Identifying the Potential of Grey-Green (Hybrid) Infrastructure Approach Implementation in *Kampung Kota* (Case Study: Bandung Regency, Indonesia)

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Introduction

Consideration of environmental sustainability aspect is important to urban and peri-urban development. Meanwhile, metropolitan areas in Indonesia face various obstacles, such as environmental and socio-economic problems. Climate-related problems such as urban heat islands and floods, are a growing threat in hydro-meteorological and climatological risk caused by rapid urbanization and climate change [1]. The phenomenon brings various effects the metropolitan area population, including Bandung Metropolitan Area (BMA), Indonesia. The growth in both urban and peri-urban of the BMA generates various urban development impacts such as land use change, limited space for residential, expensive land price, as well as the disaster-related impacts such as a decrease in the runoff capacity of the ground surface in the last 20 years, environmental quality decline, and lead to disasters such as floods, landslides, forest fires, and land drought[2]. As a result, the urban and peri-urban experiences the slum areas and informal settlement areas development as one challenge of the BMA development. In Indonesia, a slum in an urban area is well-known as *kampung kota*, which are term for a traditional low-income settlement [3]. The land use change brought various impacts, such as an increase in speed and volume of surface runoff and decreased time of concentration, as well as influenced the water quality [4]

It is urgent to tackle this problem by allowing more room for slum settlement upgrading, including providing basic infrastructure that is environmentally friendly considering the climate problem occurrence in urban areas and their surroundings. In Indonesia, a slum in an urban area is well-known as *kampung kota*, which are term for a traditional low-income settlement[5]. Currently, there is still lack of research about the environmental-friendly infrastructure provision technique in Bandung and Indonesia, especially in the micro-scale like *kampung kota*. The environmental-friendly infrastructure provision can be a suitable approach to tackle infrastructure provision needs and environmental issues in slum areas at once.

A green infrastructure approach is considerably one infrastructure development approach with sustainable and environmental-friendly principles. In this context, green infrastructure is equal to urban green infrastructure, and it refers to natural and eco-friendly approaches to delivering and operating infrastructure in the urban area[6]. However, applying only green infrastructure approaches in a highly urbanized area is difficult due to limited land space with a grey infrastructure-based development. It might not be sufficient for tackling the climate change problem in an urban context with only green infrastructure, as it is unable to meet the scale of predicted future climate hazards.

Therefore, a hybrid combination of green-grey infrastructure approaches can be a solution to tackle the challenges of *kampung kota* in BMA region. It is relevant as the city needs to implement an integrated and multi-disciplinary approach to form good city management, to tackle urban challenges more comprehensively. Besides,

[1] Depietri and McPhearson, "Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction," 2017.
[2] Fuadina, Rustiadi, and Pravitasari, "The Dynamic of Land Use Changes and Regional Development in Bandung Metropolitan Area."
[3] Tunas and Peresthu, "The Self-Help Housing in Indonesia: The Only Option for the Poor?," 2010.
[4] Sagala et al, "Sustainable Urban Drainage System (SUDS) as Nature Based Solutions Approach for Flood Risk Management in High-Density Urban Settlement," 2022.
[5] Tunas and Peresthu, "The Self-Help Housing in Indonesia: The Only Option for the Poor?," 2010.

implementing green-grey infrastructure is considerably cheap [7]. So, it can be also run independently without government intervention (self-help infrastructure provision).

Further research is necessary to see how far the influence of hybrid infrastructure provision in *kampung kota* in the BMA region to solve sustainability problem, especially related to flood problem in *kampung kota*. The research will also identify several factors that need to be considered to implement hybrid infrastructure in *kampung kota* scale. in addition, this research also examines the opportunity of implementing hybrid infrastructure as environmentally friendly infrastructure in *kampung kota* with consideration to the *kampung kota* characteristic.

Data Collection and Research Method

There are several methods of data collection supporting this activity. In this research, the author uses secondary data for analysis. There are three types of data collected to support the research process. First, the author used field observation results provided by the Bandung Regency local government which was held in 2022. Secondly, several government official data's, including the Bandung Regency's Major Decree on Slum and Settlement, Urban Slum Prevention and Quality Improvement Plan (*RP2KPKP Bandung Regency*), Citarum Watershed Action Plan, Regional Spatial Plan of Bandung Regency (*Rencana Tata Ruang Wilayah Kabupaten Bandung*), used to understand current regulation and plan of infrastructure development in the study area. Finally, the author also used journals obtained from databases: Google Scholar, Scopus, and Research Gate to support the research. The research uses an indirect observation and desk review approach as the research methodology. An indirect observation approach is used to analyze the field observation documentation report, which was done by the local government of Bandung Regency, and the local policy document. Indirect observation understood as activity of observing event without direct participation from the researcher [8]. In this research, indirect observation was used for defining the implementation factor of hybrid infrastructure in a *kampung kota*. Another research method used in this research is desk review based on journal. The method is used to form the hybrid infrastructure technique criteria to be assessed according to characteristics of *kampung kota* and its stormwater infrastructure condition.

Bandung Urban Metropolitan Area Development

Over the past few decades, the rapid growth of populations has contributed to development challenges in the BMA region. Apart from the environmental impact, physical development is also affected by this situation. For instance, the BMA development activities resulting a decrease in housing and infrastructure delivery to households. In addition, suburbanization in BMA peri-urban has reduced the productive land area and led to the increase of high-density residential areas in the urban fringe and peri-urban zone, the emergence of slum settlement, unequal infrastructure provision in the urban fringe and peri-urban area, and the tendency of land use function shifting [9]. One example of the inequality of infrastructure provision is poor water and stormwater infrastructure provision and management in the informal settlement area.

So far, the conventional approach is still the main method for providing drainage infrastructure in Bandung Regency. It is a grey, concrete-based infrastructure that is considered as the approach for infrastructure provision. Consequently, it creates impermeabilization of the land surface and leads to a greater volume of surface runoff. This caused a flood in the urbanized area, especially for the settlement in the lower area [10], including the riverbank area.

Therefore, a sustainable infrastructure planning and development approach being one main issue in the informal settlement planning and development in Bandung

[7] Depietri and McPhearson, "Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction," 2017.
[8] Ciesielska, Boström, and Öhlander, "Observation Methods."
[9] Vitriana, "The Growth of Metropolitan Bandung Raya (MBR) and the Increase of Urban Housing Matters"; Fuadina, Rustiadi, and Pravitasari, "The Dynamic of Land Use Changes and Regional Development in Bandung Metropolitan Area."
[10] Sagala et al., "Sustainable Urban Drainage System (SUDS) as Nature Based Solutions Approach for Flood Risk Management in High-Density Urban Settlement."

Metropolitan Area. According to the 2016-2036 Regional Spatial Plan (*Rencana Tata Ruang Wilayah*) of Bandung Regency, one of the strategies to support settlement improvement is to provide or improve essential services for settlement areas. Among those basic services is wastewater and rainwater management infrastructure. It is necessary to improve the drainage service in settlement areas to create a good settlement environment, as well as avoiding disaster risks.

Kampung Kota and the Problems

In Indonesia, urban slum areas known as *kampung kota*, which means urban village. The *kampung kota* appears during the colonialization era to distinguish the housing area between the colonizers and natives [11]. The *kampung kota* phenomenon in Indonesia is unique due to its categorization. It is not categorized as a slum, but the settlement condition is still far from the ideal condition of the settlement. The *kampung kota* is known for its high-density settlement, lack of public infrastructure provision, sometimes located in an unattractive place such as riverbanks or steep slopes, or unutilized public-owned land, while also the housing condition is decreasing over time [12]. Research shows that informal settlement in low-income Asian countries appears to increase by approximately 10% within 1 km of waterways [13]. In Mexico City, about 36% of informal settlements in the city are located on ecological conservation zone [14]. Therefore, it makes the informal settlement a high-density settlement which is vulnerable to flood disaster [15]. It shows that the *kampung kota* is vulnerable to disaster. Moreover, the high number of informal settlements or *kampung kota* in the riverbank being an important issue that needs to be addressed by local government.The high number of informal settlement or *kampung kota* in the riverbank also mentioned as one important issue that have been identified by the local government, and it has been introduced in the Urban Slum Prevention and Quality Improvement Plan (RP2KPKP) of Bandung Regency. Moreover, the water management in the informal settlement and *kampung kota* in Bandung Regency are still considered limited, especially regarding stormwater management in the neighborhood. A small-scale ecologically friendly solution can be a suitable solution for stormwater management in areas with informal settlements or *kampung kota* characteristic. However, studies about sustainable urban water management in *kampung kota* barely available. That creates the concept still not popular in low- and middle-income countries in Asia, Africa, and Latin America[16], including in Indonesia. The green infrastructure or a combination of green-grey infrastructure can be a viable solution to achieve sustainable urban water and storm water management in the informal settlement, especially for *kampung kota* in Indonesian-context. For instance, the green infrastructure implementation can solve water flow problem in urbanized areas and support sustainable urban development [17]. Therefore, it is necessary to identify the components and techniques of hybrid infrastructure for *kampung kota* scale.

Hybrid Green-Grey Infrastructure for Sustainable Stormwater Infrastructure Approach as Ecological Friendly Infrastructure Concept and Techniques

According to [18], grey infrastructure focuses on flood protection rather than water quality improvement. Grey infrastructure approaches often cannot tackle the root causes of risk and enhance the population's vulnerability in the long term. Combining both these approaches to solve one case considerably brings multiple benefits and

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[11] Tunas and Peresthu, "The Self-Help Housing in Indonesia: The Only Option for the Poor?," 2010.
[12] Kustiwan and Ramadhan, "Strategi Peningkatan Kualitas Lingkungan Kampung-Kota Dalam Rangka Pembangunan Kota Yang Inklusif Dan Berkelanjutan: Pembelajaran Dari Kasus Kota Bandung"; Anindito et al., "A Quantitative Perspective on Kampung Kota: Elaborating Definition and Variables of Indonesian Informal Settlements: Case Study: Kelurahan Tamansari, Bandung City."
[13] Vollmer and Grêt-Regamey, "Rivers as Municipal Infrastructure: Demand for Environmental Services in Informal Settlements along an Indonesian River."
[14] Wigle, "The 'Graying' of 'Green' Zones: Spatial Governance and Irregular Settlement in <scp>X</Scp> Ochimilco, <scp>M</Scp> Exico <scp>C</Scp> Ity."
[15] Sagala et al., "Sustainable Urban Drainage System (SUDS) as Nature Based Solutions Approach for Flood Risk Management in High-Density Urban Settlement."
[16] Pauleit et al., "Urban Green Infrastructure in the Global South."
[17] Maryati, Humaira, and Adianti, "Green Infrastructure Development in Cisangkuy Subwatershed, Bandung Regency: Potential and Problems."
[18] Depietri and McPhearson, "Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction," 2017.

functions [19]. An integrated urban green and grey infrastructure combines "green" (natural; living) and "grey" (human-made; anthropogenic) infrastructure constituents to provide facilities in support of vital ecosystem services and functions to urban communities [20]. Combination of green and grey infrastructure approaches in terms of infrastructure provision called as hybrid infrastructure approach [21], and some literatures mentioned that it can also mixed with a blue infrastructure approach which is an approach that is usually used in marine or sea, used the natural ecosystem support to provide infrastructure [22]. In this study, green infrastructure can also refer to the blue infrastructure approach. A mixed approach to infrastructure provision performs in several ways, such as by adding improved or additional services or functions to grey infrastructure [23].

In terms of a hybrid approach for stormwater management, traditional stormwater management is currently still focused on the reduction of peak flow discharge rate from the site to minimize or avoid flooding in the area [24]. This is called conventional stormwater infrastructure management and is still prevalent in many urban areas [25]. Therefore, to cover the shortcomings of the conventional development concept in the green stormwater infrastructure/low-impact development practice, Shafique and Kim followed the triple bottom line and makes the city sustainable and resilient to climate change. Various problems can be solved by implementing green infrastructure to support sustainable urban development, such as solving the water flow problem in urbanized areas [26], or combining several green and grey infrastructure as a network to reduce flood damage: rainwater harvesting; open detention basins; and pipes [27]. Combining pipes infrastructure and rainwater harvesting as a form of green infrastructure approach can increase net benefit and cost and increase capacity to reduce flood damage [28]. In addition, other benefits of a mix green-grey infrastructure can improve the management of urban water, heat, and other climate driven threats [29]

There are several terms used for sustainable urban stormwater management worldwide, such as low impact development (LID), sustainable urban drainage system (SUDS), and water-sensitive urban design (WSUD), are other terminology used by the researcher in doing green infrastructure-related research[30]. All of them provide similar definitions. The LID approach describes as an approach for planning and design for stormwater runoff management with its practice [31], the SUDS, BMP, and decentralized rainwater/stormwater management are also described as an approach for measuring the sustainable stormwater management [32]. Several LID techniques are green roofs, green walls, bio-retention cells (rain gardens), permeable pavements, infiltration trenches, and vegetative swales and rain barrels [33].

The SUDS also provide similar techniques, there are rainwater harvesting, green roof installation, permeable pavement, bioretention system, vegetation (tree), swales (bio-swales, green swales), and infiltration basin [34]. For WSUD techniques, several techniques considered in the WSUD literature are infiltration system, permeable pavement, bio-retention system, swale (bioswale), rainwater harvesting system, geo

[19] Matthews, Lo, and Byrne, "Reconceptualizing Green Infrastructure for Climate Change Adaptation: Barriers to Adoption and Drivers for Uptake by Spatial Planners."
[20] Wesener and McWilliam, "Integrated Urban Green and Grey Infrastructure."
[21] Depietri and McPhearson, "Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction," 2017.
[22] Depietri and McPhearson, "Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction," 2017.
[23] Ibid.; Branny et al., "Smarter Greener Cities through a Social-Ecological-Technological Systems Approach."
[24] Shafique and Kim, "Green Stormwater Infrastructure with Low Impact Development Concept: A Review of Current Research."
[25] Ibid.
[26] Maryati, Humaira, and Adianti, "Green Infrastructure Development in Cisangkuy Subwatershed, Bandung Regency: Potential and Problems."
[27] Alves et al., "Assessing the Co-Benefits of Green-Blue-Grey Infrastructure for Sustainable Urban Flood Risk Management."
[28] Ibid.
[29] Depietri and McPhearson, "Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction," 2017.
[30] Fletcher et al., "SUDS, LID, BMPs, WSUD and More – The Evolution and Application of Terminology Surrounding Urban Drainage."
[31] Dietz, "Low Impact Development Practices: A Review of Current Research and Recommendations for Future Directions."
[32] Hoyer, *Water Sensitive Urban Design : Principles and Inspiration for Sustainable Stormwater Management in the City of the Future*; Woods-Ballard R et al., "The SuDS Manual."
[33] Dietz, "Low Impact Development Practices: A Review of Current Research and Recommendations for Future Directions."
[34] Woods-Ballard R et al., "The SuDS Manual."

cellular systems, detention pond [35]. All these components can be implemented depending on the characteristic of the location, including the *kampung kota* scale.

Case Study: Kampung kota in Bandung Regency (*Kampung* Bojong Suren, Pasawahan Ward, Dayeuhkolot District, Bandung Regency)

According to the Slum Decree on Location of Slum Housing and Settlements in the Bandung Regency document, there are 280 villages within 31 districts, equal to 576,03 hectares in the Bandung Regency which categorized as slum area. One of the villages in the Bandung Regency categorized as a “heavy slum” area is Kampung Bojong Suren in Pasawahan Ward, Dayeuhkolot District. This area has 3,23 hectares of slum area with legal land title. According to the Bandung Regency’s Major Decree on Slum and Settlement, there are 1394 people in the village, or equals 415 person/km2 in terms of population density. The Pasawahan Ward is located at the boundary between Bandung City and Bandung Regency, precisely in the south of the Buah Batu district. The area is dominated by a residential and industrial zone. Pasawahan Ward is one of the *kampung kota* in Bandung Regency that prioritized to be managed and revitalized by the local government, including Kampung Bojong Suren as part of the ward and considered as *kampung kota*. Kampung Bojong Suren is located in an unfavorable location between the river and the industrial complex, and occupied the unutilized land beside the river, which is supposed to be a greenbelt zone.

Figure 1.
Map of Kampung Bojong Suren, Bandung Regency
Source: Dinas Perumahan dan Kawasan Perukiman Kab. Bandung, 2022

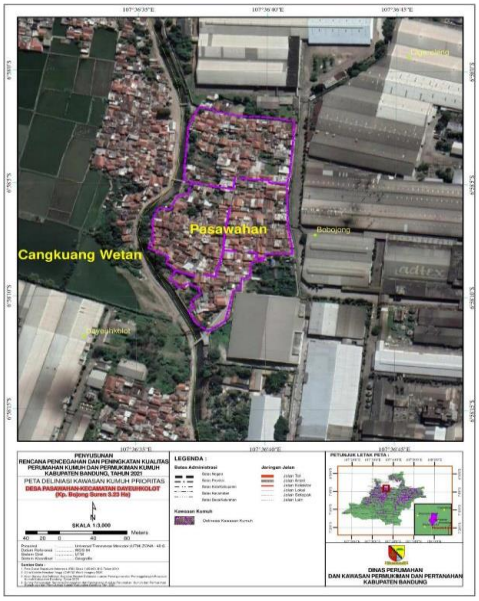


Figure 2.
Area Characteristic and Stormwater Infrastructure Condition in Kampung Bojong Suren
Source: Dinas Perumahan dan Kawasan Perukiman Kab. Bandung, 2022

Based on Figure. 1, Kampung Bojong Suren is dominated by the high-density, unplanned settlement and incrementally developed. According to Bandung Regency’s Major Decree on Slum and Settlement document, 230 housing units are incrementally developed without housing quality standard and planning intervention. Besides, there are 15 housing units which still do not yet meet the minimum technical building standard. In addition, compared to other types of informal settlements around the world, the Kampung Bojong Suren is dominated by an alley of 2-2,5-meter width as the circulation way around the settlement with concrete material and creates an impervious pavement. In addition, figure.2 shows a small drainage line built adjacent

[35] Hoyer, *Water Sensitive Urban Design : Principles and Inspiration for Sustainable Stormwater Management in the City of the Future*; Ahammed, “A Review of Water-Sensitive Urban Design Technologies and Practices for Sustainable Stormwater Management.”

to the alley, which is the area for the stormwater and wastewater flow in the settlement. Most of the drainage lines are in poor condition. According to the Bandung Regency Slum Decree document, approximately 1.084 meters of drainage line is broken and cannot drain off the wastewater and rainwater. Another thing is that we can find a retention pond in this informal settlement. However, according to the observation, the pond does not work for storing water.

Implementation Factor of Hybrid Green-Grey Infrastructure Opportunities in Kampung kota

Recognizing the characteristics of *kampung kota* is important to choose which technique is suitable to be implemented at this type of settlement. Four criteria have been established as indicators to assess the suitability of each green-grey infrastructure technique to be applied as part of hybrid infrastructure.

According to Table. 1, four factors need to be considered in determining the appropriate technique to support sustainable stormwater management in *kampung kota*. The first factor is the opportunity for green and grey infrastructure to apply to the micro-scale environment. In this context, what is meant by micro-scale is the scale of settlement. Not all techniques can be applied in a limited space like a high-dense settlement area. Some types of green infrastructure require a large enough space to operate correctly and have a maximum impact, especially in overcoming water absorption into the ground. For instance, the infiltration basin needs a green open space to be built [36].

The second factor is the opportunity to implement at a low cost. This factor needs to be considered due to the population characteristic that is dominated by low-income people [37]. By considering the population economic characteristic, it can open the opportunity for implementing hybrid infrastructure through bottom-up schemes or citizen-led initiatives. Thus, this opens an opportunity for urban village communities to independently improve the quality of rainwater infrastructure in their environment.

The third factor is the suitability of hybrid green-grey infrastructure component to be implemented in a highly dense settlement with lots of alleyways as its characteristic. In contrast to the other factor, the opportunity to apply to micro-scale settlements, this factor considers the circulation characteristic of *kampung kota* in Indonesia, which mostly dominated an alley with approximately only 2-2,5 meters width [38]. This factor is often overlooked in research studies related to *kampung kota*.

The last factor is the opportunity to apply in informal settlements. Here, the informal settlement is understood as slums without any ownership status, either land or houses. In Indonesia, according to the Ministry of Public Works and Public Housing Regulation on Improvement of Quality on Slum Housing and Slum Settlements (*Peraturan Menteri PUPR* 02/PRT/M/2016), slum areas are divided into two categories based on its land legalization status and ownership. Land ownership is another reason why it is essential to consider this criterion. The land ownership status can identify which green-grey infrastructure components that can be applied with local government intervention, and which one that can be provided by the local residential community. Despite its land ownership legalization concern, supporting the low-income group is still necessary due to their status as vulnerable group. Low-cost and simple construction and maintenance can be two primary factors to assess the possibility of each hybrid infrastructure element to be implemented in such conditions. This research discusses the opportunities for implementing hybrid green-grey infrastructure in *kampung kota* with legal and non-legal status regarding land ownership. In the case study of Kampung Bojong Suren, the land and house ownership status are legal. In other cases, the land ownership in *kampung kota* areas could also be found in illegal status. Therefore, the approach is divided into two categories: *kampung kota* with legal land ownership status and no land title.

[36] Hoyer, *Water Sensitive Urban Design : Principles and Inspiration for Sustainable Stormwater Management in the City of the Future*.
[37] Lathif, "Living in Alleys: A Story of Kampung Kota"; Kusno, "Middling Urbanism: The Megacity and the Kampung"; Putra, Horne, and Hurley, "Place, Space and Identity through Greening in Kampung Kota."
[38] Putra, Horne, and Hurley, "Place, Space and Identity through Greening in Kampung Kota."

Analysis: Hybrid Green-Grey Infrastructure Opportunities in *Kampung kota*

There are seven out of 19 green-grey infrastructure components that possibly can be implemented in *kampung kota* scale. Using the case study of Kampung Bojong Suren to describe the characteristics of *kampung kota.* Considering four factors that have been elaborated, the analysis shows various components are possible to be implemented. **Permeable pavement, green roof, rainwater harvesting, and another permeable surface such as grass or gravel** are highly possible to be implemented at *kampung kota* scale. Other components that are also applicable in the *kampung kota* are grass swale and rain gardens/bioswale. Meanwhile, **concrete pavement** is the only grey infrastructure component possibly implemented in *kampung kota*. However, the other three stormwater grey infrastructure components possibly implemented in a *kampung kota* with legal land ownership are sewer, pipes, and drainage channels. All three components are difficult to set up in *kampung kota* with illegal land ownership (slum) setting due to impossibility of government intervention in providing these components. The installed pavement can alleviate flooding in the alley, recharge groundwater, and improve pavement quality[39].

Meanwhile, rainwater harvesting is one component that can also be stored when it rains. Both these components can contribute well to stormwater runoff management and cooling the area. The permeable pavement, also known as pervious pavements[40], provides a pavement for pedestrian walkways and vehicular traffic. The pavement will allow stormwater to infiltrate the surface and into the underlying layer.

In *kampung kota*, the circulation characteristic for mobility is an alley road with 1.5-2 meters long and can only be passed by pedestrians and two-wheeled vehicles. This situation can be an opportunity to apply permeable pavement components in kampung kota because of the similar setting. The cost to set up the component is more expensive compared to the conventional pavement (concrete), but there is a positive impact by installing this component in *kampung kota*. The other permeable surface components, such as grass or gravel, are considered cheaper and easily installed [41], so it would be possible to implement them in the *kampung kota*, even with the bottom-up approach.

Another component that is possibly implemented with a hybrid infrastructure approach is the rain garden, also referred to as swales and bioswales [42]. Rain gardens are one of low-impact development practices used in the residential areas to capture stormwater runoff, recharge groundwater, or remove water pollutants [43]. The rain garden is usually installed in private properties, such as residential or office areas.

Table 1.
***Assessment of Hybrid Infrastructure Implementation Opportunity in* Kampung Kota**

Green-Grey Infrastructure Components/Techniques		Opportunity to Implement in Micro-scale level	Low-Cost Opportunity	Opportunity to Implemented in Alley Way	Opportunity to Implement in Informal Settlement (No land title)
Green Infrastructure	Permeable Pavement	v	v	v	v
	Green Roof	v	v	v	v
	Rainwater Harvesting	v	v	v	v
	Green wall	v	x	x	v
	Other permeable surface (grass, gravel)	v	v	v	v
	Grass Swales	v	v	v	v
	Bioretention	x	x	x	x

[39] Newell et al., "Green Alley Programs: Planning for a Sustainable Urban Infrastructure?"
[40] Woods-Ballard R et al., "The SuDS Manual."
[41] Muttuvelu, Wyke, and Vollertsen, "Are Permeable Pavements a Sustainable Solution? A Qualitative Study of the Usage of Permeable Pavements."
[42] Hoyer, *Water Sensitive Urban Design : Principles and Inspiration for Sustainable Stormwater Management in the City of the Future*.
[43] Bak and Barjenbruch, "Benefits, Inconveniences, and Facilities of the Application of Rain Gardens in Urban Spaces from the Perspective of Climate Change—A Review."

	Infiltration Trench (Filter Trench)	v	x	x	x
	Filter strip	x	x	x	x
	Infiltration Basin	x	x	x	x
	Rain gardens/ Bioswales	v	v	v	v
	Infiltration Trench	v	x	v	x
	Soakways	x	x	x	x
	Detention Basin	v	v	x	x
	Retention Ponds	x	x	x	x
	Geocellular Storage System	x	x	x	x
	Open Green Space	v	v	x	v
Grey Infrastructure	Sewer	v	v	v	x
	Pipes	v	v	v	x
	Drainage Channel	v	v	v	x
	Concrete pavement	v	v	v	v

Source: Own Construct, 2022

In *kampung kota* scale, a rain garden can be set up in a small size in front of a house or at the public places like neighborhood square. However, due to the small space, there will be only little impact when the flood comes. Moreover, there are fundamental differences regarding the opportunity to apply a hybrid infrastructure approach at the *kampung kota* scale. The legal status of the land is a crucial matter, considering that regulations of the Ministry of Public Works and Public Housing Regulation on Improvement of Quality on Slum Housing and Slum Settlements (Peraturan Menteri PUPR 02/PRT/M/2016) which states it will be difficult for the government to intervene in residential areas that do not have legal status in their dwellings. On the other hand, kampung kota with clear (legal) land status can apply a hybrid infrastructure approach in their residential environment, either with government intervention or independently.

Conclusion and Recommendation

This paper explores the opportunities of providing a hybrid green-grey infrastructure approach in *kampung kota* with a study case in Kampung Bojong Suren, Bandung Regency. Currently, infrastructure development policies in Bandung Regency still refer to the conventional grey infrastructure approach. Based on the identification results, there are several key points that need to be pointed out. The research shows that not all green infrastructure components are suitable with *kampung kota* condition. Several factors need to be considered in determining the suitable component to be apply on *kampung kota*, including the availability and need of land, the level of difficulty in the construction process, the land legal status, and the level of inundation that occurs when rains or flood happens. It should be noted that only the legally built *kampung kota* possibly applies the hybrid infrastructure approach. It is not necessary to be a planned settlement due to the characteristic of *kampung kota* built incrementally.

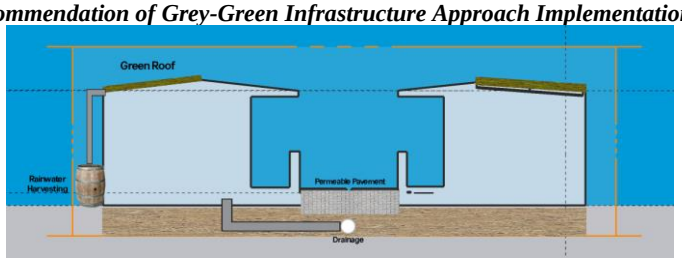
Various green infrastructure-based components possibly applied to support the hybrid infrastructure approach are permeable pavement, green roofs, rainwater harvesting, another permeable surface (grass, gravel), and rain gardens. Then, these components will combine with the grey infrastructure in one infrastructure provision scheme. Those components can be combined into one scheme as hybrid infrastructure (green-grey). In figure. 3, we can see an illustration of the opportunity to implement a hybrid infrastructure scheme in *kampung kota* scale. In the scheme, we can see how the process of installing green-grey infrastructure components allows it to be carried out in narrow alleys, such as the situation in *kampung kota*. Placing permeable pavement and drainage parallelly can increase the efficiency in the process of

rainwater runoff. Other scheme of hybrid infrastructure that possibly works in *kampung kota* is combining the green roof, pipe line, and rain barrel/tank into a network.

The hybrid infrastructure approach is evidently providing new opportunities for infrastructure provision, both with the top-down approach by the government, as well as community-scale initiation. The latter is considered due to the possibility of creating action at a low cost. While its predicted requires much money, this research demonstrates the opportunity of hybrid infrastructure implementation at an affordable cost. Also, it is worth to consider the impact of the green-grey infrastructure approach is implementation at the *kampung kota* scale. In Bandung Regency, the infrastructure provision policy has not yet defined the existence of *kampung kota* as special factor that needs to be considered. Therefore, it is necessary for the policymaker to recognize more about various green infrastructure techniques and provide a quantitative analysis to measure its benefit, possibly with the cost-benefit studies [44].

Several things can be recommended regarding recommendations on policies that need to be carried out by local governments. First, the authority needs to establish a design guideline for the application of a green infrastructure development approach, green-grey infrastructure, which is stipulated in regulation or official provision from an authorized government institution. Second, it is necessary to create an engineering-based study regarding the installation of the elements at *kampung kota*. It is necessary to have a pilot project so there will be a measured recommendation of hybrid infrastructure provision. Thirdly, it is essential to encourage the implementation of green infrastructure development or green-grey infrastructure not only through top-down schemes from the government but also through bottom-up approaches through community-based activities. The activities will likely consider the enormous opportunities for implementing green-grey infrastructure components. In addition, it is necessary to provide some education regarding the opportunity and benefits of implementing a hybrid infrastructure approach. Various ways can be done to transfer knowledge from the expert to local citizens. Methods such as participatory planning and co-production planning between government and citizens can be done to spread knowledge of hybrid infrastructure. In addition, more empirical studies and a pilot project is necessary considering a limited number of researches in this field of work.

Figure 3.
Illustration of Recommendation of Grey-Green Infrastructure Approach Implementation in Kampung Kota



Source: Own Construct, 2022

[44] Teotónio, Silva, and Cruz 2018)

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