasks and services like street sweeping and waste gathering from houses. This diversity of income is a common phenomenon for urban kampungs. The previous research of housing costs of low-income kampung dwellers also shows that the lower income inhabitants can earn up to just 8% of what higher income inhabitants earn. This shows that the range of income within the kampung is very diverse. In this study 6 different urban kampungs were compared.

The field research area contains mostly dwellings and shops.

The buildings in the peripherique of the boundary are mostly old Dutch colonial building that contain shops. The centre area which is considered the kampung contains mostly informal housing.

Informal housing might be in poor physical and economical condition and for an outsider it might be considered as a slum. But this is incorrect. A study from Japan explained the kampung as follows: *"It should be emphasized that kampung is not a slum. Kampung shows a different appearance from the urban settlements in western cities. Destruction of social structure and crimes are rarely seen in the kampung. It is also not a discriminated settlement but a community as an urban settlement has its special characteristics as an autonomous community model. That has its own social system and values."*³

Other important functions located within the site are: an electronic appliances marketplace located south along the river. A mall and hotel located in the centre of Kampung Braga. And finally the site contains many car repair and tire shops all along the north side of both kampungs.

Dwellings in the kampung are usually just 1 or 2 stories high. Buildings are most commonly constructed with a stone base and a wood top construction. Dwellings expand over time depending on the different needs. This can be confirmed from a kampung study in Surabaya where transformation process of kampung dwellings over time involves the addition of extensions to the existing structure.⁴

2) Benjamin, S., & Arifin, A. (1985) *The housing costs of low-income Kampung Dwellers*, London. United Kingdom: faculty of development and planning

3) Funo, S., Yamamoto, N., & Silas, J. (2002) *Typologie of Kampung houses and their transformation process, A study on urban tissues of an Indonesian city*, Japan, Kyoto University.

4) Benjamin, S., & Arifin, A. (1985) *The housing costs of low-income Kampung Dwellers*, London: faculty of development and planning.

2. Problem Statement

Building in Indonesia is most commonly done by self-building. Previous research has stated that 80% of low income housing consists of self-build dwellings⁵. This was later confirmed by observations of the informal settlements themselves. The combination of this self-build culture in Indonesia with a limited amount of trained experts leads to a decrease in building quality and building safety in dwellings.

As the third city of Indonesia, Bandung will experience a staggering growth from a population of 2,5 million to date towards a population of 4 million inhabitants in 2030. (bandung municipality numbers) This staggering amount of influx of people means almost a doubling of the population in a short period of 12 years. Thus increasing the need for fast solutions concerning high density dwellings.

The substantial increase of the population will lead to a big demand in additional dwellings to be build. The majority of these dwellings are constructed in the informal building sector. The process of building consists out of an enormous consumption of material resources. This raises problems concerning material scarcity and sustainability.

For this research paper the main focus will be on defining and finding sustainable future focussed building materials that do not limit or compromise the ability for future generation to meet their own needs.

With the large increase in housing that will be build it is important for designers, governments and the people themselves to get insight of building materials and future focussed strategies like reuse and upcycling within the potentials of the area.

1.2 Research Questions

The previous stated problems lead to the following research questions:

What are the building material flows that are at work within urban kampung areas and what is their potential within the existing systems to increase reuse and upcycling?

Sub-questions are:

- What are the building material flows in Bandung?
- What are the building material flows in urban kampung areas?
- What materials and waste flows have potential for reuse and upcycling within urban kampung area's?
- How can the re-use and upcycling of buildings materials be increased within urban kampung areas?

5) Tunas, D., & Darmoyono, L. (2010) *Self-Help Housing in Indonesia*. Jakarta, Indonesia.

3. Methodology

A multitude of research methods have been applied for this research study. The combination of these different research methods leads towards creating a strategy for building materials that can be used effectively for future challenges. A diagram has been added to elaborate the research methodology. (figure 2)

To obtain information of general building material input a literature study is conducted. The research data gives insight in the average amount of building material per square metre used within Bandung, type of main building materials and the amount of building material waste. This results in a quantitative building material flow analysis.

To determine the more specific input of the urban kampung areas introduced in this paper a field research was applied. The method of field research through observations and interviews forms the main body of the research.

A total of 6 interviews have been conducted for this study important to note that some interviews have been conducted with key informants in relation to the subject of research.

The interviews were mainly important to determine the origin of the building materials and the different actors and stakeholders that are in place.

By method of site observations the specific building material input flows of kampung Braga were determined. Because of the lack of quantitative data estimations have been made based on the data from the bandung analysis.

Within this part of the research input building material flows of the site are observed through analysis of three different types of dwellings depending on income. The buildings materials are categorized on four different aspects: roof, structure, infill and openings.

The building material output was defined through observations within the kampung. Different disposal locations within the kampung were analysed on content. Additional field research is applied to determine potential waste flows from industries that could be applied as building materials and products.

The case study research is applied to showcase different methods and ways of handling (waste) building materials. The case studies are selected to illustrate that by incorporating design within the production value can be added which makes the products a viable option to use in the kampung communities.

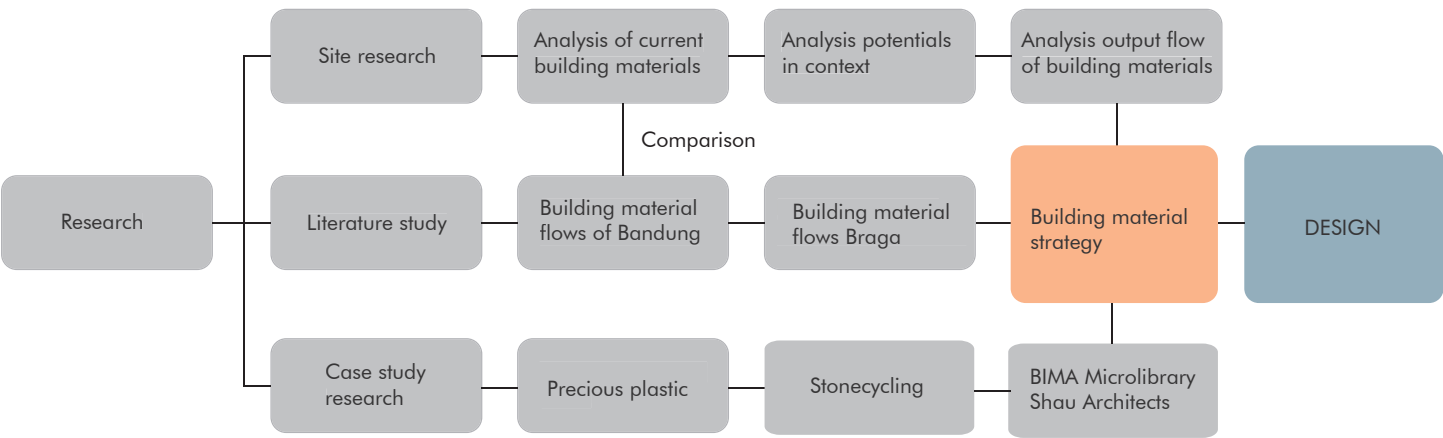


Figure 2: Research Methodology

4. Building material input Bandung

Determining the input and output flows of building materials is a complicated process. Especially for this specific context where informal housing is most common way of building. This leads to a lack information about the building material inventory.

However a crucial study⁶ that was conducted in 2014 by Surahman *et al.* gives insight of the general building material flow of Bandung. The study examined 247 dwellings in Bandung. The buildings were compared within 3 categories. Simple (lifespan of 20 years or less), Medium (lifespan of 35 years) and luxurious (lifespan of 50 years or more). Lifespan of dwellings had a direct relation with the income of the inhabitants.

In Bandung the average amount of building materials in dwellings is 2.06 tons per square metre. There is a slight difference between the different lifespans of dwellings. Buildings with a longer lifespan tend to use more mass for the construction of the dwelling. For example simple houses in Bandung contain around 1.88 tons per square metre, luxurious houses have an average of 2.26 tons per square metre.

Waste flows from building materials mostly end up in landfill areas around the city. The total waste flow is calculated from the waste that is generated from the current material stock.

By 2020 primarily simple houses will be demolished because of their shorter lifespan. The total amount is calculated at 12.6 million tons of waste building material.

From the data the total mass of the different materials can be derived in kg/m² of a dwelling. As expected concrete has a significant percentage from the total material flow.

The data used for the material flow analysis can be found appendix A.

The building material stock represented in the research consisted out of 247 dwellings. This results in a total building material stock of 77.2 million tons (7720 billion kg)

It is calculated that 12.6 tons of building material from that stock will become waste in a period of 6 years. (2.1 million tons a year). This is about 2.7 % of the total stock which degrades over time.

By applying the percentages found in figure 4 of the different building materials it is possible to define the building material waste flow analysis shown in Figure 5. In this analysis the assumption is made that the input of the stock of 210 billion kilo's grows or stays the same. Output of waste material is assumed to be brought to landfills with limited to no recycling.

Material	Simple (kg/m ²)	(%)	Medium (kg/m ²)	(%)	Luxurious(kg/m ²)	(%)	Total (kg/m ²)	(%)
Concrete	1302.9	69.20%	1542	69.20%	1571.3	69.50%	1429.1	69.2 %
Timber	143.1	7.60%	161.5	7.20%	43.2	1.91%	139.1	6.75%
Clay bricks	371.7	19.70%	414	18.60%	451.2	19.97%	397.7	19.30%
Clay Roof tiles	20.7	1.10%	30.3	1.36%	0	0%	22.2	1.10%
Asbestos	0.6	0.03%	0.3	0.01%	0	0%	0.4	0.02%
Rest	44.2	2.35%	79	3.55%	193.6	8.57%	75	3.36%
Total	1883.2 Kg/m ²		2227 Kg/m ²		2259.3 Kg/m ²		2063.6 Kg/m ²	100%
Total Building material waste flow Bandung								

Figure 3: Building material data Bandung

6) Surahman, U., Higashi, O., & Kubota, T. (2014) *Embodied energy and CO2 emissions of building materials for residential buildings in Jakarta and Bandung*, Indonesia, CEPT University.

It is also interesting to look at the type of building materials used. The study showed that the main type of roofing material applied are clay roof tiles. Asbestos are also used in limited quantity. The use of asbestos for roofing diminishes for the medium and luxurious houses.

For the structure mainly concrete is used for all categories. A small percentage of the structure consists of timber.

Walls/infill are mainly made from bricks and a marginal part form concrete blocks. Foundations are mostly made from concrete however about one third of simple dwellings uses stone.

Figure 4 shows how the building materials are applied for the different functions of the building. This data is also used to estimate the building material flows of Kampung braga.



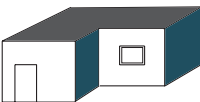
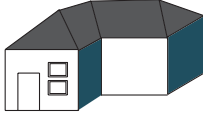




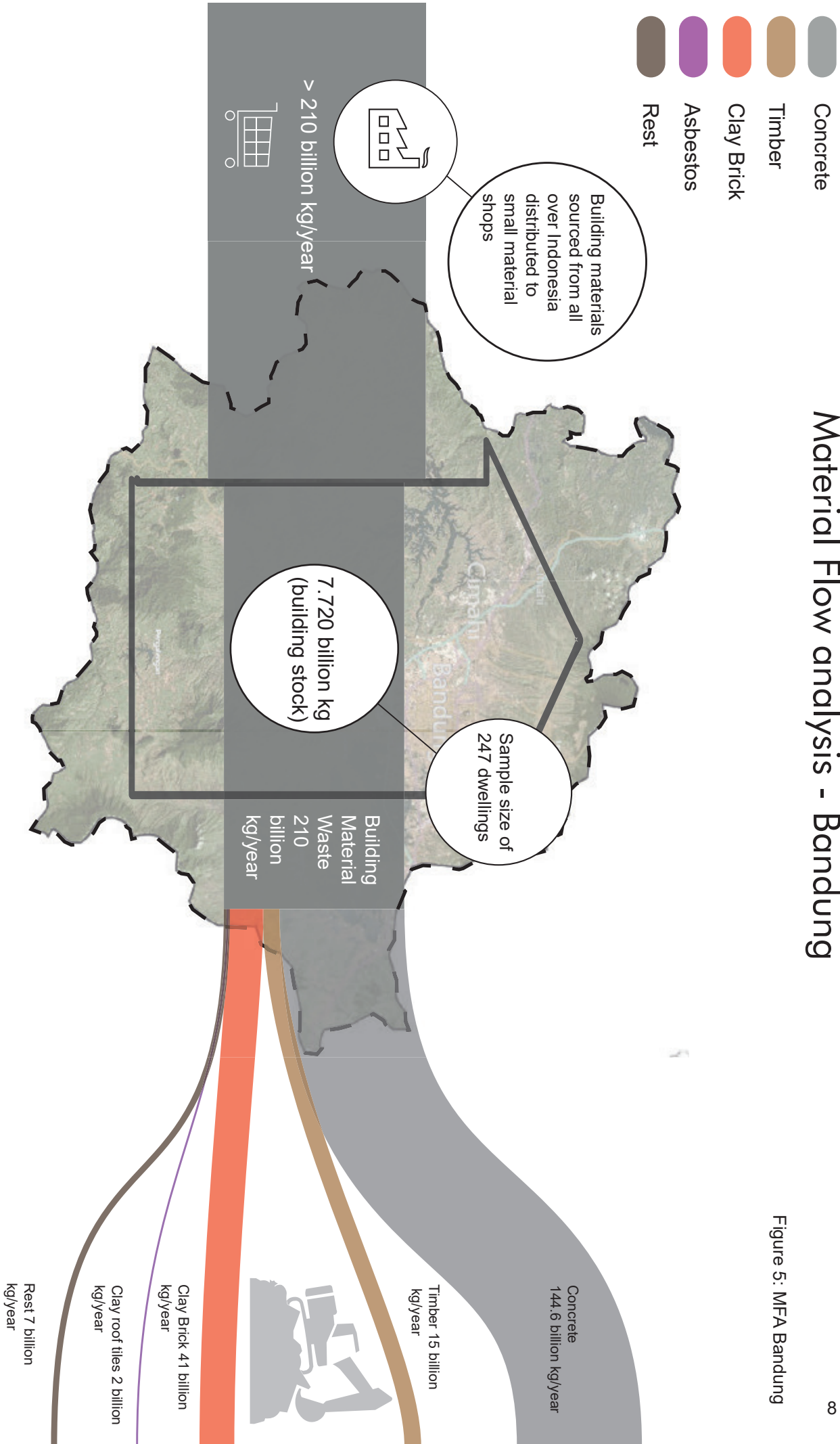
 Average of 2.06 ton/m2 of building materials	 Simple house	 Medium house	 Luxurious house	Total
 Roof	74% Clay roof tiles 12% Asbestos roof	94% Clay roof tiles 5% Asbestos roof	100% Concrete roof	56% Clay roof tile 33.3% Concrete roof 5.6% Asbestos
 Structure	94% Concrete 6% Timber	93.25% Concrete 6.75% Timber	98.2% Concrete 1.8% Timber	95.15% Concrete 4.85% Timber
 Infill	98% Clay brick 2% Concrete block	100% Clay brick	97% Clay brick 3% Concrete block	98.33% Clay brick 1.66% Concrete block
 Foundation	64% Concrete 36% Stone	70% Concrete 30% Stone	87% Concrete 13% Stone	73.66% Concrete 26.33% Stone

Figure 4: Housing material composition

Material Flow analysis - Bandung

Figure 5: MFA Bandung



Indonesia

System Boundary Bandung City

Landfills/Incineration

5. Field Research

The site was analysed for a period of 14 days. The field research is a qualitative research achieved primarily by observations and interviews. This is the most prominent research method used within this research. Obtaining more knowledge about the context and culture is crucial to be able to create tailor made design solutions for the local conditions. This is to create in the end a successful and “working” design.

Within this field research 6 interviews were held in order to gain a good understanding about complete flow of building materials within urban kampung area's. The questions were aimed to create a solid understanding from the origin of the building materials till the end of life and reuse of the building materials. Getting a good understanding of the complete lifecycle and location of the building materials gives input towards answering the research question in how to improve reuse and upcycle strategies within the current system.

For the field research it is important to define the boundaries of the site. The scope of this study encompasses the area in the centre of the city Bandung called Kampung Braga and Kampung Cikapundung. Both located on the east and west bank of the river respectively. The boundaries of the field research are clearly determined by big traffic ways that surround the area.

This area is chosen for the field research because of the high amount of informal housing represented here. The high amount of informal housing can be explained through history. Originally the area along the river in the centre of the city was unoccupied green area. However periods of big governmental instability combined with massive globalisation lead to a large influx of people moving to the city. Without the governmental control they were able to start occupying the open area along the river.

It is important to note that conclusions done within this research are from this specific area and might differ for other kampungs. However it does provide a good base line and understanding about the flow of building materials within urban kampungs in general.

5.1 Building Material Origin

Where do the building materials come from?

To obtain information about the origin of the building materials interviews were conducted with four different people within the kampung. It was remarkable that all informants pointed to the same building material shop located at Sasak Gantung. Sasak Gantung is a street approximately 1 km south from Kampung Braga (see Appendix D).

The knowledge that the majority of building materials come from this specific shop. The analysis of the available building material stock automatically tells something about the building materials that are available to use within the kampung.

The available stock is analysed by observations and a price list is provided of the available materials. (See Appendix D Origin of building materials)

Building materials are usually transported from Sasak Gantung by non motorized methods e.g carried or transported by hand carts. Interviews with the vendor revealed that about two third of the building materials bought are transported by the client themselves. The remaining on third of clients order the material from the shop after which they get transported by grobak (handcart).

Potential reasons most of the building materials are collected by individuals themselves involve: Less costs, the relative close vicinity of the building material shops and the ability to check the quality of the materials bought.



Figure 6: Building Material Transportation

The location where the shop obtains its building materials from was also incorporated within this research. The transportation distance range differs greatly: Steel is obtained from Cilegon located at the north west side of the island of Java 258 km from Sasak Gantung. Borneo wood is obtained in Borneo and Sumatra. Albasia wood is sourced from Tasikmalaya located next to kampung Naga at 100km distance. For the complete list of building material locations see appendix D.

The great distance of materials sourcing indicates that Sasak Gantung is a primary seller concerning building materials. Building materials are purchased directly from the manufacturer or provider of natural resources. Small building materials shops found in other urban kampungs can be seen as secondary traders which source their building materials from closer distances or from shops like the one found at Sasak Gantung.

5.2 Building material input site

What building materials are used?

Understanding which building materials are used for the construction of dwellings provides not only an important body of knowledge about the context, but also makes the comparison possible for the building material input flow (building the building) and output flow (which building materials are commonly reused?).

For this analysis it is important to represent the kampung as a whole.

Therefore three different buildings are analysed depending on difference in lifespan. Simple houses (20 years), medium houses (30 years), and luxurious houses (50 years). From all categories one house is selected and analysed. The conclusions are pictured in figure 7. The complete analysis is shown in Appendix B.

The buildings are analysed within four important aspects of buildings: roofing, structure, infill and openings.

The concluding scheme (figure 8) displays the most common observed building materials for the different categories. The scheme is ordered in such a way that the most common building materials are located at the top.

Roof - the most common material for roofing are corrugated sheets. These are found from different materials like iron, asbestos and plastics. Clay tile roofing is also very common within the kampung. For very temporary structures or protection against rain plastic tarps are used as roofing material.

Structure - most structures in the kampung are either made from concrete or timber. Additional levels are most commonly constructed with timber. Roof structures consist out of timber or steel profiles.

Infill - Bricks and Corrugated sheets are very commonly used as infill material. Additionally different types of plastics are used in different forms mostly as waterproofing materials of the facade. Plywood applied on a basic timber frames is also a common infill material and method.

Openings - openings are usually constructed with old timber frames for doors and windows. Glass is not commonly applied to all openings it is more common that basic ventilation openings suffice, occasionally with a decorative addition.

5.3 Site specific building material analysis

What are the building material flows in urban kampung areas?

From the specific site of kampung Braga there was no data available to determine the building material flows. However by applying the data from the research of Surahman *et al.* it is possible to get an rough estimation of the material flows within kampung Braga. (Figure 9).

To determine the total building material stock in dwellings the same value of 2 tons per square metre is applied. This results in a total building material stock of: 6.02 million tons.

total waste material per year is estimated at 2.7% of the total stock: 16.25 billion kilograms.

The type of building materials found for the different functions of the building in the study of Surahman *et al.* does not reflect the materials used in the kampung. For example concrete is way less prominent in kampung Braga then in the rest of Bandung. This is taken in account and elaborated on in appendix C.



Simple house

- Brick base structure
- Timber top construction
- Corrugated sheets as roof and infill



Medium house

- Concrete base structure
- Timber top construction
- Corrugated sheets as roof
- Infill of brick and corrugated sheets



Luxurious house

- Stone base construction
- Timber top construction
- Clay roof tile roof
- Brick infill

Figure 7: Observational analysis building materials kampung braga

Roof	Structure	Infill	Openings
 Asbestos or corrugated iron sheets	 Concrete	 Clay brick	 Timber
 Clay roof tiles	 Borneo Timber	 Asbestos or corrugated iron sheets	 Glass
 Plastic tarp	 Clay brick	 Plastic sheeting	 Ceramic Ventilation opening
 Zinc roof	 Steel profilesP	 lywood	 Glass brick

Figure 8: Concluding scheme most common building materials

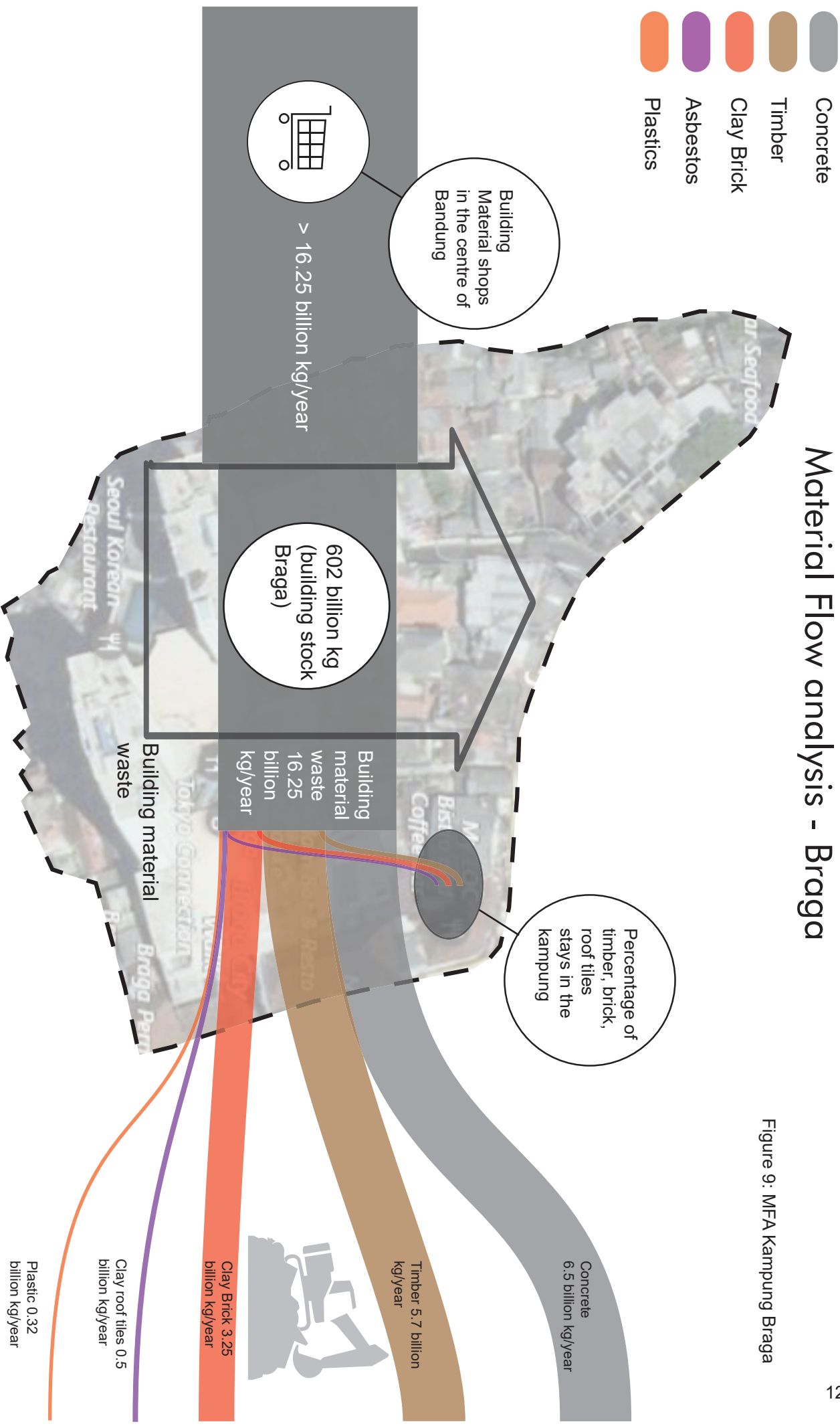


Figure 9: MFA Kampung Braga

Bandung City

System Boundary kampung Braga

Landfills/incineration

5.3 Current Building Material Re-Use

What happens with the building materials after use?

End of use life is realized after the building materials decrease in use value through degradation processes or demolition. A majority of building materials becomes waste. In this chapter a comparison is made with the input flow defined earlier in chapter 4 and the output flow observed in the field.

The output flow of building materials does not all end up as waste material. Certain building materials are already reused within the kampung.

Building materials that are deemed valuable enough to keep are stored within open spaces in the kampung. The building materials are stored in open spaces because the rest of the kampung is so dense that storing materials elsewhere would deem impractical.

Ownership of these building materials is not clear. In principle everyone from the community can gather the building materials they need.

However interviews conducted revealed that it is common courtesy to ask an elder if certain materials are reserved.

To define which building materials get reused or are deemed valuable enough a site analysis is conducted. The several open spaces that are used for collection of building materials are mapped and their composition is examined (figure 7).

The results are shown in figure 8.

The composition revealed the materials that are most commonly reused are: timber, brick/ stone waste and clay roof tiles.

It also revealed that plastic, an important material used for roofing and infill is almost not reused. Glass is also not reused. Questioning why these materials are not reused is important. Glass is for example a brittle material and has no value for reuse when broken. Plastics have potential for reuse and are durable materials however they are not valued as high as timber, bricks and corrugated sheets. These materials are valued high because of their convenience as building material (especially timber). Bricks and corrugated sheets are also very durable.

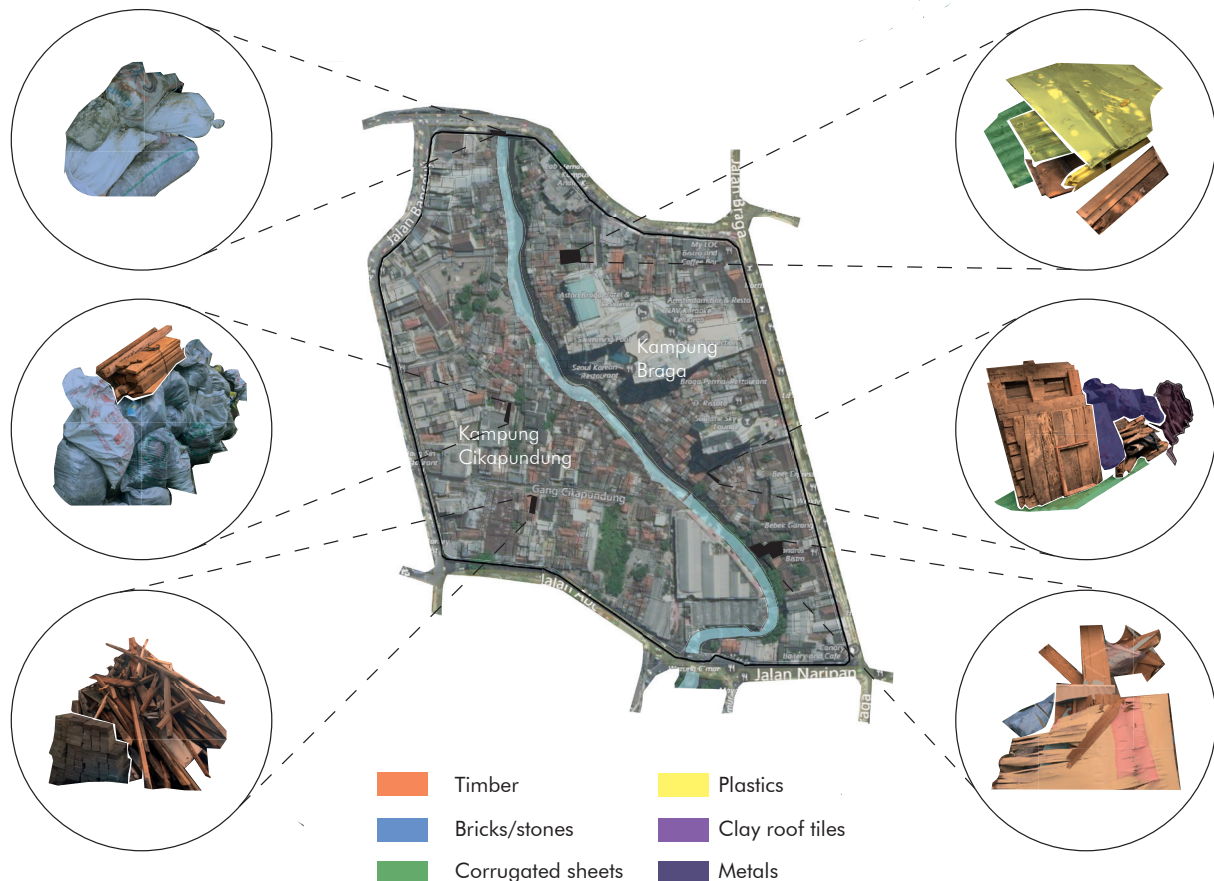


Figure 10: Reused building materials composition analysis

Output flow maintained within the kampung

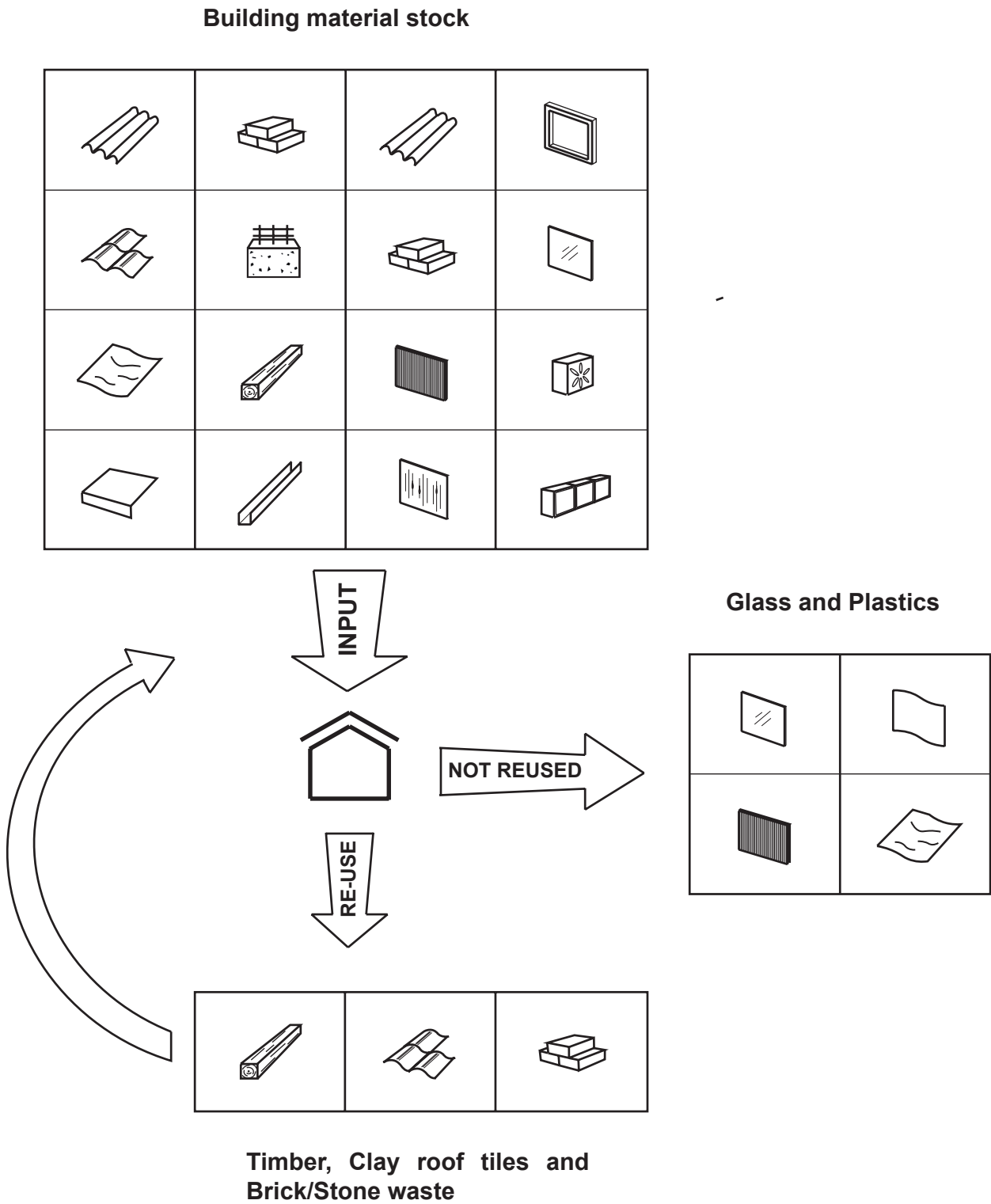


Figure 11: Building materials output flow

5.4 Building Material Potentials

What materials and waste flows have potential within Kampung Braga?

There are more potential flows within the research area other than building materials flows from dwellings. In order to find these flows it is important to define the functions of the entire area. As mentioned before the main functions located within the area are: dwellings, electronic appliances market, the mall, hotel and tire (repair) shops.

Observations revealed the tire repair shops offer a potential source for building materials. The other functions within the area have waste flows that are not efficient for reuse or upcycling concerning building materials. For example the electronic appliances market contains waste material that consists out of several different types of material, these are hard to separate making reuse or upcycling of the material difficult.

It is important to note that the car-repair industry in this part of the city has a long history. Interviews with academics from the heritage and preservation of Bandung revealed that Braga street was the first place where cars were sold and maintained in Bandung.

The function has remained through time and has an important historical role. Current observations have revealed many second hand tires are stored within the kampung. Tires are reused constantly. This is done by local workers who use homemade chisels combined with a burner to carve out new profiles for tires. The waste produced by creating new profiles for tires is left on the ground. Two shapes are generated: short chippings that can be upcycled into rubber tiles for terraces, roofing and acoustic mats for walls and floors and long strands that can be woven into infill panels.

This indicates there is potential in waste materials from these local industries for building materials. The reuse of rubber as building materials is one example of potentials in the context. Further and broader context research is necessary in order to find more potentials in the context.



Figure 12: Rubber tire waste

7. Case studies

The following case studies are selected because of their importance to showcase methods to reuse and upcycle materials. They serve as inspiration and are important to further assess a strategy that could be implemented within urban kampung areas to increase reuse and upcycling.

7.1 Precious Plastic

The primary goal of this small company is to decrease overall plastic pollution. They strive to achieve this by setting up containers with different processing machines to be able to create products from plastic waste. The containers can be placed all over the world which follows their global vision on tackling the plastic pollution problem. The machines needed for processing can be self build for low costs.

Precious plastic facilitates all tools needed to get started.

Different machines are used to be able to create products from plastic waste. A shredder breaks big plastic elements in smaller pieces to facilitate use in other machines. The Extrusion heats up the plastic and can create filament which can be used for 3d printing. An injection machine can create different products with different moulds through injection moulding and the compression machine allows for bigger elements to be moulded.

The products that can be created vary from phone cases to door handles but also building scale elements like tiles and building blocks can be created.



Figure 13: Precious plastic machines and products

7.2 Stonecycling

Stonecycling founded in 2013 saw an opportunity with the huge waste potential from the construction sector which accounts for 30% of all waste generated. Different initiatives for recycling these materials were already in place but they generally lead to the downcycling of the materials. For example used as infill material for roadbeds. Additionally raw materials become ever more scarce which will prove to be a huge challenge for the future.

Stonecycling started developing new materials from waste material that most importantly did not compromise on structural integrity and aesthetics. Especially by focussing on the aesthetics additional value could be secured within the materials (upcycling).

The process involves crushing waste brick and stone waste to create an aggregate to apply in new bricks. About 60-70% of each brick is made from waste. The products have three different finishes and multiple different sizes. The bricks are mostly machine made but can also be made by hand. This makes the products very exclusive.

A disadvantage of the very labour intensive production is that the prices make it less suitable for general construction.



Figure 14: Stonecycling

7.3 BIMA microlibrary

The BIMA microlibrary designed by Shau Architects is a pavilion type building that functions as a small public library. The micro library is situated in an area with many low and middle class income dwellings. The project is part of a "100 Micro Libraries" program in 2012. This program was initiated by the mayor to improve the lack of education facilities within Bandung.

The building is located in small park-like area with playgrounds. Before the building was constructed the location functioned as a stage for community gatherings. This function has been maintained by elevating the library above the ground. The resulting space is covered against rain improving the original community space.

What makes the project interesting is the upcycling of a waste materials in the facade. Originally Shau Architects wanted to locally source jerrycans for this project. However the availability was too limited for this project.

Instead of jerrycans they found icecream buckets sold in bulk on an online marketplace called Tokopedia. A number of 2000 ice cream buckets were used for the facade. The buckets are connected to a steel frame and can be applied in two ways to allow for patterns to be made. The facade is permeable so additional interior sliding panels are added for protection against heavy rain. Shau later used the same idea to create lamps from the same ice buckets.

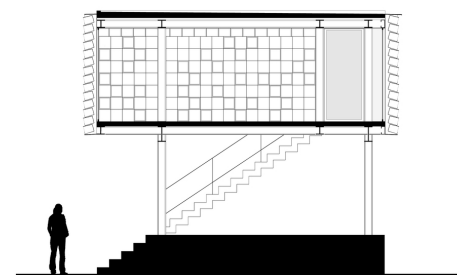
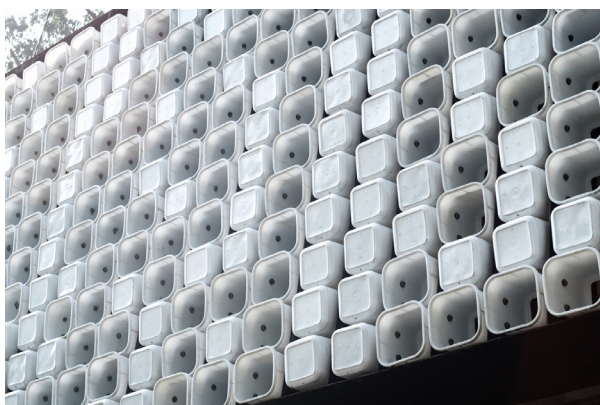
Roof: The roof is a simple concrete slab.

Structure: The structure is made from steel I-beams on a concrete foundation.

Infill: Ice cream buckets. The material is a suitable solution to the tropical climate in Bandung. It is durable water resistant and lets light through and the appliance allows for ventilation.

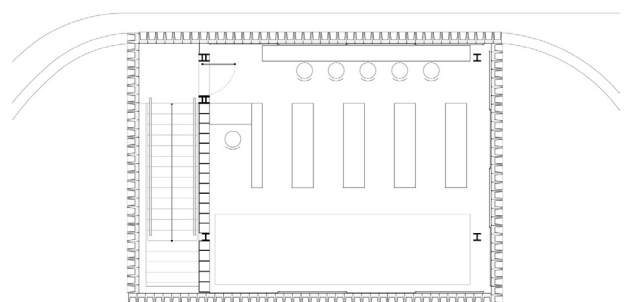
Openings: there is a limited amount of openings the translucent ice bucket facade allows for light to enter the building.

Construction methods are not suitable for self-building because of the high end connections and structure used.



SECTION

0 1 2 m



FIRST FLOOR PLAN

N
0 1 2 m

Figure 15: Images BIMA Microlibrary

8. Conclusion

The main goal of this study was to analyse the material flows of kampung Braga in order to create a suitable strategy to increase reuse and upcycling in urban kampung areas. By combining the data from a previous building material study in Bandung with the information of the observational analysis an estimation of the quantitative building material flows of kampung Braga could be made.

The building material flows of Bandung were based on a sample group of 247 dwellings. The waste flows from this dwelling stock are calculated at 210 billion kg a year. The waste flows that are deemed to have the most potential for reuse and upcycling are visualised in figure 5. These are: concrete 144.6 billion kg/year, timber 15 billion kg/year, clay bricks 41 billion kg/year and clay roof tiles 7 billion kg/year. The choice of these materials is primarily based on amount of mass and availability.

The observational site analysis revealed that the specific context of kampung Braga did not reflect the same appliance of building materials as the study of Bandung. For example in kampung Braga the second floor of dwellings was mostly built with a timber structure explaining the relative higher amounts of timber found in the waste flow. The following material flow analysis (figure 9) revealed that concrete is still the most common building material waste (in mass): 6.5 billion kg/year. Note that both studies are based on mass and concrete has a relative high mass compared to the other materials. At second place timber: 5.7 billion kg/year. The other materials were clay bricks 3.25 billion kg/year, clay roof tiles 0.5 billion kg/year and plastics 0.32 billion kg/year respectively. These materials are determined most suitable to target for reuse and upcycling.

The differences between the study and the analysis of the site can be explained by the scope of research. The broad scope of Bandung incorporates all types of housing also housing of relative higher income areas. This is in strong contrast with the urban kampung site which is in comparison a relative low income area.

Further analysis of input flow of building materials showed that all the building materials originate from the same building material shop. Origin and location of these materials varies but are obtained from within Indonesia. The building materials observed in this shop are similar to the materials observed within the context further confirming the input flow of building materials.

The output flow of building materials was observed within the kampung. The majority of waste from demolition or degeneration is transported to landfill areas. A small portion of building materials is stored in the kampung for potential reuse (see figure 9). The already limited space within the kampung is used for the storage of these materials indicating there is a certain value attached to these materials.

The comparison of the input flow of building materials versus the output flow of building materials concludes that the main building materials that have value are: timber, clay roof tiles and clay bricks. This indicates that the rest of the materials like the plastics found within the area are not valued and are transported to landfills. This means that plastics form a good potential group to start recycling and upcycling in urban kampung areas.

The biggest potentials of waste sources from local industries are found with the tire repair shops. Tire waste like chippings and strings are currently seen as a waste product but have potential as building products like acoustic mats for walls and floor or rubber tiles for terraces and rubber tiles.

To improve reuse and upcycle strategies for building materials both the current reuse/recycling of building materials and the currently non reused building materials should be addressed. Materials that are now transported to landfills can be processed locally into new building products like the example of the case study of precious plastic indicates.

The use of processing facilities is the main strategy to increase reuse and upcycling in urban kampung areas (figure 16). To fit the needs and the structure of the kampung such a facility should preferably be small scale and require limited expertise to operate. The small scale is important because this decreases the distance from where building materials are sourced. This offers a bigger incentive for the kampung inhabitants to make use of these upcycled building materials. Different processing facilities can be placed in different urban kampungs. The limited expertise keeps in line with most common method of building which is self building (80%). Additionally this can guarantee safety requirements and the ability that everyone should be able to make use of these facilities.

The materials that have the most potential for reuse and upcycling are derived from the material flow analysis of kampung Braga. These are: concrete, timber and clay brick. The case study of Stonecycling shows a great way to incorporate stone waste and brick into new building products.

Unused material potentials like plastics and the tire waste should gain inherent value as potential building material. A great case study example is Precious Plastic that creates building products and adds value through design. By adding value to the building products made from waste the processing facilities can potentially in future scenario create small circular economies in urban kampung areas.

Lastly designers working in this context should be strongly connected with the community, new building systems or ideas should not be implemented only from a top down perspective but should incorporate the strong existing community system.

Building Material Strategy

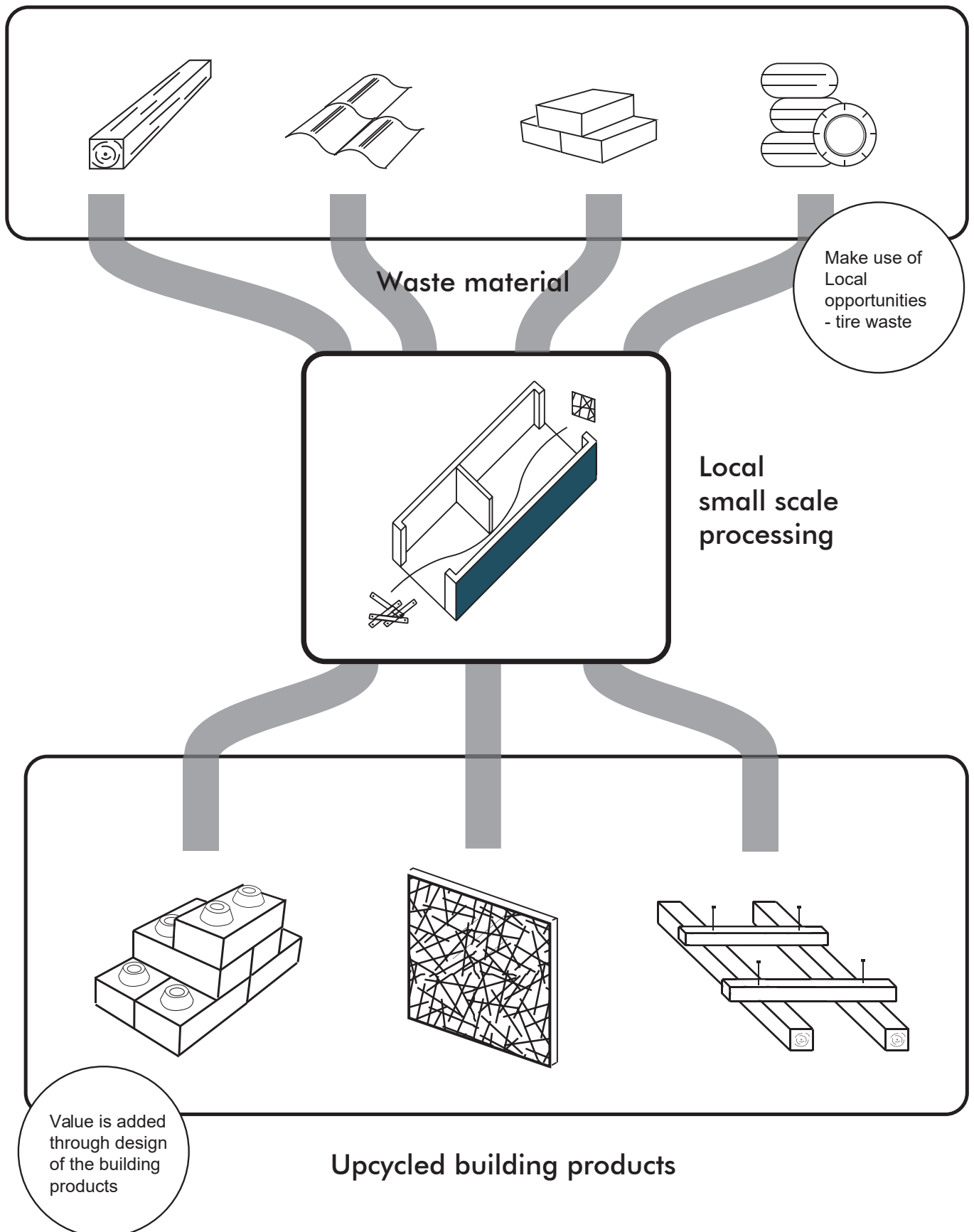


Figure 16 :Building Material Strategy

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8 Illustrations

Figure 1. Site (own image 2018)

Figure 2. Research Methodology Scheme (own image 2018)

Figure 3. Building material data (Surahman, U., Higashi, O., & Kubota, T. (2014) *Embodied energy and CO2 emissions of building materials for residential buildings in Jakarta and Bandung*, Indonesia, CEPT University.)

Figure 4. Housing material composition (own image 2018)

Figure 4. Analysis building materials site (own image 2018)

Figure 5. Material flow analysis - Bandung (own image 2018)

Figure 6. Building material transportation (own image 2018)

Figure 7. Observational analysis building materials kampung Braga (own image 2018)

Figure 8. Concluding scheme most common building materials (own image 2018)

Figure 9. Material flow analysis - Braga (own image 2018)

Figure 10. Reused building material composition analysis (own image 2018)

Figure 11. Building material output flow (own image 2018)

Figure 12. Rubber tire waste (own image 2018)

Figure 13. Images Precious Plastic. Retrieved November 8, 2018, from <https://preciousplastic.com/>

Figure 14. Images Stonecycling. Retrieved November 8, 2018, from <https://www.stonecycling.com/>

Figure 15. Images BIMA Microlibrary. Retrieved June 2, 2018, from <https://www.world-architects.com/de/architecture-news/works/microlibrary-bima>

Figure 16. Building material strategy (own image 2018)

Appendix A - Data material flow analysis - study Surahman *et al.*

Table 3 Current building material inventory

(unit: kg/m²)

Materials	Density (kg/m ³)*	Simple houses		Medium houses		Luxurious houses		Whole sample	
		Jakarta	Bandung	Jakarta	Bandung	Jakarta	Bandung	Jakarta	Bandung
1. Stone	1,450	729.8	623.1	696.5	682.6	529.0	603.9	678.4	644.7
2. Clay brick	950	494.9	371.7	309.2	414.0	413.3	451.2	407.4	397.7
3. Concrete brick	2,300	0.0	7.5	0.0	0.0	0.0	0.0	0.0	3.6
4. Cement	1,506	142.9	118.8	175.7	185.0	187.4	227.2	164.1	157.6
5. Sand	1,400	717.5	561.0	623.1	674.4	583.8	740.2	655.3	626.8
6. Steel	7,750	16.6	17.3	36.6	37.7	30.5	34.0	27.0	27.4
7. Ceramic tile	2,500	30.8	15.5	33.9	34.2	59.5	77.4	37.5	30.0
8. Clear glass	2,579	0.8	1.2	0.8	1.3	1.3	6.2	0.9	1.8
9. Wood	705	105.0	143.1	131.0	161.5	159.8	43.2	125.6	139.2
10. Gypsum	1,100	0.0	0.3	7.0	1.3	23.0	24.4	7.1	3.4
11. Paint	700	2.0	1.6	5.4	4.4	10.0	12.4	4.9	4.0
12. Clay roof	2,300	16.6	20.7	40.9	30.2	0.0	0.0	22.8	22.2
13. Concrete roof	2,500	0.0	0.0	0.0	0.0	49.9	39.2	9.6	4.4
14. Asbestos roof	2,200	5.6	0.6	2.1	0.3	0.3	0.0	3.2	0.4
15. Zinc roof	3,330	1.2	0.8	0.1	0.1	0.0	0.0	0.5	0.4
Total		2,263.7	1,883.2	2,062.3	2,227.0	2,047.8	2,259.3	2,144.3	2,063.6

*: (SNI, 1989)

		Bandung		
		Simple	Medium	Luxurious
Major building materials (%)				
Structure	Concrete	100	100	100
Foundation	Stonene	36	30	13
	Concrete	64	70	87
Floor	Cement	75	0	0
	Ceramic	25	100	100
Walls	Clay brick	98	100	97
	Con-block	2	0	3
Roof	Clay roof	74	94	0
	Concrete roof	0	0	100
	Zinc roof	14	1	0
	Asbestos roof	12	5	0

Appendix A - Material flow analysis - Calculations

MFA Data Bandung:

Material	Simple (kg/m2)	(%)	Medium (kg/m2)	(%)	Luxurious(kg/m2)	(%)	Total (kg/m2)	(%)
Concrete	1302.9	69.20%	1542	69.20%	1571.3	69.50%	1429.1	69.30%
Timber	143.1	7.60%	161.5	7.20%	43.2	1.91%	139.1	6.92%
Clay bricks	371.7	19.70%	414	18.60%	451.2	19.97%	397.7	19.30%
Clay Roof tiles	20.7	1.10%	30.3	1.36%	0	0%	22.2	1.10%
Asbestos	0.6	0.03%	0.3	0.01%	0	0%	0.4	0.02%
Rest	44.2	2.35%	79	3.55%	193.6	8.57%	75	3.36%
Total	1883.2 Kg/m2		2227 Kg/m2		2259.3 Kg/m2		2063.6 Kg/m2	100%

MFA Bandung

Total (kg/m2)	(%)	MFA total 2.1 million tons /210 billion kg a year)
1429.1	69.30%	144.6 billion kg of concrete/year
139.1	6.92%	15 billion kg of timber/year
397.7	19.30%	41 billion kg of clay bricks/year
22.2	1.10%	2 billion kg of clay roof tiles/year
0.4	0.02%	0.04 billion kg of Asbestos/year
75	3.36%	7 billion kg of rest/year
2063.6 Kg/m2	100%	16.255 billion kg
Material	(%)	MFA (total 16.255 billion kg a year)
Concrete	40%	6.5 billion kg concrete/year
Timber	35%	5.69 billion kg timber/year
Clay bricks	20%	3.25 billion kg clay bricks/year
Clay Roof tiles	3%	0.49 billion kg clay roof tiles/year
Plastics	2%	0.32 billion kg plastics/year
Total	100%	16.255 billion kg

MFA Braga:

Waste flow calculation Braga:

Kampung braga					
29266 m2 stock	X 2.06 ton/m2:	6.02 million tons			
Waste per year (2.7%)					
0.01625 million tons or 16.25 billion kg					

Appendix B - Current Building Material Analysis

1) Low income House

Housing with very temporary character. Fire from 1970's destroyed the original dwellings from these group of people. Lack of sufficient income and limited support from the government lead to this way of temporary living.

Location:



Conclusions:

Roof - mostly corrugated Iron/asbesto sheets, plastic tarp

Structure - Timber or Brick structure (if brick only base layer)

Infill - Corrugated Iron or plastic sheets

Openings - Occasionally glass but mostly just uncovered openings

2) Medium income House

Solid brick base with a more more temporary timber construction on top.

Location:



Conclusions:

Roof - Corrugated Iron sheets and aluminium sheets

Structure - Concrete structure and timber top construction

Infill - Corrugated plastic sheets and Plywood

Openings - Timber woodframes and decorative ventilation holes

3) High income House

Relative old house from 1959. House expanded through history through several new additions. A Total of 6 families lives here.

Location:



Conclusions:

Roof - Clay roof tiles

Structure - Natural stone base with timber top

Infill - Plastered plywood and traditional bamboo weaving (also plastered)

Openings - Glass windows and openings as ventilation openings





Appendix C - Building Material Flow Analysis Kampung Braga

Bandung Average



Average of 2.06 ton/m²
of building materials

Total

 Roof	56% Clay roof tile 33.3% Concrete roof 5.6% Asbestos
 Structure	95.15% Concrete 4.85% Timber
 Infill	98.33% Clay brick 1.66% Concrete block
 Foundation	73.66% Concrete 26.33% Stone







Material	Total (kg/m ²)	(%)
Concrete	1429.1	69.2 %
Timber	139.1	6.75%
Clay bricks	397.7	19.30%
Clay Roof tiles	22.2	1.10%
Asbestos	0.4	0.02%
Rest	75	3.36%
Total	2063.6 Kg/m ²	100%

Kampung Braga Average (based on observations)



Average of 2.06 ton/m²
of building materials

Total

 Roof	55% corrugated iron 45% Clay roof tiles
 Structure	50% Concrete 50% Timber
 Infill	90% Clay brick 10% Plastics
 Foundation	60% Concrete 40% Stone



Material	(%)
Concrete	40%
Timber	35%
Clay bricks	20%
Clay Roof tiles	3%
Plastics	2%
Total	100%

Appendix D - Building Material Origin



Sasak Gantung Material Shop

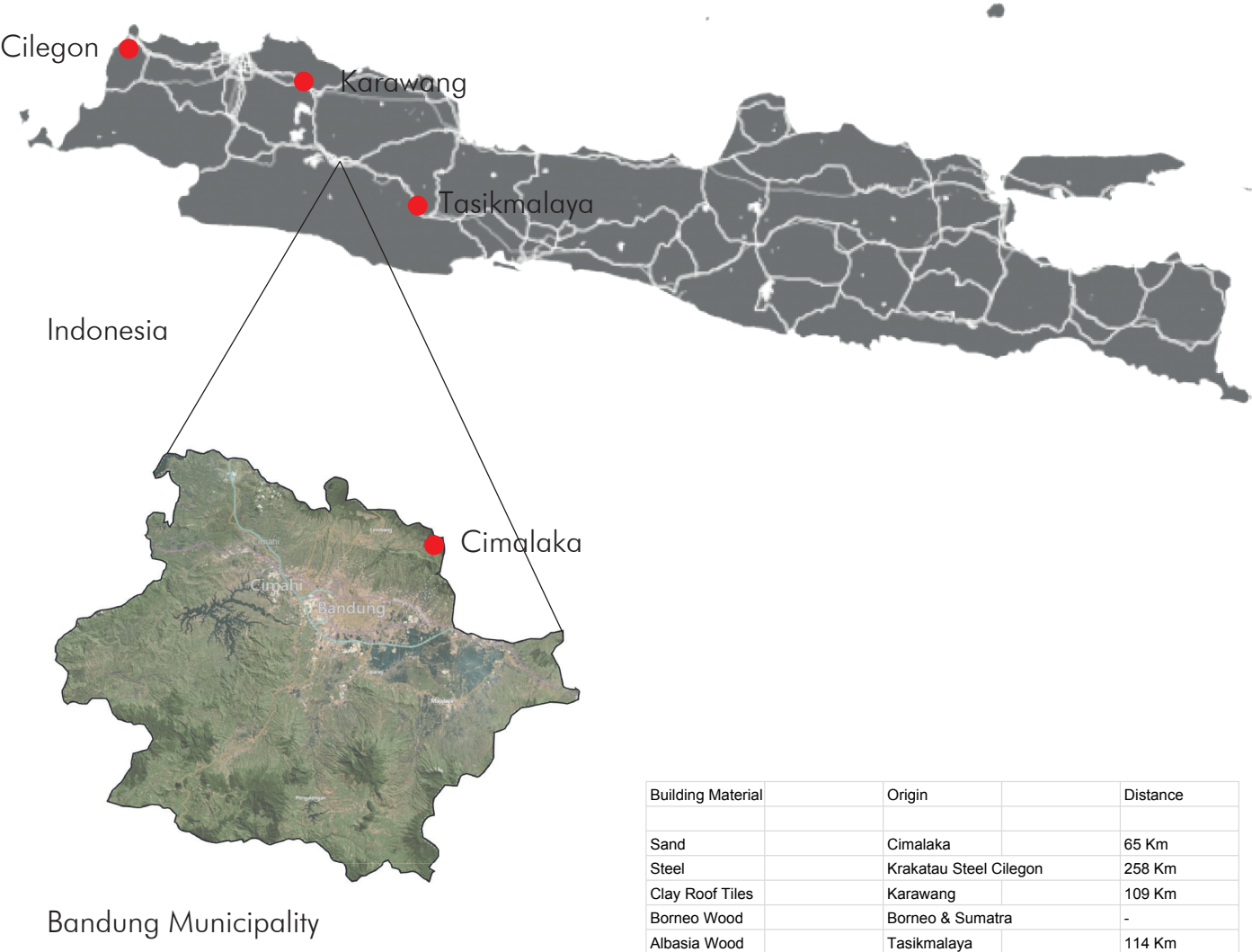


Material transport by Grobaks (handcarts)

Building material Stock - Sasak Gantung



Building Matreial Origin Location



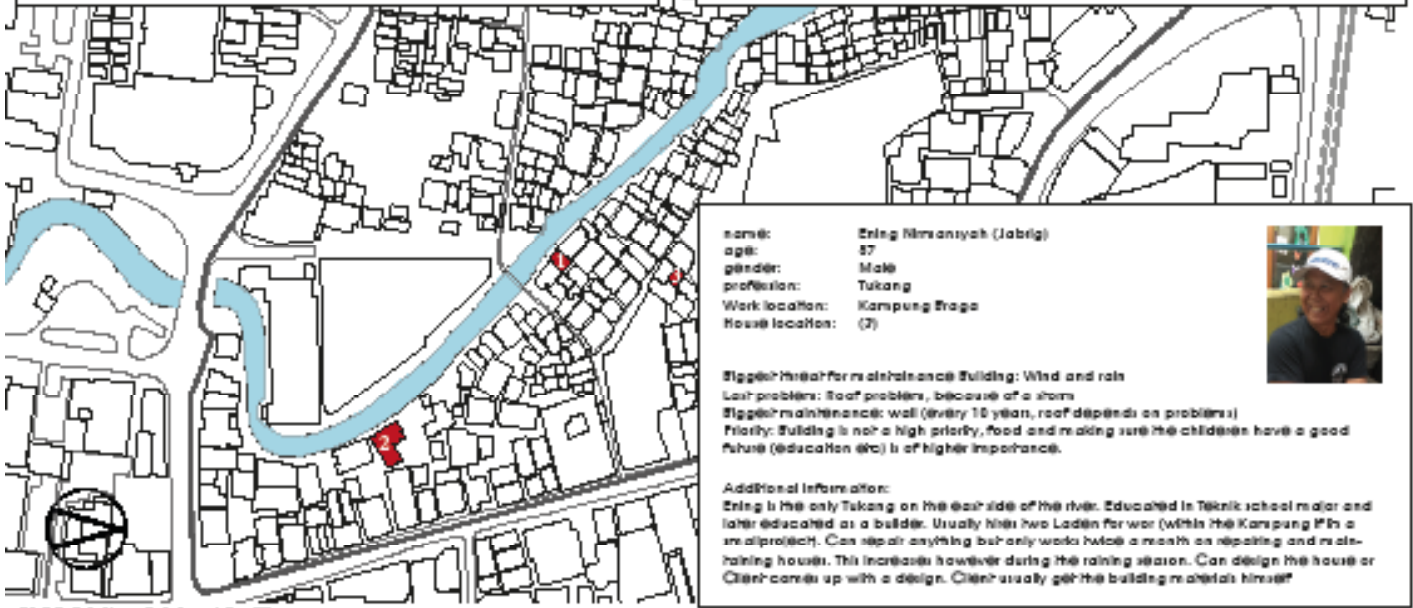


Bandung Municipality



Bandung Colonial Centre

Appendix G - Conducted Interviews (partially)

<p>name: Isah</p> <p>age: 41</p> <p>gender: Male</p> <p>profession: Uffrock trader</p> <p>Work location: Cisaribi (18 min away)</p> <p>House location: (1)</p> <p>Biggest threat for maintenance Building: Flooding and rain</p> <p>Last problem: Walls paint peels off. Big maintenance is painting the walls once a year just before Lebaran (sugar festival).</p> <p>Priority: Building maintenance has priority only when it's necessary.</p> <p>Additional information:</p> <p>House along the river. Flood problems occur when the rainwater can not be processed quickly enough towards the river. High income. Would like to add another story but does not think the construction can hold it. Buildings are constructed in a very informal way. Remission is only needed from neighbour 1-2 houses away.</p>	
<p>name: Fani</p> <p>age: 69</p> <p>gender: Male</p> <p>profession: Monsieur Mobile</p> <p>Work location: Jl. Sanoesay</p> <p>House location: (2)</p> <p>Biggest threat for maintenance Building: Flooding and rain</p> <p>Last problem: Roof, problems with leaking and interior finishing was just</p> <p>Priority: Building maintenance has priority only when it's strictly necessary, owner wish to sell his house so only keeps the bare minimum.</p> <p>Additional information:</p> <p>House dates back to almost 1989 (as long as the owner remembers). House contains 9 families and you can clearly see multiple extensions to the original house. This is also visible in the use of materials. Also rent out a house at the square.</p>	
	
<p>name: Ering Rismansyah (Jabrig)</p> <p>age: 57</p> <p>gender: Male</p> <p>profession: Tukang</p> <p>Work location: Kampung Baga</p> <p>House location: (3)</p> <p>Biggest threat for maintenance Building: Wind and rain</p> <p>Last problem: Roof problem, because of a storm</p> <p>Biggest maintenance: wall (every 10 years, roof depends on problems)</p> <p>Priority: Building is not a high priority, food and making sure the childrens have a good future (education etc) is of higher importance.</p> <p>Additional information:</p> <p>Ering is the only Tukang on the east side of the river. Educated in Teknik school major and later educated as a builder. Usually hires two Lادين for work (within the Kampung) in a small project. Can repair anything but only works twice a month on repairing and maintaining houses. This increases however during the raining season. Can design the house or Client comes up with a design. Client usually get the building materials himself</p>	