

RESEARCH ARTICLE



Assessing Urban Level Changes Using GIS and Statistical Analysis in the Kedungsepur Metropolitan, Indonesia

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ABSTRACT

From 2010 to 2020, the Kedungsepur Metropolitan Corridor experienced spatial transformations, converting agricultural areas into built-up areas. This study seeks to identify new insights by examining the correlation between socioeconomic facilities and built-up areas, typically analyzed separately. Satellite imagery interpretation was used to determine the proportion of built-up areas, apply the K-Means Cluster method for the urban level, and conduct statistical analysis using the chi-square test. The findings reveal that the Semarang—Ungaran—Salatiga Corridor has the greatest built-up areas. The average change in built-up area within the Kedungsepur Metropolitan Corridor from 2010 to 2020 was 3.25%. Additionally, the Central Semarang Subdistrict had the highest level of socioeconomic facilities. However, the Chi-Square test results indicated differences between the observed and expected frequencies of built-up area percentages in each subdistrict for both 2010 and 2020. Surprisingly, no correlation was found between urban-level changes related to built-up areas and socioeconomic facilities. These results suggest that urban changes in the primary city are relatively stagnant, while more intensive development occurs in secondary cities within Kedungsepur. The dominant driving factor for urban transformation is the change in built-up areas, which indicates the intensified growth of secondary cities.

Introduction

Semarang City, the capital of Jawa Tengah Province, is involved in the Kedungsepur metropolitanization concept. Semarang City is functionally linked to the surrounding cities, including Kendal Regency, Demak Regency, Ungaran (a part of Semarang Regency), Semarang City, Salatiga City and Purwodadi (a part of Grobogan Regency) [1]. Kedungsepur was formed due to the city center's increasing population growth rate caused by urbanization, migration, and population increase. According to the Statistics of Jawa Tengah Province in 2020 [2], Semarang City, with a population of 1,653,524, is the most populous locality in Kedungsepur. Additionally, it boasts the highest population density and growth rate in the region. The rapid increase in the urban population aligns with rising demands to fulfill necessities, directly influencing urban development. As an area poised for ongoing development, Kedungsepur must actively accept a rapid increase in socioeconomic activities that can trigger changes in its function. Kedungsepur is a strategic location that actively develops settlements, trade, and services within the metropolitan corridor.

The rise in urban populations and activities has led to a greater demand for larger urban spaces. Nevertheless, the available space in the city is limited and fixed, pushing the increasing need for housing and activity locations to the suburbs. Housing and social facilities needs also compete with business demands, while the overall land area remains unchanged. Consequently, in suburban areas, urban land acquires nonurban land. The growth of major cities worldwide demonstrates rapid changes over time due to various physical and environmental factors. As urban functions expand, urban characteristics extend to neighboring areas, leading to spatial integration between areas. Often, a city's physical development diverges from prepared urban

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plans [3]. The city's physical boundaries are constantly changing, resulting in the city's physical boundaries not always being within its administrative boundaries.

The emergence of overgrowing new buildings is a process of physical development of the area towards "urbanise." This phenomenon occurs in areas close to the city. Accordingly, urban functions have shifted to suburban areas, expanding their physical appearance to the outside. The expansion of suburbanization into the peripheries of metropolitan areas, led to the development of satellite cities, often happening in unplanned and disorganized areas [4]. As a result, suburban areas have experienced spatial changes. Urban area expansion characterizes the development of settlement locations in suburban areas, resulting in the establishment of supporting facilities such as trade, education, health, places of worship, and financial services. Its service ranges and facilities are more diverse and expand its influence area. In regional planning, it is essential to determine whether a settlement or place qualifies as an urban area, based on various activities. Urban areas have different functions, and their facility needs differ from those of rural areas.

Through the interpretation of high-resolution satellite imagery, physical spatial changes can be seen through the expansion of built-up areas along the Kedungsepur Metropolitan in different years. The growth of the built-up regions along the Kedungsepur Metropolitan is an effort to meet the demand for housing and various supporting facilities for socioeconomic activities as a result of investment expansion from growth centers to suburban areas. One of the main factors in this change was the ease of transportation, which connects areas to other regions that are already high in urban areas [5]. The shape of the built-up area can be used to assess Kedungsepur's urban level. If most of the surface is covered by buildings with very complex characteristics, the area already shows urban characteristics. At the same time, the areas that still have rural characteristics are mostly green open spaces, such as paddy fields. The spatial changes from 2010 to 2020 have changed some of the agriculture along the corridor to built-up areas and developed supporting facilities. As a city grows, its facilities and service range become more diverse, thereby identifying the urban level.

Materials and Methods

As shown in Figure 1, in this research, Kedungsepur defined according to Presidential Regulation Number 78 of 2017 [1], which outlines the spatial plans for the urban areas of Semarang, Kendal, Purwodadi, Demak, Ungaran, and Salatiga. The unit of analysis in this study is the 37 sub-districts located in the Kedungsepur Metropolitan Corridor. The variables in this study can be divided into independent and dependent variables [6]. The predictor variables analyzed in this research were the number of socioeconomic facilities (X1), which consisted of educational, health, worship, trade, and financial facilities, as well as built-up areas [7], which were distinguished into built-up areas from 2010 (X2) and built-up areas from 2020 (X3) in the form of a percentage of built-up areas. The dependent variable or output was the urban level, which consisted of the urban level derived from the socioeconomic facilities (Y1), the urban level due to the percentage of built-up area from 2010 (Y2), and the urban level derived from the rate of built-up area from 2020 (Y3).

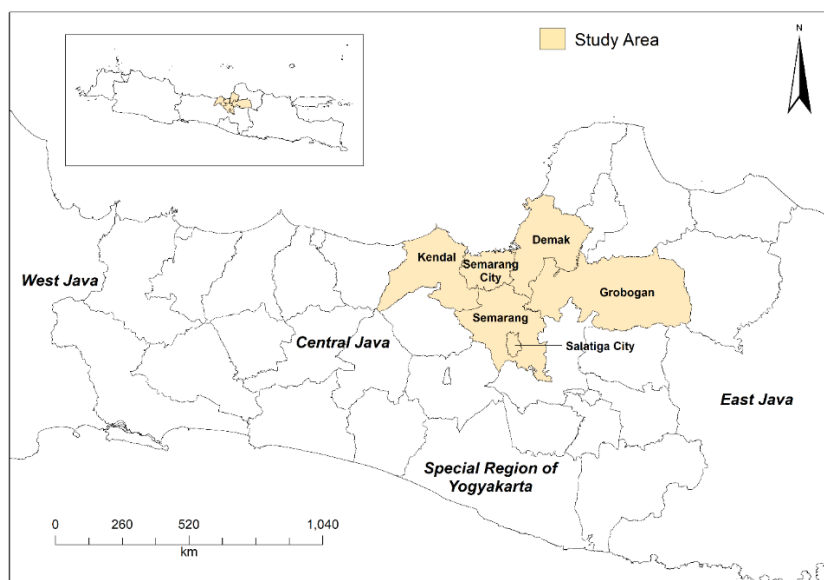


Figure 1. Study area.

This study used data collection methods with satellite imagery interpretation [8,9] by focusing on the interpretation, namely tone, site, shape, association, pattern, shadow, size, and texture [10,11], secondary data documentation, and field observations. Satellite imagery interpretation was used to analyze the urban level of the research location by calculating the proportion change in the built-up area on SPOT-5 and Google Earth. According to Hu et al. [12], both imageries were high-resolution imagery for mapping regional land cover. The time-series images helped identify urban and rural development [13]. Two analytical techniques were used in this study. K-Means Cluster, which refers to Santoso [14] is used for the urban level based on the grouping of the research area with the number of socioeconomic facilities in 2020. Finally, a T-test was used to analyze the variation among the averages of the proportions of built-up areas from 2010 and 2020. In this case, the scale and sample used met the conditions mentioned by Widhiarso [15] for conducting the parametric test comparison.

Results and Discussion

The delineation of urban corridors in the Kedungsepur area resulted in four corridors based on satellite imagery processing and the creation of the Kedungsepur Metropolitan Corridor lines. First, the Semarang-Kendal Corridor consists of six sub-districts. Second, the Semarang-Demak Corridor consists of seven sub-districts. Third, the Semarang-Purwodadi Corridor consists of 11 sub-districts. Finally, the Semarang-Ungaran-Salatiga Corridor consists of 13 sub-districts. Urban functions and the completeness of urban socioeconomic facilities determine the hierarchy and urban characteristics [16–23]. The concentration of socioeconomic facilities in urban areas results in migration from rural to urban areas [24].

Therefore, it is necessary to examine the allocation of these facilities to assess the development of Kedungsepur through the dispersion of its socioeconomic facilities. The exclusion of traffic and transportation systems from this research is based on their lack of alignment with the growth of the city population, urban settlements, and economic-business development [25,26]. Hence, this study analyzed the number of educational and health facilities regulated in SNI 03-1733-2004 [27]. The place of worship facilities is analyzed and regulated in the Minister of Religion and Minister of Home Affairs Number 9 of 2006 [28]. Trading facilities are regulated by Presidential Regulation Number 112 of 2007 and Law Number 10 of 1998 [29].

Urban Level in Kedungsepur Based on Facilities

According to the analysis of educational facilities in 2020, all sub-districts in the Kedungsepur Metropolitan Corridor have educational facilities for high schools, middle schools, primary schools, and kindergartens. The educational facilities aligned with SNI 03-1733-2004 mean that all subdistricts in the Kedungsepur Metropolitan Corridor in 2020 for educational facilities service have met national standards. Based on the analysis of the number of healthcare facilities from 2020, all subdistricts in the Kedungsepur Metropolitan Corridor have health centers, which include integrated health posts (*posyandu*), primary clinics, dentists, midwives, nurses, and mobile public health center activities. However, not all subdistricts have hospitals and not all public health centers in each subdistrict have specialist doctors and ambulances. In line with Law Number 36 of 2009 about Health in Article 16, it states, "The government is tasked with ensuring that health resources are accessible to the entire community in a fair and equitable manner [30]," it can be inferred that the fulfilment of health facilities in the Kedungsepur Metropolitan Corridor in 2020 was incomplete because of the uneven allocation of healthcare facilities at the subdistrict level.

Based on an analysis of the number of worship facilities in 2020, all sub-districts in the Kedungsepur Metropolitan Corridor have mosques, but not all areas have churches, temples, viharas, and relenting. In line with the regulation of Minister of Religion and Minister of Home Affairs Number 9 of 2006, Article 13 that "the establishment of a house of worship is based on the composition of the population for the services of the religious community concerned [28]". Semarang City has the highest diversity of worship facilities. Based on population data according to religion in the Kedungsepur area in 2020, Semarang City is the most diverse. Thus, there is a balance between the diversity of beliefs of the population and the places of worship.

Based on the analysis of the number of trading facilities in 2020, a large number of traditional markets are mostly in regency areas, while the highest number of modern markets are in the growth center area of Semarang City. This condition aligns with Bintoro [31], Pujiyanto and Rodiyah [32], who explain that modern market development increasingly threatens the presence of traditional markets in cities because consumers prefer to be spoiled with all modern market facilities. Modern markets are higher than traditional markets in Semarang.

Types offices according to Bank Indonesia Regulation Number 15/13/PBI/2013 [33], namely payment points, mobile cash, cash offices, functional offices, Islamic banks, sub-branch offices, branch offices, and regional offices. Based on an analysis of the number of financial facilities in the Kedungsepur Metropolitan Corridor in 2020, the highest number of bank offices is in the central area of Semarang City. In line with Barorah [34], the city center is the leading choice for banks in office locations. However, bank offices previously concentrated in the central city area have spread to suburban areas. In line with this study, the number of bank offices is high in the central area of Semarang City and the city center in suburban areas, namely in Sidorejo, Demak, West Ungaran, and Purwodadi. The results of the clustering process for the number of socioeconomic facilities in 2020 are listed in Table 1.

Table 1. The result of the clustering process.

Facilities	Very urban	Urban	Rather urban	Rather rural
Educational	-0.24	0.92	-0.32	3.84
Health	-0.11	1.09	-0.23	-0.05
Worship	-0.09	1.64	-0.38	0.41
Trading	0.91	1.56	-0.48	-0.44
Financial	2.17	0.65	-0.47	-0.31

The results of the K-Means Cluster analysis of the Kedungsepur Metropolitan Corridor area yielded the following information:

1. Very urban areas experience very advanced economic conditions, primarily due to banking and financial factors, further supported by trade factors in developed modern markets. The Kedungsepur Metropolitan Corridor categorises four subdistricts as very urban: South Semarang, Central Semarang, East Semarang, and Sidorejo.
2. Urban areas provide good services in all fields, especially in social, economic, health, and religious affairs. This category contains six sub-districts: Banyumanik, Ngaliyan, Pedurungan, Purwodadi, West Semarang, and West Ungaran.
3. Rather urban areas have good health and economic, educational, and religious affairs. This category includes 26 subdistricts, including Argomulyo, Bawen, Bergas, Brangsang, Candisari, Demak, Gajahmungkur, Gayamsari, Genuk, Godong, Gubug, Kaliwungu, Karangawen, Karangtengah, Kebonagung, Kendal, Penawangan Saying, North Semarang, Sidomukti, Tegowanu, Tingkir, Monument, Tuntang, East Ungaran and Wonosalam.
4. Rural people have the highest number of schools and religious facilities. However, health, trade, and financial facilities require improvement. There is only one subdistrict in this category, namely, Mranggen.

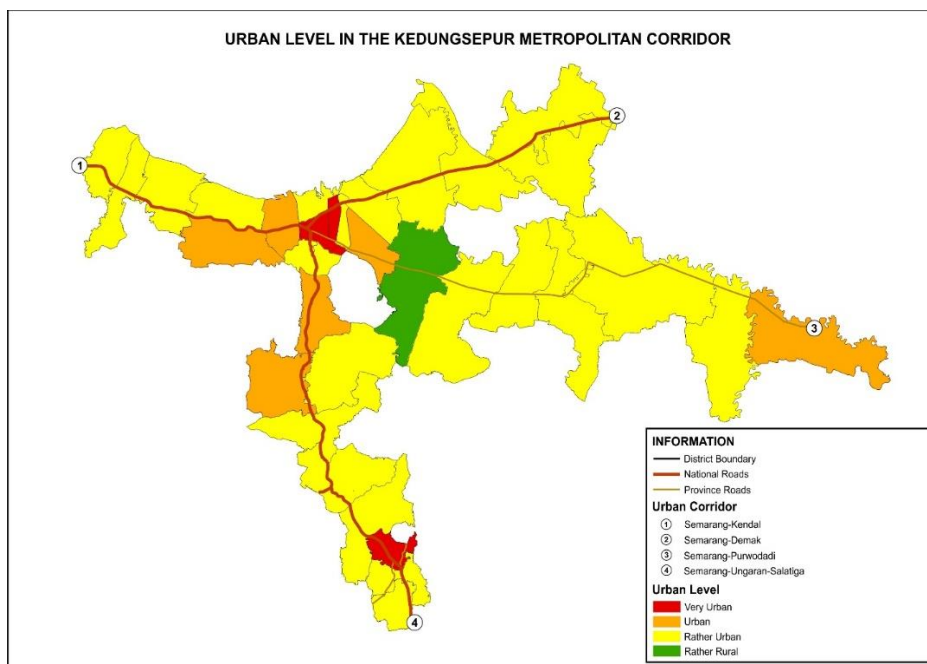


Figure 2. Urban level in the Kedungsepur metropolitan corridor.

The spatial distribution at the urban level in the Kedungsepur Metropolitan Corridor is shown in Figure 2. The urban area is located in the center of Semarang City and Sidorejo Subdistrict. Moore and Kukliński [35], Wardhana and Haryanto [36] stated that a growth center attracts growth, especially in the economy. The area with high socioeconomic facility development is in the Semarang—Ungaran—Salatiga Corridor. In line with Rondinelli and Ruddle [37], Hestuadiputri [17], Berdegué et al. [38], and Utari [39], the role of a city is the influence that the city spreads to other cities behind it, meaning that Semarang City as the center of growth has influenced the area behind it, including Ungaran and Salatiga City, through the distribution of socioeconomic facilities such as hospitals and other urban-exclusive amenities on the Semarang-Salatiga route.

Spatial Changes of Urban Level Based on Built-up Area

The expansion of cities is a significant aspect of urbanization [40]. In observing the physical changes of urban areas, it is possible to use the approach of built-up areas, roads, and buildings through imagery interpretation [41–51]. According to the analysis of the percentage of land cover in the Kedungsepur Metropolitan Corridor in 2010 and 2020, the highest percentage of built-up area was in the Central Semarang Subdistrict, reaching 99.36% in 2010 and 99.42% in 2020, while the area with the highest percentage of non-built-up areas was the Karangtengah Subdistrict, reaching 88.45% in 2010 and 87.13% in 2020. The Semarang—Ungaran—Salatiga Corridor has the most significant built-up area. The areas with the largest cultivated rice fields are in the Semarang—Purwodadi and Semarang—Demak Corridors. Areas with natural vegetation are primarily located in the southern part of Kedungsepur, namely, the Semarang—Ungaran—Salatiga Corridor, which has higher topographical conditions than the other corridors. The type of water land cover is mainly located in the northern coastal area, namely the Semarang—Kendal and Semarang—Demak Corridors. The open land-cover type was the smallest.

Based on the urban level of the percentage of built-up areas in 2010 and 2020, most of the areas in the Kedungsepur Metropolitan Corridor are classified as rural. Very urban areas form a spatial distribution pattern clustered in Semarang City [19,23,52–54]. Moreover, as the city center, Semarang City influences nearby areas, making the surrounding area in the urban category [55]. Consistent with the findings of Giyarsih et al. [56], Kurniawan [57], Dadashpoor and Malekzadeh [58] explained that the stages of spatial change start from the rural center at several points in the road corridor, which is generally a transportation hub. Based on the urban level per corridor, the highest built-up area development is the Semarang—Ungaran—Salatiga Corridor, followed by the Semarang—Purwodadi Corridor in 2020.

The high development of built-up areas in the Semarang—Ungaran—Salatiga Corridor is due to the attractiveness of Salatiga City and the distance factor. This is in accordance with Dewa and Buchori [59] stated that Salatiga has experienced significant growth in the development of trade areas and educational areas. According to Hanafiah [60], Tarigan [61], and Nugroho [62], it is one of the essential elements in spatial planning, which is close to other cities such as Magelang, Surakarta, and Yogyakarta. However, compared with other corridors, namely the Semarang-Kendal, Semarang-Demak, and Semarang—Purwodadi, which are still classified as rural because the distance to other cities is quite far.

The changes in urban areas is one of them characterized by high population density, part of the area is built-up, and its economy is non-agricultural [17,57,63–69]. In line with population data per sub-district in the Kedungsepur Metropolitan Corridor from Statistics Indonesia in 2020, very urban categories based on the percentage of built-up areas are areas with a population density of 7,000 to 13,000 people per km², which are located in most of Semarang City. Although subdistricts are still considered rather rural, namely the Tugu Subdistrict, this is due to the lowest population density, which is only 1,000 people per km².

Identical land use change [57,70–73] in line with the analysis of changes in the percentage of the built-up area from 2010 to 2020, it shows that as many as 37 subdistricts in the Kedungsepur Metropolitan Corridor have all experienced changes in the percentage of built-up area with an average change of 3.25%. The area with the most significant change was in the Tuntang Subdistrict from 2010 to 2020 at 13.57%. Tuntang Subdistrict has an attractive topographical condition which is predominantly flat than the surrounding areas, and there is a crossing of the Semarang-Salatiga artery road—followed by the Genuk Subdistrict, which experienced a change in the percentage of the built-up area of 10.18%. Genuk Subdistrict, due to the spatial plans of Semarang City, is a priority area for suburban, industrial, and transportation.

The area with the lowest change in built-up area from 2010 to 2020 was the Central Semarang Subdistrict, at only 0.06%. This is because of the small area, only 1.39% of Semarang City's total area, which is different from the land needs of its population. The slight expansion of the built-up area in the center of Semarang City

proves that there has been an almost stagnant condition owing to the high density. This stagnant condition is in line with the findings of Sari and Winarso [74], Wastiko and Pigawati [75], which inferred that the Central Semarang Subdistrict is almost close to saturation, fragmentation, and complexity of landscape pattern [76]. At the same time, urban activity was very intensive in the Simpang Lima area; ultimately, the built-up area could no longer develop, leading to the expansion of the surrounding area [21,77–79].

Furthermore, a change in the built-up area is observed per corridor. It was found that the urban corridor with the most significant changes in the built-up area from 2010 to 2020 is the Semarang—Ungaran—Salatiga Corridor. Concurrently, the lowest was in the Semarang—Kendal Corridor. Therefore, urban-level changes occur more frequently in suburban areas or in satellite cities, in line with research Rangkuti et al. [80] showing that increased use of built-up areas that push the urban level is a form of an increase in population and urban activities.

The dominance of urban-level changes that occurred in satellite cities was also due to the low cost and availability of land for settlement. These factors are the main reason migrants prefer to occupy satellite cities rather than the city center. As Yunus [81] explained, population growth in cities continues to increase, but the availability of space in the city center continues to decrease, causing it to spread to the outskirts of the city and result in urban development towards the suburbs. Hence, the currently developing concept is that of a satellite city where land costs, density, and access to economic opportunities are better than in more central areas [82]; the same is true in Metropolitan Kedungsepur.

The Difference Between the Percentage of Built-up Areas in 2010 and 2020

Based on the data processing of the percentage of built-up area in 2010 and 2020, a chi-square test was carried out with the test results, as shown in Table 2. According to Junaidi [83], the chi-square compares the observed and expected frequencies of each category. The null hypothesis assumes no difference in the built-up area percentages between the observed and expected values in each subdistrict for both 2010 and 2020. By contrast, the alternative hypothesis suggests a difference in these percentages.

Table 2. The result of the Chi-Square test.

Category	2010		2020	
	N	Expected N	N	Expected N
High	9	12.3	11	12.3
Medium	8	12.3	6	12.3
Low	20	12.3	20	12.3
Total	37		37	
Asymp. Sig.	0.027		0.017	

Chi-square results show that the Expected N percentage of built-up area in 2010 and 2020 for high, medium, and low categories should have a distribution or expected value of 12.3. By looking at the value of the chi-square analysis, there is a difference between the observed and expected frequencies with an Asymp. Sig. $0.027 < 0.05$, indicating that there was no significant relationship between the variables of the percentage of built-up area in 2010. Similarly, with Asymp. Sig. $0.017 < 0.05$ in 2020, meaning there was no significant connection between the variables of built-up area percentage in 2020. The percentage of built-up area in the Kedungsepur Metropolitan Corridor was significantly different between 2010 and 2020, which is in line with the findings of Oktavia [84]. Thus, built-up area growth is significant in the Kedungsepur Metropolitan Corridor, and for the last ten years, it has been quite intensive.

New Indications of Urban-Level Driving Factors in Kedungsepur Metropolitan Corridor

Two factors were identified that determine the urban level: facilities and the proportion of built-up areas. Thus far, these two variables have been used separately. The author attempted to juxtapose the two in a study, as shown in Table 3.

Table 3. Number of subdistricts based on the urban level in Kedungsepur metropolitan corridor.

Urban level	Number of subdistricts	
	Based on facilities	Based on built-up area
Very urban	4	8
Urban	6	3
Rather urban	26	7
Rather rural	1	19

Table 3 shows no correlation between urban-level changes based on built-up areas and socioeconomic facilities. The urban level category based on facilities indicates the dominance of the urban category, followed by the urban category. This means that the centripetal force is still dominant towards the center. If the facilities measure urbanity, the concentration is already in or around the city center. The growth to the outside (centrifugal force) tended to be small. Consequently, this indicates that development towards the center tends to stagnate.

On the other hand, the urban level based on the percentage of built-up area shows that the rural category dominates the existing category, followed by the very urban category. This means that the physical development of the area is more intensive on the outside and in suburban areas. The centrifugal force outward from the city center indicates the dynamics of the suburbs.

Urban-level changes based on land use and availability of facilities show that Kedungsepur is undergoing a transformation that leads to urban characteristics. Driving factors cause these changes to continue. The dominant driving factor is the rate of change in land use in the form of intensively built-up areas in Kedungsepur's satellite cities. This finding is antithetical to Torquati et al. [85], who state that preferences in choosing a place to live, which is often based on proximity to facilities and utilities, will encourage locations close to the city center to be more developed. In addition, an increase in population should be followed by an increase in supporting facilities, so that the availability of facilities at one time will determine the level of regional development [86].

Furthermore, the discussion is conducted in the context of the primary city (Semarang City) with secondary cities around it (Kendal, Demak Ungaran, Salatiga, and Purwodadi). In this case, development was more intensive in this area. These two findings indicate that the urban spatial changes in the primary city are relatively stagnant and occur more intensively in the secondary cities of Kedungsepur. Thus, urban driving factors are more dominant owing to changes in built-up areas, indicating more intensive development in secondary cities. This is a new indication for measuring urban development; the driving factor determining urban development is built-up area.

Conclusions

The urban level measured by socioeconomic facilities in 2020 is dominated by centripetal forces or towards the primary city. The changes in the percentage of built-up area in the Kedungsepur Metropolitan Corridor from 2010 to 2020 averaged 3.25%, with the highest change in the Tuntang Subdistrict and the lowest in the Central Semarang Subdistrict. The chi-square test results show differences in each sub-district regarding the percentage of built-up area in 2010 compared to 2020. The changes in the urban level based on the built-up area show the dominance of centrifugal force, which can be observed in the development of secondary cities. This indicates that urban changes in the primary city were relatively stagnant and occurred more intensively in the secondary cities of Kedungsepur. The new indication found in this study is that urban driving factors are more dominant owing to the development of built-up areas, which indicates more intensive development in secondary cities.

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