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Transportation Network Connectivity in Nusa Cendana University Campus Environment

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Abstract. The objectives of this research are, (1) To determine the connectivity index of the transportation network in the Undana campus environment, and (2) To determine and increase the level of efficiency of traffic movements in supporting the accessibility needs of transportation users in the Undana campus environment. campus environment. The method used is a quantitative descriptive method which is used to analyze data by describing or illustrating the data that has been collected as it is. The results of the analysis in this research are, with the beta index value (β) of 1.05 indicates that road network connectivity is not arranged linearly or simply. Meanwhile, the gamma index (γ) value of 0.38 indicates that the condition of transportation network connectivity is still low. Therefore, infrastructure planning is proposed as a solution to increase the mobility and connectivity index values. Several traffic engineering management scenarios are proposed based on the results of the analysis, namely widening roads, limiting public transportation, scheduling traffic movement activities, improving the safety of traffic signs, encouraging the use of public transportation by providing temporary stops, and monitoring traffic. engineering management.

Keywords: Connectivity, Transportation Network, Traffic Engineering Management.

1. Introduction

Kupang City, the capital of Nusa Tenggara Timur Province, spans an area of 180.45 km^2 and has a population of 468,913 people. As one of the largest cities in NTT, Kupang City is experiencing significant development, evidenced by the ongoing infrastructure projects throughout the area [1], [2]. According to Bolla et al. [3] the development in Kupang City has led to an increased use of both private and public transportation. The progress and growth of a region are closely tied to the availability of adequate transportation. Transportation not only facilitates the movement of people and goods but also enhances accessibility and connectivity between regions [4], [5]. Improved transportation infrastructure leads to better network connectivity, which in turn improves accessibility between spaces—an important factor for the movement of people and goods across different areas. A higher accessibility index promotes faster movement of people and goods, which is particularly beneficial in sectors such as education.

Nusa Cendana University (UNDANA) is a prominent state university located on Jalan Adi Sucipto, Penfui, Kelapa Lima, Kupang City, East Nusa Tenggara Province [6]. As the first state university in NTT, it attracts students from various regions and cities, reflected in the annual increase in student enrollment. Currently, the university has approximately 33,689 students, 1,320 lecturers, and over 600 educational staff members. The UNDANA campus covers an area of 104 hectares and includes 9 faculties and a postgraduate program. These faculties are interconnected through both academic and non-academic activities and include the Faculty of Teacher Training and Education, the Faculty of Science and Engineering, the Faculty of Social and Political Sciences, the Faculty of Animal Husbandry and Marine Fisheries, the Faculty of Law, the Faculty of Agriculture, the Faculty of Medicine & Veterinary Medicine, the Faculty of Public Health, and the Faculty of Economics and Business.

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The limited transportation options connecting the 9 faculties and the Postgraduate Program within the university impact the activity patterns of students, employees, campus management staff, and the community. This limitation also slows down the movement of people and goods within the campus environment. Located in the lowlands, UNDANA benefits from a flat topography, which facilitates the movement of people and goods since the terrain is not hilly or uneven, thus not obstructing mobility. However, despite the flat terrain, the current transportation modes within the campus are still limited. Transportation is crucial for spatial interactions between regions and is vital in supporting regional development processes [2], [5], [6]. Areas with diverse geographical conditions require an integrated transportation system to meet the community's needs. Essentially, transportation systems are developed to connect different land use locations, enabling the movement of people and goods from one place to another and thereby fostering economic growth [7], [8]. The main goal of transportation is to create efficient and safe connectivity between various locations, facilitating human movement, trade, and social interaction. An effective transportation system aims to provide efficient connectivity between different places and regions.

According to Li et al. [9], connectivity is defined as the number of different road network connections or nodes that facilitate travel from the starting point to the final destination. This connectivity is influenced by the number of intersections along the road and the overall integration of the area into a transportation network system. It involves providing multiple routes to move from the starting point to the final destination, utilizing land, sea, or air transportation. In this context, transportation network connectivity refers to the availability and accessibility of interconnected transportation facilities that enable efficient mobility from one place to another. Good transportation network connectivity not only provides easy accessibility between regions but also accelerates the mobility of goods and people, thereby boosting economic growth in the region. Akhmad Zhang et al. [10] also emphasize that connectivity is a characteristic component in a graph that indicates the level of interaction between points or the number of nodes in a graph. Barrientos et al. [11] assert that transportation network connectivity is a crucial element in the public transportation service system of a region or city. A well-integrated intermodal public transportation network is supported by comprehensive route coverage, schedules tailored to the movement needs of people and goods, and seamless integration of physical infrastructure, multimodal transfer points, service routes/ schedules, and service tariffs.

Transportation network connectivity is a key aspect of accessibility, which is a critical element of the transportation system. An inefficient transportation system can negatively impact the performance and productivity of campus residents, leading to issues such as tardiness, difficulty in reaching destinations, and prolonged travel times [9], [12]. Moreover, a poor transportation system can also adversely affect the environment and the community around the campus, resulting in congestion, air pollution, and safety concerns. The campus, being a densely populated area with high activity and mobility from students, lecturers, staff, guests, and the surrounding community, experiences significant transportation use. This extensive use of transportation leads to various traffic performance issues on campus, including congestion, road service levels, speed, and density on heavily trafficked roads.

Given the increasing number of people engaging in activities within the campus environment, addressing these transportation problems necessitates effective traffic engineering management within the Undana campus. This research represents a collaborative effort between lecturers and students to tackle these transportation challenges.

2. Method

This research was conducted in the Undana campus area, located in Lasiana Village, Kelapa Lima District, Kupang City. The study employed a quantitative descriptive approach, which is used to analyze data by describing or depicting the collected data as it is. The focus of the study was on 10 key nodes in the campus road network. The required data included primary data consisting of geometric road data, traffic volume, speed, and traffic density. Secondary data comprised information sourced from literature, including books and journals. Data collection methods involved field observations and documentation of study objects during the research period. The data analysis technique employed in this research was quantitative, which included calculating transportation network connectivity indices and analyzing traffic engineering management through road network performance, presenting descriptive statistics based on the collected numerical data.

3. Result and Discussion

3.1 Transportation Network Connectivity in Undana Campus Environment

Connectivity within the Undana environmental area depends on regional conditions, which vary in their characteristics, including the types of transportation services available on campus. Current issues in the campus environment include a lack of optimal integration between different modes of transportation, particularly in terms of guidelines for public transportation modes regarding connectivity and accessibility services. The condition of transportation facilities and infrastructure often fails to provide adequate accessibility, hindering the connection between the road network and transportation modes. Therefore, for the campus area, the connectivity index for the road network is an important indicator. This index measures connectivity per node within the road network of the campus. A higher index value indicates a greater number of road networks connecting each network node [13].

Based on observations in the Undana campus environment, research on road network connectivity identified twenty-one road network segments and twenty nodes, as illustrated in the following map image in Figure 1. Based on Figure 1 above, the results of a Network Analysis are presented, using a method that facilitates finding routes or directions within road networks to create an effective transportation network. An interconnected road network, consisting of lines (edges) and connecting intersections (vertices), links various routes from one destination point to another using ArcGIS 10.3 software. The roads on the Nusa Cendana University (Undana) campus are described as follows: The first road stretches from the entrance gate to the rear security post, while the second road section leads to the Rectorate Building and ICT Center. The third road section connects the Auditorium intersection with the exit, and the fourth road section stretches from the intersection of the Faculty of Teacher Training and Education (FKIP) to the intersection of the Faculty of Science and Technology (FST). The fifth road is located in front of the Auditorium Building. The sixth road section connects the *Lembaga Penelitian dan Pengabdian kepada Masyarakat* (LP2M) intersection to the Auditorium, and the seventh road connects the Faculty of Public Health (FKM) with FST.

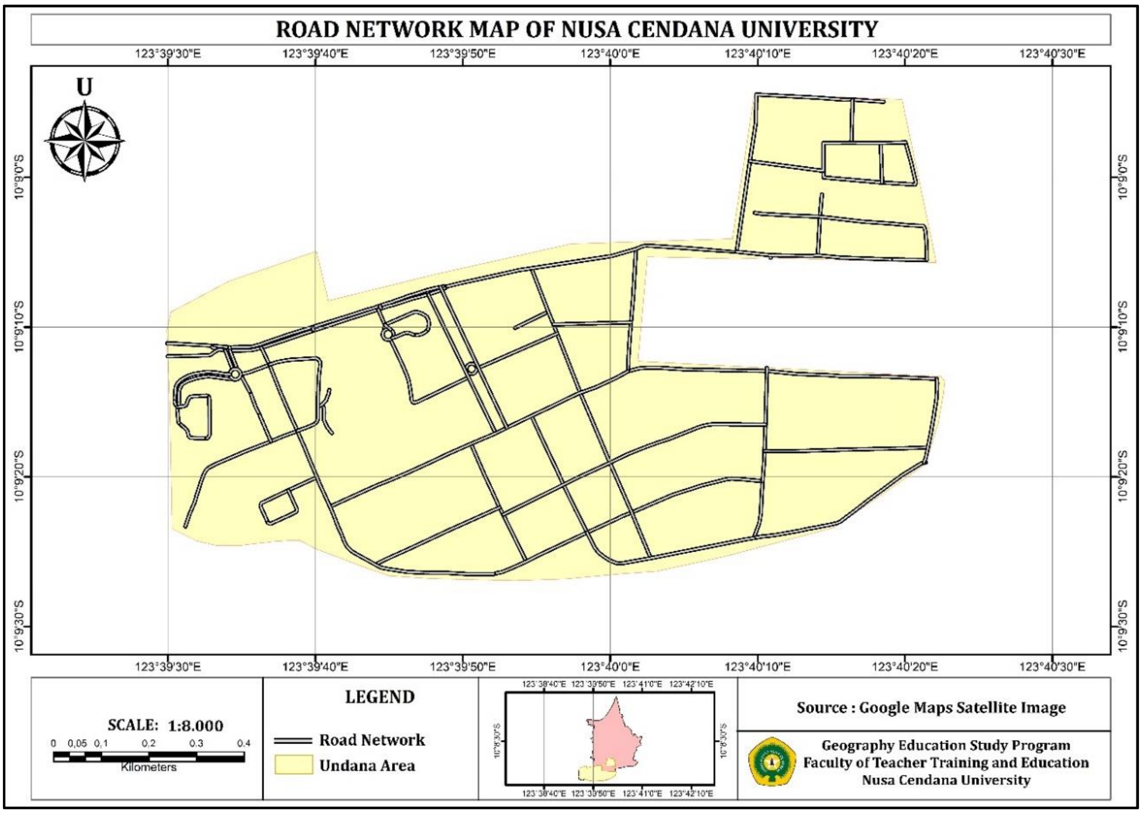

Figure 1 Map of Road Sections and Nodes in the Undana Campus Environment

The eighth road stretches from the back security post to the front of the Old Faculty of Medicine and Health Sciences (Old FKP), while the ninth road section connects the intersection of the FST Mechanical Engineering Study Program with the Faculty of Agriculture (FAPERTA). The tenth road section also connects the FST intersection with FAPERTA, and the eleventh road runs from behind the FST to the security guard post at the back gate of Undana. The twelfth road section connects the Old BAK Building with the Mechanical Engineering Study Program, and the thirteenth road section stretches from the Computer Center (PUSKOM) to the FST intersection. The fourteenth road section continues from point eleven to the corner of the Kupang Agricultural Polytechnic (Politani) campus. The fifteenth road stretches from the front of the FKIP building to the LP2M building, and the sixteenth road is in the FKIP and Faculty of Economics and Business (FEB) area. The seventeenth road connects two intersections leading to FKIP to the road in front of the Civil Engineering Study Program Building. The eighteenth and nineteenth roads lead to the Teacher Professional Education (PPG) Campus and the Veterinary Medicine Study Program. The twentieth road section continues from point seventeen (in front of the Civil Engineering Study Program Building) to point fourteen (corner of the Politani Campus). Finally, the twenty-first road section is within the PPG Campus and Veterinary Medicine Study Program area.

All these roads play an essential role in connecting various facilities and buildings on the Undana campus, facilitating mobility and accessibility for students, lecturers, and staff. This extensive network ensures that the academic and non-academic community can easily move from one place to another. The connectivity index of the campus road network is analyzed based on the number of road segments and nodes, using the Beta (β) and Gamma (γ) indices as described by Zanandrea et al. [14]. The results show that the connectivity index value for the Undana campus environment is 21 edges, 20 vertices, a Beta Index of 1.05, and a Gamma Index of 0.38. Transport network connectivity refers to the extent to which a region or system is well connected between various transport infrastructures, facilitating the movement of people and goods from one place to another

[15]. According to Ogryzek et al. [16], the connectivity of an area is influenced by the location and efficiency of road construction. This construction is not fixed to a strict or centralized plan but instead follows the needs and conditions of a place, often requiring adjustments to the area's topographic conditions. Based on the results of the Undana topographic map overlay, the university is located at a relatively low altitude, making connectivity within the campus crucial for road and transportation route accessibility. The slopes, inclines, or sharp bends can significantly affect the proper layout of roads or transportation routes.

Strengthening the connectivity system is necessary for development to ensure transportation network activities function efficiently, thereby supporting the development of transportation accessibility. A connectivity system comprises interconnected transportation facilities that enable efficient mobility from one place to another. The results of the connectivity index analysis reveal the following the analysis indicates that the level of connectivity between nodes in the transportation network within the Undana campus is complex, as evidenced by a beta index value (β) of 1.05 and a gamma index (γ) of 0.38. A beta index value greater than 1 signifies a highly irregular and complex road network with numerous intersections, indicating significant connectivity between elements in the network. This complexity implies that the road network is not organized linearly due to many irregular turns, intersections, and branching paths. A beta index value of 1.05 suggests numerous alternative routes and roads are available, but it also introduces navigation complexity, meaning there are multiple paths or routes to reach a particular destination. Conversely, a gamma index value of 0.38 indicates that the road network is not well connected, and accessibility remains challenging. The low gamma value suggests inefficient routing and difficulty in achieving good connectivity within the network. Consequently, transportation users in the Undana campus environment still face difficulties in navigating the area. The road network infrastructure on the campus is insufficient, resulting in suboptimal connectivity on environmental roads. As human mobility increases, there will be a need for traffic engineering scenarios to address these issues. Several factors contribute to the low levels of connectivity, including: (1) lack of integration between modes of transportation, such as campus buses, (2) insufficient transportation networks to accommodate traffic volume, (3) absence of clear road signs or traffic signals to guide transportation users.

These factors indicate that inadequate policies related to improving road network accessibility are a primary cause of weak connectivity in the transportation system. Furthermore, the availability of transportation facilities and infrastructure must be enhanced. Despite low accessibility for transportation users and pedestrians, the impact on traffic characteristics improvement is minimal. Therefore, in the Undana campus area, implementing a connectivity scenario is essential to achieve optimal development goals. This scenario should include integrated infrastructure planning to facilitate easy mobility from one place to another. Hence, the current low level of transportation network connectivity necessitates effective traffic engineering management.

3.2 Traffic Engineering Management at Undana

The research focused on twenty network nodes, from which ten were selected as key reference points for managing traffic engineering. These ten nodes are frequently used by transportation users to connect different road network segments, facilitating movement to their destinations. For these ten road segments, data was collected on road length, effective width, traffic flow, and sidewalks. This inventory serves as the basis for determining vehicle volume, speed, and density in traffic engineering management. The study observed the distribution of location points on the road network during three critical periods: before active lectures (when new students begin their courses), during active lectures (when the entire academic community is present), and during graduation and other events. The research map below illustrates the distribution of these observed location points within the campus environment. Data was collected during peak hours or specific moments to understand movement patterns and density on the road network. This approach helps in identifying traffic flow and congestion areas, enabling more effective traffic management strategies.

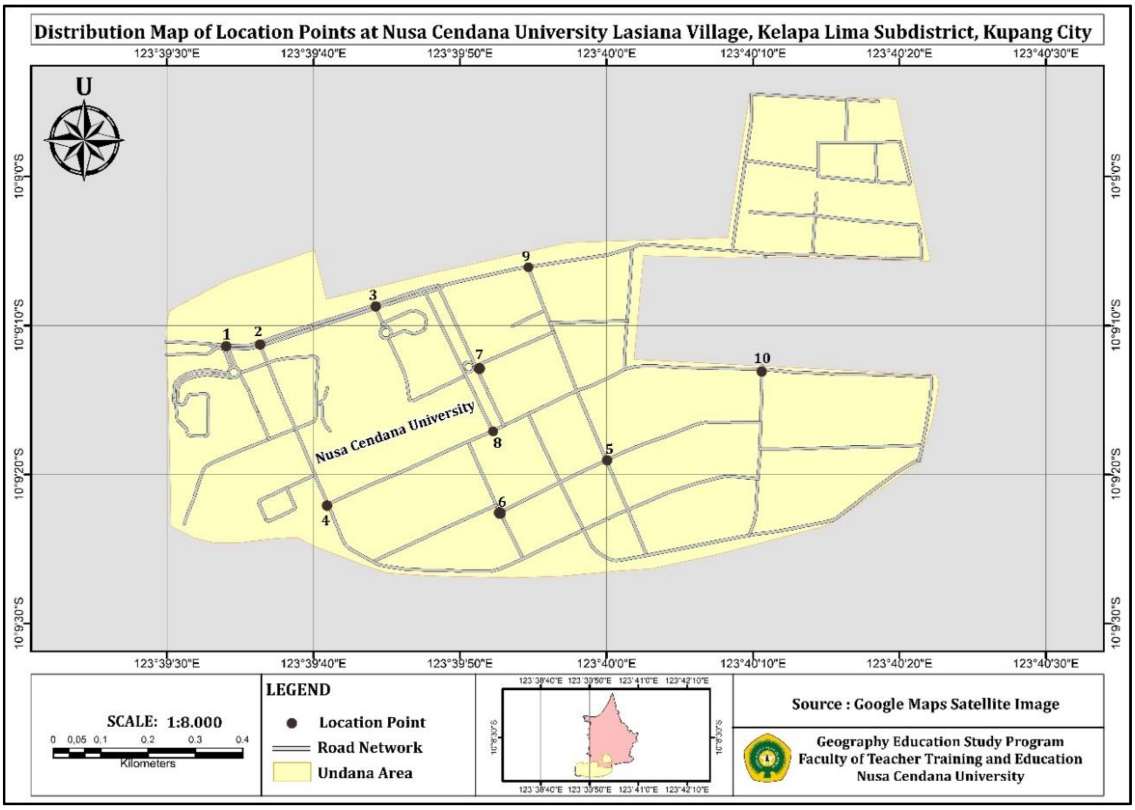

Figure 2 Research Map of Location Point Distribution

Table 1 Inventory of Undana Road Sections

street name	Road type	Flows	Road length (m)	Effective Path (m)	Sidewalk width Left pm	Sidewalk width Left l	Sidewalk width Correct pm	Sidewalk width Correct l
Entrance gate point 1	2/2 UD	2	941 m	5	941	2.10	223	1.32
Point 2 of the road to FKIP	2/2 UD	2	831 m	5.32	841	2.73	841	2.73
Point 3 goes to the Auditorium	2/2 UD	2	320 m	4.20	-	-	320	1.70
The fourth point on the road to LP2M	2/2 UD	2	267 m	4.90	267	1.70	267	1.70
Fifth point on the road to FST	2/2 UD	2	974 m	5.20	-	-	-	-
The sixth point of the road between the intersection in front of the FKIP Hall	2/2 UD	2	267 m	4.90	267	1.70	267	1.70
The seventh point of the road in front of the Auditorium Building	2/2 UD	2	320 m	4.20	-	-	320	1.70
The eighth point on the road between the LP2M intersection and the Auditorium	2/2 UD	2	320 m	4.20	-	-	974	2.73
Ninth point on the road in front of FKM	2/2 UD	2	548 m	6.20	269	3.10	2.69	3.10
Point ten on the road to the Polytechnic	2/2 UD		240 m	7	240	2.27	240	2.27

Note: The road function is used for the environment

The road sections discussed are the primary access routes used by both academic and non-academic members of the Undana community. These roads vary in infrastructure characteristics, such as road length and width, which were obtained from road inventory surveys. Notably, the road sections with the smallest effective width of 4.20 meters are the third point towards the Auditorium, the seventh point in front of the Auditorium, and the eighth section between the intersection leading to LP2M and the Auditorium. The traffic volume on roads in the Undana area was measured using a traffic count survey (Traffic Counter) conducted during three key periods: before active lectures (when new students begin their courses), during active lectures (when the entire academic community is present), and during graduation and other events. The traffic volume was recorded from 07:30 AM to 05:00 PM and included motorbikes/motorcycles (MC), light vehicles (LV), and heavy vehicles (HV).

To convert traffic volume from vehicles per hour to passenger cars per hour (pcu/hour), the number of vehicles passing the observation point within one hour, including motorbikes, light vehicles, and heavy vehicles, was counted. The traffic volume data was then converted to passenger car units per hour (pcu/hour) using the 1997 Indonesian Road Capacity Manual (MKJI) standards. This calculation is based on the equivalent number of passenger cars (EMP) for two-lane urban roads with a total two-way traffic flow of ≥1800 vehicles per hour.

Table 2 Calculation table for total passenger car equivalent (EMP)

Road Type	Total two-way traffic flow (Kend/H)	LV	Emp (Equivalent to Passenger Car) H.V	MC
Two undivided paths	0	1.0	1.3	0.4
(2/2 UD)	≥ 1800		1,2	0.25
Four undivided paths	0		1.3	0.4
(4/2UD)	≥ 3700		1,2	0.25

Note: Light Vehicle (LV) is 1.0; Heavy Vehicles (HV) of 1.2; and motorbikes/motorcycles (MC) of 0.25

The following is the average vehicle volume/hour with passenger cars in 10 hours per day obtained from the results of road network performance analysis:

Table 3 Calculation Results Using Momentum

No	Point name	Momentum: Before starting college q = n/t Kend/hour	Middle School / Hours	Active Lectures q =n/t Kend/Hour	Middle School / Hours
1.	Section I	1,543.12	498	1,688.12	519.16
2.	Rus II	1,251.12	381.5	1,569	483.25
3.	Street III	472.62	142.71	697.87	224.69
4.	Street IV	165.62	54.18	254	98.6
5.	V Street	276.87	102.4	334.25	101.03

Based on Table 3, the highest number of vehicles passing through the first road section (entrance) occurs during the period before active lectures, from 07:00 to 17:00, totaling 1,543.12 vehicles per hour (Kend/hour), equivalent to 498 Passenger Car Units per hour (PCU/hour). This peak traffic volume reflects the influx of new students at the start of the academic year, indicating significant movement of motorbikes and light vehicles entering the campus. Road speed data was collected through speed surveys using Moving Car Observers (MCO) at various points on the Undana campus roads. Speed measurements were conducted during three key periods: before active lectures (at the beginning of new student orientation), during active lectures (when the entire academic community is present), and during graduation and other events. Unfortunately, the specific speed values at each point on the Undana roads are not provided in the query.

Table 4 Calculation results using the following formula

No	Point Name	Speed (Km/h)	
		Before Actively Studying	Active Lectures
1.	Section I	7.78	7.40
2.	Section II	9.51	8.67
3.	Section III	11.22	8.57
4.	Section IV	8.74	8.38
5.	Section V	9.64	10.44

Based on Table 4, the speed data for two different periods indicate that before active lectures, the highest speed was recorded in the third section from 07:00 to 17:15, reaching 11.22 km/hour, while the lowest speed was on the first section at 7.78 km/hour. This variation in speed reflects the traffic dynamics where higher speeds are observed in sections with lower traffic volumes, such as the third section leading towards the Auditorium, compared to the congested first section which serves as the main entrance and experiences heavier traffic. Comparing average speeds from morning (07:00) to afternoon (17:00), differences are noted across different sections during each period. Before active lectures, the highest average speed is found in the third section due to reduced traffic volume compared to the first and second sections. Conversely, the first section exhibits lower speeds because it handles traffic entering from outside the campus. During active university periods, the fifth section shows the highest speed of 10.44 km/hour from 07:00 to 17:00, attributed to traffic dispersing from the entrance towards subsequent sections, though speeds remain relatively low across the first four sections.

Graduation periods show a different pattern where the fourth section towards LP2M records the highest average speed due to reduced traffic from preceding sections, although traffic disperses towards the fifth section leading to FKIP. Conversely, the seventh and eighth sections have the lowest speeds at 5.17 km/hour as they are endpoint destinations with high traffic volumes. Density calculations for each road section are derived from dividing traffic volume (converted to passenger car units) by speed for each specific period: before active lectures, during active lectures, and during graduation events. This density metric provides insights into traffic flow efficiency and congestion levels across different segments of the Undana campus road network. The following is the density on each road section in the Undana area as follows:

Table 5 Density calculation results

No	Point Name	Density (K = q/u)	
		Before actively studying	Learn actively
1.	Part I	198.34	228.12
2.	Part II	131.55	180.96
3.	Part III	42.12	81.43
4.	Part IV	18.94	30,31
5.	Part V	28.72	32.01

Based on Table 5, it is evident that the road section with the highest density varies depending on the period observed. Before active lectures, the first road section exhibits the highest density at 198.34 vehicles per hour, whereas the lowest density is recorded on the fourth road section at 18.94 vehicles per hour. During active lectures, the highest density shifts to the first road section again, reaching 228.12 vehicles per hour, while the fifth road section has the lowest density at 32.01 vehicles per hour. According to the Indonesian Minister of Transportation Regulation No. 96 of 2015, Traffic Management and Engineering encompass planning, procurement, installation, regulation, and maintenance of road equipment facilities aimed at ensuring security, safety, order, and smooth traffic flow.

Based on the findings from traffic performance research, several activities are necessary, including planning, regulation, engineering, empowerment, and supervision, to address traffic issues and formulate traffic policy recommendations in the campus environment. As noted by Li et al. [9], optimizing existing facilities and infrastructure is crucial for improving road network performance in any area. Analyzing vehicle volume data before, during, and after active classes reveals distinct patterns. During the entry of new students (MaBa), the first section experiences high vehicle volumes, particularly motorbikes and light vehicles, due to suboptimal vehicle movement management at the start of the academic year. When classes are in session, vehicle volumes increase overall, reflecting typical academic and non-academic activities across the campus. Conversely, during graduation ceremonies and other events, there is a significant surge in vehicle volume, especially noticeable in the first and second sections leading to FKIP, coinciding with the large attendance at such events.

These fluctuations highlight specific traffic patterns influenced by time of day and campus events. Understanding these patterns is essential for devising effective traffic management strategies, particularly to anticipate and manage high vehicle volumes during critical times. Regarding speed data, variations are observed depending on the period studied. At the start of the academic year (MaBa), the third section enjoys the highest speed due to lower vehicle volumes diverted from the congested first and second sections. Conversely, the lowest speeds are recorded at the first section (entrance), which handles significant traffic inflow from outside the campus. During active academic periods, the fifth section records the highest speed as traffic spreads out from the congested initial sections. However, speeds across these sections remain relatively low due to sustained high vehicle volumes. These insights underscore the need for tailored traffic management strategies that account for distinct traffic dynamics during different times and events at Undana campus.

During graduations and other events, the fourth section towards LP2M shows the highest speed due to reduced traffic flow from preceding sections, allowing for increased speed levels. Conversely, the seventh and eighth sections exhibit the lowest speeds because they serve as final destination points, accumulating dense traffic and resulting in slower speeds. This highlights the importance of understanding vehicle speed patterns across campus during different events and times to enhance traffic management strategies, such as implementing specific parking patterns, dedicated lanes, or expanding road capacity in congested sections to alleviate traffic and improve overall mobility [17]. Analyzing traffic density data across various moments reveals significant insights. The first road section (entrance) consistently exhibits the highest density across all observed periods. This section remains a focal point due to its role as the primary access point for all campus activities, including new student arrivals, regular academic sessions, and major events like graduations. The high traffic density here is attributed to the continuous influx of vehicles engaged in campus mobility.

Conversely, the fourth and fifth road sections consistently display lower densities. This can be attributed to reduced vehicle volumes either due to traffic distribution or because these sections serve as exit routes from the campus. The contrast in density between the first section and others underscores the variability in traffic patterns and community activities depending on the specific events and activities occurring on campus. Understanding these density dynamics is crucial for effective traffic management planning to optimize campus mobility and ensure smoother traffic flow.

4. Conclusion

Based on the research conducted, several conclusions can be drawn, namely that transportation network connectivity in the Undana campus environment is still low and needs to be improved to achieve optimal development goals. Integrated infrastructure planning is needed to ensure smooth mobility in the campus area. Traffic engineering management strategies are needed to reduce traffic volumes and avoid congestion at times of high volume, with several techniques such as widening roads, limiting vehicles, scheduling traffic movement activities, providing temporary stopping points for public transport users, and monitoring traffic. cross. engineering management. It is hoped that these efforts can increase the connectivity index value and support the success of development in Undana in the future. The local government, through the transportation department, is carrying out an outreach program to convey policies related to transportation to the Undana campus community. The goal is so that people can know and manage transportation well.

5. Author's Declaration

Author contributions and responsibilities - The authors made major contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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Availability of data and materials - All data is available from the author.
Competing interests - The authors declare no competing interests.
Did you use generative AI to write this manuscript? - I do not use AI assistance in my manuscript.
Declaration of generative AI and AI-assisted technologies in the writing process - During the preparation of this work the author did not use AI to write, edit, or other things related to the manuscript.

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