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To cite this article: R A Ramadhan and B Pigawati 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **313** 012030

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Transit Oriented Development (TOD) on the Commuter Train Network

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Abstract. The rapid development of Semarang City has formed a metropolitan city pattern. The city of Semarang is as the core city, while the surrounding cities are as periphery. The high intensity of movement of the population from the periphery area to the core city during rush hour causes congestion at several regional liaison points. The implementation of the concept of Transit Oriented Development (TOD) is expected to solve these problems. The development of TOD-based areas in Kedungsepur has been demonstrated by the existence of commuter trains in early 2014 serving the Semarang City, Demak District, and Grobogan District, but has not provided maximum results. The purpose of this study was to examine the suitability of the application of TOD in 8 (eight) locations around the station passed by Kedungsepur commuter train by using descriptive quantitative approach and spatial analysis. The spatial analysis carried out was the analysis of variable density, and diversity. Design variable analysis was done based on observation. The results show that 8 (eight) station areas have the potential to form a TOD area. Based on the density variables, the Alastua, Brumbung, Gubug, Karangjati, Sedadi and Ngrombo areas were in the high category, while Poncol and Tawang areas were in the low category. Based on diversity variables, only the Tawang and Alastua regions met the requirements, while other station areas did not meet the requirements. Based on the design variable, the feeder is available in all station areas. Connectivity between stations with feeders in 8 (eight) locations is also good enough but needs to be supported by adequate pedestrian infrastructure.

Keywords: *Transit Oriented Development (TOD), commuter train, kedungsepur*

1. Introduction

The problems often faced by metropolitan cities are high congestion due to the use of private vehicles, and poor urban air quality due to pollution. On the other hand, the existence of public transportation has not been able to provide services according to community expectations. This condition encourages people to prefer private vehicles as a media for carrying out movements [1].

Massive and random movement patterns are the result of an urbanization process, it becomes a formidable challenge for metropolitan cities currently, especially in developing countries. The development of urban areas in developing countries takes place without any planning, spreading, spontaneous, and generally toward the suburbs or commonly known as urban sprawl [2,3]. This condition has implications



on various aspects, one of which is transportation in relation to the interaction of the inhabitants of the suburbs as the center of the settlement with the downtown area as the center of activity.

As the capital of Central Java Province, Semarang City experienced a similar phenomenon. The occurrence of settlement development leads to suburban areas occupies less suitable areas [4]. The rapid development of the city of Semarang to the outside has formed a pattern of metropolitan city with Semarang City as the core city, and the surrounding area (Kendal District, Demak Regency, Semarang Regency and Grobogan Regency) as peripheral area or better known as Kedungsepur. The data shows the population of Kedungsepur was 6.54 million people [5–10] with 9.14% growth over the past 10 years [5–10].

The expansion of the urban area of Kedungsepur has triggered an increase in the number of people moving from the peripheral area to the core city, especially during rush hours. As many as 2.67 million people went to Semarang City every working day, which 66% used private vehicles. The largest number of movements comes from Demak Regency, it is about 742 thousand people. The movement is quite massive and dominated by private vehicles. It has caused problems in congestion at some point of contact area [11]. It is getting worse because public transport such as commuter trains, BRT and urban transport have not been integrated with settlement area. These conditions indicate that the demand for the transportation sector is very large, but the existing transportation system is inadequate.

Kedungsepur has an important role in the train development in Indonesia. This is because the first railway construction in Java was the railway network connecting Semarang City (Kemijen Station) to Grobogan District (Brumbung Station). At present, Kedungsepur has a 363.17 km railroad, but only 210.14 km can be operated. Meanwhile, out of a total of 28 stations, only 17 stations were active (PT. KAI Persero, 2014). Most active rails and stations are on the path that connects the Kendal Regency-Semarang City-Grobogan Regency (see Figure 1).

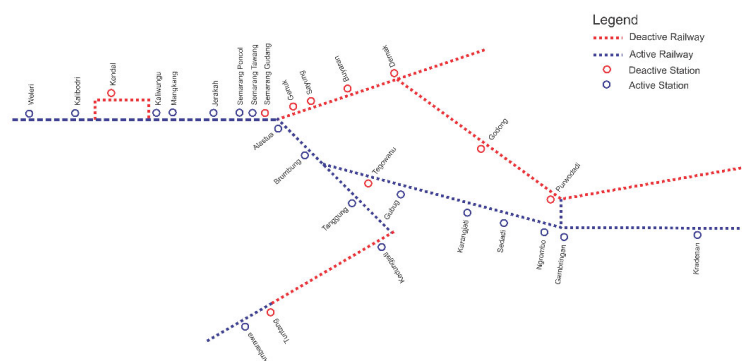


Figure 1. Illustration of Railway and Train Station in Kedungsepur

Source : PT. KAI Persero, 2014

In September 2014, PT. KAI Persero launched the Kedaperepur commuter train (Figure 2) that serves the Weleri-Semarang Poncol-Gubug route. The illustration of railway and train station in Kedungsepur can be seen in figure 1. The route with a distance of 71.76 km is taken within 1 hour 30 minutes with flat rates far near 15.000,00 IDR. For more than a year of operation, there have been some changes due to the lack of public interest in using commuter trains. The route before Weleri-Semarang Poncol-Gubug was changed to Semarang Poncol-Ngrombo, and the previous tariff of 15,000 IDR was changed to 10,000.00 IDR.



Source : PT. KAI Persero, 2014

Figure 2. Kedungsepur Commuter Train

The Kedungsepur commuter train uses 4 (four) cars of Diesel Rail Train (KRD) with capacity of 200 persons. The train operates on peak hour between 06.00-09.30 and 15.00-19.00 WIB. PT.KAI Persero data post-route change [12] shows that the number of passengers per February 2015 is 4033 passengers. This figure is not proportional to the number of people commuting from Demak and Grobogan regencies to Semarang every working day of 1.31 million people.

The impact of urbanization in Kedungsepur area is the emergence of congestion at several points of contact because of the high intensity of population movement from the peripheral areas to the core city, especially during peak hours [11]. Various alternative solutions that have been done such as widening and construction of new roads have not been able to solve the problems. One concept often used to solve transportation problems in metropolitan cities is Transit Oriented Development (TOD).

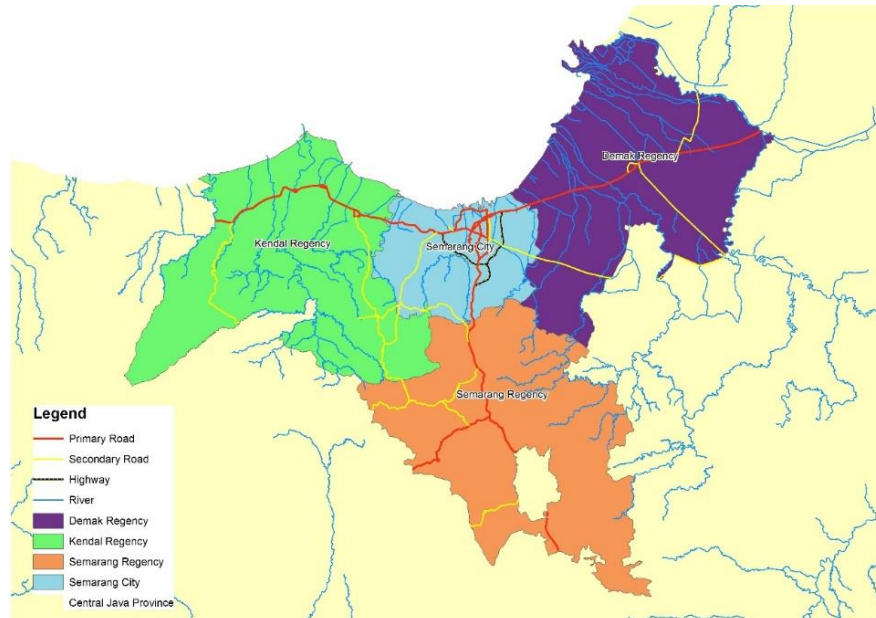
TOD can be defined as a development concept designed to encourage the use of public transport and create a pedestrian-friendly urban environment [13]. The basic idea of TOD is to design a compact, high-density city form characterized by high intensity of mixed land use to create efficient and pedestrian-friendly public transport services [14].

TOD is a development concept that integrates land use and transportation systems, which aims to encourage the use of public transport and create a pedestrian-friendly urban environment (Cervero et al., 2002; CTOD, 2009). Some notions of TOD have the same goal of encouraging the use of public transport and creating a pedestrian-friendly urban environment. [15–22].

The application of TOD in Kedungsepur is deemed possible [23]. The embryo of TOD development in Kedungsepur has been shown by the existence of commuter trains in the early semester of 2014, serving Semarang City, Demak Regency, and Grobogan Regency. The new commuter train serving Semarang Poncol-Ngrombo route is transit at 8 (eight) stations namely Semarang Poncol, Semarang Tawang, Alastua, Brumbung, Gubug, Karangjati, Sedadi and Ngrombo. However, in accordance with the concept of TOD development that to create an environment around the high-density transit area, the use of diverse land, and facilitate people for pedestrians, has not been seen in Kedungsepur. This study aimed to analyze the suitability of the application of TOD in 8 (eight) locations around the station passed by the Kedaperepur commuter trains as the perspective of the development of TOD-based areas in Kedungsepur.

2. Research Sites

The location of the study was in 8 (eight) locations around the station passed by the commuter railway routes with a minimum radius of 800 m of walking in the Kedungsepur regions. The Kedungsepur areas cover Semarang City as an urban area and 5 (five) surrounding areas, they are Kendal Regency, Demak Regency, Grobogan Regency, Semarang Regency and Salatiga City as a suburban area (see Figure 3).



Source : Geospatial Information Agency, 2014

Figure 3. Map of Case Study

3. Methods

Transit Oriented Development (TOD) research on Kedungsepur Commuter train Network used quantitative descriptive method, with spatial approach all data and information were analyzed quantitatively by utilizing High Resolution Satellite Imagery (CSRT) and Geographic Information System. The analysis technique used was network analysis and overlay. Prior to the analysis process, a selection of station locations was conducted to determine the typology of the area. This selection was needed because the indicators of TOD suitability assessment for each regional typology were different. According to Florida Department of Transportation [21] the regional typology in the development of TOD is divided into 4 (four), namely urban core, urban general, suburban, and rural which are determined through a population density approach (see Table 1).

Table 1. Regional Typology in TOD Development in Kedungsepur

Regional Typology	The Station Included in the Regional Typology	Population Density (%)
Rural	Gubug, Karangjati, Sedadi, dan Ngrombo	0-0,877193
Suburban	Brumbung	0,877194-1,946426
Urban General	Alastua	1,946427-4,755687
Urban Core	Semarang Poncol, Semarang Tawang	4.755688-7.488671

Stages of Analysis

1. Settlement density and population analysis in the station area aimed to determine the density of settlements and population at 8 (eight) station areas.
2. Diversity analysis of land use in the station area aimed to determine the diversity of land use in the station area.
3. Design analysis used feeder variables and connectivity in the station area.
4. TOD assessment analysis at 8 (eight) station areas aimed to find out the TOD profile in each station area

Table 2. Regional Typology Indicators in TOD Development in Kedungsepur

Variable TOD	Sub TOD	Variable	Indikator							
			Urban Core		Urban General		Suburban		Rural	
Density	Settlement		>35 house/ ha		25-35 house/ ha		20-30 house/ ha		5-10 house/ ha	
	Density									
	Population		>85 inhabitant/ ha		65-85 inhabitant/ ha		50-80 inhabitant/ ha		10-25 inhabitant/ ha	
	Density									
Diversity	Land	Use	20% settlement	50%	80% settlement: 20			90%	settlement:	
	Diversity		80% non-settlement	50% settlement:	non settlement			10%	non-settlement	
Design	Feeder		Available		Available		Available		Available	
	Connectivity		< 800 m		< 800 m		< 800 m		< 800 m	

To know the TOD profile in each station area, it was weighted based on the indicator in Table 2. Weighting is done equally to each variable because each variable has the same importance level. The TOD area assessment used the following criteria:

- The minimum weight of each station area is 0, while the maximum weight of each station area is 6.
- The output of this study is in the form of classification of weighting results with the following criteria:
0: not yet formed / has not fulfilled the requirements
1-5: formed with the condition / potentially formed
6: Perfectly formed

4. Results and Discussion

4.1 Analysis of Settlements Density and Population

A. Population Density

The level of population density in the station area was calculated based on the number of population per area of the station area. This analysis was conducted to assess whether the level of population density in the station area was in accordance with the TOD region typology indicators. This analysis was done by statistical descriptive technique (see Table 3).

Table 3. Comparison of Population Density of Existing Station Areas with Population Density Indicators for TOD Areas

No	Station Area	Typology	Indicator (Inhabitant/Ha)	Population Density (Inhabitant/ Ha)
1	Poncol	Urban Core	>85	69.83
2	Tawang			55.67
3	Alastua	Urban General	65-85	72.62
4	Brumbung	Suburban	50-80	81.46
5	Gubug	Rural	10-25	67.56
6	Karangjati			40.43
7	Sedadi			37.62
8	Ngrombo			63.79
Total				488.98
The Average of Population Density				61.12

Source: Results of Analysis, 2016

Average of population density in 8 (eight) station areas was 61.12 inhabitant/ha. The Brumbung area was the station area with the highest population density (81.46 inhabitant/ha) because there are many factories around the station whose employees live around the factory. Sedadi population density was the lowest (37.62 inhabitant/ha). The houses around the station are occupied on average by 1-3 persons or below the average number of family members.

There are 6 (six) station areas that have met the requirements, they were Alastua, Brumbung, Gubug, Karangjati, Sedadi and Ngrombo Regencies. On the other hand, there were 2 (two) other stations that have not met the requirements are Poncol and Tawang Regions. Unregulated station area based on population density variable was station area with urban core typology. Poncol and Tawang are were dominated by built up land with non-settlement functions such as trade and services, tourism, industry, and offices, while settlement functions have shifted to the outskirts of the city. This phenomenon is in line with the opinion of [24] who stated that socio-economic conditions may affect the preferences of people in choosing a place to live. People with low incomes will prefer to stay outside the city center because they are unable to access the expensive land prices in the city center. Thus, the development of TOD by closer access to public transportation to the center of the settlement outside the city center connected to the city center is one solution that can help the population, especially the middle class down in carrying out their daily activities.

B. Settlement Density

Settlement density is one of the important variables in the development of TOD because one of the principles of TOD is to create a region with high density and compact. The density of settlements in the station area was calculated based on the number of houses per area of the station with statistical descriptive analysis techniques (see Table 4).

Table 4. Comparison of Settlement Density in Existing Station Area with Density Indicators of TOD
Settlement Density

No	Station Area	Typology	Indicator (House/ Ha)	Settlement Density (House/ Ha)
1	Poncol	Urban Core	> 35	17.46
2	Tawang			13.92
3	Alastua	Urban General	25-35	18.16
4	Brumbung	Suburban	20-30	20.36
5	Gubug	Rural	5-10	16.89
6	Karangjati			10.12
7	Sedadi			9.40
8	Ngrombo			15.95
Total				122.26
Average of Settlement Density				15.28

Source: Results of Analysis, 2016

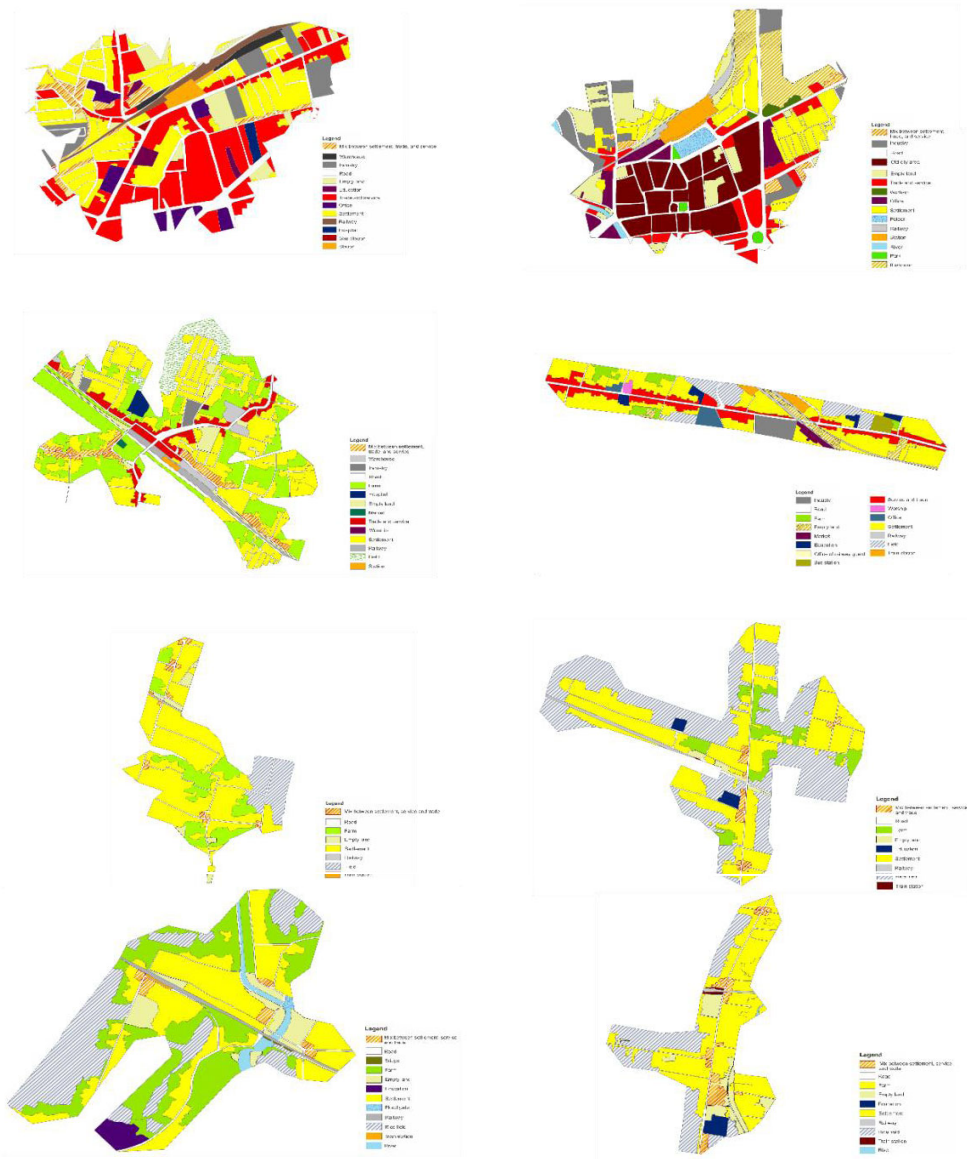
The average of settlement density in 8 (eight) station areas was 15.28 houses/ha. The Brumbung area had the highest settlement density (20.36 houses/ha) because there were many houses mostly occupied by factory employees. Sedadi area had the lowest settlement density (9.40 houses/ha). The characteristics of settlements around the station area tend to be rural, means the distance between one house and another is not too close.

There are 5 (five) station areas that have met the requirements, namely Alastua, Brumbung, Gubug, Karangjati, Sedadi, and Ngrombo, while 3 (three) station areas were not fulfilled the requirements, they were Poncol and Tawang area. Station areas that have been eligible based on settlement density variables were only station areas that have non-urban typology. This condition showed that settlements have developed around stations in non-urban areas. This phenomenon may be influenced by supporting factors such as land that has been limited to urban areas, expensive land prices in urban areas, and decreased environmental quality in urban areas. While in non-urban areas, there was still enough land for settlements with affordable land prices and better environmental quality than urban areas.

This condition showed that access to public transportation is becoming increasingly important for residents living in non-urban areas. The existence of commuter trains must be integrated with residential centers around the station to reduce the use of private vehicles from non-urban areas to urban areas. This condition is in accordance with the opinion of [24] who stated that TOD can be a solution to increase access of residents who live outside the city center to the city center. The existence of the Kedungsepur commuter train is expected to become an embryo for the realization of the TOD in Kedungsepur.

4.2 Diversity Analysis

Some experts say that diversity is the core of a TOD development because the main characteristic of TOD development is its diverse land use [18]. Diversity analysis was done by calculating the percentage of settlements and non-settlements in each station area based on Quickbird 2014 satellite image. Land use of 8 station district can be seen in Figure 4.



■: Settlement growth

Figure 4. Land Use of 8 Station District

Table 5. Percentage of Settlement and Non Settlement in the Station Area

No	Station Area	Typology	Indicator (%)	Settlement width (%)	Non-Settlement Width (%)
1	Poncol	Urban Core	20% settlement:	80% non-	30.50
2	Tawang		settlement		13.84
3	Alastua	Urban General	50% settlement: 50% non-settlement		39.25
4	Brumbung	Suburban	80% settlement: settlement	20% non-	41.32
5	Gubug	Rural			60.66
6	Karangjati		90% settlement:	10% non-	39.55
7	Sedadi		settlement		29.91
8	Ngrombo				47.53
					60.75
					58.68
					39.34
					60.45
					70.09
					52.47

Source: Results of Analysis, 2016

Each TOD typology had a different indicator (Table 5) the higher the TOD typology, the greater the non-settlement aspect weight. The TOD concept does require a balanced mix of designation with activities in an area [25]. However, the development of TOD in the regional context, there is a division of functions between urban and non-urban areas. The urban area is directed to become a center of activity so that elements of diversity must be higher. On the other hand, non-urban areas are directed to become a center for the development of settlements, so that elements of settlements must be higher. In this case, urban areas consist of urban core and urban general typologies, while non-urban areas consist of suburban and rural typologies.

There is a balanced mix of designation with activities in one area [25] in Tawang and Alastua areas. This condition indicates that the Tawang and Alastua Regions have fulfilled the diversity indicators, other stations that have not fulfilled the requirements are considered to have the potential to fulfill indicators if development interventions are well carried out.

4.3 Design Analysis

A. Feeder

Feeder analysis discusses the identification of the type and number of feeder in each station area. The analysis technique used was observation and brief interviews conducted around 8 (eight) station areas. Basically, the concept of feeder in the development of TOD is public transportation with a large capacity. This is related to the effectiveness of travel. The assumption used in this analysis was that if a feeder area is available, it can be said that the area has the potential to become a TOD area.

Table 6. Number and Types of Feeders in Each Station Area

NO	Station Area	Typology	Number of Feeder	Kind of Feeder
1	Poncol	Urban Core	5	<ul style="list-style-type: none"> • BRT (koridor IV: Cangkiran-Bandara Ahmad Yani) • City transport (Johar-Karang Ayu-Mangkang) • Taxi • Taxibike • Pedicab
2	Tawang		6	<ul style="list-style-type: none"> • BRT (corridor II : Mangkang-Penggaron, koridor III : Terboyo-Sisemut, koridor IV : Cangkiran-Bandara Ahmad Yani) • Minibus (Salatiga-Terboyo) • City transport (Johar-Kaligawe-Genuk, jurusan Johar-USM Citarum-Penggaron, jurusan Johar-dr. Cipto-Kedungmundu, jurusan Johar-dr.Cipto-Tlogosari) • Taxi • Taxibike • Pedicab

NO	Station Area	Typology	Number of Feeder	Kind of Feeder
3	Alastua	Urban General	3	<ul style="list-style-type: none"> • City transport (Penggaron-Karangroto-Genuk, Penggaron-Pedurungan) • motor rickshaw • Pedicab
4	Brumbung	Suburban	3	<ul style="list-style-type: none"> • Minibus (Purwodadi-Penggaron) • City transport (Pasar Karangawen-Penggaron) • Taxibike
5	Gubug	Rural	2	<ul style="list-style-type: none"> • Minibus (Penggaron-Purwodadi) • Motor rickshaw
6	Karangjati		2	<ul style="list-style-type: none"> • Minibus (Penggaron-Purwodadi) • Ojek
7	Sedadi		2	<ul style="list-style-type: none"> • Inter-city bus (Semarang, Demak, and Juwangi) • Taxibike
8	Ngrombo		3	<ul style="list-style-type: none"> • Inter-city bus (to Solo) • City transport (to Toroh) • Taxibike

Source: Results of Analysis, 2016

Based on Table 6, it is known that each station area already has a feeder with 2-5 feeders. However, the condition of the feeder is not yet in accordance with the concept of feeder in the development of TOD, except in Poncol and Tawang areas (we can find BRT). Basically, the concept of feeder in the development of TOD is to bring many passengers from home to the point of public transportation or vice versa, so that a feeder is needed in the form of public transportation with a large passenger capacity and little headway. Even so, the current condition of the feeder in each station area can be said to be quite good and beneficial for the community to access the station so that it can be concluded that based on the feeder sub variable, each station area has the potential to form TOD areas.

B. Connectivity

Connectivity analysis discusses the connection between feeder and station location. This analysis was carried out to see whether the current feeder stop points were in the delineation of the station area. Delineation of the station area to be the location of the study, it refers to the minimum distance of people walking in some cities that apply TOD that is 800 m. This analysis influenced the need to provide pedestrian pathways, appropriate designs for the area, and the completeness of other infrastructure to support the development of TOD.

Table 7. Number and Type of Feeder at Each Station Area

No	Station Area	Typology	Number of Feeder	Distance estimation to Feeder
1	Poncol	Urban Core	4	5-10 m
2	Tawang		6	5-10 m
3	Alastua	Urban General	3	40-50 m
4	Brumbung	Suburban	3	20-30 m
5	Gubug	Rural	2	50-60 m
6	Karangjati		2	40-50 m
7	Sedadi		2	40-50 m
8	Ngrombo		3	30-40 m

Source: Results of Analysis, 2016

Table 7. shows that the distance between the stop/shelter point and the feeder is 5-60 meters. According to the Florida Department of Transportation[21], the minimum distance that passengers have to travel for is 800 m. This means that the location of the stop/shelter point is still in the delineation of the station area or it can be said to be very good connectivity. Even so, not many people walk from/to the station

due to the unavailability of an adequate pedestrian route. Most passengers walk to access the feeder by using the shoulder of the road, not to mention the perforated shoulder and open waterways which make pedestrians less secure when walking. In addition, some types of feeders also do not have a bus stop/shelter which is certainly very dangerous for passengers when riding the feeder.

a. TOD Area Assessment Analysis

Table 8. TOD Area Assessment in 8 (eight) Station Areas

Station Area/ Variable	<i>Density</i>		<i>Diversity</i>	<i>Design</i>		Total Score	Result
	Population	Settlement		Feeder	Connectivity		
	Density	Density		Score	Score		
	Score	Score	Score	Score	Score		
Poncol	0	0	0	1	1	2	Potentially Formed
Tawang	0	0	1	1	1	3	Potentially Formed
Alastua	1	0	1	1	1	3	Potentially Formed
Brumbung	1	1	0	1	1	4	Potentially Formed
Gubug	1	1	0	1	1	4	Potentially Formed
Karangjati	1	1	0	1	1	4	Potentially Formed
Sedadi	1	1	0	1	1	4	Potentially Formed
Ngrombo	1	1	0	1	1	4	Potentially Formed

Source: Results of Analysis, 2016

Table 8. shows that all station areas have the potential to form TOD areas based on density, diversity, and design variables, where 3-5 variables are eligible to form TOD areas. In addition, each station area has its own characteristics which mean it requires different handling in order to fulfill the TOD variable.

5. Conclusion

The results show that 8 (eight) station areas have the potential to form a TOD area.

- Based on the density variables, Alastua, Brumbung, Gubug, Karangjati, Sedadi, and Ngrombo areas include into high-potential categories, while Poncol and Tawang areas include into the low-potential category.
- Based on variability variables, only the eligible areas are Tawang and Alastua areas.
- Based on design variables, the feeder is available in all station areas. Connectivity between stations with feeders in 8 (eight) locations is also good enough but needs to be supported by adequate pedestrian infrastructure.

The conclusion based on the research result is that Kedungsepur can be assumed as polycentric city which has many sub center characteristics. Its sub center has high density, so that it can be applied TOD concept, place sub center on the station area to reduce private vehicle usage and encourage public transportation usage. TOD is included in a polycentric city form that has many sub-centers. Other researchers such as [26] had actually proved that polycentric cities can be perfectly formed if the sub-center is located around the station. The TOD principle can be used in this regard to reduce the use of private vehicles and encourage the use of public transportation.

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