SAFETRANS: Implementation of Autonomous Electric Bus-Based Public Transportation to Realize Net Zero Emissions 2060

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ABSTRACT

The high number of traffic accidents and air pollution levels in major Indonesian cities, especially Jakarta, are crucial issues that demand innovative solutions in the public transportation sector. This creative idea introduces SAFETRANS, an autonomous electric bus-based public transportation system integrated with the Internet of Things (IoT) to address these challenges. The main objective of SAFETRANS is to significantly reduce human error as the main cause of traffic accidents through the application of autonomous driving technology equipped with advanced sensors such as LIDAR, RADAR, and cameras. In addition, as an electric vehicle, SAFETRANS directly contributes to reducing greenhouse gas emissions and air pollution, supporting Indonesia's commitment to achieving Net Zero Emissions by 2060 and in line with Sustainable Development Goals (SDGs) point 7 (Affordable and Clean Energy) and point 9 (Infrastructure, Industry, and Innovation). The implementation of IoT in SAFETRANS enables real-time monitoring of energy consumption, route optimization to avoid congestion, and communication between vehicles (V2V) and with infrastructure (V2I) to improve efficiency and safety. The project's development plan will be implemented over five years using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) method. This project will involve collaboration with various stakeholders, including the government through the Ministry of Transportation, the National Research and Innovation Agency (BRIN), and private companies in the automotive and energy sectors. With a total estimated funding of IDR 277,200,000,000, SAFETRANS is expected to be a safe, efficient, environmentally friendly, and sustainable mass transportation solution to improve the quality of life for urban communities in Indonesia.

ABSTRAK

Tingginya angka kecelakaan lalu lintas dan tingkat polusi udara di kota-kota besar Indonesia, khususnya Jakarta, menjadi isu krusial yang menuntut solusi inovatif di sektor transportasi publik. Gagasan kreatif ini memperkenalkan SAFETRANS, sebuah sistem transportasi publik berbasis bus listrik otonom yang terintegrasi dengan Internet of Things (IoT) untuk menjawab tantangan tersebut. Tujuan utama dari SAFETRANS adalah untuk mengurangi secara signifikan human error sebagai penyebab utama kecelakaan lalu lintas melalui penerapan teknologi autonomous driving yang dilengkapi dengan sensor canggih seperti LIDAR, RADAR, dan kamera. Selain itu, sebagai kendaraan listrik, SAFETRANS secara langsung berkontribusi pada penurunan emisi gas rumah kaca dan polusi udara, mendukung komitmen Indonesia untuk mencapai Net Zero Emissions pada tahun 2060 serta sejalan dengan Tujuan Pembangunan Berkelanjutan (SDGs) poin 7 (Energi Bersih dan Terjangkau) dan poin 9 (Infrastruktur, Industri, dan Inovasi). Implementasi IoT pada SAFETRANS memungkinkan pemantauan konsumsi energi secara real-time, optimalisasi rute untuk menghindari kemacetan, dan komunikasi antar-kendaraan (V2V) serta dengan infrastruktur (V2I) untuk meningkatkan efisiensi dan keamanan. Rencana pengembangan proyek ini akan dilaksanakan dalam lima tahun menggunakan metode ADDIE (Analysis, Design, Development, Implementation, Evaluation). Proyek ini akan melibatkan kolaborasi dengan berbagai pemangku kepentingan, termasuk pemerintah melalui Kementerian Perhubungan, Badan Riset Inovasi Nasional (BRIN), serta perusahaan swasta di bidang otomotif dan energi. Dengan total estimasi pendanaan sebesar Rp 277.200.000.000, SAFETRANS diharapkan menjadi solusi transportasi massal yang aman, efisien, ramah lingkungan, dan berkelanjutan untuk meningkatkan kualitas hidup masyarakat perkotaan di Indonesia.

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KEYWORDS
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INTRODUCTION

Based on data from the Traffic Corps of the Indonesian National Police (2023), there was an increase of around 34.6% in the number of traffic accidents in Indonesia in 2022, reaching 94,617 cases compared to 70,000 cases in 2021. The main factors causing accidents in Indonesia are caused by humans as much as 61%, vehicles as much as 9% and infrastructure and environment as much as 30% (Bureau of Communication and Public Information, 2023). Therefore, Indonesia is in the fifth position globally as the country with the highest rate of traffic accidents (Manggala & Soedarto, 2016). The largest cause of death in Indonesia comes from traffic accidents on the road. One of the causes is the lack of focus from the driver which can be triggered by fatigue, drowsiness and cell phone use while driving (Nurdjanah & Puspitasari, 2017). Traffic accidents have consequences in the form of loss of life, injury or disability which will ultimately create a financial burden for the family due to the need for funds for the medical process (Tuban et al., 2019).

Transportation is needed to ensure the mobility of the population. Based on data from the Jakarta Transportation Agency regarding the number of Transjakarta passengers, there is a tendency to increase every year. In 2018, the total number of Transjakarta passengers reached around 187.96 million and experienced an increase of around 41% to reach 265.16 million passengers in 2019. Even in the first months of 2020 (January-February), there was an increase in the number of passengers with an average increase of around 45% compared to the same period in 2019 (Nisa, 2020). The importance of public transportation as a key issue in the design of large metropolitan areas not only includes aspects of criteria that affect the quality of life of a city, but also has a close relationship with the social life of each of its inhabitants (Iclodean et al., 2020). On top of the high number of public transportation passengers, the largest air pollution is generated by transportation (CNBC Indonesia, 2023). According to information obtained from World Health Organization (WHO), air pollution causes premature deaths of up to 2 million people every year. The majority of air pollution problems come from the use of fossil fuels (Riyanto et al., 2023). Currently, Jakarta faces significant challenges related to greenhouse gas emissions, especially from the transportation sector which is a major contributor (Adi, 2023). Fossil fuel vehicles are still the dominant type of vehicle in Indonesia, especially in DKI Jakarta (Akbar, 2022). This type of vehicle is generally known as a contributor to polluting gases, considering that it is a transportation sector that uses fuels that can produce harmful emissions (Akbar, 2022). Exposure to air pollution and hot weather conditions has a detrimental impact on health, causing many residents to experience respiratory disorders such as Acute Respiratory Infection (ARI), flu, cough, cold and other symptoms (Syahputra, 2023). Achieving net zero emissions by relying on current government programs is very difficult and handling air pollution, especially in Jakarta or other areas, seems to only succeed if the sources of pollution are reduced. Solutions to address the problem of air pollution cannot happen quickly, but rather require sustained and comprehensive efforts (Basaib, 2022).

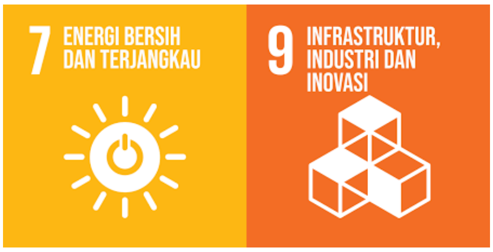

Figure 1. Sustainable Development Goals 7 and 9

There are several problems that need to be overcome, namely reducing the increase in traffic accidents, reducing the increase in air pollution, and developing environmentally friendly and sustainable transportation. Based on the various problems that have been described, the author initiated the innovation of driverless buses by using autonomous driving sensors and the Internet of Things system to reduce the rate of traffic accidents and reduce air pollution in urban environments as well as IoT systems to monitor bus energy consumption in real-time and optimizing the use of batteries in electric buses. IoT is also integrated with charging stations to ensure efficient and environmentally friendly charging schedules guided by SDGs point 7 (Clean and Affordable Energy) and point 9 (Infrastructure, Industry and Innovation).

METHODS

This study employs a qualitative descriptive approach through literature review and conceptual analysis to formulate the design of autonomous electric buses integrated with the Internet of Things (IoT) for sustainable public transportation. The research stages are structured using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) as the framework for idea development.

1. Analysis
   At this stage, the identification of needs and environmental potentials was conducted by collecting secondary data from government reports, academic journals, and international publications. The analysis focused on urban transportation challenges, traffic accident rates, the contribution of the transportation sector to air pollution, and Indonesia's commitment to achieving Net Zero Emissions by 2060.
2. Design
   The results of the analysis were used to design the concept of an IoT-based autonomous electric bus (SafeTrans). The design process included mapping the main components such as autonomous driving sensors (LIDAR, RADAR, cameras, GNSS, and IMU), energy management systems, and supporting infrastructure in the form of renewable energy-based charging stations.
3. Development
   A prototype concept was formulated, including V2V (*vehicle-to-vehicle*) and V2I (*vehicle-to-infrastructure*) communication and IoT-based monitoring. A SWOT analysis was conducted to evaluate feasibility.
4. Implementation
   The implementation plan focused on limited trials (pilot projects) in high-density urban areas, such as Jakarta. This included testing the autonomous driving system, evaluating system performance, and optimizing control algorithms. Collaboration with the government, automotive industries, and electricity providers was emphasized to support project realization.
5. Evaluation
   Evaluation was carried out by measuring success indicators, namely: (a) reduction in traffic accident rates,
   (b) reduction in carbon emissions compared to conventional buses, and (c) increase in the number of public transportation users. The evaluation results will serve as the basis for design improvements and scaling up to other Indonesian cities.

RESULTS AND DISCUSSIONS

The conceptual development of SafeTrans yielded several key results:

1. Integration of Autonomous Driving Technology
   SafeTrans incorporates advanced sensors—LIDAR, RADAR, cameras, GNSS, and IMU—enabling real- time perception of the environment, autonomous navigation, and obstacle avoidance. This reduces dependence on human drivers and minimizes risks of accidents caused by fatigue and distraction.
2. IoT-Based Smart System
   The bus integrates IoT for real-time monitoring of energy consumption, predictive maintenance, and communication between vehicles (*vehicle-to-vehicle*, V2V) and between vehicles and infrastructure (*vehicle-to- infrastructure*, V2I). This ensures optimized routes, improved safety, and efficient operation.
3. Environmental Impact Reduction
   Compared to conventional buses, SafeTrans can potentially reduce carbon emissions by approximately 50%. With the transportation sector contributing 44% of Jakarta's total fuel consumption, this innovation directly supports emission reduction and cleaner air quality in urban areas.
4. SMART Development Targets
   The SafeTrans program is characterized by Specific, Measurable, Achievable, Realistic, and Time-bound (SMART) indicators. Targets include:
   - A 25% increase in public transport usage in pilot areas.
   - At least 50% reduction in emissions compared to diesel buses.
   - Significant reduction in traffic accident rates due to minimized human error.
5. Comparative Performance
   When compared with conventional and electric buses, SafeTrans shows superior performance in terms of emission reduction, accident risk mitigation, and technological advancement (Table 1).
6. Feasibility through SWOT Analysis
   The SWOT analysis shows strengths in technological innovation, environmental benefits, and policy alignment, while weaknesses include high initial investment and public skepticism. Opportunities lie in the increasing demand for sustainable transportation, while threats include financial challenges and technology

adoption barriers.

Figure 2. Isometric Display of SafeTrans Bus

Table 1. Comparison of Bus Types.

Aspect	Conventional Bus	Electric Bus	SafeTrans
Carbon Emissions	High (Baseline 100)	Medium	Low
Accident Risk		Medium	Low
	High (Index 100)		
Energy Efficiency	Low	Moderate	High
Technology Features	Desain Engine	Battery-powered, limitde smart systems	Autonomous sensor+IoT integration

DISCUSSION

The results indicate that SafeTrans offers a transformative solution to Indonesia's urban transportation challenges. By reducing human error, which accounts for more than 60% of accidents, SafeTrans can improve road safety through autonomous navigation and decision-making. From an environmental standpoint, SafeTrans supports Indonesia's efforts to lower greenhouse gas emissions. Since the transportation sector contributes 44% of Jakarta's fuel consumption, replacing conventional buses with electric IoT-based buses would reduce air pollution and improve air quality. Moreover, IoT integration enhances efficiency by enabling smart energy management and predictive maintenance.

The challenges of high development costs and limited public trust in autonomous systems highlight the need for phased implementation. Pilot projects in controlled environments are essential to validate safety, build user confidence, and optimize operations. Overall, SafeTrans aligns with the UN Sustainable Development Goals (SDGs), particularly Goal 7 (*Affordable and Clean Energy*) and Goal 9 (*Industry, Innovation, and Infrastructure*), offering a scalable and sustainable model for smart public transportation in Indonesia and beyond.

CONCLUSIONS

This study proposed the SafeTrans concept, an IoT-based autonomous electric bus designed to improve road safety and reduce environmental impacts. SafeTrans has the potential to cut carbon emissions by up to 50% and significantly lower accident risks compared to conventional buses. IoT integration ensures operational efficiency through real-time monitoring, predictive maintenance, and energy optimization.

Although financial and social barriers exist, the benefits outweigh the challenges if supported by strong collaboration between government, industry stakeholders, and society. SafeTrans thus represents a viable pathway to achieve Indonesia's *Net Zero Emissions 2060* target while promoting sustainable and intelligent urban mobility.

Future research should focus on pilot testing, cost reduction strategies, and public acceptance studies to strengthen the feasibility of SafeTrans as a national-scale public transportation innovation.

REFERENCES

Adi. (2023). Transportation, the Main Source of Greenhouse Gas Emissions in JakartaDatabox.https://databoks.katadata.co.id/datapublish/2023/03/20/transportasi-sumber-utama-emisi-gas-rumah-kaca-dki-jakarta

Akbar. (2022). Analysis of Vehicle Exhaust Emission Test Regulations Based on Their Effect on the Air Quality Index in DKI Jakarta Using the Pearson Correlation Method and Linear Regression. J Statistics: Scientific Journal of Theory and Application of Statistics, 15(1). https://doi.org/10.36456/jstat.vol15.no1.a5216

Basaib, M. (2022, December 15). Realizing Jakarta as a Sustainable City, Control Transportation Emissions. Greenpeace Indonesia. https://www.greenpeace.org/indonesia/siaran-pers/55918/wujudkan-jakarta-kota-berkelanjutan-kendalikan-emisi-transportasi/

Bureau of Communication and Public Information. (2023). Reducing the Number of Traffic Accidents, the Ministry of Transportation Invites the Public to Switch to Public Transportation and Prioritize Driving Safety The Ministry of Transportatio of the Republic of Indonesia https://dephub.go.id/post/read/%E2%80%8Btekan-angka-kecelakaan-lalu-lintas,-kemenhub-ajak-masyarakat-beralih-ke-transportasi-umum-dan-utamakan-keselamatan-berkendara

CNBC Indonesia. (2023, August 11). The transportation sector is the largest source of pollution. CNBC Indonesia. https://www.cnbcindonesia.com/news/20230811175426-8-462326/sektor-transportasi-jadi-sumber-pencemaran-polusi-terbesar

Iclodean, C., Cordos, N., & Varga, G.O. (2020). Autonomous shuttle buses for public transport: Reviews. Energy, 13(11), Article 11. https://doi.org/10.3390/en13112917

Manggala, R., & Soedarto, J. (2016). Case Study of Factors Causing Traffic Accidents on Sharp Bends.

Nisa. (2020, September 7). Number of Transjakarta Passengers in 2018-2020 in DKI Jakarta. Sectoral Statistics of DKI Jakarta Province. https://statistik.jakarta.go.id/jumlah-penumpang-transjakarta-tahun-2018-2020/

Nurdjanah, N., & Puspitasari, R. (2017). Factors Affecting Driver Concentration. Journal of Transportation Research, 29(1), Article 1.

Syahputra, E. (2023). Jakarta Pollution and Motor Vehicle Emissions, How Critical? CNBC Indonesia. https://www.cnbcindonesia.com/news/20230927164923-4-476113/polusi-jakarta-dan-emisi-kendaraan-bermotor-segenting-apa