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Transit-oriented development using water-sensitive urban design (WSUD) approach

A case study of Tegalluar, Bandung

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ABSTRACT

The Tegalluar and Gedebage areas in Rancanumpang Village have been identified as potential transit-oriented development (TOD) sites. However, these areas face challenges due to their low elevation, which leads to ground level reductions and seasonal flooding. To address these issues, it is crucial to incorporate a water-sensitive urban design (WSUD) approach into the development of an interconnected and integrated transit-oriented area. Therefore, this study aims to propose an alternative design for the Tegalluar transit-oriented area, focusing on factors such as density, diversity, design, destination accessibility, distance to transit, and environmental considerations. A fragmental method was applied at different stages of the design and this led to the development of an alternative conceptual design simulation for the transit-oriented area based on the desired factors.

Introduction

Tegalluar has been identified as a potential transit-oriented zone, mainly due to the construction of the final stop for the Jakarta-Bandung high-speed train. This development plan aims to create two transit-oriented development (TOD) areas along the express train route (Febriyanto, Kusliansjah, and Tobing 2021). The focus of regional development efforts in both Bandung City and Bandung Regency is centered around establishing the main TOD area within a 400-meter radius. However, it has become apparent that the existing public transportation infrastructure is insufficient to meet the needs of the local population. Consequently, there has been a significant reliance on private transportation, resulting in a surge in the number of private vehicles. This phenomenon has given rise to new challenges, such as congestion and noise pollution, particularly in areas that are not well-integrated into the available public transportation system (Bachtiar and Pasaribu 2023). To address these issues, it is crucial to emphasize the importance of efficient transportation systems that facilitate the movement of people and goods, thereby enhancing time efficiency and speed. In order to achieve this, a comprehensive approach should be taken, considering factors such as land use, area conditions, and the existing road network systems. By carefully designing public transportation systems in alignment with these considerations, it is possible to alleviate congestion, reduce noise pollution, and improve overall transportation efficiency (Tamin 2000).

According to FloridaNOTA (2012), the primary objective of a transit-oriented area is to establish a compact and vibrant space characterized by mixed-use, high-density, and pedestrian-friendly developments. Typically, these areas usually cover an estimated radius of ¼ to ½ mile from the transit center. Calthorpe (1995) further explained the concept as a community of buildings with mixed functions and public

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transportation facilities for people to reside and conduct their activities. The structure normally includes public facilities, residential areas, and secondary areas (Dittmar and Ohland 2003). The inclusion of transit-oriented areas into city planning design can increase accessibility due to its encouragement of public transportation usage (Renne J. L. 2009).

According to Institute for Transportation and Development Policy (2014), there are eight principles guiding the development of transit-oriented areas. These include "walk" which was a mode of travel for short distances, “cycle” to combine travel convenience and flexibility, “connect” to ensure interconnection with roads and transportation facilities, as well as “transit” to connect and integrate parts of cities and maximize the number of people and services to be reached on foot. The others include "mix" which is a function to integrate diverse activities into a dynamic environment, "densify" to support high density with high-quality transit services and connectivity, "compact" to ensure proximity between transport facilities within the area through walking and cycling, and "shift" to minimize land in order to have a private vehicle parking space.

The main development characteristics of transit-oriented areas are ideally known as the 3D with three aspects. These include a) density for the density or intensity, b) diversity for the diverse areas and high land uses, and c) design for the friendliness of the design to pedestrians and cyclists (Cervero and Kockelman 1997). The 3D was further expanded to two other aspects including Destination Accessibility and Distance to Transit (Ewing and Cervero 2010). It is important to note that transit-oriented areas tend to have a high density around transit points with mixed-land functions such as residences, offices, and commercial buildings. These can be supported by facilities for pedestrians as well as to accommodate the activities of the people living in these areas (Land Use Planning & Policy 2005).

Tegalluar had both design and non-design issues. The first issue was due to the absence of an alternative design produced based on the aforementioned five aspects. The second issue was related to the physical carrying capacity of the environment due to its location on the lowest point in Bandung. It is pertinent to note that Bandung has an altitude of 669 and 668 meters above sea level with a slope range of 2.5%. The area normally experiences a land subsidence rate of 15 cm/year due to the prevalence of soft clay soil, thereby leading to flooding (Dwiputri 2017).

The water-sensitive urban design (WSUD) is a method that involves applying a green infrastructural concept to reduce flood problems and minimize environmental damage. It is important because it can integrate the countermeasures against rainwater and run-off into the design of areas experiencing a land surface decline. The main goal of this method is to include urban planning and design approaches related to water resources and environmental management in the process of designing the development of an area process (Victorian Stormwater Committee 1999).

It was discovered that the development of the transit-oriented area in Tegalluar, as a new growth point, was not based on the government policies implemented to achieve TOD areas using the WSUD approach. This means there is a need to conduct alternative design simulations for this area with reference to the five aspects of TOD and WSUD. Therefore, this study was conducted to make the transit-oriented area become a new growth point as well as to provide alternative simulations to be used by the government in resolving issues related to the implementation of TOD using a WSUD approach.

Method

In this study, a research method inspired by the fragmental process and the synoptic method (Shirvani 1985) was employed. This approach encompassed several stages, including data collection, data analysis, objective and problem formulation, and the development of a concept into a conceptual design simulation.

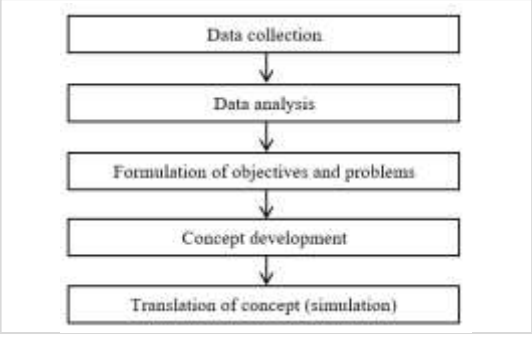

Figure 1. Fragmental method flow
Source: (Shirvani 1985)

Data collection

This study used both primary and secondary data. The primary data were obtained from direct preliminary observations on the field through the measurements of the physical condition, the transportation network system, and aspects of the study area. The problems and potentials recorded were later used to formulate objectives and problems. Meanwhile, the secondary data were retrieved from a literature review of information and policies from Rencana Tata Ruang Wilayah (RTRW) and Rencana Detail Tata Ruang (RDTR) for Bandung City and Bandung Regency (Pemerintah Kota Bandung 2011).

The identification results obtained from the delineation process were later used to identify the principles and criteria associated with the formation aspect. The subsequent stage was to formulate the criteria, principles, and concepts by measuring the five aspects of TOD using a WSUD approach. Moreover, the design concept for the transit-oriented area was developed by establishing the vision and mission of the region.

Table 1. Data collection method

Data collection	Method and stages	Outcome
Data collection	Qualitative descriptive	Criteria, variable, principle of a transit-oriented area
	Direct observation (to the field)	
	Data collection based on literature review, RTRW, RDTR	
Data analysis	Qualitative and quantitative	Physical condition of the area
	Descriptive, direct	
	Observation (to the field) related to the problems, phenomenon, and potentials	Problems and potentials evaluation Design parameter
Objectives and problems formulation	Qualitative descriptive based on the five TOD and WSUD aspects	Vision and mission Criteria Strategy Principle
Design Simulation Concept	Explorative design concept	Design concept Design alternative design simulation

Source: (Shirvani 1985)

Data analysis

The data collected from secondary sources including literature review and regulations or standards were processed using a mixed method. This was followed by the formulation of criteria and indicators based on the five aspects of a) density, b) diversity, c) design, d) destination accessibility, and e) distance to transit as well as the WSUD aspects such as a) housing layout, b) open space network, c) road layout, and d) streetscape. These were achieved through descriptive qualitative analysis by formulating a huge criteria variable from different aspects of the area as indicated in figure 2. Moreover, Pseudo-Evaluation was used for analysis which involved using descriptive methods to produce valid information concerning the results of a policy (Dunn 2004).

The evaluation analysis took the form of a synthesis derived from three existing planning and design drawings of the transit-oriented area in Tegalluar, which were sourced from the Detailed Spatial Planning (RDTR) for Bandung City and Bandung Regency, as well as the planning consultant's drawings. These drawings were analyzed in conjunction with the actual conditions on the site area, considering all the aspects previously identified and presented in table 3. The objective of this study was to identify the variables and indicators associated with both the existing and potential problems.

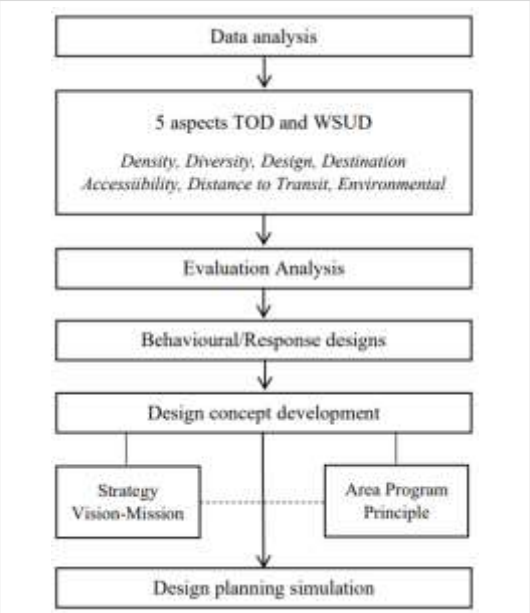

Figure 2. Data analysis stages
Source: (Ewing and Cervero 2010)

The potentials and problems linked to the policies, planning drawings, and the conditions of the existing areas were determined using the criteria, indicators, and variables from the TOD and environmental aspects. They were further used to formulate the vision and mission required to design the Tegalluar transit-oriented area supported by the design strategy and principles as well as the space program as indicated in table 2. The process was also conducted in line with the findings of the previous evaluation analysis.

Table 2. Data collection method

Criteria	Variable	Indicator
Density	• Occupancy density • Population density • Building intensity	• Min 12-38 units/ha for medium-high dense residential areas • Population: 450-1500 people/ha • Building Coverage Ratio: max 70%
Diversity	• Residential land use • Trade and service land use	• Physical condition of the area • 40% housing; 70% non-housing [more than 100%] • There are at least 4 types of mixed-use functions
Destination accessibility	• Availability of parking • Availability of public transportation modes	• Maximum ground floor parking is 15% of the plot area • Heavy rail transit, light rail transit, bus rapid transit, local buses
Distance to transit	• Connectivity between modes of transportation	• Continuous or uninterrupted and integrated connection of pedestrian and bicycle paths
Housing layout	• The distance between buildings follows the drainage path	• Distance between buildings according to topography and drainage
Open space network	• River green line • Drainage channels	• Using drainage corridors to direct runoff water directly to the nearest pond • Integrating retention ponds with public open spaces

Source: (Ewing and Cervero 2010; FloridaNOTA 2012; Institute For Transportation And Development Policy 2017; Victorian Stormwater Committee 1999; Kepala Badan Pertanahan Nasional Republik Indonesia 2017)

Result and discussion

Evaluation analysis was conducted on the study area based on the aforementioned five aspects and environmental aspect using RDTR, preliminary planning drawings, and existing conditions of the area as the source of information.

Table 3. Evaluation analysis

Aspects	Existing	Material
Density	Population density reaches 931 people/ha Maximum Building Covered Ration (BCR) intensity at 70% is 3.0-5.0	RDTR
	Building size: 70-200 meters	Preliminary planning drawings
	Consisting of 213 units and 117 families	Existing condition
Diversity	Mixed zone, residency, transportation	RDTR
	23 commercial zones, mixed stations	Preliminary planning drawings
	Mix function, residency, and green areas	Existing condition
Design	Pedestrian path: 3 m Main road: 800 m	RDTR
	Wetlands, BIUTR highways, pedestrian ways	Preliminary planning drawings
	Width of environmental path 2,5-3 m	Existing condition
Destination accessibility	Circulation patterns are connected with land functions	RDTR
	LRT, BIUTR highways	Preliminary planning drawings
	Path channel is limited Public transportation	Existing condition
Distance to transit	Area: 340 ha	RDTR

Aspects	Existing	Material
	Transit point is a bullet train station	Preliminary planning drawings
	Collective path Radius 2500 m	Existing condition
Environmental	Run-off water management Water conservation air	RDTR
	Green and Blue channels Pond retention	Preliminary planning drawings
	No spaces among the buildings 15-cm land decline	Existing condition

Source: (Bupati Kabupaten Bandung 2016; Urban+ 2010)

Table 3 shows that the aspects experiencing the most problems include destination accessibility, design, and the environment.

Table 4. Problem aspects

Criteria	Problems
Destination accessibility	Circulation patterns and road networks are not mutually connected with the area and the environment
Design	There is no separator in the circulation design, specifically those that separate vehicle and non-vehicle lanes; There is no design for crossing paths and green and non-green open spaces that are connected
Environment	Arrangement of building masses or building functions that are not following the direction of the drainage path

The aspects observed to have some potentials included density, diversity, design, and distance to transit. Therefore, the Tegalluar area was projected to have some new functions with the ability to enhance the mixed-use capabilities as well as to achieve medium to high density.

Table 5. Potential aspects

Aspects	Potential
Density Diversity Design Distance to transit	The area has the potential to incorporate new functions, thereby transforming it into a vibrant and diverse mixed-use land with a medium-high density. This development can cater to a wide range of activities and accommodate the unique characteristics and preferences of its users. The intensity of these activities would be in accordance with the standards set for a transit-oriented area.

The problems and potentials discovered were expected to be used in designing mixed land use patterns with different activities as well as to ensure connectivity, density, and high intensity in the area.

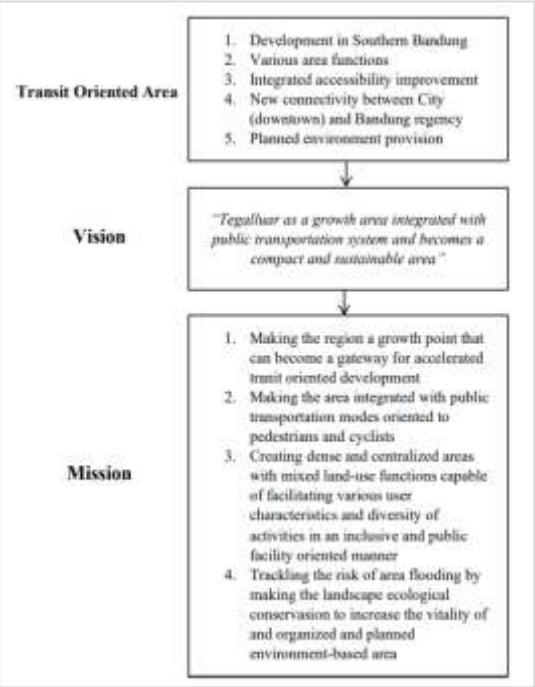

Figure 3. Flowchart of regional vision and mission derived

Design principles serve as invaluable guidelines that encompass normative aspects and possess a natural generality, making them highly applicable to the design process (Shirvani 1985). The keywords observed from the vision and mission are presented as follows:

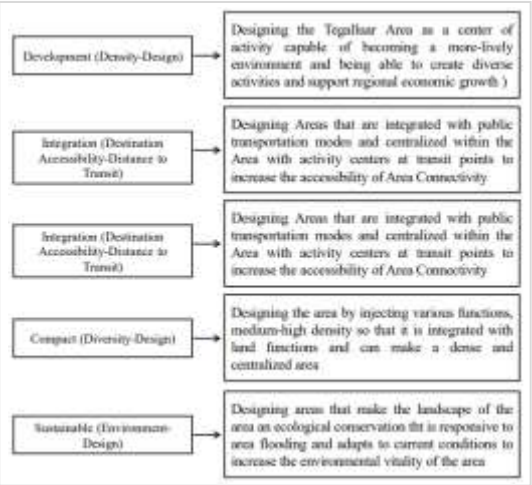

Figure 4. Design principle

A transit-oriented area usually has a high density with mixed land use consisting of residences, commercial buildings, and offices interconnected with the area around the transit point. The problems and potentials, vision and mission, as well as the design principles observed from the analysis were used to accommodate these activities in Tegalluar.

At the macro level, the Tegalluar transit-oriented area concept was based on the organization of activities within a 400 m radius. The core area was planned to be centered around the existing intermodal transportation planning point at the Tegalluar high-speed train station. This core design has four essential functions including a) commercial, b) mixed-use (residential, office, co-working), c) transit, and d) public functions as presented in figure 5. These functions were poised to serve as the foundation for the area's future growth, establishing integrated and compact spaces within the transit-oriented zone.

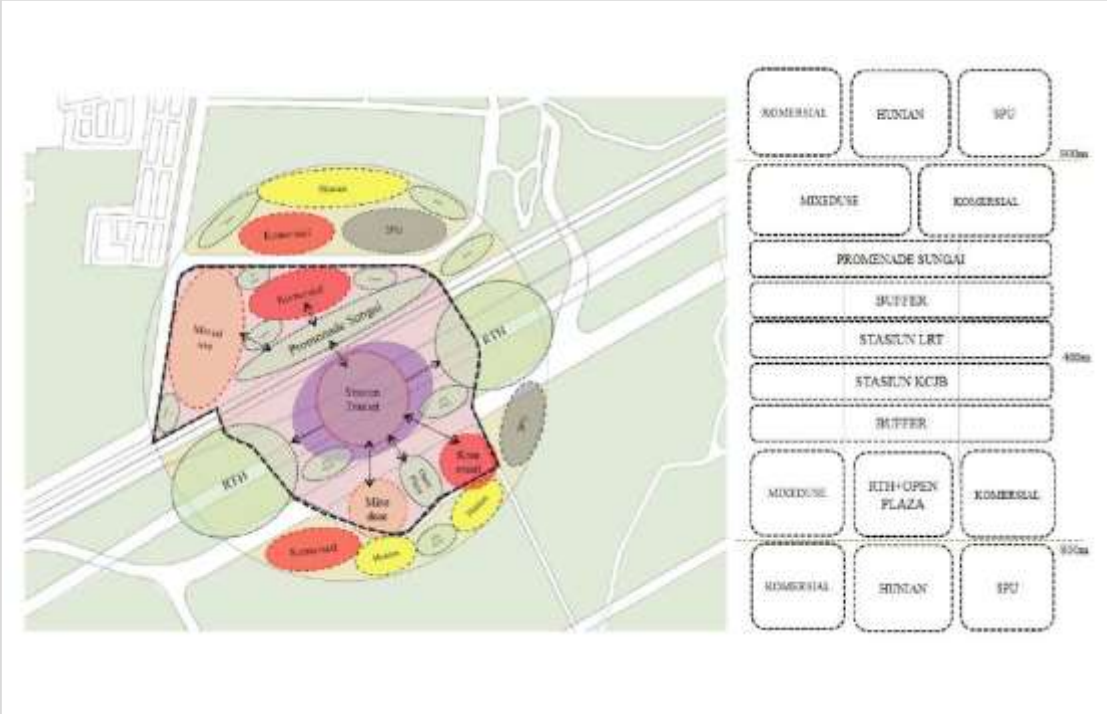

Figure 5. Design area space program concept

The analysis of the plan to construct a fast rail transportation system as a transit point led to the discovery of a micro transportation system approach consisting of activities, movements, generators, and some interconnected networks (Tamin 1993; 2000).

The pedestrian paths within the area were designed to accommodate pedestrians and cyclists. The concept was further categorized into Bandung City and Bandung Regency with the fast train station and LRT as the main transit point as indicated in figure 6.

Figure 6. Land function

The purpose was to create integration and connectivity between the transit points and areas. Moreover, the design area was traversed by the Purbaleunyi toll road and plans were made for two inner-city toll gate accesses including the BIUTR toll road and the Cimekar interchange.

Figure 7. Macro transportation network

At a micro level, the Tegalluar transit-oriented area was carefully planned to accommodate a total population of 18,415 people within a 400-meter radius. Moreover, the population density, calculated based on the projected population needs, was set at 1,540 people per hectare. Based on the diversity concept, the area had the tendency to incorporate new functions that promote mixed land uses, thereby maximizing the synergy between outdoor spaces and the public environment to create a harmonious setting.

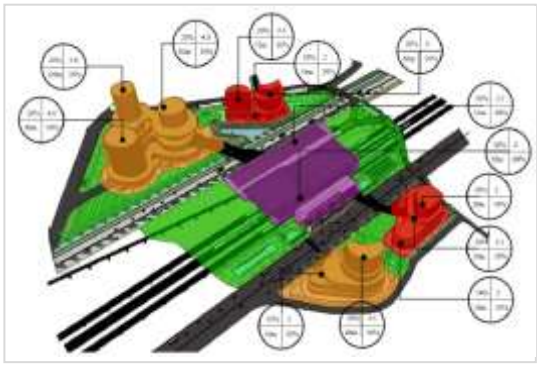

Figure 8. Building intensity concept area design

The density and diversity aspects were identified in the mass grouping of buildings with mixed usage of land as indicated by the existence of high-rise apartments with high density, parking buildings for residential and commercial areas, as well as the offices directly linked to those combined at the station. Based on the environmental factor, the reduction in the usage of private vehicles was projected to cause a decrease in congestion. Based on the physical factor, the money normally budgeted for manufacturing and infrastructure can be reduced. It was also observed from the social factor that the plan could increase social interaction within the community (Cervero 2006).

The design of the Tegalluar transit-oriented area based on space was to facilitate the movement of people as well as to provide easy access and time efficiency for public transportation.

Figure 9. Design area design concept

The pedestrian and bicycle paths were designed to be in separate lanes divided into several sections. They were also easily accessible to all transit-oriented areas in Tegalluar to ensure continuous connection.

Figure 10. Road cut design concept

The open space design was also divided into two concepts including green and non-green. The green open spaces were parks and plazas that can be used as green areas to ensure environmental sustainability while the non-green open spaces included retention lakes and run-off water reservoirs.

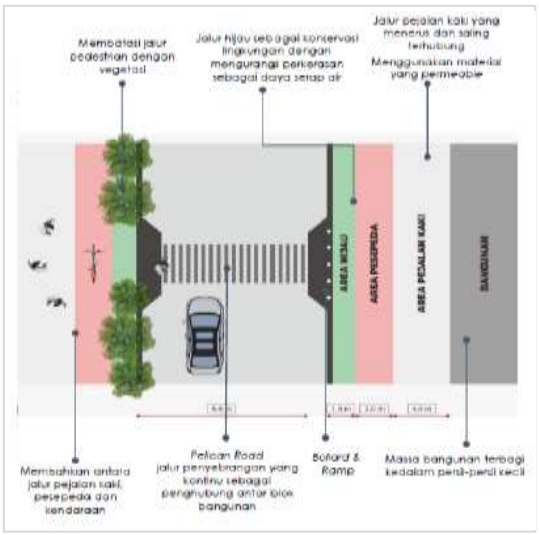

Figure 11. Site plan of road cut design concept

The destination accessibility and distance to transit aspects focused on the interconnection of road networks and public transportation modes. This was demonstrated by the accessibility, connectivity, and integration of regional circulation connected to public transportation and the road network.

Figure 12. Concept of destination accessibility and distance to transit design area

The environmental concept was part of the WSUD approach and it focused on the appropriate management of water to minimize its negative impacts on the environment of the Tegalluar area. This means WSUD was the solution to the problem of regional flooding caused by the decrease in the ground level.

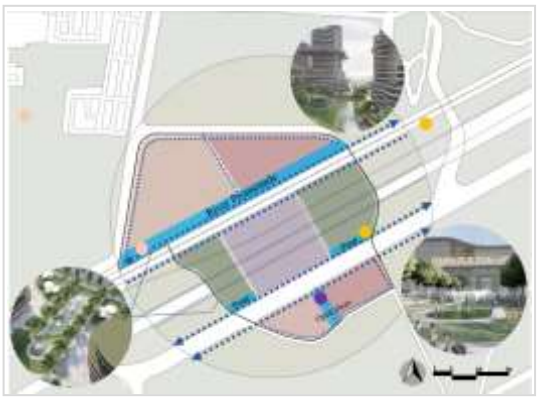

Figure 13. Design area environment concept

The WSUD principles were applied based on the Pollution National Research Council 2009 to protect natural systems through urban development as well as to integrate rainwater management methods into the design of the area (Nassar, El-Samaty, and Waseef 2017). This was indicated by the presence of vegetated swales as waterways to drain runoff into the catchment channel by reducing the speed as well as the permeable pavements constructed to absorb water and avoid easy inundation.

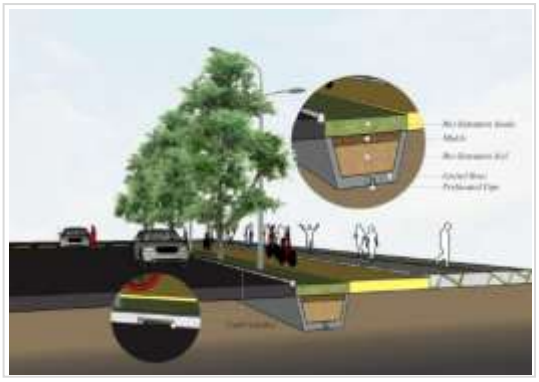

Figure 14. Details design area environment concept

Rainwater and runoff were designed to be reused as alternative sources in order to reduce excess water usage in the area. Moreover, a "roff garden" was used to ensure transpiration and evaporation by cultivating plants in buildings. It was also discovered that green open spaces such as parks or road green belts could be used as bioswales. This was necessary to conserve as well as increase the responsiveness and vitality of the environment.

Conclusion

In conclusion, the evaluation and analysis of the transit-oriented area design in Tegalluar have revealed promising possibilities on a macro level. The comprehensive assessment conducted encompassed the formulation of design aspects and the determination of the overall design concept. The primary advantage observed was the potential for Tegalluar to develop into a transit-oriented area. One notable characteristic of Tegalluar's design was the gradual decrease in growth towards the southern part of the development, with the core area strategically located within a 400-meter radius. This layout is expected to promote equitable growth and act as a catalyst for new economic opportunities in South Bandung, aligning with the five fundamental aspects of TOD. Moreover, by extending the planned area beyond the designated design zone, the southern region of Tegalluar could accommodate future population growth. This expansion would effectively complement the limitations of the current design area and ensure the sustainable development of the transit-oriented zone.

On a micro level, the design of the transit-oriented area necessitated careful consideration of the surrounding environment. The design was required to seamlessly integrate the area with different public transportation modes and incorporate multiple interconnected functions as essential elements. Moreover, there is a need for a comprehensive study of the transit-oriented area in Tegalluar with a focus on the Detailed Spatial Plans (RDTR), an assessment of the applicable Environmental Impact Analysis (AMDAL), and the formulation of City and Regency RDTRs that align with relevant regulations on space utilization and intensity. Research also needs to be specifically conducted to address design aspects that prioritize the environmental context. This means the planning, design, and development processes need to consider and incorporate environmental factors to ensure the preservation of the ecological environment in Tegalluar. The focus should be on topics such as the drainage utility system and strategies for enhancing resilience to disasters, particularly in subsidence-prone soil conditions. This shows that the design of the transit-oriented area in Tegalluar necessitated additional research on policy directives, existing conditions, and the environmental aspects within the designated design area.

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Author(s) contribution

Dian Fitria contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Haryo Winarso contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

Petrus Natalivan Indradjati contribute to methodology, supervision, and validation.