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EXPLORING TECHNICAL POLICY SOLUTION TO REDUCE URBAN HEAT ISLAND IN THE CITY OF YOGYAKARTA

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ABSTRACT

Urban Heat Island (UHI) is one of many problems which are the result of urbanization in Yogyakarta. These phenomena require the development of guidelines and planning policies which can manage the local climate. This research aims to explore the spatial planning policies solution especially technical policies which uses the theories of urban sustainability and sustainable cooling to reduce UHI. Qualitative approach was implemented to analyze the data from semi-structured interviews. The interviews were conducted with seven government officials who are responsible for making spatial planning policies from national, regional, and local level. The interviewees were asked about three categories of technical policies solution synthesized from the application of the concepts of *Cool Cities* and *Cool Worlds*. The categories are smart surface strategy, expanded green areas, and urban living labs. The interview results were triangulated with the principles of urban sustainability and sustainable cooling. The spatial planning policies solutions which have a high chance to reduce UHI, as determined from the interviews, are expanding green areas and forming urban living labs. The governments also offer alternative solutions which is expanding green area combined with smart surface strategy.

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1. Introduction

In Indonesia, the impacts of climate change can be seen from various aspects, including changes in the length of seasons, extreme air temperatures, and natural disasters. Based on data from BMKG, Indonesia experienced the hottest air temperatures in 2019 and this has been caused by human activities (Republika, 2019). The increasing temperature leads to more frequent and intense extreme heat events (Setiawati et al., 2021). The Indonesian cities such as Surabaya, Denpasar, and Medan are categorized as the cities with very strong thermal stress due to the contribution of climate change and urban development (Setiawati et al., 2021).

As the world continues to urbanize, sustainable development challenges will be increasingly concentrated on cities. In 2030, the urban areas are projected to be inhabited by 66% of the global population (Aduku et al., 2021). This condition will influence the quality of urban life especially on the microclimate (Rehan, 2014). The UN Sustainable Development Goals (SDGs) have precisely summarized the sustainable cities concept with goal 11: "Make cities inclusive, safe, resilient and sustainable" (Burkhard and Maes, 2017). A sustainable city can be identified from its environmental aspects, such as air pollution, traffic density, and climate (Moser, 2009).

The urban climate can affect the local temperature while the temperature itself depends on land surface configuration, such as the existence of buildings and vegetation. Built areas in cities have high thermal conductivity thereby saving more thermal energy than rural areas (Husna, et al., 2018). This in turn causes urban areas to have a slow rate of cooling of the surface temperature at night. Since there are more buildings in the city, the green areas have less impact on regulating urban climate and urban temperature particularly. Urban temperature has been recognized as a combination of thermal mass and albedo effects, which contributes to elevated temperatures in urban areas, commonly referred to as "urban heat islands" (Howard, 1818; Miner et al., 2017). Research about urban heat islands (UHI) is important, considering the rising temperature in urban areas causing uncomfortable living conditions in neighborhoods. This discomfort leads to decreased work performance and physical activities, poor behavior, and deterioration of social activities (Steeneveld et al., 2018). It has become the main concern for urban planners in the understanding of spatial distribution

patterns which have an impact on the emergence of UHIs.

Many studies have identified adverse effects of UHIs. These effects lead to increased temperatures of cities, which then contribute to global warming, initiate storms, or precipitation events, increase energy demand of cities, and contribute to heat-related mortality (Deilami K. et al., 2018). The United States Environmental Protection Agency (USEPA) has explained that UHIs will elevate emissions of air pollutants and greenhouse gasses (GHG) and impair water quality. The effects of this will be devastating in the summertime, especially in the tropical and arid regions (Nuruzzaman, 2015). Tropical regions like Indonesia, which experience anthropogenic heat, will have more and more increases in temperature in the years ahead. This heat problem will require the development of guidelines and planning policies which can manage the local climate.

Nowadays, land for vegetated areas is limited and this affects the spatial pattern of urbanized areas and causes the increased surface temperature. Wicahyani, et al. (2014) have shown that built-up areas are predominant in Yogyakarta, Indonesia. Meanwhile, land covered by vegetation is predominant in the region outside the urban areas. This condition reflects the different levels of urban and rural growth. The rapid growth of built infrastructure represents the urban growth due to urbanization. This growth causes urban sprawl, development intensity, and de-vegetation which is associated with population growth and can generate more UHIs (Lemonsu et al., 2015).

As the city of Yogyakarta becomes more urbanized, the buildings and population also become denser, which thereby reduces the availability of open spaces that could be converted into green areas. Marwasta (2016) states that the more intensive the physical development, especially that occurring in the suburbs, the more degraded residential comfort is (daily temperature and humidity levels). Temperatures of Yogyakarta are high and dynamic thus, spatial planning intervention is needed to deal with UHI consequences. Pratiwi (2017) reveals that spatial planning intervention to reduce city temperatures can be conducted by considering green infrastructure. Another study by Astuti (2018) also discussed that green infrastructure is still the main measure in urban climate adaptation. Both studies utilize vegetation and green infrastructure in the city of Yogyakarta in an attempt to regulate urban climate but have not seen the efforts to reduce urban temperature or the UHIs phenomena specifically. The implication of these two studies is the making of green infrastructure spatial planning which has a cross-sectoral principle. Thus, this study aims to explore planning policy recommendations especially technical policy to reduce UHI.

2. Literature Review

This study uses a combination of the theories of urban sustainability and sustainable cooling in reducing the adverse effects of UHI. The principles of both theories are incorporated in spatial planning policies which focus on technical policy. The details of the technical policy solution refer to the application of the concept of *cool cities* from ESMAP (2020) and *cool world* from SE for All (2019) offered to countries around the world experiencing UHI. This application is offered to cities in tropical or subtropical countries so that applications in Indonesia also need adjustments.

The application of this concept uses the main components; green areas and spatial planning. The green areas can mitigate the UHI through provision of cooling capacity while spatial planning can provide a technical policy solution through the expansion of green areas based on the programs from *Cool Cities* and *Cool World*. The use of spatial planning such as zoning regulations (including detailed spatial plans) are effective because spatial planning has a profound impact on the internal layout and functional organization of land uses and their regulation at the level of towns and cities (Acheampong, 2019). Policies and regulations must be put in place to reduce the need for unsustainable cooling (such as air conditioning) in residential, commercial, and industrial buildings (UN Environment, 2019).

Urban Heat Island (UHI) itself is a phenomenon where urban areas experience a higher temperature than their surrounding non-urban areas (Deilami et al., 2018). UHI represents a significant increase in the ambient temperature of an urban area that decreases as the landscape changes from dense buildings to a more vegetated area. In general, the formation of UHI in many countries which produce high LST is characterized by one key cause: urbanization. Urbanization leads to an increasing population and changes the landscape of the city and also the land structures. Simply, there is a relationship between the population and temperature in the city center (Karl et al., 1988; Bulut et al., 2007).

Two theories used in this study of UHI in Yogyakarta; *urban sustainability* and *sustainable cooling*. According to Lehman and Droege (2008), urban sustainability has eight key principles; 1) low-rise, high density compact communities; 2) functional mix with local and culture-specific uses; 3) eco-buildings which better harness sun, daylight, wind, rain; 4) integration and reuse of existing buildings with elements of local identity; 5) fine grain, with attention to architectural detail and smallness; 6) high quality public space networks; 7) reliance on public transport and use of bicycles; and 8) variety of urban greenery, integrated in the building. The next concept is the circle of sustainability from James (2015). This circle is

Table 1. Application of Cool Cities and Cool World

Aspects	Cool Cities (ESMAP, 2020)	Cool World (SEforAll, 2019)	Synthesis
Aim	Urban heat management	Help developing countries to reach sustainable cooling solutions	Urban heat management by sustainable cooling solution
Technical policies solution	• Smart surface strategy • Demonstrate urban cooling strategies with pilot projects • Expand urban forestry efforts	• Living labs (strategy, funding, technology) • Providing cool pavements and expanded vegetation area	• Smart surface strategy • Expanded vegetation area • Living labs

Source: Author, 2021 based on ESMAP, 2020 and SEforAll, 2019

the toolset to understand the condition and the quality in the cities based on four sectors: economics, ecology, politics, and culture. Each sector consists of the related detail aspects to assess the sustainability of the city. Therefore, urban sustainability in this research is focused on *the variety of urban greenery* (integrated in the building) and an *environmental perspective* which addresses the issues of *cross-sector* in urban areas.

Sustainable cooling was inspired by SDG7 and defined as green, clean, efficient and climate friendly (SEforAll, 2019). Although this term is more focused on technology and an energy perspective, the principle can be applied to this research because it supports the cooling actions from green areas. The principles of sustainable cooling solutions consist of protect, reduce, shift, improve, and leverage. The principle of reduce is considered suitable for the case of Yogyakarta as they utilize green areas and spatial planning policies as cooling solutions. The solution is one of the spatial planning categories based on the implementation characteristic of Indonesian policies; technical, strategic, and partnership. This study will focus on the technical policies solution used in Yogyakarta City to reduce UHI.

Technical policy solution itself is the combination of principles of various urban greenery integrated in building (from urban sustainability) and reduce (from sustainable cooling). These principles can be defined as active and passive strategies to reduce the high temperature in the urban area. The technical solution is considered as a passive cooling strategy which utilizes and modifies the landuse and physical condition of the urban surface area. The details of the technical policies solution are provided in Table 1 which applies the programs from the concept of *Cool Cities* and *Cool World*.

Cool Cities and *Cool World* applications have overlapping programs that can be categorized into three groups. *Cool Cities* mention a smart surface strategy program which is the same as cool pavements in *Cool World*. The adopted program is the smart surface strategy because it has a more general concept and includes various forms of surface solutions. Then expanding urban forestry in *Cool Cities* can be called an expanded vegetation area program in *Cool world*. This is because the vegetation area will accommodate various types of vegetation area. The last program that can be synthesized from both concepts is urban living labs which incorporate elements of strategy, funding, and technology in the areas used as pilot projects.

3. Research Method

This study uses a qualitative approach. The primary data was collected through semi-structured interviews. The stakeholders interviewed in this study are the government officials from Bappeda DIY, Agraria and Spatial Affair Agency, university, The Center of Development Control in Java Ecoregion, Bappenas, and Ministry of Environment and Forestry which are involved in the spatial planning of the city. The overview of interviewees is provided in Table 2. These interviews were conducted to collect data regarding policies that contribute to and support the spatial plan making process which can reduce UHI.

The interview explored the spatial planning policies especially technical policies based on the principle of urban sustainability and sustainable cooling. Technical policies are consisted of three categories; smart surface strategy, expanded green areas, and urban living labs. The interview aimed to explore spatial planning policies as a solution for the reduction of UHI in the City of Yogyakarta. Thus, the interviewees were asked about those categories. The interviewees from various sectors provided different perspectives on how to deal with the UHI phenomenon.

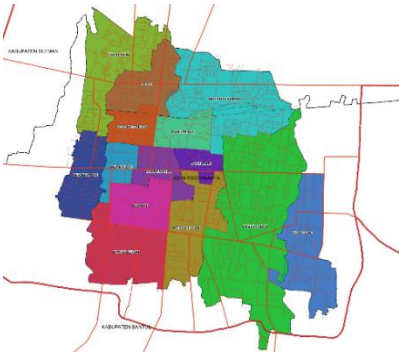

Figure 1. Map of the Administration of Yogyakarta City
Source: Environmental Agency of Yogyakarta City (2018)

The analysis of these interview results was conducted in four steps. Firstly, Interview Responses Coding which code the word of technical policies solution mentioned by interviewees. Advantages of coding are; acquire deep, comprehensive, and thorough insights into the data, making the data easily accessible and retrievable, ensuring validity and transparency, and giving a voice to one's participant (Linneberg and Korsgaard, 2019). Second step is Interview Result Tabulation which was collecting the highlight and most mention answers of interview results based on government level into the table. Third is Interview Responses Description which was describing the interview responses by providing quotes from the interviewees. Quotations are applied in a way that shows respect to participants and that they are presented in a reliable manner, including that they maintain participants' confidentiality (Polit & Beck, 2016; Eldh et al., 2020). The last step is Triangulation Analysis which was performed to analyze the interview responses so that they become more comprehensive by reconnecting to theories of urban sustainability and sustainable cooling. Triangulation is seen as a way of adding complexity and depth to the data and analysis (Marvasti, 2004).

Table 2. List of Interviewees

Level	Institutions	Name
National	Ministry of Environment and Forestry (MoEF) – directorate general of climate change control planning division	P1 N1
National	Ministry of Environment and Forestry (MoEF) – directorate general of climate change control – mitigation and adaptation	H1 N2
National	Bappenas – Directorate of Environmental	P2 N3
Regional	The Center of Development Control in Java Ecoregion (CDCJE/ P3EJ) – Forestry sector	H2 R1
Regional	Provincial Planning Board (Bappeda) – Sector Environmental and Forestry	H3 R2
Local	Agrarian and Spatial Affair Agency (ASSA) of Yogyakarta City	P3 L1
Local	University – Urban and Regional Planning Department	A L2

4. Results and Discussions

4.1 Results

Important interview results for each program are highlighted in Table 3. The description and analysis of the interview results are discussed in the following section. The description and discussion of each program are based on the detailed technical policy solution from Table 1. It elaborates the policies and the implementation at various levels of government to reduce the UHI in Yogyakarta City.

a. Smart surface strategy

Based on the interview results, the smart surface strategy has not been applied optimally at every level of government. However, at the national level, the government has attempted to create a special institution that handles Green Buildings, namely the Green Building Council Indonesia (GBCI). Most of the interviewees said that the existence of the smart surface strategy was only in urban commercial buildings. In the case of Yogyakarta, only several hotels have green roofs.

"Since 2009, we have joined the GBCI to formulate green building concepts in Indonesia. However, currently the implementation of green building is still within the scope of Jakarta." (Bappenas, Planner 2 – P2 at National level – N3)

Interviewees also stated that regional and local governments had actually made policies to regulate this smart surface strategy. At the regional level, this can be seen in RTRW DIY Province, Regional Regulation No. 2 of 2021 which contains a section that regulates the proportion of green areas. Meanwhile, at the city level, the smart surface strategy is regulated in the RTBL of the city of Yogyakarta which is a derivative of the RTRW and RDTR (a set of zoning regulations).

Smart surface strategy is regulated and mentioned in a small part of RTRW and RTBL." (ASSA, P3 L1)

b. Expanded vegetation area

Interview results show that expanding vegetation areas is always a reliable solution because it is relatively easy to do. At the national level, MoEF has made efforts to add green areas through revegetation of critical lands. The same thing has been done at the regional level by planting trees outside urban areas. These actions are expected to contribute to reducing urban temperatures. Meanwhile, at the city level, the implementation of this strategy is quite challenging due to limited areas and land competition.

"*The addition of green areas is carried out by rehabilitating critical lands. This activity is expected to contribute to decreasing the urban temperature because the reference temperature in rural areas changes*" (MoEF, P1 N1)

At the city level, the Mayor of Yogyakarta City has made regulation No. 5 of 2016 regarding public green open space. It regulates how to build and manage the public green area. At the regional level, regulations regarding expanding green areas are contained within the spatial plan of the DIY Province. In the section related to green open space, it is stated that 30% of Yogyakarta must be green areas.

c. Urban living lab

An (Urban) Living lab, based on interview results, is defined as an experimental program that applies climate mitigation and adaptation in a village or RW. The most successful living lab in the city of Yogyakarta is the Climate Village Program (Proklim). This program has been regulated in the national regulation (MoEF), Minister Regulation No. 84 of 2016. This regulation is the basis for the government at every level to realize Proklim's objectives.

The implementation of the regulation was seen in 2019, with 10 new Proklim villages across 10 sub-districts in Yogyakarta (Danurejan, Kotagede, Gondomanan, Jetis, Mergangsan, Pakualaman, Wirobrajan, Tegalrejo, Gondokusuman, Ngampilan). Jetis sub-district had the highest number of RWs in the submission of the new proklim (7 RW). The increase in the number of Proklim projects proves that people's perceptions and behavior towards climate change have changed. Communities are considered to have become more adaptive to climate change.

"*When we monitored Yogyakarta in 2019, there were 10 new villages proposed as Proklim. The increase in the number of Proklim means that there is improvement in the public's mindset towards climate change*." (MoEF, H1 N2)

Interviewees stated that the Proklim in Yogyakarta took the form of green villages, vegetable aisles, and medicinal plant gardens. The scope of Proklim is not limited to the adding of green areas, but also other elements of climate adaptation, such as waste management through waste banks.

4.2 Discussions

a. Smart Surface Strategy

Smart surface strategy has been regulated in the regulations of each level. Each level makes efforts to use the principles of eco-building and variations of urban greenery that are integrated in the building. In addition, these regulations also mention passive cooling to reduce the urban temperature. One of the regulations at the national level is the Ministry of Public Works regulation No. 30 of 2006 concerning Technical Guidelines of Facilities and Accessibility in Building and Environment. An application at the national level is the establishment of a national platform, Green Building Council Indonesia (GBCI), which is responsible for transforming buildings to become more sustainable. The regional and local level regulate this strategy in spatial plans. However, only city parks and green roofs were planned for building in the city.

The regional and local levels have not implemented this strategy due to unclear funding mechanisms. The only implemented is urban park and green roof from private sectors. Thus, this strategy has not become a development priority in the city. The regional or local government should collaborate with the private sector for the provision of subsidies for this program. There are, however, several hotels in Yogyakarta that have installed smart surfaces in the form of green roofs. Although these installations were motivated by commercial and aesthetic purposes, it is hoped that this action will contribute to a decrease in the

Table 3. Highlight of Interview Results

Aspects	National	Regional	Local
Smart surface strategy	Policy: • Climate adaptation action regulation, • Regulation of Ministry of Public Works No. 30/2006 concerning Technical Guidelines of Facilities and Accessibility in Building and Environment, Technical guidelines of green buildings Implementation: • Ecosystem-based and artificial ecology-based adaptation action, • GBCI	Policy: Local Government Regulation No. 2 of 2021 about local spatial plan of DIY Province Implementation: No implementation due to high operational budget	Policy: • environmental and building plan (RTBL) • DED Implementation: • only implemented by hotels • no implementation because of the city image has a strong influence on the buildings
Expanded vegetation area	Policy: • Ministry Regulation No.2/2020 about implementation procedures, support activities, giving incentives, as well as counting and controlling forest and land rehabilitation activities, • Law 26/2007 about spatial plan and national spatial plan Implementation (location): • Critical land, • Roofs, cemeteries, roads	Policy: • Local Government Regulation No. 2 of 2021 about local spatial plan of DIY Province (in the part of establishing green area) Implementation (location): • City center, • Sub urban or rural area outside the City of Yogyakarta	Policy: • Regulation of Mayor No. 5/2016 regarding public green open spaces Implementation (location): • Urban activity center (Solo Street) • Roofs
Urban living lab	Policy: Minister Regulation No. 84/2016 about Proklim Implementation: • Proklim, • Musrembangnas	Policy: Minister Regulation No. 84/2016 about Proklim Implementation: Proklim with the focus activities on waste management and revegetation	Policy: Minister Regulation No. 84/2016 about Proklim Implementation: • Taman Budaya (Cultural Park) in Giwangan, • Along with the national target (20,000 new Proklim) of 2019, Yogyakarta has added 10 new Proklim across the 10 sub-districts • Urban farming

temperature of the city.

b. Expanded vegetation area

Expanding the green area is also one of the urban greenery variation and passive cooling action. It aims to create urban sustainability and sustainable cooling through the utilization of green areas to reduce the urban temperature. This solution is considered the easiest and most funding efficient at every level. Implementation, however, is hindered by the lack of land to add green areas. A combination approach with previous solutions in urban surface engineering is needed here. The urgent area for this expanding is Malioboro and Solo Street. Furthermore, adding green areas could be done by rehabilitating critical land outside the city because urban areas can no longer accommodate vegetation. The addition of green areas in sub-urban or rural areas is expected to reduce the UHI.

c. Urban living labs

Living Labs test and demonstrate not only technologies but also mitigation, business, governance, and funding models (Cool World, 2018). Proklim, which is an urban living lab, strives to achieve urban sustainability and sustainable cooling through reducing GHG emissions with climate adaptation actions, as mentioned earlier. Proklim is a fairly comprehensive program, which utilizes all principles of urban sustainability and sustainable cooling, that deals with the local climate in urban areas. The urban sustainability principles such as variety of GUI and sustainable cooling such as reduce can be seen in Proklim activities which vary from green villages, vegetable aisles, urban farming, to waste banks. The cross-sector principle is also included in the variety of activities because it has different emphasis. These activities facilitate the prioritized needs of the village. For example, certain villages fit the waste bank type as they are areas designated for landfill by the government.

Through climate adaptation actions from the community, it is expected that urban temperatures can decrease and reduce the UHI phenomenon. Proklim is not only a transfer of technical knowledge, but also a matter of governance in managing a village and community. That being said, currently the city of Yogyakarta is still dominated by the transfer of technical knowledge to obtain the ideal type of Proklim.

5. Conclusion

Based on the results and discussions, it can be concluded that Yogyakarta has a set of policies that indirectly can reduce UHI. Technical policies solution consists of smart

surface strategy, expanded vegetation area, and urban living labs. As a complex issue, UHI requires the formulation of a set of policies originating from various levels so that there is multilevel coordination. Policies that have been implemented well are; expanded vegetation area and urban living lab which have the highest chance to reduce UHI. Then, the alternative solution offered by the interviewees is combining the strategies of expanded vegetation area through smart surface strategy since the city has limited land.

This study mainly explores the technical policy and its implementation which contribute to reduce UHI in Yogyakarta City. The concept of spatial planning policies should incorporate the value of urban sustainability and sustainable cooling which is compatible with Indonesian policy characteristics. Thus, suggestion for future research is to evaluate the effectiveness of each policy implemented to reduce UHI.

The online interview method had limitations, such as information clarity. In addition, complicated bureaucracy meant that essential interviewees had to be replaced. Another limitation was during the obtaining of spatial data from local (city) government agencies. RDTR and RTBL as detailed spatial data are inaccessible for the public even for academic research purposes.

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