

Evaluation of Contraflow Implementation on the Road to Universitas Andalas Limau Manis Campus

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ABSTRACT

The increase in traffic volume due to the growth in the number of vehicles and the rising student population at Universitas Andalas has led to delays on the road leading to the Limau Manis Campus, especially in the area around the Main Campus Gate. The campus administration subsequently implemented traffic management measures by applying contraflow to the right lane of the road segment. This report presents an evaluation of the implementation of contraflow, which needs to be conducted to assess changes in traffic performance before and after its application, as well as to predict future performance of the road segment. Data were collected by counting vehicles in fifteen-minute intervals. The Indonesian Road Capacity Guidelines (PKJI) 2023 were used to analyze road performance. The results of the study indicate an improvement in traffic performance on the road segment after the implementation of contraflow. However, this improvement will only sustain for the next 10 years, thus making contraflow an impermanent solution to the problem. Therefore, other more sustainable solutions should be pursued.

Keywords: contraflow, traffic performance, limau manis campus, roundabout, oneway.

INTRODUCTION

The Universitas Andalas Limau Manis Campus is a very active environment, bustling with students pursuing their education as well as visitors engaging in a variety of activities. It is also a favorite destination for newcomers, both from the Sumatra region and from various parts of Indonesia. As the number of people engaging in activities on campus increases, the volume of vehicles entering and exiting the campus also grows, which in turn leads to traffic issues.

Currently, Universitas Andalas faces complex traffic challenges. Many members of the academic community complain about delays caused by morning traffic, as well as difficulties in finding parking spaces because of already full parking areas, especially for motorcycles. The high number of vehicles and suboptimal public transportation system have not effectively met the mobility needs of the campus community. These complaints require swift action and the right solutions from the university, as the impacts can be economically detrimental, prolong travel times, and increase air pollution. Furthermore, this situation can also affect mental health, heighten stress levels, and reduce productivity.

One approach that can be used to address this problem is transport demand management (TDM), namely, the distribution of demand within the area to avoid overloading any single space through the implementation of contraflow policies. The use of contraflow in the United States was designed to be used under threat from catastrophic storms [1]. The application of contraflow is expected to be suitable when certain sections of the road have considerably lower demand than others. To date, the implementation of contraflow seems to be able to reduce traffic loads on the road section leading to the campus; however, an evaluation is needed to determine the effectiveness of this contraflow implementation.

This study aims to evaluate the effectiveness of contraflow on the right lane of the road section between the Universitas Andalas Main Gate and the intersection leading to the Universitas Andalas Hospital. With a data-driven approach, it is hoped that the results of this study can contribute to improving transportation efficiency and creating a more comfortable, productive, and sustainable campus environment.

The issues discussed in this study are limited to the following aspects: The traffic performance evaluated is the vehicle traffic performance on both the left and right lanes of the road section between the Universitas Andalas campus gate and the Universitas Andalas Hospital intersection. The performance analysis follows the guidelines outlined in the PKJI 2023 [2]. Performance predictions are made for the next 3, 5, and 10 years.

Transportation refers to the movement of people or goods using means powered by either human effort or machines. The main function of a transportation system is to support the smooth flow of human activities in daily life. Various experts have provided definitions of transportation from different perspectives, although there are fundamental similarities in substance. Etymologically, the term "transportation" comes from the Latin word *transportare*, which means to carry or to move. Thus, transportation can be defined as the activity of moving an object from one location to another [3].

According to Broaddus et al. [4] transport demand management (TDM) is a strategic approach aimed at improving the effectiveness of the transportation system by limiting the use of private vehicles and promoting the use of more efficient, healthier, and sustainable modes of transportation, such as public transit. TDM seeks to reduce the frequency and distance of private vehicle trips by providing alternative modes of transport, offering incentives, and supporting changes in individual mobility behavior. Cumulatively, implementing TDM can have a significant impact on travel patterns and the efficiency of the transportation system such as in Netherlands and China [5, 6].

Pradana [7] adds that TDM is a policy approach aimed at optimizing the use of the transportation system through strategies that encourage changes in people's travel behavior. The main focus of TDM is the diversion of travel patterns, whether in terms of time, route, mode of transportation, or travel destination, so that travel demand distribution can be carried out more evenly and efficiently. The primary goal of TDM is to improve the efficiency of urban transportation systems by restricting the use of non-essential private vehicles and encouraging the use of healthier and more environmentally friendly modes of transportation, such as public transport and non-motorized vehicles. To understand the economic benefits of TDM implementation, transportation needs to be viewed as a commodity with dimensions of demand and supply. In this context, the transportation agency plays an important role in designing, building, and managing road infrastructure and transportation services, including vehicle regulation. Transportation planning policies are generally oriented toward improving the supply aspect, such as traffic volume and motor vehicle speed, which can be measured using indicators such as the length of paved roads, parking capacity, the number of motor vehicles, and vehicle kilometers traveled (VKT). Conversely, the demand aspect of transportation is more complex to measure, as it relates to people's mobility needs and the distribution of goods by businesses. To date, there is no institutional clarity regarding the party responsible for managing transportation demand, considering that mobility decisions are influenced by various factors, such as travel time, convenience, and cost [8, 9, 10].

According to Pradana [7], there are three fundamental concepts in the implementation of transport demand management (TDM) strategies that aim to create a more efficient transportation system:

a. The "How" Concept

This concept focuses on changing the behavior of transportation users by encouraging people to switch from private vehicles to public transportation or from single-occupancy vehicles to those that can carry multiple passengers.

b. The "When" Concept

This concept emphasizes the regulation of travel times. The strategy aims to reduce traffic congestion by directing road users to avoid traveling during peak hours and to choose travel times outside of the busiest periods.

c. The "Where" Concept

This concept is related to the selection of routes or travel destinations. In routes that often experience traffic congestion, policies such as road pricing can be implemented to reduce the volume of vehicles, prompting users to choose alternative routes that are less congested.

A photograph of the Universitas Andalas Main Gate prior to the implementation of contraflow is presented in Figure 1. In front of the gate, there is a relatively large roundabout with the words "Universitas Andalas" in the center. Traffic must go around a portion of the roundabout, even when the intention is to go straight. Some vehicles intending to make a U-turn circle around the roundabout, whereas others have already turned around at the end of the median before the roundabout. This situation can disrupt the smooth flow of traffic.



Figure 1. Universitas Andalas Main Gate Before the Implementation of Contraflow

To implement contraflow, a few renovations were made to the appearance of the gate, particularly concerning the roundabout. The old roundabout was removed and replaced with a small, droplet-shaped curve at the end of the median. As a result, vehicles traveling straight no longer have to turn around part of the roundabout but can go straight into the gate, as the roundabout at the end of the median is relatively small.

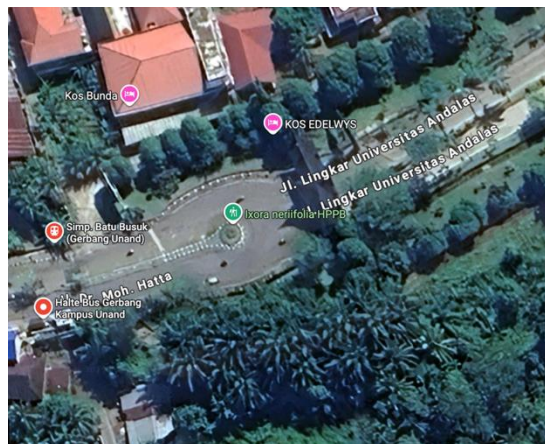


Figure 2. Universitas Andalas Main Gate After the Renovation of the Roundabout and Implementation of Contraflow

Several factors are suspected to cause traffic congestion on the road sections that are the objects of this study, including the following [11, 12, 13].

a. Rush Hour

At certain times, such as in the morning before classes begin and in the afternoon after classes end, there is a significant increase in the number of vehicles entering and leaving the campus area. Congestion occurs when the capacity of the roads in and around the campus is unable to

accommodate the volume of vehicles during peak hours. Consequently, vehicle queues and travel times increase, thereby impacting the productivity of campus users [13, 14].

b. Dependence on Private Vehicles

Many students, lecturers, and staff prefer to use private vehicles, such as cars or motorcycles, as they feel more comfortable, safe, or flexible. This dependence on private vehicles is even higher among those living in areas with limited access to public transportation or for those with high mobility needs. This dependence leads to an increase in the number of private vehicles entering the campus every day. Campus areas with limited parking spaces experience high pressure to accommodate the growing number of vehicles, resulting in prolonged congestion, especially at the entrances and parking areas [15, 16].

c. The road geometry that hampers traffic is the presence of a large roundabout in the middle of the road segment. Basically, the Universitas Andalas Main Gate does not disrupt the traffic flow because the gate is located outside the right-of-way of the road; however, the presence of a roundabout in front of the gate causes a bottleneck for vehicles. In addition, the uphill road alignment towards the campus [17].

In the context of traffic management, contraflow can be defined as a strategy that utilizes lanes in the opposite direction on road segments experiencing high levels of congestion [18, 19]. The main objective of implementing this concept is to temporarily increase road capacity to reduce traffic [18]. The use of contraflow has been frequently conducted on roads in major cities, such as Jakarta and Bandung, especially when there is an imbalance in the traffic load between the left and right lanes.

RESEARCH METHODS

Primary data is data collected by the researcher directly from the data source or respondents. The primary data referred to in this study includes Traffic volume and data related to the road capacity.

The data that has been collected will then be analyzed to determine the degree of saturation, by comparing the traffic volume with the road capacity. This will be carried out for the current condition as well as predictions for the next 5 and 10 years.

RESULT AND DISCUSSION

This research was conducted after contraflow was implemented. The road, which was previously type 2/2 D, was changed to two types: 2/1 UD for the left lane towards Universitas Andalas Limau Manis Campus, and 2/2 UD for the right lane median. This means that the lane from the direction of the Universitas Andalas Rectorate Office towards the Universitas Andalas Main Gate, which previously had two one-way lanes to the gate, was changed to two two-way lanes. Traffic data prior to the implementation of contraflow was obtained by adding up the traffic volumes on lanes 1, 2, and 3 heading towards campus and lane 4 in the opposite direction towards the gate. The data is presented in Table 1 and Table 2.

Table 1. Traffic Volume Toward Campus Before Contraflow Implementation (in pcu/hour)

Time Interval	HV	LV	MC	Total
06.45-07.45	13	913	1289	2215
07.00-08.00	13	1030	1444	2487
07.15-08.15	13	1002	1395	2410
07.30-08.30	13	835	1025	1873
07.45-08.45	12	644	742	1398
08.00-09.00	12	568	653	1233

Table 2. Traffic Volume from Campus to Pasar Baru Before and After Contraflow (in pcu/hour)

Time Interval	HV	LV	MV	Total
06.45-07.45	3	171	536	884
07.00-08.00	4	216	701	1315
07.15-08.15	5	217	751	1589

07.30-08.30	6	208	700	1744
07.45-08.45	6	189	604	1650
08.00-09.00	6	154	531	1482

Table 3. Traffic Volume on 2/1 UD Lane Toward Campus After Contraflow Implementation (in pcu/hr)

Time Interval	HV	LV	MC	Total
06.45-07.45	10	517	1637	2165
07.00-08.00	9	581	1815	2405
07.15-08.15	8	590	1741	2339
07.30-08.30	7	514	1274	1794
07.45-08.45	5	427	929	1361
08.00-09.00	5	414	832	1251

Table 4. Traffic Volume on 2/2 TT Lane Toward Campus After Contraflow Implementation (in pcu/hour)

Time Interval	HV	LV	MC	Total
06.45-07.45	4	396	532	932
07.00-08.00	5	449	620	1074
07.15-08.15	7	412	614	1033
07.30-08.30	8	321	458	786
07.45-08.45	8	217	324	548
08.00-09.00	8	154	266	427

Traffic Performance Analysis Before the Implementation of Contraflow

Road Capacity Analysis (Before)

Road capacity can be calculated using Equation 2. It is determined based on the basic capacity (C_0), lane width adjustment factor (FCLJ), adjustment factor for PA capacity on undivided road types (FCPA), capacity correction factor owing to KHS on the road (FCHS), and city size adjustment factor (FCUK). According to [reference], these factors can be used to determine the capacity value of a road segment. A road that was originally 4/2 D is considered as two separate road sections in the analysis, namely, a 2/1 UD section and a 2/2 UD section. Because the analysis is conducted separately for the left and right lanes, both roadways become one-way streets on each of their lanes.

Table 4. Road Capacity Calculation before Contraflow towards Campus

Adjustment Factors				
C_0 (PCU/hr)	FCLJ	FCPA	FCHS	FCUK
3400	0,92	1,00	0,94	0,90

Table 4 shows that the adjustment factor for PA capacity on undivided road types (FCPA) is not applicable because FCPA values are intended only for undivided road types, whereas the road capacity calculation before contraflow assumes the use of fast- and low-speed road types (4/2 D). The road capacity calculation can be determined based on Equation (3) as follows:

$$\begin{aligned}
 C &= C_0 \times FCLJ \times FCPA \times FCHS \times FCUK \\
 &= 3400 \times 0,92 \times 1,00 \times 0,94 \times 0,94 \\
 &= 2763,90 \text{ pcu/hr}
 \end{aligned}$$

Capacity after implementation of contraflow are as follows:

$$\begin{aligned}
 C_{2/1UD} &= C_0 \times FCLJ \times FCPA \times FCHS \times FCUK \\
 &= 3400 \times 0,92 \times 1 \times 0,94 \times 0,94 \\
 &= 2763,90 \text{ pcu/hr}
 \end{aligned}$$

$$\begin{aligned} C2/2 \text{ UD} &= C_o \times FCLJ \times FCPA \times FCHS \times FCUK \\ &= 2800 \times 0,87 \times 1 \times 0,90 \times 0,94 \\ &= 2060,86 \text{ pcu/hr} \end{aligned}$$

Degree of Saturation

The degree of saturation and road capacity during peak hours were shown in Table 5 an Table 6.

Table 5. Degree of saturation values before contraflow towards the campus

Time Interval	Volume (Pcu/Hr)	Capacity (Pcu/Hr)	Degree of Saturation
07.00-08.00	2487 (4/2 UD)	2763,90	0,90
07.00-08.00	2907 (2/1 UD)	2763,90	1,05

Table 15 Degree of saturation values for road type 2/2 UD

Time Interval	Volume (Pcu/Hr)	Capacity (Pcu/Hr)	Degree of Saturation
07.00-08.00	1074	2060,86	0,52

Comparison before and after contraflow

Table 6. Comparison of Degree of Saturation Before and After Contraflow

Road type	Before	After
4/2 D	0,90	-
2/1 UD	1,05	0,87
2/2 UD	0,21	0,52

As shown in Table 6, the implementation of contraflow has resulted in a more balanced traffic flow than before the implementation of contraflow. On the left lane, which is a 2/1 UD lane, the degree of saturation decreased from 0.90–1.05 previously to 0.87 afterwards; meanwhile, the degree of saturation on the lane towards the campus gate increased from 0.21 to 0.52.

Prediction of Traffic Volume Growth Impact for The Prediction Years

Referring to a study conducted in 2024, the average number of vehicles entering the Andalas University campus each day is 12,000, comprising 80% motorcycles, 19.35% light vehicles, and 0.65% buses. It is conservatively assumed that the traffic volume growth rate follows the average annual growth of private vehicles at 6%, based on data and trends of increasing numbers of motor vehicles in Indonesia, as recorded by the Central Statistics Agency (BPS) and various other automotive industry sources.

Table 7. Projection of vehicle volume heading to campus in the future

Prediction Year	Volume (Pcu/Hr)	Note
Now	2.405	Peak Hour
Next 3 years (2028)	$2.045 \times 1,06^3 = 2.436$	Increase 1,29 %
Next 5 years (2030)	$2.045 \times 1,06^5 = 2737$	Increase 13,80 %
Next 10 years (2040)	$2.045 \times 1,06^{10} = 3.662$	Increase 52,27 %

Table 8. Projection of vehicle volume from the campus in the future

Prediction Year	Volume (Pcu/Hr)	Note
Now	1.074	Peak Hour
Next 3 years (2028)	$1.074 \times 1,06^3 = 1.279$	Increase 19,09 %
Next 5 years (2030)	$1.074 \times 1,06^5 = 1.437$	Increase 33,80 %
Next 10 years (2040)	$1.074 \times 1,06^{10} = 1.923$	Increase 79,05 %

Road capacity can be determined from previous calculations for road types 2/1 UD and 2/2 UD, where the capacity obtained is 2,763.90 Pcu/hour for the 2/1 UD road type and 2,060.86 Pcu/hour

for the 2/2 UD road type. Table 20 Projection of V/C calculation for the 2/1 UD lane towards the campus in the next 3, 5 and 10 years after contraflow.

Table 9. Projection of V/C calculation for 2/1UD lane toward campus in the prediction years after contraflow

Predicted Year	Volume (Pcu/Hr)	Capacity (Pcu/Hr)	V/C	Note
Now	2.405	2763,90	0,87	Bad
Next 3 years (2028)	2.436	2763,90	0,88	Bad
Next 5 years (2030)	2.737	2763,90	0,99	Bad
Next 10 years (2040)	3.662	2763,90	1,32	Very Bad

Tabel 10. Projection of V/C calculation for 2/1UD lane from campus in the prediction years after contraflow

Predicted Year	Volume (Pcu/Hr)	Capacity (Pcu/Hr)	V/C	Note
Now	1.074	2060,86	0,52	Stable
Next 3 years (2028)	1.279	2060,86	0,62	Stable
Next 5 years (2030)	1.437	2060,86	0,70	Almost Bad
Next 10 years (2040)	1.923	2060,86	0,93	Bad

Discussion

The V/C ratio on the 4/2 D road segment before the implementation of contraflow was 0.90. Looking at the left lane, where a two-lane, one-way undivided road is in effect, the V/C value had even reached 1.05. This value corresponds with the actual conditions in the field before contraflow was implemented, where there was a buildup of vehicles moving very slowly toward the campus. After the implementation of contraflow, part of the traffic volume heading toward the campus shifted to the right lane, leading to a reduction in traffic volume in the left lane (2/1 UD), making the traffic flow smoother and reducing the degree of saturation to 0.87. This means there was a 17% decrease in the degree of saturation. Conversely, in the direction from the campus toward the gate, the traffic volume that previously was only heading toward the gate is now shared with the flow toward the campus and operates as a 2/2 UD road. The degree of saturation, which was previously only 0.28, increased to 0.52.

Overall, the implementation of contraflow has an impact on the road segment because it significantly changes the degree of saturation, as seen from the V/C analysis results. On the 2/1 UD road segment, there was a decrease in the degree of saturation from 1.05 to 0.87 after contraflow was implemented, which means an increase in traffic flow smoothness. On the 2/2 UD road segment, the V/C increased from 0.28 to 0.52 because, after contraflow was enforced, vehicles were moved to the right lane. Meanwhile, on the 4/2 D road segment, V/C was 0.90 before contraflow was implemented, which is relatively lower than the 2/1 UD segment before contraflow. In terms of space utilization, the implementation of contraflow increased the effectiveness of space usage, which was previously relatively unbalanced, making it more balanced. Contraflow is an effective option for reducing the degree of saturation on road segments that are quite congested, especially on those configured as 2/1 UD, by moving/diverting a portion of the vehicles to the adjacent lane that was less utilized.

The current implementation of contraflow can improve traffic performance on these road segments, but prediction results show that in 10 years, the degree of saturation on this road will increase sharply from 0.87 to 1.32. Thus, it can be said that the implementation of contraflow is only effective in the short term, while in the long run, new policies are still needed to control the number of vehicles entering Universitas Andalas at the same time.

CONCLUSION

Based on the research conducted, the results show that the application of Transport Demand Management policy, in this case, the equalization of road space usage through contraflow, is considered effective in addressing traffic congestion problems at the entrance area of Universitas Andalas Limau Manis Campus in a short term. The congestion has been reduced and the level of service of the road is increased. However, in the long term, contraflow becomes increasingly less effective and the level of service will drop into poor or very poor category. The data shows that the number of vehicles is increasing continuously. Without any addition management such as increasing the road capacity or pushing the private vehicle user to reconsider their mode choice, and giving incentive to public transport users, then in the next 5 or 10 years, the degree of saturation will exceed one. Based on the results of this study, it is recommended that the relevant authorities maintain contraflow during peak hours while continuing to seek policies that will offer sustainable solutions to congestion at this gate. One that should be considered is an effort to manage demand through the promotion of Trans Padang public transportation, reducing the use of private vehicle at certain times, providing incentives for public and non-motorized transport users, implementing parking fees, and partial restrictions on the use of private vehicles by certain groups in the academic community, for example, first-year students.

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REFERENCES

- [1] Lim, E., & Wolshon, B.. Modeling and Performance Assessment of Contraflow Evacuation Termination Points. *Transportation Research Record: Journal of the Transportation Research Board*, 1922(1922), 118–128, 2005. <https://doi.org/10.3141/1922-16>
- [2] PKJI. *Pedoman Kapasitas Jalan Indonesia*, No. 21/SE/Db/2023 (Issue 021). 2023.
- [3] Andriansyah. *Manajemen Transportasi dalam Kajian dan Teori*. Jakarta: Fakultas Ilmu Sosial dan Ilmu Politik Universitas Prof. Dr. Moestopo Beragama. 2014.
- [4] Broaddus, A., Litman, T., & Menon, G. *Manajemen Permintaan Transportasi. Sustainable Transport: A sourcebook for policy-makers in Developing Cities* 9-49. <http://www.sutp.org>. 2009.
- [5] Farahmand, Z. H., Gkiotsalitis, K., & Geurs, K. T. Mobility-as-a-Service as a transport demand management tool: A case study among employees in the Netherlands. *Case Studies on Transport Policy*, 9(4), 1615–1629. <https://doi.org/10.1016/j.cstp.2021.09.001> 2021.
- [6] Huan, N., Hess, S., & Yao, E. Understanding the effects of travel demand management on metro commuters' behavioural loyalty: a hybrid choice modelling approach. *Transportation*, 49(2), 343–372. 2021. <https://doi.org/10.1007/s11116-021-10179-3>
- [7] Pradana, M. F. Pendekatan Transportation Demand Management sebagai Pengurai Kemacetan di Kota Serang dan Kota Cilegon. 2014. <https://www.researchgate.net/publication/331564504>
- [8] Babapourdijojin, M., Corazza, M. V., & Gentile, G. Systematic Analysis of Commuting Behavior in Italy Using K-Means Clustering and Spatial Analysis: Towards Inclusive and Sustainable Urban Transport Solutions. *Future Transportation*, 4(4), 1430–1456. 2024. <https://doi.org/10.3390/futuretransp4040069>
- [9] Cohn, J., Ezike, R., Martin, J., Donkor, K., Ridgway, M., & Balding, M. Examining the Equity Impacts of Autonomous Vehicles: A Travel Demand Model Approach. *Transportation Research Record: Journal of the Transportation Research Board*, 2673(5), 23–35. 2019. <https://doi.org/10.1177/0361198119836971>

- [10] Piras, F., Sottile, E., & Meloni, I. Modal Share Change following Implementation of Travel Demand Management Strategies. *Transportation Research Record: Journal of the Transportation Research Board*, 2672(8), 731–741. 2018. <https://doi.org/10.1177/0361198118773195>
- [11] Guo, S., Zhou, D., Fan, J., Tong, Q., Zhu, T., Lv, W., Li, D., & Havlin, S. Identifying the most influential roads based on traffic correlation networks. *EPJ Data Science*, 8(1). 2019. <https://doi.org/10.1140/epjds/s13688-019-0207-7>
- [12] Pan, Y. (Annie), Cheng, Q., Li, A., Zhang, J., Guo, J., & Chen, Y. Analysis of congestion key parameters, dynamic discharge process, and capacity estimation at urban freeway bottlenecks: a case study in Beijing, China. *Transportation Letters*, 17(6), 984–1003. 2024. <https://doi.org/10.1080/19427867.2024.2404349>
- [13] Samal, S. R., Gireesh Kumar, P., Cyril Santhosh, J., & Santhakumar, M. Analysis of Traffic Congestion Impacts of Urban Road Network under Indian Condition. *IOP Conference Series: Materials Science and Engineering*, 1006(1), 012002. 2020. <https://doi.org/10.1088/1757-899x/1006/1/012002>
- [14] Jha, M. K., Jaiswal, R., Varma, D. S. K., Rankavat, S., Bachu, A. K., & Jha, P. K. A Machine Learning Approach to Traffic Congestion Hotspot Identification and Prediction. *Future Transportation*, 5(4), 161. 2025. <https://doi.org/10.3390/futuretransp5040161>
- [15] Cruz, L., Barata, E., Ferreira, J.-P., & Freire, F. Greening transportation and parking at University of Coimbra. *International Journal of Sustainability in Higher Education*, 18(1), 23–38. 2017. <https://doi.org/10.1108/ijshe-04-2015-0069>
- [16] Taylor, B. D., & Fink, C. N. Y. Explaining transit ridership: What has the evidence shown? *Transportation Letters*, 5(1), 15–26. 2013. <https://doi.org/10.1179/1942786712z.0000000003>
- [17] Bakibillah, A. S. M., Kamal, M. A. S., Susilawati, S., & Tan, C. P., *The Optimal Coordination of Connected and Automated Vehicles at Roundabouts*. 2019. <https://doi.org/10.23919/sice.2019.8860072>
- [18] Hausknecht, M., Au, T. C., Stone, P., Fajardo, D., & Waller, T. (Dynamic lane reversal in traffic management. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, 1929–1934. 2011. <https://doi.org/10.1109/ITSC.2011.6082932>
- [19] Pyakurel, U., Nath, H. N., & Dhamala, T. N. Partial contraflow with path reversals for evacuation planning. *Annals of Operations Research*, 283(1–2), 591–612. 2018. <https://doi.org/10.1007/s10479-018-3031-8>
- [20] Zhao, J., Liu, Y., & Wang, T. Increasing Signalized Intersection Capacity with Unconventional Use of Special Width Approach Lanes. *Computer-Aided Civil and Infrastructure Engineering*, 31(10), 794–810. 2016. <https://doi.org/10.1111/mice>