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IMPACT OF GREEN CAMPUS TRANSPORTATION PROGRAMS ON EMISSION REDUCTION TARGET 2030

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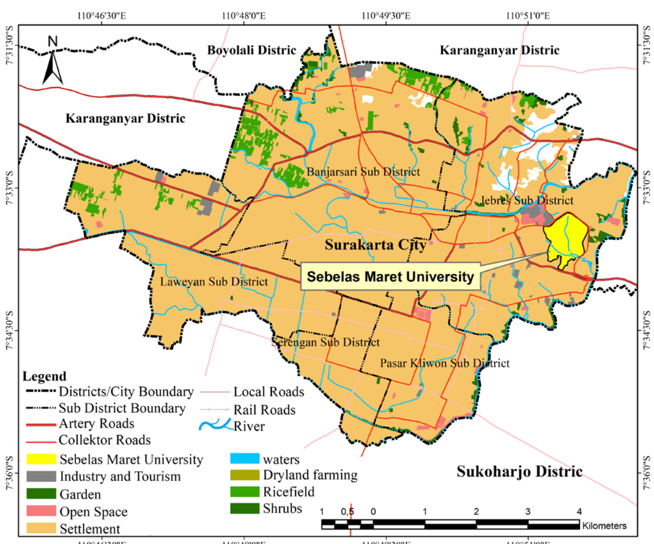
Graphical abstract



Abstract

The effects of climate change on the environment, human health, and economy are significant. Global warming and climate change are primarily caused by emissions of greenhouse gases, especially carbon dioxide. In response, Sebelas Maret University, an Indonesian higher education institution located in Surakarta, Central Java, established the Emission-Free Day, held on the first Friday of every month beginning in July 2020. This study aims to evaluate the efficiency of the Emission-Free Day in achieving 2030 emission reduction goals. This study analyzes the effect of the Emission-Free Day on reducing emissions from motorized vehicles on college campuses. The Tier-1 method, applying emission factors from the Guidelines for National Greenhouse Gas Inventory published in 2006 by the Intergovernmental Panel on Climate Change (IPCC), was used to estimate the emission reduction. The findings indicate that while the Zero Emissions Program aligns with the Sebelas Maret University Green Campus Policy, its contribution to the 2030 emission reduction targets specified in the Nationally Determined Contribution (NDC) is negligible. Additional measures are required to enhance emission reduction efforts, such as the establishment of a Centralized Parking Facility, the implementation of an RFID card system to restrict vehicle access to the campus, the introduction of a ridesharing program, the provision of employee shuttle services, and the promotion of the use of public transportation. These attempts will support global emission reduction efforts and significantly contribute to achieving NDC targets. The study emphasizes the significance of instituting a variety of complementary programs to effectively combat emissions from motorized vehicles and promote a sustainable and low-carbon campus environment.

Keywords: Climate change, emission control, greenhouse gasses, sustainability, Tier-1 method.

1.0 INTRODUCTION

Climate change has significant and pricey consequences for the environment, human wellness, and the worldwide economy, therefore being one of the most urgent challenges that humanity encounters today. Carbon dioxide and other greenhouse gases released into the atmosphere are the main contributors to global warming and climate change. According to [1], carbon dioxide emissions represent approximately eighty percent of all greenhouse gas emissions that lead to global warming. Carbon dioxide (CO2) emissions were the primary cause of global warming between 1750 and 2005 [2]. The Paris Agreement, which was adopted by 195 member nations after the 21st Conference of the Parties (COP) in Paris at the end of 2015, generated a fresh enthusiasm for worldwide cooperative climate change policy and action and established multiple fresh perspectives in international climate policy negotiations [3].

In November 2016, the Paris Agreement came into force. As part of the Paris Agreement, nations are required to submit a Nationally Determined Contribution (NDC) document to the UNFCCC Secretariat as a sign of their commitment to reducing GHG emissions [4]. This NDC represents the participating countries in the Paris Agreement's national commitment to participate in GHG emission reduction initiatives adapted to each nation's circumstances and capacities. In the NDC, Indonesia pledges to minimize greenhouse gas emissions by 29 percent by itself and 41 percent with global support by 2030 [5]. The ten (10) components of Indonesia's NDC cover climate resilience, low-carbon initiatives, adaptation, and mitigation.

Universities can now be compared to " little towns " due to their size, population size, and various diverse campus functions, which directly and indirectly impact the environment. Various organizational and technical measures could significantly decrease the damage to the environment and emissions caused by colleges' energy and material waste in educational and research activities, administrative functions, and residential areas [6]. The growth of the campus has increased fossil fuel consumption and the use of motorized vehicles [7]. Additionally, it is evident that environmental sustainability requires consideration from a different angle. University campuses have an essential part in training future graduates who can lead businesses or other organizations and even establish new ones [8]. As a result, it is important to introduce sustainability concepts and practices to new graduates.

In recent years, university rankings have improved all across the world. They place little to no emphasis on environmental issues, instead focusing exclusively on the significance of the study and academic achievement [6]. Fortunately, numerous institutions worldwide have made an effort to green up their campuses. Interest in Green Campus initiatives has considerably increased since the Sustainability in Higher Education (SHE) declaration in 1972 [9]. In Malaysia, there were attempts to establish a system of university green infrastructure that provided good facilities for bikers, joggers, and walkers [10]. Numerous sustainability analysis methods for universities have been generated, as shown by [11] and [12], which emphasize their advantages and disadvantages. Recently, a few fresh models have been created, such as Graphical Assessment of Sustainability in Universities (GASU) [13]; TUR (Three-dimension University Ranking) [14]; Campus Sustainability Assessment Framework [15]; and lastly, UI Green Metric [16].

Universitas Indonesia (UI) created the UI GreenMetric World University Ranking in 2010 as a forum for universities to collaborate on information and best practices for attaining sustainability throughout their institutions [16]. This system is presently one of the most extensively adopted and utilized methods for evaluating campus sustainability. The UI Green Metric World University Ranking platform, an online device that allows universities to directly submit statistics in accordance with the GM index's main categories, includes the rate associated with each university's website. [17]. Due to its significance and widespread dissemination, UI Green Metric has been the subject of numerous analyses and evaluations in the literature in an effort to refine the evaluation criteria [16], [18], [19]. Several assessments of the Green Metric (GM) index with other international assessment methods (GREENSHIP, STARS, and the College Sustainability Report card) have been recommended [18].

Many colleges have adopted the idea of the "green campus," which has also caught the attention of academics worldwide. [19] conducted research on university social responsibility (USR) on green campuses, which joined UI Green Metric. The result showed that students who attend green campuses have higher corporate social responsibility (CSR) of students' self-consciousness (SSC). As a part of higher education in Indonesia, Sebelas Maret University, located in Surakarta, Central Java, Indonesia, as shown in Fig. 1, is committed to being a Green Campus. The implementation of the green campus program at UNS has been carried out since the campus was built, but the actual structured operation began with the issuance of the Rector's Regulation of the Sebelas Maret University No. 827A/UN27/KP/2013 concerning The Guidelines for the Management of an Environmentally Friendly Campus (Green Campus) Sebelas Maret University.

Development of a sustainable campus at UNS involves the entire academic community, namely: leaders, employees, lecturers, students, research institutions, student organizations, and also alums. In addition to various university elements, green campus programs are developed by collaborating with outside parties, government institutions, and stakeholders. The UI GreenMetric World University Rankings have ranked UNS as one of the Top 10 Universities in Indonesia, the 7th Best Green Campus in Indonesia, and the 99th Most Sustainable University in the World for 2020 [20]. This fact shows evidence that implementing sustainable development at Sebelas Maret University, using the indicators set by UI GreenMetric, is improving. However, many indicators still need to be improved in quality and quantity.

Figure 1 shows that UNS is surrounded by arterial and city collector roads, making UNS a shortcut for residents. This condition generates an increase in emissions in the campus area. UNS has been implementing the Emission-Free Day since July 2020 in order to reduce emissions [21]. This agenda hold one day a month, every first Friday. This research aims to analyze the significance of Emission-Free Day Program on the emission reduction targets by the year 2030. The emission reduction of motorized vehicles on campus was obtained by adopting the Tier-1 method with emission factors determined from the Guidelines for National Greenhouse Gas Inventory, Intergovernmental Panel on Climate Change (IPCC) 2006. Moreover, this study also tried to give alternative solutions to reduce carbon emissions at Sebelas Maret University due to academic transportation.

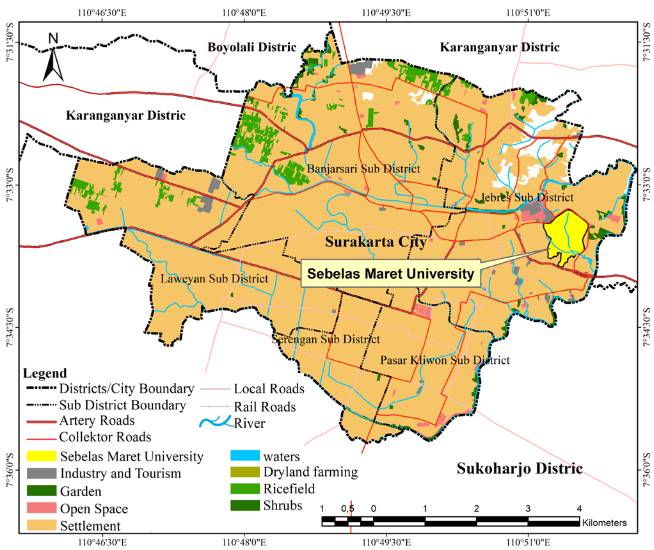


Figure 1 The location of Sebelas Maret University.

2.0 EMISSION GROWTH PROJECTION

Regression is the most popular statistical technique for prediction, optimization, and control [22]. The use of the linear regression method in the traffic volume projection of this study is still reliable by considering the literature review results [23], which indicate that most traffic models are in the form of one or two algorithms, linear or non-linear. The findings also state that traffic volume forecasting depends on the interaction between local and global variables, which can be linear or non-linear, depending on location factors, and the level of analysis. Furthermore, it was also stated that the linear regression model was used as a benchmark to determine the increase in the use of non-linear models in more complex research.

Furthermore, the study conducted by [24] utilized the linear regression method for analyzing traffic information in real-time while employing artificial intelligence algorithms to improve traffic conditions. This study examined five regression techniques for determining transportation volume in Porto, Portugal: linear regression, minimal sequential optimization (SMO) regression, multilayer perceptron, M5P model tree, and random forest. The M5P regression tree outperforms other models based on observed data

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body responsible for assessing climate change research's impact. The IPCC produces comprehensive Assessment Reports summarizing the present knowledge regarding climate change, its effects and potential future hazards, and strategies to slow its progression. In 1996, the IPCC published principles for greenhouse gas inventories, updated in 2006 as the Guidelines for National Greenhouse Inventories. Five volumes comprise the Guidelines: General Guidance and Reporting; Energy; Industrial Processes and Product Use; Agriculture, Forestry, and Other; and Waste. In analyzing emissions due to transportation, the guidelines in Volume 2: Energy is utilized and depends more thoroughly on the Mobile Combustion chapter [25].

In 2012, the Government of the Republic of Indonesia implemented the 2006 Guidelines for National Greenhouse Inventory in the Regulation of the Minister of Environment of the Republic of Indonesia about the implementation of the Greenhouse Gas Inventory. Book II – Volume 1 of the Methodology for Calculation of Greenhouse Gas Emission Levels, Energy Procurement, and Use Activities involves the estimation of emissions of pollutants from transportation activities [26].

Emissions research, mainly due to transportation, is one of the focuses of the IPCC [27]. There are two approaches to greenhouse gas emissions determination from mobile sources in IPCC. The choice between the two approaches, namely vehicle kilometers traveled (VKT) and the fuel consumption-based method, depends on the data availability. VKT approach is considered more accurate according to a study conducted by [28]. Hence this study uses the VKT method considering the data source.

3.0 RESEARCH METHODS

Data for vehicle projection analysis is obtained from Primary Traffic Counting data. Traffic counting is a method to identify the quantity and category of vehicles at particular times and locations, which can be conducted manually and automatically [29]. This research implements manual traffic counting since it was the most popular method used in Indonesia, given that it does not require complex arrangements and may eliminate counting errors due to Indonesian drivers' tendency to disregard lanes and drive despite discipline [30].

The traffic volume in this study is calculated by the number of vehicles passing through a point on the road per unit of time. The counted vehicles include light vehicles (cars) and motorcycles, and heavy vehicles are excluded due to their infrequent use in the university area. Light vehicles are defined as motorized vehicles with two axles, four wheels, and axle distances ranging from 2.0 to 3.0 meters (including passenger cars, microbuses, and small trucks). Furthermore, motorcycles are defined as motorized vehicles with two or three wheels. Traffic counting is carried out for five days during working hours (07.00-16.00) for one week in June. As stated by [31], the surveyors will get exhausted after two or three hours and need an intermittent rest period. Hence, two individual surveyors were stationed at each survey point, taking turns to work every three hours.

The survey was carried out from 2 main campus gates (Gate A and Gate B), which are located on the South and North side of the campus, as shown in Figure 2. The periodic interval of 15 minutes is utilized, as stated in the data collection form. The traffic volume used for the analysis is the average daily number of vehicles entering the university area during working hours. The data collection is conducted from 2015 to 2019. Data for 2020 and 2021 are not used for projections due to the Covid-19 pandemic. Currently, from the year 2022, conditions have returned to normal. The average number of motorcycles and cars is then multiplied by 260 working days to calculate emissions without a zero-emission policy and 248 days for emissions with a zero-emission policy.

Each type and number of vehicles is projected using linear regression and generates Eq. 1 for the number of motorcycles and Eq. 2 for the projection of the number of cars. The prediction of the number of motorcycles entering the Sebelas Maret University campus area can be represented in Eq. 1, where the independent variable (*X*) is the year of the projection, and the dependent variable (*Y1*) is the number of motorcycles/day. For the prediction of the number of cars entering the Sebelas Maret University in Eq. 2, the independent variable (*X*) is the year of the projection, and the dependent variable (*Y2*) is the number of cars/day. The variables *Y*1 and *Y*2 are obtained from regression analysis, with the R^2 values are 0.9693 and 0.8387, respectively. In addition, the confidence level of Eq. 1 and Eq. 2 is 95%.

$$Y1 = 2308.5X - 4630880.9 \quad (1)$$

$$Y2 = 185.4X - 371681 \quad (2)$$

The Tier-1 method is used along with emission factors from the Guidelines for National Greenhouse Gas Inventory, Intergovernmental Panel on Climate Change (IPCC) 2006, to determine the number of emissions generated by the daily use of automobiles on campus [25] and Guidelines for the Implementation of the National Greenhouse Gas Inventory [26]. The number of CO_2 emissions from road transport is determined by using Eq. 3.

$$Emission = \Sigma_a (Fuel_a \times EF_a) \quad (3)$$

Where, *Emission* is the emission of CO2 (kg), *Fuel*is the quantity of fuel sold (TJ), EF_a is the emission factor (kg/TJ), and *a* is the type of fuel. The number of fuel consumption is influenced by the calorific value which is shown in Eq. 4.

Fuel consumption (TJ) = 1000 liter 3 *calorific value* (TJ/l) (4)

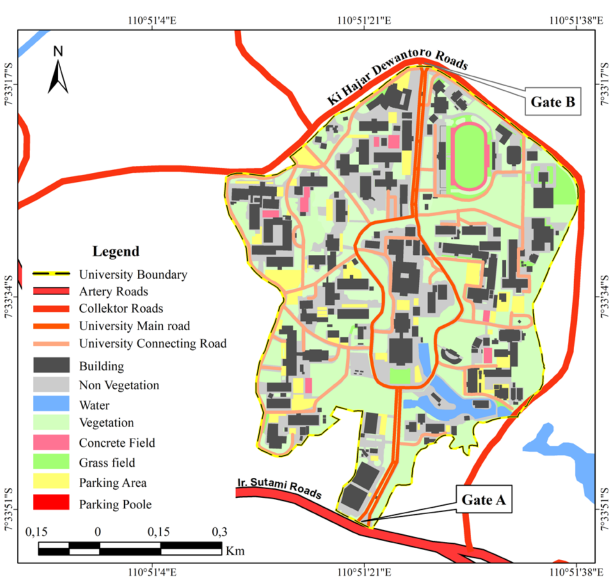


Figure 2 Traffic counting location.

Emissions calculations are conducted by applying Eq. 3 and Eq. 4. The comparisons of car fuel usage were taken from the characteristics of vehicles in Surakarta in a study conducted by [32], with the result of 88% premium and 12% diesel. The distance for calculating fuel consumption is obtained from the average distance from the gate to each faculty from the two main gate points, which is 1.2475 km [33]. The fuel consumption for motorcycles, cars with premium fuel, and cars with diesel fuel is 40 km/liter, 10 km/liter, and diesel 9 km/liter, respectively [34].

The variations of calorific fuel values in Indonesia are shown in Table 1.

Table 1 Calorific fuel values in Indonesia (modified from [26])

Fuel	Calorific value	Use
Premium (including Pertamax and Pertamax Plus)	33×10^{-6} TJ/liter	Motor vehicles
Diesel fuel	36×10^{-6} TJ/liter	Motor vehicles Power plants
Diesel oil	38×10^{-6} TJ/liter	Broiler industry Power plants
Natural gas	$38{,}5 \times 10^{-6}$ TJ/Nm^3	Industrial needs Households Restaurants
LPG	$47{,}3 \times 10^{-6}$ TJ/kg	Households Restaurants
Coal	$18{,}9 \times 10^{-3}$ TJ/ton	Power plants Industrial needs

4.0 RESULTS AND DISCUSSIONS

4.1. The Prediction Of Emission Reduction

The projected growth in the number of vehicles and the number of emissions generated is shown in Table 2. The implementation of the Emission-Free Day program by UNS once every month on the first Friday can reduce 4.62% of emissions in the campus area. The number of emission reductions due to the Emission-Free Day program in UNS is determined by applying Eqs. 3 and 4, with the results presented in Table 2. The calculations show that from 2022 to 2030, this program can contribute to the CO_2 emission reduction of 497,240.48 kg.

Table 2 The projected emission reduction due to the Emission-Free Day program in UNS

Year	Motor cycle	Car	CO_2 emission without program (kg/year)	CO_2 emission with program (kg/year)	Emission reduction (kg)
2022	36,906	3,198	962,433.93	918,013.90	44,420.03
2023	39,215	3,198	1,007,053.75	960,574.35	46,479.40
2024	41,523	3,569	1,080,569.87	1,030,697.42	49,872.46
2025	43,832	3,754	1.139.608,53	1,087,011.22	52,597.32
2026	46,140	3,939	1,198,627.87	1,143,306.59	55,321.29
2027	48,447	4,125	1,257,705.83	1,199,657.87	58,047.96
2028	50,757	4,310	1,316,763.81	1,255,990.10	60,773.71
2029	53,066	4,496	1,375,880.42	1,312,378.24	63,502.17

Year	Motor cycle	Car	CO_2 emission without program (kg/year)	CO_2 emission with program (kg/year)	Emission reduction (kg)
2030	55,374	4,681	1,434,899.76	1,368,673.61	66,226.14
Total					497,240.48

In its Nationally Determined Contribution (NDC), Indonesia targets a reduction of 314 million tons of CO2 emissions in the energy sector by the year 2030, with transportation as one of the aspects that must be managed. With an emission reduction contribution of 497,240.48 kg, the UNS Emission-Free Program could only contribute 0.00015% nationally. Moreover, the transportation sector emission inventory by the Surakarta City Environment Service in 2021 is 285,259.80 tons/year. Compared to when the restrictions on community activities due to the COVID-19 pandemic were still ongoing, UNS was only able to contribute around 44,420.03 kg or approximately 0.0155%. This contribution is considered insignificant, considering the number of students and staff of UNS in 2021 is 8.13% of the total population of Surakarta city. On the other hand, by acknowledging the risks of the greenhouse gas impact generated by vehicle exhaust emissions, the contribution of UNS is concerning and needs to be improved. This problem is critical as Sebelas Maret University, one of Indonesia's significant institutions, is expected to contribute better to the environment.

This finding is congenial with research conducted by [35] about green campus initiative recognition and carbon footprint reduction measurement in Universiti Tenaga Nasional Malaysia. [35] stated that 54% of the students preferred green commuting, such as cycling, walking, carpooling, or taking campus shuttle facilities, while the rest chose traditional commuting. This gap needs serious consideration since this can accelerate carbon emissions on the campus. The awareness of carbon emissions needs to be promoted among students who choose traditional commuting.

Campus facilities are encouraged to conserve energy and reduce emissions in order to support the "green" idea. Its ultimate objective is to highlight the university's sustainable growth. The university should employ sustainable development as this central organizing principle in order to operate effectively and create a university that can guide and lead the sustainable development of society [36]. To ensure the effective administration of campus facilities, a competent university-level management and coordination system must be established. A solid top-level design is highly significant for creating and maintaining an energy and resource-efficient campus, with energy conservation as the foundation. Therefore, making campus infrastructure development and operation as efficient as possible is critical.

A system of appealing behavioral change psychology tactics that can provide feedback would maximize students' engagement in decreasing carbon emissions. The psychological factors comprise behavioral research conducted by students using data from a dedicated online interface and energy delegates to raise awareness and influence energy-saving habits [37]. The study showed that weekly email reminders of energy usage sent to students did not encourage students' motivation. Therefore, a real-time feedback system and a designated energy delegate are needed to maintain awareness, which is expected to motivate students to adjust their actions to reduce their energy usage.

By altering the travel trends of academic travelers, the academic community significantly contributes to reducing greenhouse gas emissions. This perspective discusses the gap between "normal" academic travel routines, such as flying to conferences throughout the globe, and present hot-topic areas of study within the discipline of transportation studies, such as "sustainable mobility," "sustainable accessibility," "resilient and healthy cities," "participated planning concepts and practice," and "active and responsible citizenship." Transportation academics who study and promote sustainable mobility, referred to as "sustainable transport academics," remain oblivious to this contradiction. Nevertheless, other transport researchers remain to stand up for academics' environmentally friendly transportation [38]. Therefore, organizing multiple options and participants will be essential, including conference organizers, funding sources, individual researchers, and communities. Although some of these steps may seem evident, it is essential to consider them as a component of this fresh scholarly system of operation that achieves the ultimate objective of decreasing greenhouse gas emissions while preserving academic quality and productivity.

The policies to reduce emissions must be further improved by the university. Transportation policies on campus should focus mainly on restricting the quantity of vehicles accessing the campus location. The vital role of the university leaders in regulating work areas is an essential issue in the policy-making of 47,087 academics of Sebelas Maret University. Some alternative solutions to reduce emissions in the campus area are: making Centralized Parking Facilities such as parking buildings, application of Radio Frequency Identification (RFID) cards for restrictions on vehicles entering UNS, implementing of ridesharing program, procuring employee shuttle facilities, and launching programs for the use of public transportation.

4.2. Alternative Solutions

4.2.1 Parking Management

The study conducted by [39] showed that the construction of parking buildings in 2 locations near the main gate, as shown in Figure 3, could reduce CO2 emissions due to cars by 26.03 - 51.41%. Additionally, research carried out by [33] stated that the emission reduction for motorcycles for about 32,93 - 53,92%. The position of UNS, which is surrounded by arterial roads and collector roads in the city of Solo, makes the UNS Campus a shortcut for residents, thereby increasing the number of vehicles in the campus environment.

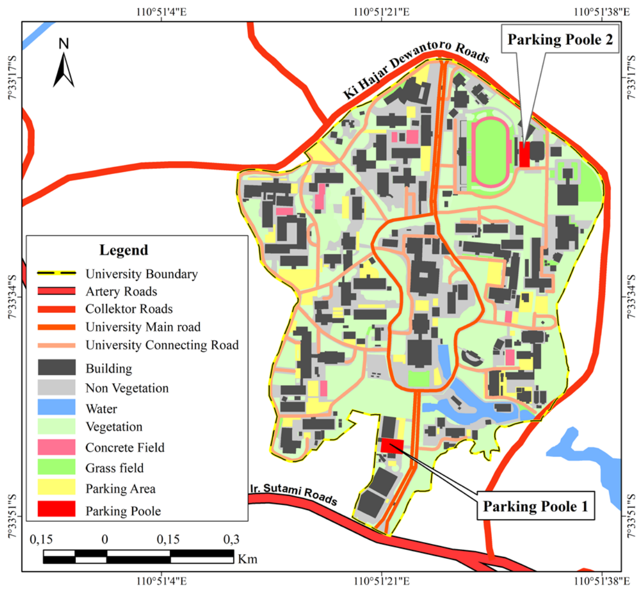


Figure 3 The UNS parking pool location plan

[40] According to the New York County Screen Line Traffic Report, a total of 1,416,277 vehicles entered the New York City region, most of which were passenger cars. Considering that 5% of vehicles, on average, anticipate having trouble finding a parking spot, this equates to around 140,995 automobiles needing intelligent assistance. Driving a passenger vehicle results in an average CO_2 emission of 411 grams per mile [40], considering the fuel efficiency of 21.6 miles per gallon. Due to poor parking system planning, traffic rerouting, and a lack of smart parking technologies, New York City traffic emits 29 metric tons of CO_2 daily. 30% of the vehicles were cruising, blending in with the regular traffic flow, and it took an average of 8 minutes to locate a parking spot. Cruising for parking wastes about 1.61 million vehicle miles each year, using an additional 47,000 gallons of gas and emitting 730 tons of carbon dioxide [41]. Internet of Things (IoT)-enabled smart parking systems can be used to bypass parking hazards and explain how doing so reduces greenhouse gas emissions [40], [41].

One of the fundamental components allowing IoT technologies is Radio Frequency Identification (RFID) technology, which facilitates the identification of people and objects. RFID technology is used to validate automobiles entering and leaving the parking lot, locate and identify parked cars, and manage smart parking spaces [42]. RFID in parking management is usually aimed at reducing the time to find a parking space so that it can reduce fuel consumption and affect emissions [41]. So this RFID can be used in certain areas to limit incoming vehicles. With RFID, the use of private vehicles that enter the campus is registered in the system, thus limiting the number of vehicles that will enter the campus area. With this policy, not everyone can enter the campus area to reduce the emissions produced by these vehicles.

An RFID Card system can be applied to academics which also functions for parking control to resolve emission problems. The implementation of a smart parking system to minimize traffic and save people time by employing a mobile app to direct vehicles to nearby free parking spaces, smart traffic management to track and find parking spaces, and showing the available areas in the mobile application [43]. [44] conducted a survey that resulted in 91% of the academics agreeing to the RFID program.

4.2.2 Ridesharing

The implementation of ridesharing and the provision of shuttle facilities can potentially reduce the use of private vehicles. Ridesharing can be done between students or staff, while shuttle facilities can be provided for academic staff. The potential for ridesharing implementation is relatively high considering research conducted at the Surakarta City Hall, showing that employees who use cars are willing to implement ridesharing policies of 55.32%. In comparison, employees who use motorbikes are 31.68%. In addition, the number of eager employees to use the shuttle facility at the Surakarta City Hall is 46.81% for car users and 39.75% for motorbike users [45].

Ridesharing is typically defined as the sharing of vehicles by people using the same travel routes and schedules to minimize the total number of trips and distance traveled. The primarily shared vehicles are private automobiles, vans, taxis, and shuttles, and the most frequently shared itineraries are domestic travel and commuting [46]. The two-month-long study analyzed the transportation habits of about 8,900 privately-owned vehicles in Changsha, China, to determine the advantages of ridesharing to reduce carbon emissions from personal vehicles. Considering a maximum distance between journeys of fewer than ten kilometers and a scheduled time frame of under sixty minutes, ridesharing could lower the total number of kilometers traveled in the study area by approximately 24 percent. For a more moderate maximum travel distance of 2 kilometers and a passenger timetable of fewer than forty minutes, the reduced miles traveled could be equivalent to approximately 4.0 tons of CO_2 emissions.

The use of ridesharing could reduce traffic pollution. Using Shanghai as an example, [47] demonstrated how ridesharing could save gasoline consumption by 22.88% and 15.09%, respectively, in ideal and practical conditions. According to spatial analysis, ridesharing reduces emissions on the most heavily polluted routes. This research's findings confirm that a comprehensive evaluation of emission reduction performance should be a component of the key requirements for developing ridesharing transportation-environmental regulations. Ridesharing is insufficient to reduce emissions on its own. However, it should be developed with emission reductions or equivalent requirements as the specific improvement goal. Any policy that seeks to promote unofficial sharing services offered by current private drivers or official services provided by Transport Network Companies (TNC) should be carefully evaluated in terms of how it can result in environmental benefits through modifying customer behavior, controlling transport consumer demand, or implementing operational approaches.

A mobile phone study of GPS data in urban ridesharing conducted by [48] selected the case study of the Tokyo area, with more than 1 million GPS travel records, and trained a deep learning model to discover this potential. The computation result showed that, on average, ridesharing could reduce the trip distance by approximately 26.97%, indicating a substantial similarity between people's travel habits in Tokyo and a sizable quantity of ridesharing potential. Additionally, it is estimated that the number of CO_2 will be reduced by 84.52% if half of the original public transit users in our case study switch to ridesharing. When all of the original public transit users switch to ridesharing, a rebound effect will result in an 83.56% reduction in CO2 emissions. Ridesharing can help with city issues, including traffic congestion and the air quality in these central business districts. A study about the potential of ridesharing can shed light on how decision-makers and service providers for ridesharing make decisions.

The study conducted by [49] evaluated the tangible environmental advantages of ridesharing as an outcome of the alteration in the mode of transportation and the supplementary ecological effects as a result of the shift in perspective regarding automobile purchasing. Beijing, the largest city in China, was selected as the observational setting because of its particularly significant traffic jams and challenges with getting an automobile. In accordance with estimations, ridesharing directly conserves 26,600 TCE (Ton Coal Equivalent) of energy yearly and lowers CO2 and NOX emissions by 46,200 and 253.7 tons, respectively. Furthermore, employing ridesharing services will lead to long-term energy savings and emission decreases due to a reduced need to purchase new automobiles. Encouragement of electric transportation between ridesharing vehicles and converting to environmentally friendly electricity generations, and improving vehicle efficiency, can further enhance the environmental benefits of ridesharing, with a maximum impact reaching 67% of energy savings and 57% emission reductions in CO2 compared with 2016 levels of fuel-related consumption of energy and emission levels.

4.2.3 Public Transportation

The application of public transportation is not only benefits for the campus area but also for the city. Hence it is fully supported by the government of Indonesia, both in terms of improving facilities and financial subsidies. Unfortunately, this program is not very attractive to people. The research results in Surabaya showed that reducing emissions from private vehicles to conventional public vehicles is only 0.0343% [50]. In Jakarta, the existence of TransJakarta, which in 2012 had the potential to reduce emission levels by 0.185513 million tons of CO2 [51], was only able to contribute 0.0806% of the total emissions generated on the road. The low contribution is based on the inventory of CO pollutant emissions in the road segmentation in Jakarta in 2012, reaching 229,943 Gg/Year [52].

An empirical study is managed by [53] using a model based on a structural equation and machine learning approach to examine the effect of a bus rapid transit (BRT) system on the concentration of residual pollution in the peripheral areas of the TransJakarta corridors. The results showed that the change in modality by the BRT system had a greater effect on swiftly reducing pollution such as PM10 than on O3 due to the proximity of near-source small-scale environments. Motorcycles contributed the most to emissions in Jakarta, especially during the workweek. The main obstacle is reducing the use of motorbikes along the BRT lanes to further minimize the emission of hydrocarbons. Providing motorcycle parking spaces next to BRT stations is one option that might be considered, which would strongly encourage motorcycle riders to switch to buses (TransJakarta) for their private transportation.

The poor contribution to reducing emissions from public transportation shows that the involvement of academics as part of the community who understands the dangers of greenhouse gases is vital. Besides contributing directly to reducing exhaust emissions from private vehicles, the academics must act as an example for the surrounding community to use public transportation. It is believed that model examples using campus figures such as professors and officials will have more impact on society.

Conversely, results from the Evaluation of Bus Rapid Transit's Effect on Air Pollution in Mexico City [54] indicate that BRT is an efficient environmental policy that lowers CO, NOX, and PM10 emissions. Depending on the city area, CO concentrations were reduced by 5.5 to 7.2%, NOX by 4.7 to 6.5%, and PM10 by 7.3 to 9.2%. Further research is needed to ascertain whether commuters exhibit a persistent behavioral change (moving from private vehicles to BRT) and whether the treated area's traffic congestion was actually alleviated.

In developing countries, the public transportation system, such as BRT, is ineffective as a result of slow speeds, operating on lanes shared with other vehicles, long waiting times, and significant headways between buses and other vehicles [55]. In order to evaluate various and innovative approaches to enhancing the effectiveness and performance of BRT, a number of different scenarios with multiple design factors have been put up. A reduction of up to 4% in bus travel time results in an increase of up to 5% in vehicle travel time, which has substantial adverse environmental effects and increases pollutant emissions. Exclusive bus lanes positively affect fuel use and pollutant emissions from an environmental standpoint. [55] also stated that the exclusivity of bus lines would result in a 40.6% reduction in bus CO emissions and a 3.1% increase in auto CO emissions.

4.2.4 Other Alternatives Offered By Universitas Sebelas Maret

To reduce emissions in the university area, Universitas Sebelas Maret has undertaken various initiatives, including shuttle services, pedestrian facilities, and a zero-emission vehicle policy. Data acquired from [56] reported that the university already provides two free emission-free shuttle vehicles, with five passengers capacity per shuttle and a total of 10 shuttle service trips per day. Unfortunately, the population of shuttle users is very minimal, approximately <0.21% of the total academic community of the university.

Moreover, the number of emission-free vehicles, such as bicycles, used by the university's academic community is also very low, at around 193 units per day [56], which is not more than 0.41%. The university also had constructed pedestrian pathways to connect all the main buildings, designed for safety and convenience, and in some parts, even equipped with features for disabled individuals. However, the interest of the people to use this facility remains minimal. This is due to the hilly contours within the campus area, the ease of using private vehicles within the campus area, and the less popular culture of walking in Indonesian society, particularly in Surakarta.

The reasons mentioned above are the factors that reinforce the zero-emission days policy implementation to reduce emissions in the area of Universitas Sebelas Maret.

5.0 CONCLUSIONS

The implementation of the Emission-Free Day program at UNS has resulted in a decrease of 4.62 percent in campus emissions. Nevertheless, nationally, the program's contribution to overall CO_2 emission reduction is only 0.00015%. Similarly, UNS contributes approximately 0.0155% to the transportation sector's emission inventory in Surakarta City. Considering the institution's scale and significance, these percentages indicate that the UNS's current contribution to emission reduction is deemed negligible.

Consequently, there is an urgent need for improvements and increased efforts to address the greenhouse gas impact caused by vehicle exhaust emissions. As a significant institution in Indonesia, UNS has the capacity to make a more substantial and positive contribution to the environment. Other programs are needed, such as the establishment of a Centralized Parking Facility, the application of an RFID card for restrictions on vehicles entering UNS, the implementation of a ridesharing program, the procurement of employee shuttle facilities, and the launching of a program for the use of public transportation to increase the contribution of emission reduction.

The contribution of reducing emissions from the use of public transport, which is still low, requires the involvement of the academic community. Besides, academics are considered to understand the dangers of greenhouse gases due to exhaust emissions. Therefore, they are expected to act as an example for the community by using public transportation.

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