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Building Amphibious Settlements in Kampung Baru, Jakarta

Group 4 – **Urban Flooding**

Marjan Khaleghi (Nagoya University)

Heni Puji Astuti (Universitas Gadjah Mada)

Sarifah Hidi Ladana (Ministry of Marine Affairs and Fisheries)

Faten Ermala Che Othman (Universiti Teknologi Malaysia)

Zhu Deng (Tsinghua University)

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1 Introduction

1.1 Background

Floods are one of the natural hazards which have a great impact on urban activities and the frequency of urban flooding has been increasing during the last few years. Floods in Indonesia are considered to be one of the country's major natural disasters. Jakarta – the capital of Indonesia - has experienced many floods in the past, such as those in 1996, 2002, 2007, 2013, and 2014. At the same time that floods are increasing, the capacity of the soil to absorb water is also being reduced. This is being caused by the decreasing amount of water in catchment areas, decreasing green open space in the urban areas, and soil compaction due to the massive construction of office buildings, malls, housing, apartments, factories, roads and other infrastructure. At present the total area of green open space in the city is only 9%, while ideally it should be 30% of the total area of the DKI (Daerah Khusus Ibukota - Special Capital Region) in Jakarta. In addition to the naturally low topography (especially North Jakarta) the high number of locations that have elevations below sea level is also due to groundwater extraction and massive construction activities. Poor drainage also exacerbates the problem of flooding in Jakarta. Meanwhile, global climate change has caused sea level to rise and more rainfall at higher intensity during the wet season, increasing flood risk.

Indonesia is an archipelago in Southeast Asia that has many big cities that grow in coastal areas. An increase of one meter of sea level would flood 405,000 hectares of land and reduce Indonesia's overall territory by flooding lowland areas. One of these is the capital city of Indonesia, Jakarta, where some coastal areas have already been damaged due to floods and tides.

Since 2007, the government of the DKI in Jakarta has spent a great deal of effort on dealing with the floods (Team Mirah Sakethi, 2010), including the construction of flood canal. The channel of the canal has been planned since the days of the Dutch Colonial Government, but have never been realized. The flood canal would be built to channel the flow of rainwater and water from upstream directly to the sea, so that water does not inundate Jakarta, which is 40% below sea level. The Thirteenth River Normality Program in Jakarta has also become an important element in water management and flood control carried out by the Provincial Government. The government 'normalizes' the river by maintaining a minimum width and depth at every part of the river so that the river can drain water and there is no overflow from the river. River normalization activities include the cleaning of the river from mud deposits and deepening it so that the capacity of river to collect water can increase. This is done by dredging the river at points prone to water flow congestion. River maintenance is another routine activity of the DKI Jakarta Provincial Government. This activity is carried out by dredging rivers which experience siltation due to both silt and garbage. In addition to improving and increasing the capacity of rivers and waterways, the DKI Jakarta Provincial Government is also trying to make these locations more comfortable for residents. Riverbanks and channels previously made of soil are now being lined with concrete to reinforce river walls and waterways so that they can withstand large volumes of water.

Stakeholders for urban flooding mitigation can be generally grouped into three categories (Fitriyah et al. 2014):

1) **Beneficiaries:** people who receive benefits/impacts directly or indirectly; including flood control communities, environmentalists, etc.
2) **Intermediaries:** community groups or individuals who can provide consideration or facilitation in flood mitigation, including: institutions, consultants, experts, NGOs, and professionals in the natural resources sector. The directly authorized institutions include:
    a) BNPB (National Disaster Management Agency of the Republic Indonesia) which can contribute to disaster management, emergency response management, rehabilitation and construction in an equitable and equal manner, and
    b) PUPR (Ministry of Public Works and Housing of the Republic Indonesia) which can contribute to expanding the road infrastructure network, canal management, river management, flood canals, etc.
3) **Decision/policymakers:** institutions authorized to make decisions and create legal foundations, such as government institutions and water resources councils. The directly authorized institutions for Jakarta are:
    a) PUPR (Ministry of Public Works and Public Housing of the Republic Indonesia), which can contribute to the regulation of road infrastructure, road network expansion, canal improvement, river management, and urban planning
    b) The Ministry of Social Affairs of the Republic Indonesia, which can contribute to providing information to the community about the importance of flooding infrastructure, such as floating houses, to overcome flooding in Jakarta, and

c) The Ministry of Environmental and Forestry of the Republic Indonesia, which can contribute to regulating project development from an environmental approach.

1.2 Study area: Kampung Baru

In Jakarta, there are 13 rivers in total. Unfortunately, nearly all of them are highly polluted. The Ciliwung River is the city's major river with the length of nearly 120 km and very high annual discharge, which means that the riverfront area can be very easy affected by urban flooding.

The Kampung Baru is a slum and densely populated village near the Ciliwung River. During rainy seasons with intense rainfall, the Kampung Baru village is often affected by urban flooding physically and socioeconomically because of the lack of drainage systems and buffer zones, as well as the dense population and number of houses.

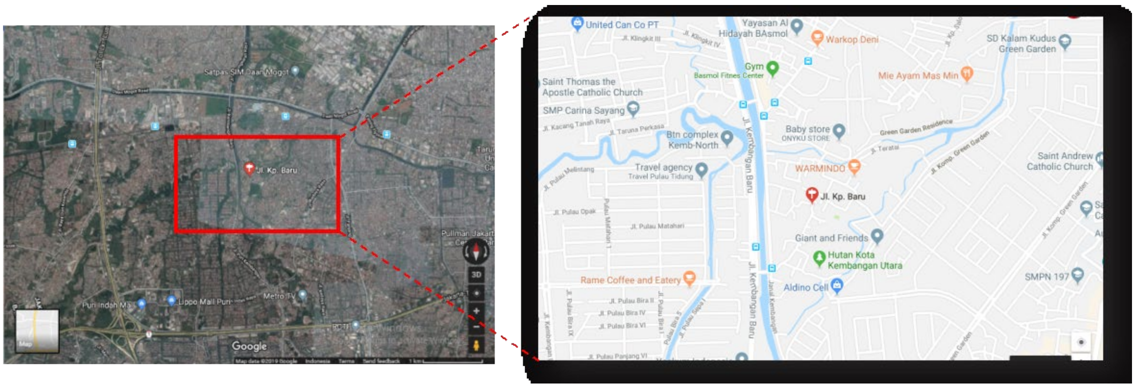


Figure 1. Map of Kampung Baru, Jakarta (from Google Map)

Figure 2. Flooding in Kampung Baru, Jakarta, in 2007
(Screenshot from Brinkman JJ Deltares' presentation, March, 2019)

1.3 Amphibious resilience: goals, strategic and technical steps

Amphibious houses, or the floating houses, rest on a concrete foundation under normal circumstances and start floating when the water level rises and also during flooding. Amphibious houses are a system for "building amphibious settlements" that have a unique way of working. At the base of each house there is a cube-shaped concrete foundation that has a cavity in it, so it can provide buoyancy during floods. After the water level drops, the house will immediately return to its original position where the hollow concrete foundation is supported by wooden pillars. Electricity and clean water are channeled through pipes which can move flexibly, so that the pipe follows the motion of the house as the house floats. A typical amphibious house can withstand up to 4-6 meters of rising water levels. When the water level rises, there is no need to worry that the house will be carried away by water flow, because on either side of the house's foundation there are pillars that serve as a mooring. With this innovative design, the City of Jakarta could take one step further in the fight against urban flooding. Amphibious houses are an alternative solution to tackle this challenge.

This proposed project is highly innovative for three reasons. First, the idea of a floating resilient house can incorporate multiple other innovations, such as providing renewable energy, income generation, and food production before, during and after floods. Second, a participatory approach can be included so that it can provide learning methods and developmental evaluation to encourage the engagement of community members in the project. Third, the design of the up-scaling strategy is also highly innovative in the way that it draws on extensive local insights gained through collaborative learning approaches that will help understand both the effectiveness of the resilience innovations and of the participatory processes used to develop and implement them.

An amphibious residence could incorporate the following elements:

1) An amphibious house can be built using local materials to be resilient to floods and wind;
2) Wall can incorporate vertical gardens using hydroponics to enhance food security and income;
3) Underground and overhead tanks can be used for storage to provide safe water supplies;
4) A rainwater harvesting system could be added with a filter for filtration. Later this water can be used daily for household needs as well as during an emergency like a flood;
5) A fishing unit could be attached to the house using aquaponics to provide protein and income during flood conditions;
6) A small hybrid solar panel or turbine could generate electricity

The technical steps of building an amphibious house include:

1) Identifying environmental conditions that will best suit floating housing areas;
2) Making a systematic and conceptual construction of floating house buildings in accordance with the local culture;

3) Providing information to the public about environmental concerns so that the environment is maintained before, during, and after construction;
4) Testing the resilience of floating homes in the face of flooding.

2 Literature Review

2.1 Dealing with floods

According to EM-DAT (International Disaster Database), floods affected the largest number of people of any type of natural disaster, with more than 35 million people affected, accounting for 57% of the total recorded number disaster victims in 2018 (CRED and UNISDR 2019). We are facing more uncertainties and more extreme weather conditions every day due to climate change, and this has made more people and settlements vulnerable. During the course of time, different mitigation strategies have been taken, including constructing barriers such as dikes and levees. However, these kinds of measures are also becoming more and more vulnerable and prone to probable disastrous failures as part of the consequences of climate change which calls for greater adaptability (English, Klink, and Turner 2016). On the other side of the spectrum, there is a lot to learn from local knowledge in terms of design principles in relatively resilient flood-prone rural areas in different parts of the world like the settlements in Mekong Delta in Vietnam, traditional stilt houses in Thailand, and various other examples in Nigeria, the United States, Cambodia, and so on (English et al. 2016; Liao, Le, and Nguyen 2016). These flood proofing measures (both temporary and permanent) including both mitigation and adaptation have been already applied in the context of Singapore, the Netherlands, Hong Kong, Italy, and the UK (Liao et al. 2016). One of these permanent mitigation strategies, which is regarded as an amphibious measure, can be observed in both rural areas and big cities in Fig. 3 and Fig. 4.

Figure 3. Elevating the house floor as part of flood mitigation measures in rural areas of Vietnam (Liao et al. 2016)

Figure 4. Applying elevating measure in a public housing block in Singapore (Liao et al. 2016)

2.2 Adaptive amphibious design and retrofitting

Recently, dealing with the uncertainty of climate-related disasters such as floods has meant taking the aforementioned techniques and measures to another level which concentrates on the concept of adaptability. Many architectural firms and organizations have proposed their ideas; from completely inventive design models (Fig. 5) to applying non-invasive retrofitting techniques. As for the latter, the Buoyant Foundation Project (BFP) is a good example which seeks to provide sustainable, low-impact flood mitigation measures, especially for low-income, vulnerable communities (Fig. 6). In this sense, amphibious architecture can be defined as taking retrofitting measure for the existing structures, and also designing new models of houses that can float when it floods instead of facing flood inundation (English et al. 2016). This concept can bring about so many different advantages both economically and socially in both the short- and long-term.

Figure 5. Amphibious house models by H&P Architects

Figure 6. Amphibious retrofits in the Mekong river delta (photo by Poorna Patange)

2.2.1 Local materials and traditional techniques in Indonesia

The RAFTA 2011 Model (Kusliansjah and Suriansyah 2013) is an innovative design for a floating house on a waterfront, built from the assembly of manufactured production parts and able to float and maintain its functional floor height above the water surface when exposed to either a high tide or flood.

Table 1. Materials of RAFTA 2011
Source: Karyadi, 2010

Sub-Structure Material of RAFTA 2011		Upper-Structure Material of RAFTA 2011	
Floor construction	*Galvanished Steel*	**Roof**	*Zinkalume*
Anchor	*Galvanished Steel Ring Pipe*	**Roof Truss**	*Light steel Construction*
Floating platform	*PVC*	**Ceiling**	*PU (poly urethane) panel*
Reservoir	*PVC*	**Wall panels**	*PU panel*
Bio-septictank	*PVC*	**Floor panels**	*GRC Panel*
Platform pad	*Galvanished Steel*	**Bridge accesses**	*Galvanished Steel Ring Pipe*

RAFTA 2011, The innovation of the ...

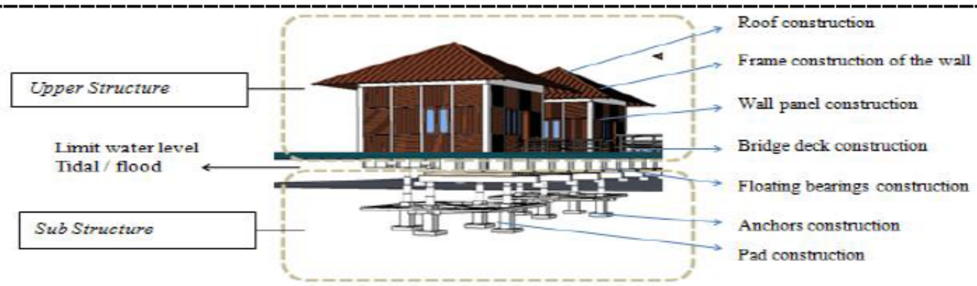


Fig.3. Anatomy of RAFTA 2011
Source: Karyadi K. et al, 2010

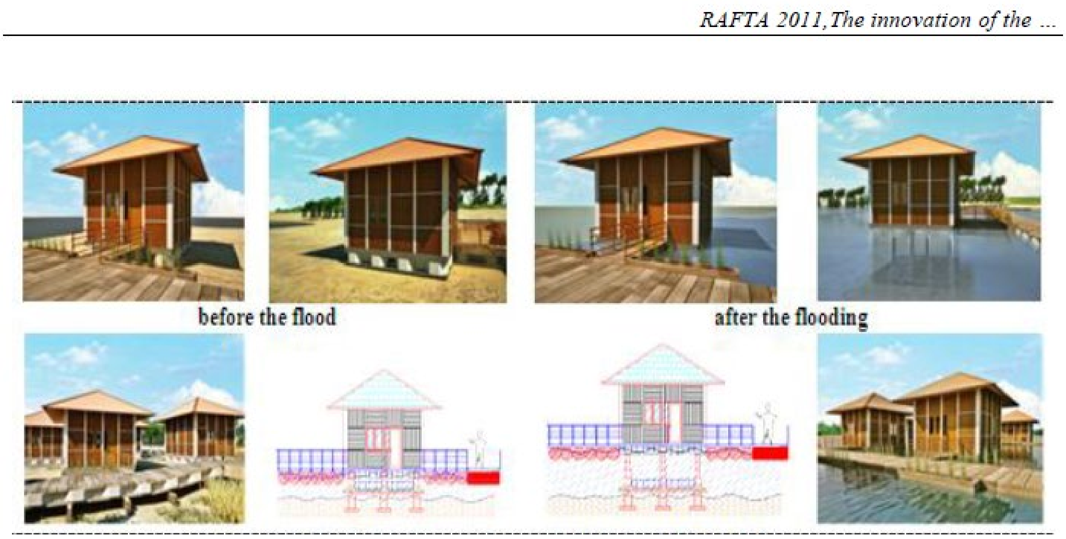


Figure 5. Innovation Design of RAFTA 2011 Model (Kusliansjah and Suriansyah 2013)

One example of a material for building amphibious houses is bamboo. Bamboo is an extremely strong fiber with great compressive and tensile strength and a high mass-to-weight ratio. Bamboo can be bent, woven, curved, shaped, molded, or laminated, making it an extremely flexible material. It grows in groves with a foundation consisting of a network of underground rhizome stems and roots that regenerate themselves. It is a plant that can sustain itself with very little maintenance, just requiring routine cutting. The compost of this environmentally friendly material fertilizes the next generation by nourishing the soil. The bamboo pavilion at Expo 2000 in Hanover by architect Simon Velez exemplifies the remarkable strength and flexibility of bamboo. There, he showcased a two level circular bamboo structure, 40 meters in diameter, with a peripheral overhang that is seven meters wide

Bamboo has a natural starch content in its core that is attractive to boring insects. Once infected, the insects quickly bore through the bamboo, destroying its structural integrity and slowly breaking it apart. This fact has led to a reluctance to use bamboo as a structural material, though there have been limited advancements in the commercial use of insecticides and chemical treatments to combat boring insects.

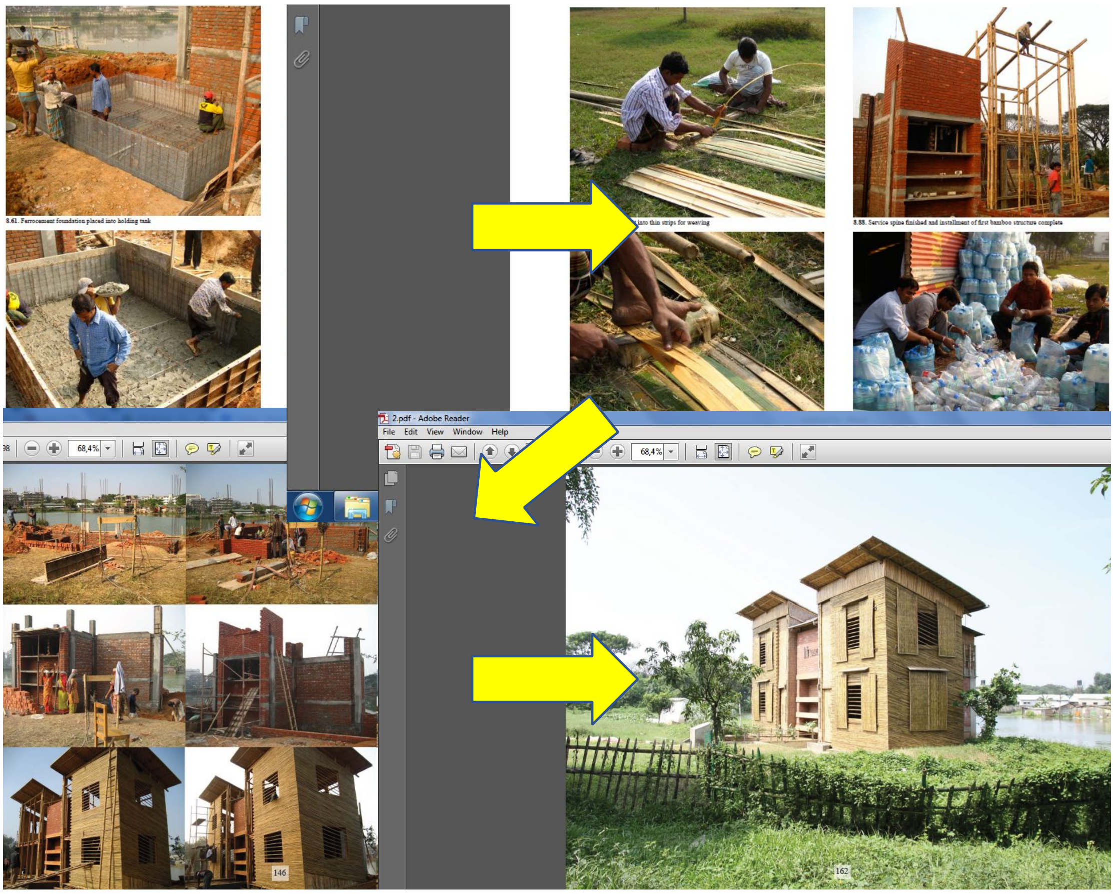


Figure 6. Amphibious House Design in Asia (Prosun 2011)

The role of insulation materials in property level resilience is complicated, because they are often inaccessible, being situated within the cavity, under the floor, or behind other finishes. Therefore, it is important for insulation to retain integrity when flooded and not slump within a cavity. It must dry quickly and retain thermal performance, while not impeding the drying of adjacent materials. Experimental evidence and experience suggest that fiberglass, mineral fiber (aka mineral wool/rock wool/stone wool), and blown-in mica can slump and degrade during wetting. Although recent tests on mineral insulation shows that it can dry out without degradation when sufficiently supported and drained (Sanders, 2014), it is slow to dry out, particularly within a cavity. Closed-cell insulation is more rigid and is therefore often recommended, but there are very few tests that demonstrate its post-flood thermal performance. Waterproof insulation materials have been tested (Technitherm), and as they have been shown to resist penetration by floodwater, their thermal integrity is retained. (Proverbs and Lamond 2017)

2.3 Awareness

It is noteworthy that resilience has a multifaceted nature and cannot be achieved only through physical measures. Hence, having an awareness of flood risk and flood dynamics are very important criteria for local residents, which can increase flood-response capacity (Liao et al. 2016). As a matter of fact, the collaboration between academia, practitioners and local people, and the implementation of amphibious measures by locals can contribute to raising awareness and resilience (Marfai, Sekaranom, and Ward 2015).

2.4 International frameworks

This research topic and objectives is based on the **Sendai Framework**, under **Priority 4**, *"Enhancing disaster preparedness for effective response and to 'Build Back Better' in recovery, rehabilitation, and reconstruction"*.

3 Aim and Objectives

3.1 Research Aim

To improve physical resilience in the pre-disaster phase of urban flooding in Kampung Baru.

3.2 Research Questions

1) Is the design of amphibious houses an appropriate solution for resilience to urban flooding in Kampung Baru?
2) How are stability, durability, and sustainability considered in designing amphibious houses?
3) What key factors need to be considered in the selection of suitable construction materials and techniques?
4) Are the amphibious house prototypes developed by this research adapted well to the nature of flooding environment?
5) Do the inhabitants of Kampung Baru accept the amphibious house prototypes as suitable and acceptable to their needs?
6) What are the benefits of the house-design prototypes to the inhabitants in Kampung Baru?

3.3 Research objectives

1) To achieve flood-resilience through flexible, cheap, and local construction materials and techniques.
2) To design house prototypes using traditional techniques and modular design.
3) To consult with the inhabitants in the process of Eco-DRR design and teach them about the construction and maintenance process.

Table 1: Objectives and specific research questions for the project

Objectives	Specific questions	Limitations/assumption
To achieve flood-resilience through flexible, cheap, and local construction materials and techniques.	Q1. Is the design of amphibious houses an appropriate solution for resilience to urban flooding in Kampung Baru? Q2. How are stability, durability, and sustainability considered in designing amphibious houses? Q3. What key factors need to be considered in the selection of suitable construction materials and techniques?	Relevant literature/ Availability of the data
To design house prototypes using traditional techniques and modular design	Q4. Are the amphibious house prototypes developed by this research adapted well to the nature of flooding environment?	Awareness Campaign/ Implementation
To consult with the inhabitants in the process of Eco-DRR design and teach them about the construction and maintenance process	Q5. Do the inhabitants of Kampung Baru accept the amphibious house prototypes as suitable and acceptable to their needs? Q6. What are the benefits of the house-design prototypes to the inhabitants in Kampung Baru?	Implementation/ Maintenance

4 Methodology

4.1 Techniques of data collection and analysis

4.1.1 Literature review

Firstly, there will be a review of all the amphibious housing projects over the world focusing on technical details, including the materials, sources of materials, and the construction methods as well as architectural structure. Secondly, there will be a comprehensive assessment of amphibious houses to understand the socioeconomic and environmental impact of them. This will include the use of socioeconomic databases and remote sensing data (i.e. land-use change data) to provide basic data for further study. The timeline for the literature review can be found in Part 6.

4.1.2 Feasibility studies

Feasibility studies are at the heart of the project planning process. They are designed to help planners identify problems and opportunities, formulate alternative solutions, evaluate them, and select a preferred solution approach in a systematic, effective, and efficient manner.

Feasibility studies look at the viability of projects with an emphasis on identifying potential problems and recommending a practical solution. The outcome of a feasibility study will determine if the identified problems can be addressed and if so how. Feasibility studies provide details about the various options and determine which option is the best in terms of successfully accomplishing the stated project goals and objectives.

Overview of the Feasibility Study Process

The proposed feasibility study follows a five-step process through a structured approach to problem-solving that provides a rational framework for decision-making (Department of Water Resource 2014). The five steps are:

Step 1 - Identifying problems and opportunities

This step encompasses a discussion of the project area and background, the identification of problems and opportunities, framing of the study objectives, and defining potential constraints through communication and engagement with involved agencies and stakeholders. Scoping meetings provide a structured opportunity to inform and receive feedback from these agencies and stakeholders. As for the case study of the project, this step includes gathering information about the history of settlements in Kampung Baru, measuring the resilience of the houses and also the community in terms of dealing with the floods, appraising the advantages and disadvantages, and identifying the influential stakeholders and their role in making Kampung Baru more resilient.

Step 2 - Inventorying existing condition and forecasting conditions

The second step of the planning process is to develop an inventory and forecast of critical resources (physical, demographic, economic, and social, etc.) relevant to the problems and opportunities under consideration in the planning area. The planning team uses this information to further define and characterize problems and opportunities. In the case of Kampung Baru the researchers will measure the condition of resources qualitatively and quantitatively in order to be able to vision the future with or without the countermeasures which is a very important step in planning.

Step 3 - Formulating alternatives plans

An alternative plan consists of a system of structural and/or non-structural measures, strategies, or programs formulated to meet, fully or partially, the identified study planning objectives subject to the planning constraints. In practice, the alternative formulation process also involves developing alternatives that are the bookends that represent by a large degree interest of various parties. Then through trade-off analyses, the most reasonable, balanced, and the cost-efficient alternative is developed by selecting the reasonable management actions from the bookend alternatives to form an alternative that best achieves multiple benefits, meets project objectives with reasonable cost, and to some degree, represents the interests of all parties. Early coordination with resources and permitting agencies can be very helpful in identifying the types and scopes of mitigation that might be necessary. Due to this, an alternative of utilizing a fabrication technique that is familiar to the local people has been considered in order to help to maintain the houses. For example, a real scale amphibious house prototype that is cost-effective and flood resilience has been proposed in this study.

Step 4 - Evaluating alternatives

Criteria to evaluate the alternatives should include all significant resources, outputs, and plan effects (especially the study planning objectives and other criteria important to Step 5 – Trade-off analyses and selection of preferred alternative participating stakeholders).

On the other hand, the analysis may suggest opportunities for further refinement of alternative plans or changes in configurations to improve the trade-off between multiple benefits, leading to the selection of a preferred alternative.As for the case study of this project, this step consists of criteria to evaluate the alternatives of materials that are suitable for designing amphibious houses in Kampung Baru. Together with local people and some stakeholders, the research team will decide and evaluate alternatives which give benefits for developing the design.

Step 5 – Trade-off analyses and selection of preferred alternatives

All the alternative plans and designs from the previous steps will be gathered to make a list of pros and cons. A single alternative plan will be selected for a recommendation from among all those that have been considered and measures that can be adjusted to local conditions in Kampung Baru. The analysis may involve: 1) developing a general understanding of the relationship between inputs and outputs (i.e., map out the input-output curve) for a particular benefit category, and 2) conducting incremental, refined analyses in the vicinity of the optimal area to determine the most reasonable or optimal magnitude for that feature (or management action).

This section summarizes each step. Although the process is described as a linear, sequential process, in reality, it is an iterative, interactive process. As more information is acquired and developed, it is often necessary to reiterate some of the previous steps in order to formulate a cost-efficient, multi-benefit integrated plan that meets the state's objectives.

4.1.3 Interviews and Focus Group Discussion

An in-depth field investigation survey (interview) will be carried out using a sample of community members located throughout the river basin in order to reach a representative sample of households and genders of respondents. This step focuses on exploring information about the households, such as comfort and safety level, exposure to risk of flooding, and knowledge related amphibious houses before, during, and after the implementation of the project.

Besides conducting an interview, a focus group discussion (FGD) will be held as a way to gather local people and stakeholders to discuss good options of design for amphibious houses in Kampung Baru. This focus groups will consist of local people from the community of Kampung Baru, the Ministry of Public of Work and Housing, the National Agency for Disaster Management, the Ministry of Environment and Forestry, and non-governmental organizations working in the community. The focus group will emphasize the benefit of amphibious house prototypes discussed, teach stakeholders about how to adapt and mitigate flooding in this area, showcase designs the community may be interested in. In addition, community members will be allowed to share information related to local construction and traditional techniques of designing houses, and informed about funding options for housing.

4.1.4 Choosing materials

Design, to a large extent, is entangled with materials that are going to be used in the construction process. Every single material has its own potential advantages and disadvantages. Considering designing amphibious houses in Kampung Baru, resilience and eco-friendliness are two of the most important items. However, there are more factors that need to be considered like cost, easy access, durability, stability, flexibility (in space figuration by residents and in design), easy maintenance/replacement, the possibility of pre-fabrication, and aesthetic matters in terms of the appearance. In order to comprehensively consider all these items, the research team is going to search for local materials and the aforementioned criteria will be presented during group discussions with locals and stakeholders to grasp the opinions and attitudes toward the materials. Based on the results of this phase and also the empirical research and existing implemented projects in Indonesia and worldwide, the research team will assign values to these criteria and do a cost-benefit analysis for the sake of choosing the best materials for this project.

4.1.5 Designing amphibious houses

During this phase, the research team is going to focus on designing at least 3 alternatives (amphibious houses) with the selected materials. These alternatives are going to be designed with buoyant foundations constructed on soil ground with capabilities of floating up with rising water levels so that in the event of a flood, the houses could independently rise with water levels. In each case, the research team will consider the provision of water, electricity, and toilets at the time of flooding as well.

3D digital models along with non-digital models (in the scale of 1:100 or 1:50) are going to be made. Next, the different modeled alternatives will be shared with local people and stakeholders in focus group discussions in order to consider every aspect of the design from a boarder perspective and provide the opportunity for the future residents to talk about their opinions and concerns in this phase. The intention is to experiment with the stability and reliability of the amphibious design by building a 1:1 prototype of a selected model in Kampung Baru with local people on a large dugout space under the house which can be filled with water for the sake of the experiment. It is noteworthy that not only the houses themselves but also the relations between the individual housing units (as a whole settlement) will be considered in the design process.

5 Conclusion

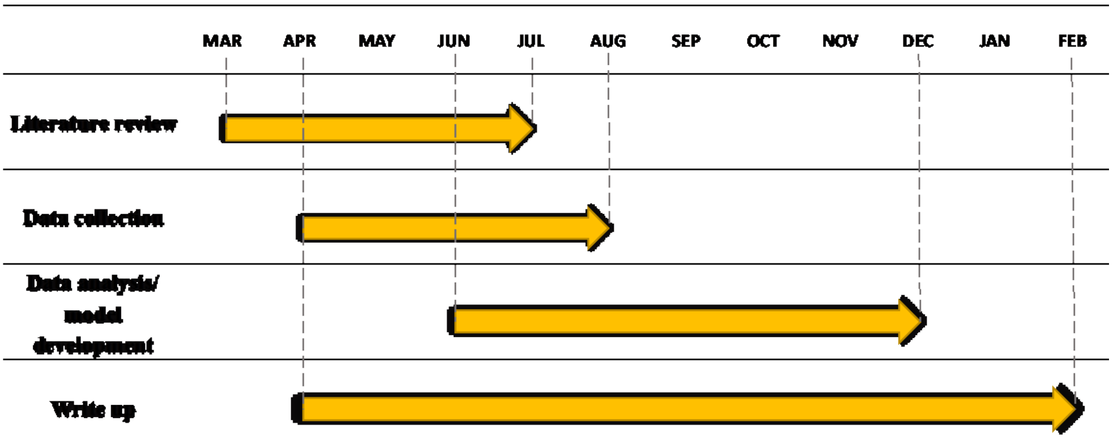
Amphibious architecture is a sustainable flood mitigation strategy that allows an ordinary structure to float on the surface of rising floodwater rather than succumb to inundation. A buoyancy system beneath the house displaces water to provide flotation as needed, and a vertical guidance system allows the rising and falling house to return to exactly the same place upon descent. Amphibious architecture is a flood mitigation strategy that works in synchrony with a flood-prone region's natural cycles of flooding, rather than attempting to obstruct them (Urkude et al. 2019).

Building Amphibious Settlements in Kampung Baru, Jakarta

Amphibious architecture is a response to the risk of floods in low lying areas. It seems that in the advent of rising sea levels due to climate change and disastrous floods, there is a greater need for flood protection at the scale of residential structures. Residents in flood-prone areas around the globe are showing resistance to permanent static elevation, which has been a common strategy to keep homes above water levels. Despite the efforts of raising the structure on a plinth or stilts, protection from floods remains unpredictable due to a limit in elevation. A house raised high above the ground disrupts the connection of the residents to the neighborhood and causes daily inconveniences.

Kampung Baru is already a built settlement facing complicated difficulties during flooding which has affected its residents' quality of life (QOL). This proposed project is a contribution to raising the QOL of people living in Kampung Baru by designing and building amphibious houses in order to promote the resilience and adaptability in terms of dealing with floods. It is critical to note that a further on-site field study is needed in order to evaluate the state of the existing buildings in Kampung Baru and carefully consider the possible collaboration between different stakeholders, including NGOs and local people, for the implementation of this project.

6 Timeline



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