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The Economic Impact of the Road Infrastructure Utilization and the Consumption of Electrical Energy in the Kedungsepur Urban Area

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Abstract. Kedungsepur is a national urban area located in the northern region of Java Island, comprising of six autonomous regions: Semarang City as the principal urban center, along with Kendal Regency, Semarang Regency, Salatiga City, Grobogan Regency, and Demak Regency as supporting areas. Kedungsepur holds significant economic importance in Central Java, contributing approximately 24% to the total Gross Regional Domestic Product (GRDP) over the past two decades. To strengthen Kedungsepur 's role in the regional economy, the government has invested in infrastructure, aiming to bolster the overall economy in Central Java, particularly in the northern region. Therefore, it is important to assess the economic impact of providing infrastructure in the Kedungsepur area to determine the extent to which infrastructure contributes to the regional economy. To measure the economic impact of infrastructure in Kedungsepur, this research uses a regression model with panel data and uses GRDP data as the dependent variable, and infrastructure utilization, especially road utilization and electricity consumption as independent variables. To ensure that regional economic growth in Kedungsepur is influenced by the existence of infrastructure, this research also uses household consumption data as a control variable. The research results show that regional economic growth in Kedungsepur is not only influenced by infrastructure utilization, but also household consumption. Among these, road usage emerges as the primary contributor to the economic growth of the Kedungsepur region, surpassing the impact of electricity consumption and household spending.

Keywords: Economic Impact, Road Infrastructure Utilization, Electrical Energy Consumption, Kedungsepur

INTRODUCTION

Infrastructure is a pivotal component of urban areas, serving not only to meet the basic needs of urban residents but also to underpin the urban economy. Numerous studies have demonstrated the significant role of the availability and utilization of infrastructure in supporting regional economic development. Research in four major cities in China shows that the urban infrastructure, especially transportation infrastructure, has a positive influence on the urban economy [1]. The development of transportation infrastructure, especially roads and ports, in China has notably enhanced the efficiency of goods circulation, thus influencing the competitiveness of regionally produced products [2], while also creating spillover effects in surrounding areas [3].

Another interesting fact regarding the contribution of infrastructure to regional development was discovered by Lall who focused his research on infrastructure and regional growth in India. His findings showed that the spillover

effect of the transportation infrastructure on regional development was higher in underdeveloped regions compared to developed ones [4]. Achour and Belloumi also concuded that investment in transport infrastructure in Tunisia have been instrumental in driving higher economic growth [5], similar trends have been observed in Pakistan [6]. Furthermore, Muvawala, et al found that the road development in Uganda significantly contributes to economic growth [7].

Melnikov and Furmanov have also identified the significant impact of road and telecommunication infrastructure provision on the economic growth dynamics in Russian regions [8]. Novitasari et. al found that the infrastructure provision in the urban areas in West Java, Jakarta and Banten, has both positive and negative contribution on economic growth and poverty levels [9]. The role of infrastructure in boosting the regional economy is highly dependent on the level of utilization of infrastructure in supporting economic activities [10]. Sun et al. revealed that the provision of urban infrastructure, when synchronized with urban policy, yields a higher contribution to urban economic growth [11]. it is clear that infrastructure provision and the optimization of infrastructure functionality serve as pivotal drivers of regional economic advancement.

The provision of physical infrastructure in Turkiye has contributed significantly to increasing regional income both directly and indirectly [12]. Providing infrastructure not only generates economic growth but also contributes to poverty alleviation and reducing income disparities. A study conducted by Zhang et.all found that China's infrastructure investments have effectively reduced local poverty in rural areas in sub-Saharan African countries [13]. In line with the findings of Zhang et al., research by Nugraha et al. in Indonesia [14], and research by Zolfaghari et al. in Iran [15] offer additional empirical evidence that infrastructure positively impacts in alleviating poverty and reducing income inequality. Those studies found that the provision of basic infrastructure, social infrastructure, energy infrastructure, and transportation has reduced income inequality indirectly.

The presence of infrastructure plays a pivotal role stimulating economic activities that significantly benefit the urban and regional economy. Currently, urban areas have taken on an increasingly crucial role in economic development. These urban centers serve as hubs for a wide array of economic activities, effectively propelling overall economic growth [16]. Consequently, the development of urban infrastructure becomes a key priority in meeting the demands of economic growth in urban areas, including Indonesia. However, infrastructure development requires substantial financial resources. In light of these financial constraints, the Indonesian government is compelled to strategically prioritize infrastructure development within urban areas that hold pivotal positions within the national economy.

One of the major urban areas that has a strategic role nationally is the Kedungsepur Urban Area (Kendal-Demak-Ungaran-Semarang-Purwadadi), strategically located in the middle of the economic corridor of the North Coast of Java. The Kedungsepur urban area serves as the primary transportation hubs for Central Java to support production activities in the surrounding area. To support the important role of the Kedungsepur urban area, the Indonesian government has undertaken various infrastructure components. These include the development of the Tanjung Emas port, the development of Ahmad Yani Airport, the development of a national network and toll, facilitating connectivity between economic hubs, ports, and airports, all of which are integral to Central Java's import-export operations. Infrastructure development in the Kedungsepur urban area in the last ten years (2010-2020) is expected to have an important impact on the regional economy.

This research aims to measure the economic role of infrastructure in the Kedungsepur urban area. This research employs regression method to measure the influence of infrastructure to economic growth on Kedungsepur, and assumes that there is a relationship between the GRDP and the level of development and effective functionality of infrastructure. The independent variable used in this research is infrastructure utilization, so it can complement previous research which used the physical condition of infrastructure and the value of infrastructure investment as independent variables. Details of the variables used in this research are explained in the data and method section.

RESEARCH METHODOLOGY

Numerous studies aimed at quantifying the economic ramifications of infrastructure development employ regression models as a primary tool to ascertain the infrastructure's contribution to regional economic growth. The majority of these studies hinge on data related to physical infrastructure and the financial investment in infrastructure. For example, Wan et al. delved into the impact of road infrastructure on economic circulation using regression analysis to gauge its influence in China. Their findings underscore the pivotal role of road networks in the efficient distribution of key commodities within the production and distribution systems [2]. Wu et al., in a study on port infrastructure's

impact on regional development in China, also emphasized the crucial role of road networks in bolstering regional development and fostering positive spillover effects in surrounding areas [3]. Furthermore, Lall's research, employing the regression method, substantiates the phenomenon by highlighting the significant contributions of road networks and energy systems to regional development [4]. Additional empirical evidence provided by Melnikov et al [8], Novitasari et al [9], and Nugraha et al [14] reinforces earlier research findings regarding the pivotal roles of road networks and electrical energy in fueling regional economic growth. As such, this research leverages road and energy infrastructure data as independent variables and employs a regression model to assess the economic impact of infrastructure provision in Kedungsepur. To capture a holistic view of the regional economy, this study introduces household consumption variables as control factors. The inclusion of control variables reflects the distinct economic landscape in Indonesia, where regional economic dynamics are significantly influenced by household consumption. This choice is also informed by general equilibrium theory, which posits that regional economies are profoundly affected by both investment and consumption factors [17].

The road infrastructure parameter is the annual average of daily traffic that crosses the Kedungsepur urban area in a year expressed in passenger car units per day, while the energy consumption parameter is the amount of electrical energy consumed in a year expressed in megawatts (MW), and the consumption aspect as a control variable will be represented by household consumption expenditure in a year expressed in rupiah. Data was obtained from the Central Statistics Agency and local government agencies in the Kedungsepur urban area. Detailed data can be seen in table 1.

TABLE 1. Detailed Data and Parameters

No	Variables	Data	Parameter	Source of Data
1	Dependent Variable	GRDP	Rupiah	Statistical Beurau
2	Independent Variables	Road Infrastructure (Road Use)	Passenger Car Unit per Day	Inter Road Management System (IRMS)
		Electrical Energy	Mega Watt (MW)	Statistical Beurau
3	Control Variable	Household Consumption	Rupiah	Statistical Beurau

Source: Analysis, 2023

The regression method offers a more comprehensive insight into the relationship and influence of infrastructure availability on the regional economy. The conceptual regression model, designed to quantify the economic impact of infrastructure development within the urban enclave of Kedungsepur, can be represented as follows:

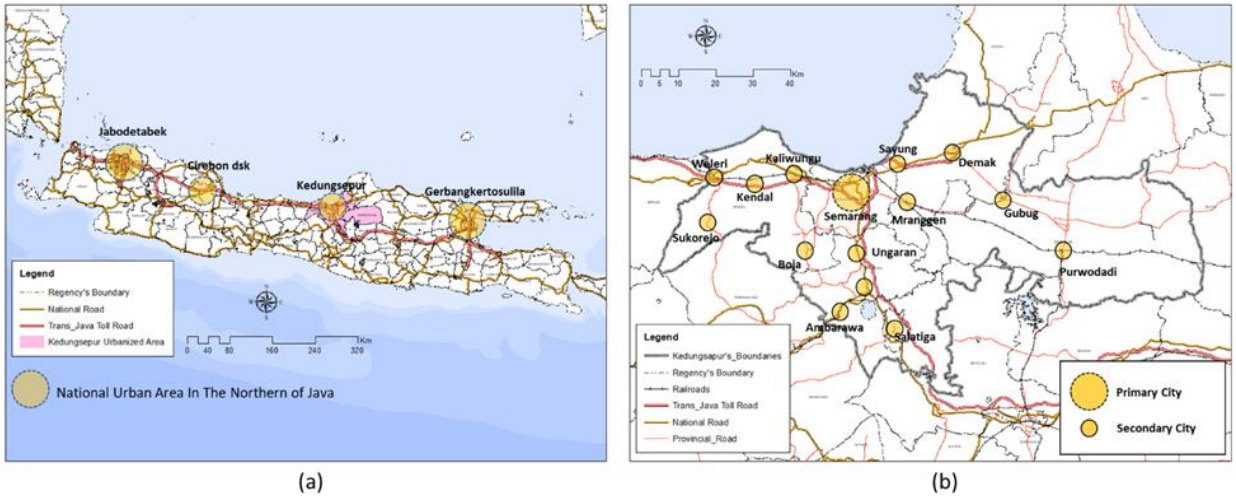
$$GRDP = a1X1 + a2X2 + a3X3 + C \quad (1)$$

where,
GRDP = Gross Regional Domestic Product
a_n = the regression coefficient for each independent variables
X1 = The Road Utilization represent by the number of vehicle that across Kedungsepur Urban Area
X2 = Electrical Energy Consumption
X3 = Household Consumption
C = The regression constant

RESULT AND DISCUSSION

The Kedungsepur urban area (KUA) is situated on the North Coast of Central Java Province, serving as the primary economic corridor connecting the economic hub of Jabodetabek to Gerbang Kertosusila in East Java, on the island of Java. Kedungsepur encompasses six autonomous regions: Semarang City, Semarang Regency, Grobogan Regency, Demak Regency, Kendal Regency, and Salatiga City. The Kedungsepur urban area comprises the core urban area, namely the City of Semarang, along with 14 medium-sized and small cities that support the core urban areas. These cities are located in autonomous districts/cities around the City of Semarang (refer to Figure 1). The primary role of the Kedungsepur urban area is to serve as a hub for industrial development, tourism, the creative economy, trade and services, as well as the maritime industry and international maritime services [18]. The presence of industrial zones such as the Kaliwungu Industrial Area/SEZ, the Tugu Wijaya Kusuma Industrial Area, the industrial area in Demak

Regency, and the industrial area in Semarang Regency serves as empirical evidence of the significant role played by the Kedungsepur urban area in national industrial development.



(a) (b)

FIGURE 1. The regional context of KUA (a) and City System in KUA (b)

The government has developed various critical infrastructure such as road networks, energy networks, telecommunications networks, clean water systems, and sanitation systems to support the role of the Kedungsapur urban area, and to enhance economic efficiency and deliver added value to the regional economy in the urban area of Kedungsepur. Based on data from the Central Statistics Agency (BPS), regional economic value added in the Kedungsepur urban area has increased significantly. In 2010 Kedungsepur's urban GRDP was IDR 151 trillion and will increase to IDR 261 trillion in 2021. Kedungsepur's urban GRDP accounts for 2.4% of Indonesia's total GDP. While the GRDP value of the Kedungsepur area is not the largest when compared to other urban areas in northern Java, its development has been notably significant over the last five years. The average annual economic growth in the Kedungsepur urban area over the past decade has reached 5.1%. Moreover, following the COVID-19 pandemic, the economic growth in the Kedungsepur area surpassed that of other urban areas along the North Coast of Java (see figure 2).

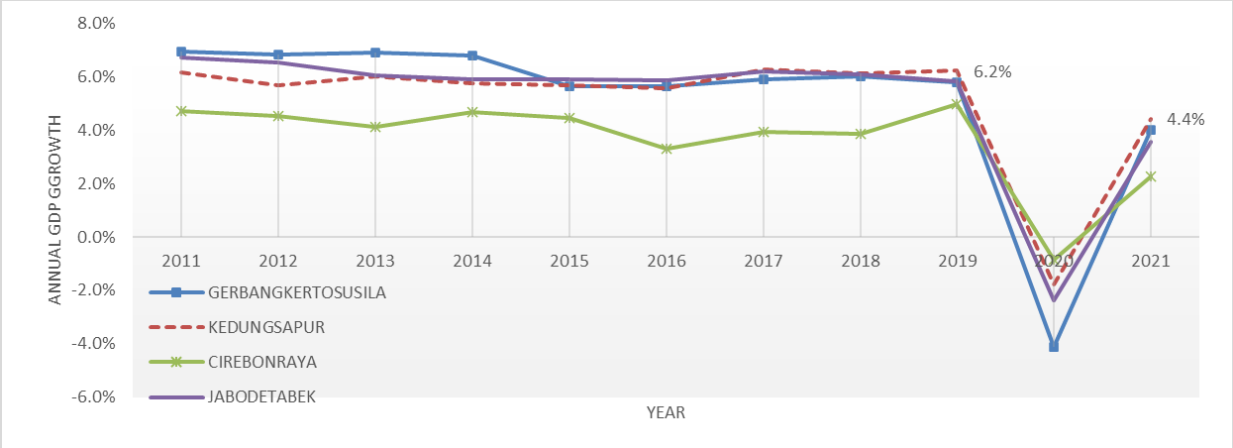


FIGURE 2. Annual Economic Growth of National Urban Area in Northern Java
Source: BPS, 2022, Analysis, 2023

The city of Semarang as a primary urban area has the biggest role in supporting the regional economy in the Kedungsapur urban area with a contribution of 55% of the total GRDP in the Kedungsapur area. The development of the Gross Regional Domestic Product (GRDP) in the City of Semarang over the last decade has demonstrated remarkable growth. This development underscores the central role of the City of Semarang as a core city, benefiting

from excellent infrastructure support. This, in turn, fosters regional competitiveness and bolsters the efficiency of the existing economic sectors.. Economic development in the city of Semarang is expected to have an impact on the economy of the surrounding regions. The existence of road infrastructure is one of the instruments to strengthen economic linkages between the City of Semarang and the surrounding area. This economic interaction will contribute to regional income, thus contributing to the economic growth of districts and cities around Semarang City. Based on BPS data, the economic development of the Semarang City area is also followed by the economic development of the surrounding area.

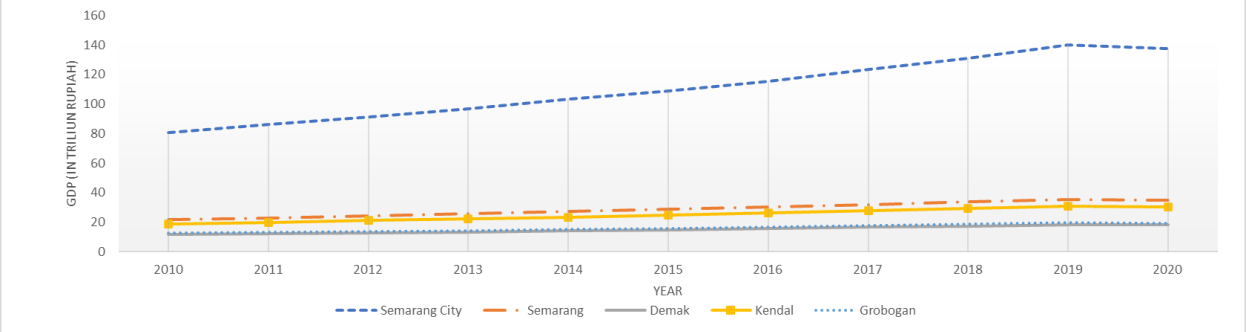


FIGURE 3. GRDP of Kedungsepur Urban Area 2010-2020
Source: Statiscal Beaureau, 2022, Analysis, 2023

Figure 3 shows that GRDP growth in the Kedungsapur area had a positive trend until 2019. However, there was a decline in 2020 caused by the Covid-19 pandemic. This development is inseparable from the strong economic interaction between the City of Semarang and its surroundings , which have significantly contributed to the growth of the surrounding economy. To strengthen economic interaction, the road infrastructure plays a crucial role. Numerous studies have demonstrated that road infrastructure, serving as the fundamental transportation network for the movement of goods and services, plays a pivotal role in facilitating production across diverse regions surrounding Semarang City. This infrastructure also facilitates the marketing of products within Semarang City and beyond, with the support of key distribution facilities including Tanjung Emas Port, airports, and railways.

The role of road and energy infrastructure in the Kedungsepur Urban Area shows good performance, this can be seen from the ability of the existing road network to support the movement of people and goods in the Kedungsepur urban area. There was a significant increase in the number of movements of people and goods using motorized vehicles in Kedungsepur from 2010 to 2020. Based on IRMS data obtained from the Directorate General of Highways of the Ministry of Public Works, the number of vehicles crossing national roads in the Kedungsepur area grew around 2% to 3.5% per year on each section of the national road that crosses the urban area of Kedungsepur. The national road section serves as the primary economic artery of Java Island. The increase in the number of vehicles utilizing this national road section is a strong indicator of regional economic growth, driven by the movement of goods and services. Similarly, electrical energy consumption in the Kedungsepur area has exhibited year-on-year growth, ranging from 4.6% to 9.9%. The most substantial growth has been observed in Semarang City, the central urban hub of Kedungsepur. Regional economic development in Kedungsepur is also followed by developments in public consumption. The consumption value of the people in the Kedungsepur area reaches 49.75% of the total regional gross income in the Kedungsepur area. This condition illustrates that the main support for Kedungsepur's GRDP growth is domestic consumption by households. A detailed description of regional economic development and the level of infrastructure use in Kedungsepur can be seen in table 2.

TABLE 2. Regional Economic and Infrastructur Utilization Data in Kedungsepur 2010-2020

No	Region	Years	GRDP (billion Rupiah)	Road Use (PCU per day)	Electrical Consumption (MW)	Household Consumption (billion Rupiah)
1	Semarang City	2010	80824.10	489650	2160.00	35933.02
2	Semarang City	2011	86142.97	497657	2200.00	37950.61
3	Semarang City	2012	91282.03	566112	2100.00	40094.77
4	Semarang City	2013	96985.40	569855	2160.00	42210.87

No	Region	Years	GRDP (billion Rupiah)	Road Use (PCU per day)	Electrical Consumption (MW)	Household Consumption (billion Rupiah)
5	Semarang City	2014	103109.90	593098	2260.00	44222.79
6	Semarang City	2015	109110.70	671751	4704.42	46240.40
7	Semarang City	2016	115542.60	694449	4891.61	48594.51
8	Semarang City	2017	123279.90	646208	3737.34	51059.82
9	Semarang City	2018	131266.40	711112	3904.76	54188.40
10	Semarang City	2019	140199.50	776016	4086.63	56979.84
11	Semarang City	2020	137609.70	670126	3962.40	54271.36
12	Semarang Regency	2010	21572.14	182608	560.00	13403.46
13	Semarang Regency	2011	22925.46	183315	610.00	14053.51
14	Semarang Regency	2012	24306.72	187901	830.00	14740.70
15	Semarang Regency	2013	25758.12	185589	890.00	15409.80
16	Semarang Regency	2014	27264.11	133864	960.00	16061.99
17	Semarang Regency	2015	28768.33	223108	970.00	16775.35
18	Semarang Regency	2016	30292.47	202310	960.00	17500.21
19	Semarang Regency	2017	32002.98	189827	480.00	18260.89
20	Semarang Regency	2018	33817.68	187703	520.00	19176.71
21	Semarang Regency	2019	35639.31	185580	1300.00	19972.23
22	Semarang Regency	2020	34687.62	186780	1320.00	19662.11
23	Kendal Regency	2010	18798.28	220103	700.00	11584.76
24	Kendal Regency	2011	20032.43	225583	740.00	12143.20
25	Kendal Regency	2012	21075.72	249541	790.00	12708.58
26	Kendal Regency	2013	22386.12	312053	880.00	13296.71
27	Kendal Regency	2014	23536.83	206225	910.00	13914.92
28	Kendal Regency	2015	24762.33	252281	950.00	14480.65
29	Kendal Regency	2016	26139.41	343988	1020.00	15123.11
30	Kendal Regency	2017	27649.78	398185	1060.00	15880.88
31	Kendal Regency	2018	29245.66	351066	1030.00	16603.99
32	Kendal Regency	2019	30916.39	303948	1140.00	17381.02
33	Kendal Regency	2020	30443.69	202632	1080.00	17300.93
34	Salatiga City	2010	5845.47	35321	119.23	3968.97
35	Salatiga City	2011	6230.22	36027	128.32	4174.21
36	Salatiga City	2012	6574.90	36750	139.06	4397.07
37	Salatiga City	2013	6989.04	37240	157.16	4621.14
38	Salatiga City	2014	7378.04	38232	164.89	4830.25
39	Salatiga City	2015	7759.18	38990	174.62	5059.95
40	Salatiga City	2016	8168.24	39800	190.15	5281.53
41	Salatiga City	2017	8624.24	40573	200.26	5536.01
42	Salatiga City	2018	9127.85	41384	193.30	5817.58
43	Salatiga City	2019	9666.44	42211	195.83	6109.78
44	Salatiga City	2020	9503.71	41056	205.78	6040.14
45	Demak Regency	2010	11647.74	96300	738.91	3263.77

No	Region	Years	GRDP (billion Rupiah)	Road Use (PCU per day)	Electrical Consumption (MW)	Household Consumption (billion Rupiah)
46	Demak Regency	2011	12275.70	99214	792.01	3375.10
47	Demak Regency	2012	12823.23	139122	855.15	3430.57
48	Demak Regency	2013	13499.23	189569	963.14	3482.39
40	Demak Regency	2014	14078.42	128315	1006.76	3367.15
50	Demak Regency	2015	14913.00	134754	1062.01	3568.63
51	Demak Regency	2016	15672.48	134660	1151.88	3534.95
52	Demak Regency	2017	16584.12	143066	1209.12	3677.92
53	Demak Regency	2018	17479.88	128107	1169.04	3701.18
54	Demak Regency	2019	18417.01	113148	1118.20	3698.07
55	Demak Regency	2020	18374.56	96502	1288.23	3790.24

Source: Statistical Beaureau, 2010-2020, IRMS, 2010-2020

Based on the data on the table 2, it shows that there is an indication of a fairly strong relationship between the development of GRDP and the development of the number of vehicles crossing national roads which is a representation of the benefits of providing road infrastructure. Meanwhile, the development of energy consumption shows a fairly strong relationship between the development of GRDP and the consumption of electrical energy. The correlation value between vehicle development and energy consumption shows a value of 0.9 which indicates a very strong relationship, while the correlation between GRDP and electricity consumption shows a value of 0.7 which indicates a strong positive relationship. An overview of the relationship between the development of GRDP and the level of use of infrastructure can be followed in Figure 4 and 5. The correlation of the variables can be seen in table 3

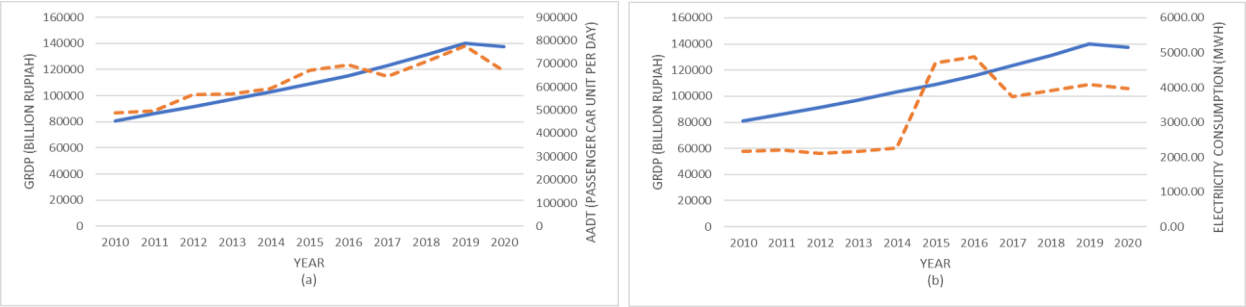


FIGURE 4. (a) Relationship between GRDP and Number of Vehicle (b) Electrical Energy Consumption
Source: Analysis, 2023

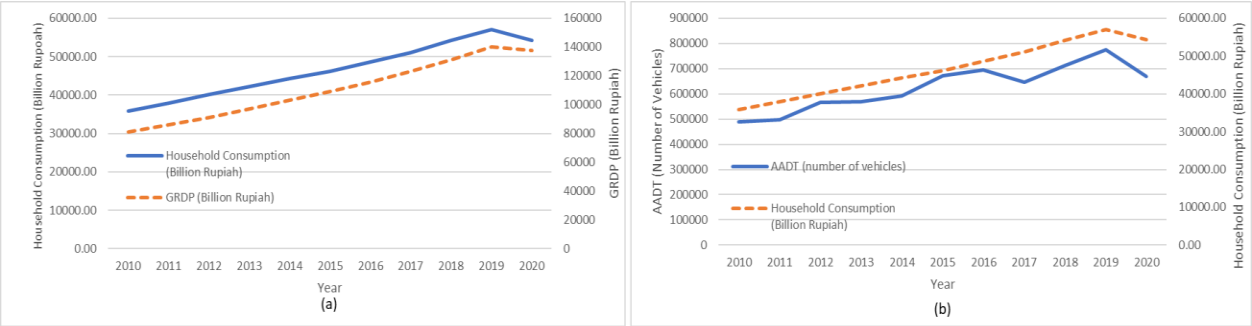


FIGURE 5. (a) Relationship between GRDP and Household Consumption (b) and Number of Vehicles and Household Consumption
Source: Analysis, 2023

TABLE 3. Correlation Value Matrix

	GRDP	Road Use	Electrical Energy Consumption (ELC)	Household Consumption (HHC)
GRDP	1			
Road Use	0.919698	1		
Electrical Energy Consumption (ELC)	0.743093	0.839943776	1	
Household Consumption (HHC)	0.996698	0.939449517	0.749965829	1

Source: Analysis, 2023

Table 3 shows that there is a strong correlation between dependent variable (GRDP), and independent variables (Road use, electrical energy consumption, and household consumption). In addition to the correlation among the dependent and independent variables, the table also reveals a substantial correlation between the independent variables themselves. To address the issue of multicollinearity, a two-stage least squares regression was conducted. The regression analysis uses a panel time series data for the 2010-2020 period from five regencies in the Kedungsepur Urban Area as sample data. The panel area are Semarang City, Kendal Regency, Semarang Regency, Demak Regency, and Salatiga City. The regression analysis showed that there is a significant role of infrastructure utilization to the regional economic of Kedungsepur urban area. The summary of the regression analysis can be seen in table 4.

TABLE 4. The Summary of Regression Analysis using Panel Data

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob**
ROADUSE	4.022907	3.395616	1.184736	0.2418
ELC	2.245918	0.842587	2.665502	0.0103
HHC	2.241423	0.126030	17.78484	0.0000
C	-6557.221	1691.331	-3.876959	0.0003
Effect Specification				
			S.D	Rho
Cross Section Random			2105.509	0.5929
Period Random			0.000000	0.0000
Idiosyncratic random			1744.5350	0.4071
		Weighted Statistic		
R-squared		0.971253	Mean dependent var	9073.512
Adjusted R-squared		0.969562	S.D dependent var	13122.35
S.E . of Regression		2289.377	Sum squared resid	2.67E+08
F-Statistic		574.3725	Durbin-Watson stat	0.371082
Prob (F-Statistic)		0.00000		

Source: Analysis, 2023

Table 4 shows that infrastructure and household consumption contributed significantly to the GRDP value in the urban area of Kedungsepur. The contribution of these variables to GRDP in Kedungsepur urban area is around 99%, and the contents value of the regression model is -6557,22. The coefficient value of road infrastructure utilization is around 4.9 meaning that an increase in the number of vehicle density by 1 unit in the Kedungsepur area will increase GRDP by 4.9 billion, if the other variables are constant. This coefficient will have the consequence that the government must support an increase in road capacity so that the flow of transportation becomes better and does not cause traffic jams which have an impact on increasing transportation costs. Electrical energy consumption and household consumption have almost the same contribution to GRDP in the Kedungsepur urban area. The coefficient value of those two variables is around 2.24. That is, if the value of electricity consumption for 1 unit will contribute to an increase in the GRDP value of around 2.24 billion rupiahs, if other variables are constant. This constant value indicates the potential for a decline in the regional economy in the Kedungsepur urban area if infrastructure utilization decreases due to a shortage of road infrastructure and provision of electrical energy infrastructure. Lack of road infrastructure will lead to increased transportation costs. The increase in transportation costs will cause inflation due to rising market prices for consumer goods and will cause a decrease in consumer purchasing power. This finding aligns with previous studies conducted by Wan et al. [2], Lall [4], and Muvawala et al. [7], all of which emphasize the significant role of infrastructure in regional economies, particularly regarding road and energy infrastructure. The presence of road infrastructure has a more pronounced impact on the economy of Kedungsepur. These findings in Kedungsepur further corroborate the results of previous research conducted in Indonesia by Novitasari et al., who investigated the influence

of infrastructure in urban areas in West Java, Banten, and Jakarta [9], as well as the research by Nugraha, who examined the contribution of infrastructure to regional economies in Indonesia. [14].

CONCLUSION

Based on the regression panel data analysis, it can be concluded that the utilization of infrastructures in the Kedungsepur Urban Area plays a significant role in regional economic of Kedungsepur Urban Area. The presence and the utilization of infrastructure have a positive impact on GRDP of Kedungsepur urban area, this finding is consistent with the previous research in Indonesia by Novitasari et al [9] and Nugraha et al [14]. The absence of adequate infrastructure provision will lead the decrease of economic growth in Kedungsepur urban area. Among the various types of infrastructure, road infrastructure makes the most substantial contribution to the GRDP value. Increasing road capacity in the future is expected to further enhance the regional economy of Kedungsepur. The increasing of road capacity will improve the flow of transportation, resulting in reduced transportation costs. Efficiency in transportation costs will lead to more stable prices for consumer, which, in turn, will not negatively affect consumers' purchasing power—assuming there are no significant increases in fuel prices. This finding is consistent with the previous research by Wan et al [2], Melnikov et al [8], Kadyraliev et al [10], and Khan et al [19] that the existence of a road network that serves traffic smoothly makes transportation costs more efficient.

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