JURNAL ARSITEKTUR
ARCADE
p-ISSN: 2580-8613 (Cetak)
e-ISSN: 2597-3746 (Online)
http://jurnal.universitaskebangsaan.ac.id/index.php/arcade

THE INFLUENCE OF SMART MOBILITY ASPECTS IN SUPPORTING BEKASI SMART CITY CONCEPT

Riyan Hermawan[1], Sri Pare Eni[2], Margareta Maria Sudarwani[3]
[1,2,3] The Master of Architecture Study Program, Universitas Kristen Indonesia
E-mail: riyanhermawan71@gmail.com, sripareeni@yahoo.com, maria.prop@gmail.com

Script Information:
Received:
5 Juli 2026
Revised:
16 Agustus
Approved:
26 Agustus 2026
Published: Print:
29 September 2026

Online:
29 September 2026

Abstract*: Urban economic growth causes mobility problems and increases emissions. However, research that addresses smart mobility by utilizing the development of information, communication, and technology (ICT) to monitor mobility and maximize the role of infrastructure needs to be further researched to support the Sustainable Development Goals 2030 Program. This research compares the impact of traffic density and emission production from conventional mobility concepts with the smart mobility concept which utilizes the Eco-Routing Navigation System and Vehicle License Plate System as part of ICT. It was found that the density of private vehicles decreased by ± 50%. The average density of light vehicles (LV) decreased from 1,304 pcu/hour to 652 pcu/hour and motorcycles (MC) from 1960 pcu/hour to 980 pcu/hour. Similarly, CO, HC, and CO_2 levels decreased by 55.8% from 34.8 kg/km to 19.44 kg/km, HC by 53.73% from 0.67 kg/km to 0.36 kg/km, and CO2 by 52.5% from 4,226 kg/km to 2,218.92 kg/km. Traffic congestion causes congestion and emissions. The application of Smart Mobility collaborated with ICT successfully controls mobility by reducing the volume of vehicles and utilizing public transportation infrastructure so that emissions can be reduced.*
Keyword: *Eco-Routing Navigation System, ICT, Smart Mobility, Sustainable Development Goals 2030, Vehicle License Plate System.*

Abstrak: Pertumbuhan ekonomi perkotaan menyebabkan masalah mobilitas dan meningkatkan emisi. Namun, penelitian yang membahas mobilitas pintar dengan memanfaatkan perkembangan informasi, komunikasi, dan teknologi (TIK) untuk memantau mobilitas dan memaksimalkan peran infrastruktur perlu diteliti lebih lanjut untuk mendukung Program Tujuan Pembangunan Berkelanjutan 2030. Penelitian ini membandingkan dampak kepadatan lalu lintas dan produksi emisi dari konsep mobilitas konvensional dengan konsep mobilitas pintar yang memanfaatkan Sistem Navigasi Rute Ramah Lingkungan dan Sistem Nomor Plat Kendaraan sebagai bagian dari TIK. Ditemukan bahwa kepadatan kendaraan pribadi menurun ± 50%. Rata-rata kepadatan kendaraan ringan (LV) turun dari 1.304 pcu/jam menjadi 652 pcu/jam dan sepeda motor (MC) dari 1.960 pcu/jam menjadi 980 pcu/jam. Begitu juga, kadar CO, HC, dan CO2 menurun sebesar 55,8% dari 34,8 kg/km menjadi 19,44 kg/km, HC sebesar 53,73% dari 0,67 kg/km menjadi 0,36 kg/km, dan CO2 sebesar 52,5% dari 4.226 kg/km menjadi 2.218,92 kg/km Kemacetan lalu lintas menyebabkan kemacetan dan emisi. Penerapan Smart Mobility yang bekerja sama dengan TIK berhasil mengendalikan mobilitas dengan mengurangi jumlah kendaraan dan memanfaatkan infrastruktur transportasi umum sehingga emisi bisa dikurangi.
Kata kunci: Sistem Navigasi Eco-Routing, TIK, Smart Mobility, Tujuan Pembangunan Berkelanjutan 2030, Sistem Nomor Polisi Kendaraan**.**

INTRODUCTION

The rising wave of urbanization is causing new problems to the urban environment as well as affecting the increase in energy consumption, the frequency of infrastructure services and the amount of waste that has a direct impact on the environment exacerbated by the increase in pollutants. urban areas in various parts of the world have generally taken strategic steps to increase their contribution to the development of smart and sustainable cities (Hristov & Chirico, 2019); The development of technology, information and communication provides the city with the capacity to manage infrastructure more effectively and efficiently (Yigitcanlar & Cugurullo, 2020). With efforts to minimize negative impacts that can affect the environment by coordinating aspects of the city to achieve social justice, economic and environmental resilience (Fonseca et al., 2020),

The Smart City is a concept of urban planning to provide benefits to society through the efficient management of resources that are interconnected through infrastructure networks that provide data about mobility, social conditions, physical form and various policies implemented (Kirimtat, 2020). By utilizing the development of integrated technology and communication to support the activities of urban communities in facing the challenges of urbanization, mobility, security and sustainability aspects (Ooms & Caniëls, 2020). Based on Boyd Cohen's research approach, Smart City is divided into 6 variables consisting of Smart mobility, Smart Environment, Smart Economy, Smart People, Smart Government and Smart Living (Widyarto et al., 2020).

Smart mobility emphasizes the application of transportation systems that promote efficiency (reduce the use of private vehicles) and encourage the use of integrated public vehicles, the application of technology, information & communication can increase productivity. This indicator provides information on urban mobility (Paiva et al., 2021). It is broadly defined as a component that not only consists of traditional transportation and logistics systems, but also information dissemination through the use of ICT. The main role of Smart Mobility is to connect resources in the urban environment with the use of ICT is considered to make it easier to achieve goals because it can adapt to the times and is more practical to implement. (Tomaszewska, 2021). The Smart Mobility is built on a sophisticated mobility management system, parking management, transportation system and so on collaborated with the development of ICT technology (Indrawati et al., 2017).

ICT is able to manipulate and transmit information such as cell phones, the Internet, radio, television, wireless networks and electronic mass media supported by data recording operation infrastructure such as: Computers, Portable Drives, and servers. Smart Mobility cannot be limited to individual behaviors because Smart Mobility is a set of varied initiatives that can represent the use of ICTs in different fields. (Orlowski & Romanowska, 2019). All initiatives on urban mobility have objectives such as:

- Reduce The Urban mobility cost
- Reduce The Air pollution
- Reduce The Congestion

The successful implementation of Smart Mobility when viewed holistically on Smart city indicators, which includes the management component and the application of technology. The planning process requires careful consideration so that the strategy decided is in accordance with the objectives. Thus, the community gap through the Smart Mobility aspect can be overcome.

RESEARCH METHOD

This research applies a quantitative research approach whose investigation process is based on a methodology that explores problems with logical thinking (Priandana & Sunarsi, 2021). The data reached by observation at research location and relevant literatures. In addition, the data obtained from the observation process is then further processed so that the impact is known to affect three aspects, such as economic, social, and environmental aspects (experimental). The resulting impact is then tested using the concept of smart mobility and the concept of conventional mobility so that the difference is known so that this can produce a complex, holistic construction of the research picture, can analyze data, and has a detailed view of the source of information.

RESEARCH DESIGN

The research design is a research design that is used as a guide in carrying out the research process (Boros, 2018). This research is subjective and has standards to help validate the research results The research design in this study starts with a "conceptual design" which can be seen in the figure below:

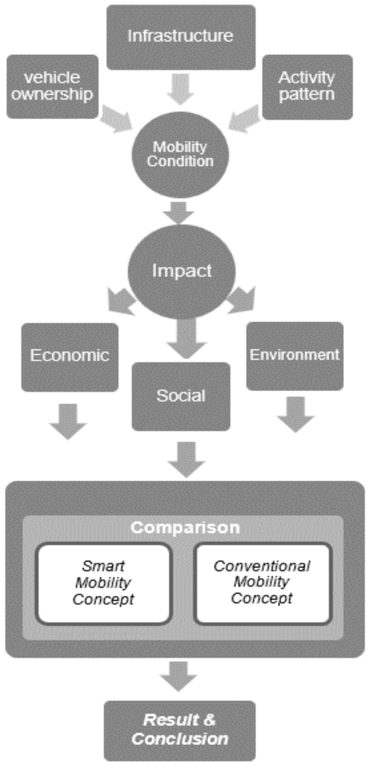

Chart 1., Research Paradigm
Source: Author, 2022

Data Collection Methods

Data Collection Process through observation, questionnaires, interviews, field surveys, Statistical data processing and secondary data collection methods that have relevance to the object of research and other relevant activities.

RESULT AND DISCUSSION

Bekasi City is one of the cities located in the province of West Java. With a total population of around 3.6 million residents (BPS, 2022). Located between large cities and districts, it makes the city one of the densest mobility centers in the metropolitan area. Economic activity has an impact on active mobility movements so that it needs to be regulated with smart mobility regulation innovations and adequate infrastructure. Until now, the provision of urban mobility facilities and services provided by the government still has shortcomings so that innovation towards smart mobility in Bekasi city is still far from expectations. More flexible use of private vehicles, lack of facilities for non-emission vehicles, less refined public transportation service facilities and so on are indicators that trigger increased carbon pollution, noise, and congestion; which ultimately security and economic growth cannot be optimally. This is considered contrary to the Sustainable Development Goals 2030 in point 11 (eleven) regarding sustainable cities and settlements.

Impact of Mobility Activity

Energy use for transportation that produces vehicle emissions is a product of people's behavior in mobilization activities. At this time the slow growing mobility activities have an unfavorable impact when viewed from the concept of sustainable development. The following is a mathematical calculation that shows the effect of the aspects of Economy, environment and social.

Economic Aspects

The economic aspect discusses about vehicle operation costs (VOC) with a speed unit of km/h that includes fixed costs, and non-fixed costs. The calculation of operational costs uses a formula developed by PT Jasa Marga and LAPI ITB

Table 1. New vehicle price list

Vehicle	Model & Brand	Price (IDR)
Car	Toyota Rush G AT	289.600.000
Motorcycle	Honda beat Matic	15.630.000
Bus	Hino FC 190	520.000.000

Source : Author, 2022

Vehicle capital cost

Vehicle capital costs are the budget capitalized by the general Public Transportation service provider or vehicle owner to obtain capital such as cars, buses and others.

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Where :

CRF = *Capital Recovery Factor* / km

i = Annual interest rate

n = Credit period

Depreciation cost

Depreciation cost is The cost of depreciating an asset due to utilization/operational factors. The asset value recorded in this calculation is the difference between the purchase price and the capitalized depreciation of the asset.

Vehicle Class I

Y = 1/(2,5V + 125)

Vehicle Class IIA

Y = 1/(9,0V + 450)

Vehicle Class IIB

Y = 1/(9,0V + 450)

V = Speed km/hour

Y = Depreciation cost per 1.000 km

Insurance Cost

The insurance cost is the cost of financial protection for losses suffered by vehicle owners due to accidents, damage or loss.

Vehicle Class I

Y = 38 / 500V

Vehicle Class IIA

Y = 60 / (2571,42857V)

Vehicle Class IIB

Y = 61 / (1714,28571V)

V = Speed km/hour

Y = Insurance Cost per 1.000 km

Fuel Consumption Cost

The Fuel Consumption Cost (FCC) is the cost used for vehicle operations borne by the owner:

FCC = Basic of FCC x (1± K_k + K_l + K_r)

Basic of FCC Vehicle Class I

Y = $0,0284V^2 – 3,0644V + 141,68$

Basic of FCC Vehicle Class IIA

Y = 2,26533 x (FCC dasar Vehicle Class I)

Basic of FCC Vehicle Class IIB

Y = 2,90805 x (Basic of FCC Vehicle Class I)

V = Speed km/hour

Table 2. Corelation Factor

Correction factor for negative slope (K_K)	g < -5%	-0,337
	-5% ≤ g < 0%	-0,158
Correction factor for positive slope (KK)	0% ≤ g < 5%	0,400
	g ≥ 5%	0,820
Correction factor for traffic conditions (K_l)	0 ≤ NVK < 0,6	0,050
	0,6 ≤ NVK < 0,8	0,185
	NVK ≥ 0,8	0,253
Correction factor for road roughness (Kr)	< 3m/km	0,035
	≥ 3m/km	0,085

Source : (MKJI, 2017)

Lubricant cost

The vehicle lubricant consumption cost is a cost used for vehicle operations.

Table 3. Lubricant Pricelist

Vehicle	Brand	Price (IDR)
Car	Castrol Magnatec dualock 10w-40	350.000
Motorcycle	MPX Idemitsu	45.000
Bus	Fastron Gold	117.000

Source : Author, 2022

Table 4. Lubricating oil consumption coefficient

Speed (Km/h)	Type of Vehicle (Lt/Km)		
	Class I	Class IIA	Class IIB
10 – 20	0,0032	0,0060	0,0049
20 – 30	0,0030	0,0057	0,0046
30 – 40	0,0028	0,0055	0,0044
40 - 50	0,0027	0,0054	0,0043
50 – 60	0,0027	0,0054	0,0043
60 - 70	0,0029	0,0055	0,0044
70 – 80	0,0031	0,0057	0,0046
80 – 90	0,0033	0,0060	0,0049
90 – 100	0,0035	0,0064	0,0053
100 – 110	0,0038	0,0070	0,0059

Source : (MKJI, 2017)

Table 5. Road hardness correction factor

Road Hardness Value	Correction Factor
IRI < 3m/km	1,00
IRI ≥ 3m/km	1,50

Source : (MKJI, 2017)

Y = Coefficient value based on speed x 1000 x Correction factor

Y’ = Lubricant consumption x Lubricant price

Tire cost

Tire cost or tire usage cost is the cost required for the operational use of the vehicle per kilometer of distance traveled:

Vehicle Class I

= 0,0008848 V – 0,0045333

Vehicle Class IIA
= 0,0012356V – 0,0064667
Vehicle Class IIB
= 0,0015553V – 0,0059333
V = Speed km/hour
Y = Tire usage cost per 1.000 Km

Table 6. Unit tire price

Vehicle	Brand	Price (IDR)
Car	Accelera R16	675.000
Motorcycle	Tubeless tire maxxis	194.000
Bus	GT Radial	1.250.00

Source : Author, 2022

Spare parts maintenance cost

Spare parts maintenance cost is the cost required for operational use of the vehicle per kilometer of distance traveled:

Vehicle Class I
Y = 0,0000064V + 0,0005567
Vehicle Class IIA
Y = 0,0000332V + 0,0020891
Vehicle Class IIB
Y = 0,0000191V + 0,0015400
V = Speed km/hour
Y = Spare parts maintenance cost/1000km

Mechanic services cost

The cost of mechanic services is the cost required for the operational use of the vehicle per kilometer of distance traveled:

Vehicle Class I
Y = 0,00362V + 0,36267
Vehicle Class IIA
Y = 0,002311V + 1,97733
Vehicle Class IIB
Y = 0,01511V + 1,21200
V = Speed km/hour
Y = Mechanic working hour / 1000 Km

Table 7. Expenditure cost per person/km by type of transportation mode.

Cost Indicator (IDR)	Public Transportation				Private Vehicle	
	City bus	Taxi	Microbus	Taxibike	Car	Motorcycle
Number of passanger (Person)	40	3	10	2	1	1
Fixed cost						
- Vehicle capital cost	79,25	108,3	32,5	60,65	325	121,3
- Depreciation	26	183	57,92	15,63	579,2	31,26
- Insurance	29,76	147	44	11,88	440	23,75
Non-fixed cost						
- Energy cost	46,48	489	146,76	516,4	1.467,6	1032,8
- Lubricant cost	473,85	473	141,8	91,13	1.418	182,25
- Tire cost	5	36	10,8	7,76	108	15,52
- Spare part	6,38	85	25,5	6,9	255	13,75
- Mechanic seervices cost	0,68	23	2,72	6,8	27,2	13,59
Total	**667,4**	**1.544,3**	**465**	**717,15**	**4.337,8**	**1.434,22**

Source : Author, 2022

Social Aspects

The social cost is based on the congestion cost, which is the difference between the marginal social cost (cost allocated by users) and the marginal private cost (vehicle operating cost) generated by the additional vehicle volume on the same road section. The data that has been collected is then managed and divided into several interrelated sections such as:

- Daily traffic volume data management.
- Management of road section condition data.
- Determination of peak mobility activity hours.
- Vehicle operation costs.
- And Traffic congestion cost.

After the data was collected, it was analyzed with the data processing method from MKJI 2017 to obtain the cost of congestion. the location of monitoring traffic conditions is carried out at JL. General Sudirman (in front of the Matahari Department Store Kranji). The number of vehicles that have been recorded is then converted to Passenger Car Units (PCU) to facilitate the calculation of road capacity.

Table 8. Passenger car equivalent score

Road type	2-way total traffic flow (Veh/Hour)	PCE (Passenger car equivalent)		
		HV	LV	MC
4/2 D (four lanes divided)	≥ 1050	1,25	1,0	0,25

Source : (MKJI, 2017)

Table 9. Total traffic density per-hour

Time	QA (From Bekasi to Jakarta)			QB (From Jakarta to Bekasi)			Total	
	HV	LV	MC	HV	LV	MC	Veh/Hour	Pcu/Hour
06.00-07.00	132	336	5880	168	612	3924	11052	3774
07.00-08.00	300	408	6264	264	564	4968	12768	4485
08.00-09.00	228	1116	5064	446	852	3450	11156	4939
09.00-10.00	216	696	3348	372	1020	3708	9360	4215

Time	QA (From Bekasi to Jakarta)			QB (From Jakarta to Bekasi)			Total	
	HV	LV	MC	HV	LV	MC	Veh/Hour	Pcu/Hour
10.00-11.00	276	744	4248	336	484	2808	8896	3757
11.00-12.00	240	792	2976	312	876	2424	7620	3708
12.00-13.00	168	564	1668	336	698	1944	5378	2795
13.00-14.00	192	552	3156	216	540	2580	7236	3036
14.00-15.00	204	758	3228	420	804	3912	9326	4127
15.00-16.00	264	732	4080	384	756	4236	10452	4377
16.00-17.00	348	612	4572	324	696	5124	11676	4572
17.00-18.00	168	780	5376	300	532	6756	13912	4930
18.00-19.00	158	528	4596	180	504	5412	11378	3957
19.00-20.00	216	504	2904	126	444	2976	7170	2846
20.00-21.00	192	648	1584	192	624	4884	8124	3369
21.00-22.00	84	576	3624	228	516	3780	8808	3333

Source : Author, 2022

Based on the results of the analysis, it is found that the dominant type of vehicle on Jl. Jendral Sudirman is Motorcycle (MC) of 125,454 units, followed by light vehicles (LV) of 20,868 units and heavy vehicles (HV) of 7,990 units. So that the traffic volume for 16 hours is 76,300 units of vehicles from Bekasi to Jakarta and 78,012 units of vehicles from Jakarta to Bekasi or the traffic volume is 62,220 pcu/16 hours. The state of traffic fluctuations in the observed area can be seen that the volume of vehicles will be high in the morning at 07.00-08.00 with a volume of 12,768 units of vehicles / hour and then will reach its highest peak in the afternoon at 17.00-18.00 with a volume of 13,912 units of vehicles / hour. The following is the average volume of vehicle activity per hour:

Table 10. Average hourly traffic

Vehicles	HV	LV	MC	Total
Veh/hour	500	1305	7841	9646
Pcu/hour	625	1305	1961	3891

Source: Author, 2022

Based on the average table it is obtained in the review area for heavy vehicles (HV) is 500 units / hour, light vehicles (LV) is 1305 units / hour and motorcycle vehicles (MC) is 7841 units / hour. From the monitoring results there is congestion at peak hours this will increase the duration of the trip which has an impact on increasing operational costs. An indicator that can be seen is the decrease in speed. The higher the level of congestion, the longer the duration of the trip. The following are the results of monitoring the speed of vehicles when passing through the review area from Bekasi to Jakarta or vice versa:

Table 11. Vehicle speed average

Time	Speed (km/h)
06.00-07.00	12
07.00-08.00	7,25
08.00-09.00	10,72
09.00-10.00	17,5
10.00-11.00	20
11.00-12.00	25
12.00-13.00	40,5
13.00-14.00	22
14.00-15.00	16,5
15.00-16.00	11
16.00-17.00	8,85
17.00-18.00	5,46
18.00-19.00	9,56
19.00-20.00	21,7
20.00-21.00	23
21.00-22.00	19,5

Source: Author, 2022

The Speed level has an influence on the state of traffic density, the higher the density level, the lower the speed level and vice versa. This can be seen in the table above which shows the lowest speed at 17.00-18.00 with a speed of 5.46 km / h with a volume of 13,912 vehicles / hour or 4,930 pcu / hour.

Table 12. Congestion charge with vehicle operating cost formula calculation.

Time	Speed km/h	Public Transportation				Private Vehicle	
		City bus	Taxi	Microbus	Taxibike	Car	Motorcycle
		Avarage passanger (Person)					
		40	3	10	2	1	1
06.00-07.00	12	311	2.526	758	1.195	7.577	2.391
07.00-08.00	7,25	377	3.043	913	1.332	9.130	2.664
08.00-09.00	10,72	324	2.629	789	1.228	7.886	2.457
09.00-10.00	17,5	273	2.216	665	1.095	6.647	2.191
10.00-11.00	20	262	2.116	635	1.027	6.347	2.053
11.00-12.00	25	243	1.958	587	944	5.873	1.887
12.00-13.00	40,5	211	1.671	501	776	5.012	1.552
13.00-14.00	22	253	2.047	614	992	6.140	1.983
14.00-15.00	16,5	279	2.261	678	1.094	6.783	2.188
15.00-16.00	11	321	2.605	781	1.221	7.814	2.442
16.00-17.00	8,85	348	2.819	846	1.281	8.458	2.561
17.00-18.00	5,46	427	3.423	1.027	1.444	10.269	2.888
18.00-19.00	9,56	338	2.740	822	1.460	8.220	2.520
19.00-20.00	21,7	255	2.056	617	997	6.169	1.993

20.00-21.00	23	245	2.015	605	975	6.046	1.950
21.00-22.00	19,5	264	2.134	640	1.036	6.403	2.071
Congestion cost total (IDR)		**4.731**	**38.258**	**11.478**	**18.097**	**114.774**	**35.791**
Congestion cost Average (IDR)		**296**	**2.391**	**717**	**1.131**	**7.173**	**2.237**

Source : Author, 2022

Environment Aspect

Environmental aspects are calculated based on the level of air pollution. Emissions generated in the form of Carbon Monoxide (CO), Hydrocarbons (HO), and Carbon dioxide (CO_2) Model Calculation of emission load (g/km) is obtained by the Ideal Gas Equation formula. Concentration of each gas and Value of Air Fuel Ratio (AFR) obtained from the reading of the gas analyzer with air density of 1.293 kg/m3. Data processing is carried out on data from previous studies obtained from direct measurement of motor vehicle emissions which include: calculation of average exhaust gas and Air Fuel Ratio (AFR) values, calculation of the amount of emission factors from fuel with the calculation of the emission factor ideal gas equation.

a. $PV = nRT$

b. $PV = \frac{M}{m} \times R \times T$

c. $\frac{m}{v} = \frac{P\ x\ M}{R\ x\ T}$

d. Conversion of gas concentration (% to ppm)

$$1\% = \frac{1\ part}{100\ part} = \frac{10^4\ x\ 1\ part}{10^4\ x\ 100\ part} = 10^4\ x\ \frac{1\ part}{10^6\ part} = 10.000\ ppm$$

e. Conversion of gas concentration (ppm to g/m^3)

$$\frac{g\ Gas}{m3\ Air} = \frac{Gas\ Concentration(ppm).BM(g/mol).0{,}001(g.L/g.m3)\ x\ P(atm)}{0{,}0821\ (L.atm/mol.K)\ x\ T\ (°K)}$$

BM CO = 28 g/mol, HC = 13 g/mol, and CO_2 = 44 g/mol.

f. Emission Factor Calculation (g/km)

$$FE\left(\frac{g\ gas}{kg\ Fuel}\right) = \frac{g\ Gas}{m3\ Air} xAFR\left(\frac{g\ Air}{g\ Fuel}\right) : density\ of\ air\left(\frac{kg}{m3}\right)$$

g. Emission Factor Calculation (g/km)

$$FE\left(\frac{g\ gas}{km.Vehicle.}\right) = \frac{g\ Gas}{kg\ Fuel} x\ fuel\ requirement\ per\ km\left(\frac{kg\ Fuel}{km.Vehicle}\right)$$

Table 13. Emission factor from vehicles

Motorcycle (g/km)			Car (g/km)			City Bus (g/km)		
CO	HC	CO_2	CO	HC	CO_2	CO	HC	CO_2
0,047	0,004	26,91	1,19	0.006	30,59	0,51	0.005	26,5

Source: (Rusdiani et al., 2018; Prasetyo, 2015; Grigoratos et al., 2019)

Table 14. Emissions production by transportation mode.

Emissin Factor (g/km)	Public Transportation				Private Vehicle	
	City Bus	Taxi	Microbus	Taxibike	Car	Motorcycle
Total of Passanger (person)	40	3	10	2	1	1
Type of Emission Gas						
- Karbon monoksida (CO)	0,013	0,4	0,119	0,0235	1,19	0,047
- Hidrokarbon (HC)	0,00013	0,002	0,0006	0,002	0,006	0,004
- Karbon dioksida (CO_2)	0,66	10,19	3,06	13,455	30,59	26,91

Source : (Rusdiani et al., 2018; Prasetyo, 2015; Grigoratos et al., 2019)

Based on the results of the analysis of traffic density for 16 hours on Jl. Jendral Sudirman, Bekasi city starting from 06.00-22.00 it was found that there were 7,990 units of heavy vehicles (HV), light vehicles (LV) as many as 20,868 units and motorbikes (MC) as many as 125,454 units. So it can be concluded that when analyzing traffic density for 16 hours, heavy vehicles (HV), light vehicles (LV) and Motorbikes (MC) in producing Carbon monoxide (CO), Hydro carbon (HC), and Carbon dioxide (CO_2) can be reviewed in the table below:

Table 15. Production of CO, HC, dan CO_2

Vehicle type	Kg/km		
	CO	HC	CO_2
High Vehicle (HV)	4,07	0,04	211,74
Light Vehicle (LV)	24,83	0,13	638,35
Motorcycle (MC)	5,9	0,5	3375.97

Source : Author, 2022

Utilization of ICTs in urban mobility.

There are 2 (two) utilization of ICT (Information, Communication and technology) applied in this research to reduce negative impacts on economic, social and environmental aspects.

Eco-routing navigation System

Eco-Routing Navigation System (ERNS) is an environmentally friendly route guidance system which can contribute greatly to the reduction of vehicle operating costs (Wu et al., 2014). Basically, the route calculation in the ERNS navigation system is based on Dijkstra's algorithm with a binary heap priority queue, which functions to find the path with the smallest vehicle operating cost weight from the initial node to the last node or destination to find the most effective and efficient path to take. For each trip, the Eco-Routing navigation system can generate up to three routes based on different output minimization criteria, namely distance, travel time, and energy usage.

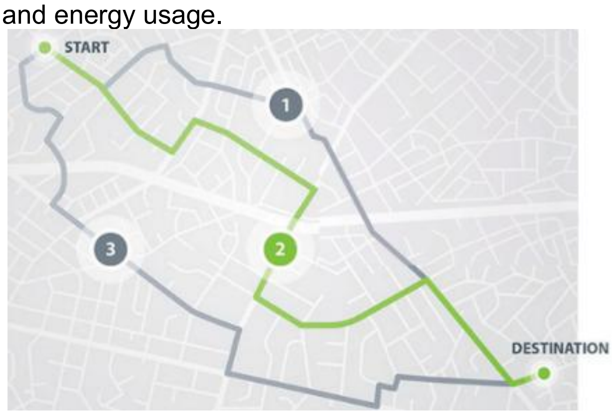

Figure 1. Example of Eco-Routing navigation System
Source : (National Renewable Energy Laboratory, 2021)

Vehicle License Plate System

Vehicle License Plate System (VLP) is an ICT application that combines hardware (camera) and software (computer program/Software) into one integrated system. The output of this system is an image of a vehicle license plate that has been integrated with owner and vehicle data (Prem et al., 2018). The VLP system utilizes artificial intelligence (AI) and genetic algorithms to detect the location of the vehicle with the license plate in question. The following is an example of the application of VLP in regulating urban mobility patterns, in this case it is assumed that the system is operated on even dates, so that even number plates are allowed to enter city roads and odd numbered vehicles cannot enter city roads The following is the working principle of the vehicle license plate displayed in the form of a flowchart:

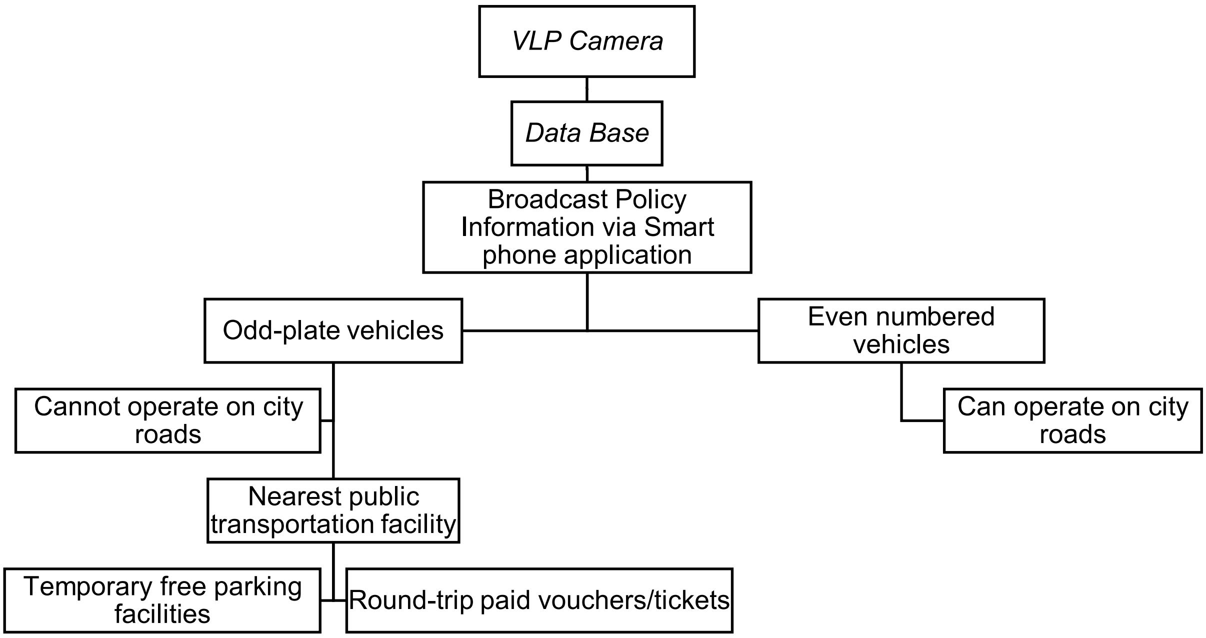

Chart 2. VLP System operation flow on even dates
Source : Author., 2022

Before the implementation of VLP, the situation in Bekasi City had a traffic density of 1,304 pcu / hour for cars or light vehicles (LV), 1960 pcu / hour for motorbikes (MC), and 624 pcu / hour for heavy vehicles, the three vehicles were monitored from 06.00 to 22.00. The following is a graphical prediction of the decrease in traffic volume that occurs in private vehicles (LV and MC) when VLP is implemented:

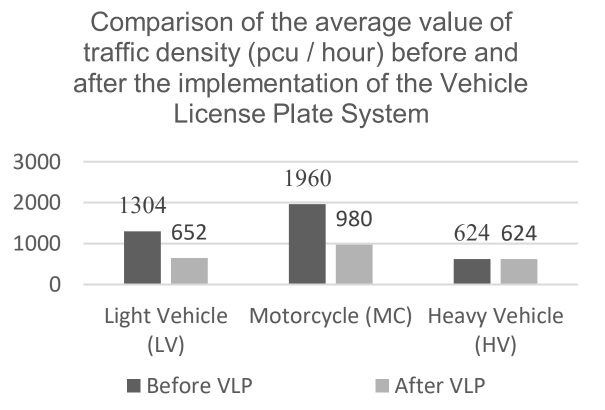

Chart 3. Comparison Chart of average traffic density values before and after VLP implementation
Source : Author, 2022

In addition, the production of pollutant gases such as Carbon monoxide (CO), Hydro carbon (HC), and Carbon dioxide (CO_2) experienced by light vehicles (LV) and private motorcycles (MC) has also decreased from the initial amount. This can be seen in the table below:

Table 16. Production emission after VLP

Vehicle type	Emission	Before VLP (kg/km)	After VLP (kg/km)
High vehicle (HV)	CO	4,07	4,07
	HC	0,04	0,04
	CO_2	211,74	211,74
Light vehicle (LV)	CO	24,83	12,42
	HC	0,13	0.065
	CO_2	638,35	319,18
Motorcycle (MC)	CO	5,9	2,95
	HC	0,5	0,25
	CO_2	3375.97	1.688
Total	**CO**	**34,8**	**19,44**
	HC	**0,67**	**0,36**
	CO_2	**4.226**	**2.218,92**

Source : Author, 2022

CONCLUSION

The implementation of Eco-Routing Navigation System (ERNS) and Vehicle License Plate System (VLP) as a utilization of the development of Information, communication and technology (ICT) system contributes positively in reducing the level of road congestion. The level of density of private vehicles (cars and motorcycles) is predicted to decrease by ± 50% from the initial average density of light vehicles (LV) 1,304 pcu / hour to 652 pcu / hour and motorcycles (MC) from the initial number of 1960 pcu / hour to 980 pcu / hour. Similarly, the level of pollutants (CO, HC, and CO_2) produced by vehicles indirectly also experienced a significant decrease, including the percentage of CO levels by 55.8% from 34.8 kg/km to 19.44 kg/km, HC levels by 53.73% from 0.67 kg/km to 0.36 kg/km, and CO_2 levels by 52.5% from 4,226 kg/km to 2,218.92 kg/km. By implementing the Smart mobility concept that utilizes ICT developments; Bekasi City has succeeded in controlling the level of urban mobility well by reducing the number of vehicle volumes on city roads, utilizing public transportation modes and reducing carbon emissions so as to create smart urban mobility.

The decrease in the level of density of private vehicles should be balanced by an increase in the level of service and the addition of environmentally friendly public transportation modes so that public interest in choosing public transportation can be met, maintained and can continue to be developed. In addition, serious supervision is also needed when the use of ICT has been applied in supporting Smart Mobility considering that in the modern era ICT is operated with the support of Artificial Intelligence (AI) which requires special handling from experts.

The development of environmentally friendly public transportation along with its supporting infrastructure has not been discussed in detail in this study. Likewise, the safety and comfort factors of ICT implementation also need to be studied further to get more complex Smart Mobility research results.

REFERENCES

Boros, P. (2018). Applying a Total Quality Framework to Qualitative Research Design: A Review. *The Qualitative Report*, *23*(1), 47–48. https://doi.org/10.46743/2160-3715/2018.3344

BPS. (2022). Kota Bekasi Dalam Angka 2022. *BPS Kota Bekasi*, 295.

Fonseca, L. M., Domingues, J. P., & Dima, A. M. (2020). Mapping the sustainable development goals relationships. *Sustainability (Switzerland)*, *12*(8), 1–15. https://doi.org/10.3390/SU12083359

Grigoratos, T., Fontaras, G., Giechaskiel, B., & Zacharof, N. (2019). Real world emissions performance of heavy-duty Euro VI diesel vehicles. *Atmospheric Environment*, *201*(January), 352–353. https://doi.org/10.1016/j.atmosenv.2018.12.042

Hristov, I., & Chirico, A. (2019). The role of sustainability key performance indicators (KPIs) in implementing sustainable strategies. *Sustainability (Switzerland)*, *11*(20). https://doi.org/10.3390/su11205742

Indrawati, Aini, N. N., & Amani, H. (2017). Indicators to measure smart mobility: An Indonesian perspective. *ACM International Conference Proceeding Series*, *2017-Octob*(October 2017), 81–85. https://doi.org/10.1145/3145777.3149826

Kirimtat, A. (2020). *Future Trends and Current State of Smart City Concepts : A Survey*. *8*. https://doi.org/10.1109/ACCESS.2020.2992441

MKJI. (2017). Kapasitas jalan Luar Kota. *Pedoman Bahan Kontruksi Bangunan Dan Rekayasa Sipil*, *2017*, 28–29.

National Renewable Energy Laboratory. (2021). *Google Taps NREL Expertise To Incorporate Energy Optimization into Google Maps Route Guidance*. Www.Nrel.Gov. https://www.nrel.gov/news/program/2021/google-taps-nrel-expertise-to-incorporate-energy-optimization-into-google-maps-route-guidance.html

Ooms, W., & Caniëls, M. C. J. (2020). *Ecosystems for smart cities : tracing the evolution of governance structures in a dutch smart city initiative* (Vol. 7). International Entrepreneurship and Management Journal.

Paiva, S., Ahad, M. A., Tripathi, G., Feroz, N., & Casalino, G. (2021). Enabling technologies for urban smart mobility: Recent trends, opportunities and challenges. *Sensors*, *21*(6), 1–45. https://doi.org/10.3390/s21062143

Prasetyo. (2015). *PEMERIKSAAN EMISI GAS BUANG dan CEK KOMPRESI PADA ENGINE TOYOTA KIJANG INNOVA di 127000km*.

Prem, E., Roy, C., Bhandari Thapa, A., Shrestha, K., Karmacharya, P., & Karna, R. (2018). Vehicle Number Plate Recognition and Parking System. *International Research Journal of Innovations in Engineering and Technology (IRJIET)*, *2*(10), 18–23. www.irjiet.com

Priandana, S., & Sunarsi, D. (2021). *Metode Penelitian Kuantitaif* (Issue 1). Pascal Books.

Rusdiani, R. R., Pembimbing, D., Magister, P., Lingkungan, D. T., Sipil, F. T., & Kebumian, L. D. A. N. (2018). *Surabaya Study of Emission Factors of Gasoline*.

widyarszewska, E. J. (2021). Barriers related to the implementation of intelligent transport systems in cities - The Polish local government's perspective. *Engineering Management in Production and Services*, *13*(4), 131–147. https://doi.org/10.2478/emj-2021-0036

Widyarto, S., Kahar, S., & Hariyanto, S. (2020). *Smart City Comprehension in Community Development*. *41*. https://doi.org/10.4108/eai.11-12-2019.2290864

Wu, G., Boriboonsomsin, K., & Barth, M. J. (2014). *Eco-Routing Navigation System for Electric Vehicles TRANSPORTATION PROGRAM Eco-Routing Navigation System for Electric Vehicles Center for Environmental Research and Technology , Guoyuan Wu , Principal Investigator Kanok Boriboonsomsin Term : October 2012-. December 2016*.

Yigitcanlar, T., & Cugurullo, F. (2020). The Sustainability of Artificial Intelligence : An Urbanistic Viewpoint from the Lens of Smart and Sustainable Cities. *MDPI Sustainability*, 2–3. https://doi.org/https://doi.org/10.3390/su12208548