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Traffic Impact Analysis of the Development of the Simalungun Regency Trade Market

Anggiat Sinurat[1], M. Arief Kurniawan[2], Pawer Darasa Panjaitan[3], Rudi Salam[4], Juniar Batubara[2], Bilson Panjaitan[2]
[1]Postgraduate Program, Universitas Simalungun Pematangsiantar, Indonesia
[2]CV Polo Consultant Medan, Indonesia
[3]Faculty of Economics, Universitas Simalungun, Indonesia
[4]Faculty of Social and Political Sciences, Universitas Medan Area Medan, Indonesia

Abstract. *This study aims to analyze the magnitude of the impact or influence caused by the Trading Market development activities, which can affect traffic performance in the surrounding area so as to minimize the impact on traffic disruption. This study uses initial calculations carried out to find the peak hour (pcu/hour), namely by changing the traffic volume data that is still in units of vehicles/hour, then multiplied by the passenger car equivalent factor (pcu). The value of the passenger car equivalent factor (pcu) refers to the Indonesian Road Capacity Guidelines (PKJI) 20223. The results show the degree of saturation of the new market road segment 2 at the highest peak hour of the existing condition is 0.55, during the construction period of 2024 is 0.60. During the operational period of 2025 is 0.57 and the prediction of 5 (five) years in 2030 is 0.67. The degree of saturation of the new market road segment 1 at the highest peak hour of the existing condition is 0.08, during the construction period of 2024 is 0.09. During the operational period of 2025 is 0.09 and the prediction of 5 (five) years in 2030 is 0.11. The degree of saturation of the Rajamin Purba road segment 1 at the highest peak hour of the existing condition is 0.86, during the construction period of 2024 is 0.88, During the operational period of 2025 is 0.89 and the prediction of 5 (five) years in 2030 is 1.05. The degree of saturation of Rajamin Purba road segment 2 during the highest peak hour in existing conditions is 0.86, during the construction period in 2024 it is 0.91, during the operational period in 2025 it is 0.88 and the 5 (five) year prediction in 2030 is 0.99.*

Keywords: *Traffic Impact Analysis, Market, Road Performance, Road Section*

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INTRODUCTION

The transportation infrastructure is a vital part of the spatial, economic, and social life of regions and cities. Roads, especially, are not only physical facilities which are used to provide movement but the structural core of the territorial integration, economic circulation, and social interaction. Good infrastructure enables mobility of both the resident and the migrant population, and as a result, access to employment, services, markets, and social networks, and therefore, it has a direct impact on the trends of regional development and urban growth (Lin et al., 2017; Nyakabawu, 2023; Murzakulova et al., 2024).

As observed in most of the developing and urbanising areas an assessment of road networks and their quality and performance still remains a crucial determinant of whether economic development is converted into widespread social good or rather leads to new forms of congestion, inequality, and spatial disintegration.

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Road networks are thus core in the development of a region or city and the development of road networks is hierarchically categorized based on their level of service and functionality. Indeed, road networks, as highlighted by Meijers et al. (2018), are complex systems whose major purpose is not to only connect cities administratively and economically, but also to organize the movement in cities and peri-urban regions. By performing this structuring role, road networks determine patterns of accessibility, condition land-use choices, and finally predetermine the spatial logic of development per se. On this point, roads do not simply mirror the development, they actively engage in the creation and orientation of the development.

Roads serve as the primary source of the transportation of people and goods, which in turn contribute to the economic activity of the country and region as a whole (Tzonevska, 2023; Onokala & Olajide, 2020). Nonetheless, to be effective in this mission, the performance of the roads needs to be defended against the unwanted addictions and growth in demand that is not controlled. The road systems that are congested to an extent that they cannot sustain their operational functions turn into a delayer, inefficiency and social cost generator. This is why barriers and disruptions of the roads and intersections should be reduced by proper organization, control, and care (Chen & Englund, 2015; Namazi et al., 2019). This is not limited to purely technical traffic engineering issues but is in the realm of urban government and developmental control.

This, in turn, leads to the need to plan, monitor, and manage the process of urban and regional development to be able to predict the magnification of the community activities and the mobility demands that they are associated with (Suchyadi et al., 2020; Seibert et al., 2017; Lu et al., 2020). This kind of cumulative impact of individual development project can slowly undermine the functional integrity of the road network without such an anticipatory control, even though individual development projects may seem reasonable when considered individually. The accretive and frequently tardy character of the transport system degradation is one of the focal issues of modern urban and regional planning.

The development and transformation of urban areas and land use remain dynamic through time with respect to the pressures of demographics, restructuring of the economy, and the policies adopted by regional and central governments (Wagner & de, 2019; Qian et al., 2015; Banzhaf et al., 2017; Onur & Tezer, 2015; Debolini et al., 2015; Kalfas et al., 2023). A very prominent example of this development is the reshaping of land into new centres of activity, such as commercial, service, and public-facility complexes. These changes are not just spatial or architectural shifts but a rearrangement of the everyday circulation patterns, relations of access and functional hierarchies at the city system.

The emergence of primary activity centres, be it as commercial hubs, markets, or service complexes, is bound to change the space structure of the location of these centres (Zhong et al., 2017; Krehl et al., 2016; Zhu & Sun, 2017). These changes are due to the fact that activity centres are focal points of attractiveness, which creates and attract trips in several directions and on several scales. As a result, the transport network around it needs to be able to absorb not only more of the movement but new space patterns and demand time patterns. It has been demonstrated by Zhao et al. (2022) and Liu et al. (2022) that the shift in the urban spatial structure directly and frequently significantly influences the patterns of movement that become a strain to the current road networks. Practically, any organized growth of activities and businesses in a specific location yields traffic effects that are not limited to the immediate locale, but also on the transport system surrounding the immediate location (Fraedrich et al., 2019; Aljohani & Thompson, 2016).

All these effects are not insignificant and all depend on the scale, type, and magnitude of the development, however, they are never insignificant. According to Grote et al. (2016) and Brown & Van (2017), these effects should be expected and treated with due care to ensure that urban areas and regions will not decline in movement and environmental standards in the long term. In this larger context, the building of business centers takes a rather sensitive place. Markets, shopping centers, trade complexes are the strongest sources and attractors of daily journeys, in particular, in those areas where they also play the role of social and service centers. Although these facilities bring significant economic life to the local areas, they also create significant burden on the transport infrastructure, and they tend to focus traffic on certain routes and cross-sections. In case these requirements are not properly incorporated in network planning, the result is a gradual but steady deterioration of traffic performance. A good example of an illustrative, albeit a very important, expression of the dynamism is the proposal of the Bandar District Trade Market of the Simalungun Regency by the Simalungun Regency Industry and Trade Office in North Sumatra Province.

Being a new hub of economic activity, the market is expected to host huge crowds of visitors, traders, and service cars, thus changing the current travel patterns and introducing extra loads to the road network. The need to go beyond intuitive or ad hoc evaluations of the impacts of traffic arises in such a situation. In its turn, the Traffic Impact Analysis (TIA) is needed to estimate and evaluate the severity of the effect of the intended development on the current roads and intersections (Padma et al., 2020; Yayat et al., 2016; Wangai et al., 2020; Igondova et al., 2016). TIA is usually called ANDALALIN in the Indonesian context; a technical exercise of making projections about volumes but a strategic tool of making predictions about the way development-induced traffic will interact with the network structures and operational constraints that already exist.

Such analysis helps the planners and decision-makers to determine those potential bottlenecks, how the existing infrastructure is sufficient, and how to build relevant mitigation strategies. The value of predicting and controlling traffic effects has been getting more and more focus in international and domestic policy and studies. Musa et al. (2023), Badi et al. (2023) and Bagloee et al. (2016) believe that, unless traffic management and planning are proactive, the urban transport systems will be reduced to a cycle of congestion, lack of efficiency, and environmental degradation. This risk is especially sharp in the areas of fast development, and the development of infrastructure is frequently not pace with the increase of the intensity of the activity.

In Indonesia, the regulatory environment indicates the same concern with the Minister of Transportation Regulation Number PM 75 of 2015 on the Implementation of Traffic Impact Analysis. According to this regulation, development of some types to be covered, such as those with commercial operations and having a building floor area of 500m 2 and above, must perform a TIA to get permission. The Bandar District Trade Market development meets these qualifications and hence falls perfectly under the mandatory ANDALALIN assessment.

It is however worth noting that formal compliance to regulatory requirements may not necessarily lead to sustainable mobility results. Various researchers have demonstrated that the analysis of traffic impacts is often perceived as a form of procedural obstacle instead of prospective planning instruments, and the long-term structural impacts and the effects of a network on a network level are not adequately considered (Yayat et al., 2016; Wangai et al., 2020). Such lack of alignment between formal procedure and strategic planning highlights the necessity of case based studies which not only implement existing methods but also show their relevance to analytical and policy relevance within concrete development settings.

In terms of methodology, traffic impact analysis is based on the analysis of the traffic volumes, road capacity and performance indicators in terms of the volume-to-capacity ratio, speed, density and level of service. These measures, as enshrined in national rules like the Indonesian Road Capacity Guidelines (PKJI), offer a common structure upon which the suitability of a road line or intersection to meet the current and projected demand can be assessed. Though these indicators are technical in nature, the implication of them is highly social and economic due to the fact that they directly influence the time of travel, reliability, safety and accessibility.

At the same time, the modern academic literature also gives a growing importance to the fact that transportation systems should not be seen as an inactive or rather mechanical phenomenon. These systems are instead viewed as dynamic and adaptive phenomena whose performance changes with time in interactions among land use, travel behavior, infrastructure provision, and policy decisions (Park et al., 2021; Fraedrich et al., 2019). That view dictates that traffic impact analysis should not be confined to immediate or opening-year conditions but should take into account medium- and long-term conditions, whereby cumulative growth and structural constraints can give rise to qualitatively different results.

Here, the example of the Bandar District Trade Market can be taken as a particularly informative one. The existing road network can be regarded as being an important means of local and inter-area transportation, and some of the routes are being run on the edges of their operational capacity before the new development comes into play. As a result, the introduction of a significant trip-generating facility can not only increase the level of congestion, but also remodel certain regions of the network to enter a new operating regime characterized by endemic instability and breakdown flow.

The resulting scenario is an indication of a larger, more thoroughly documented conflict between intensification of land-use and transportation system capacity. Sustainable urban development as described by Banzhaf et al. (2017), Wagner & de, (2019), and Kalfas et al. (2023) requires spatial planning and infrastructure planning to be integrated closely and continuously. In cases of an ineffective or lack of such an integration, choices that seem rational in terms of economics or administration may still lead to unforeseen and expensive consequences in the transportation system.

The current work, therefore, exists at a crossroad between various key arguments. On the one hand, it meets the pragmatic and regulatory imperative to evaluate the traffic effects of a particular development project when such is guided by national guidelines. Conversely, it helps in an expansion of intellectual knowledge on how commercial activity centres interact with local road networks and the way in which this interaction changes over time. The study attempts to not only focus on short-term effects but also the structural directions of network performance by focusing on present state and multi-year trends.

To be more exact, this paper will attempt to estimate the extent of the impact that the development of the Bandar District Trade Market and development can have on traffic performance in this area, specifically in road segments and intersections that are the most vulnerable to critical stress. The systematic data collection, capacity analysis, and performance assessment based on PKJI standards will enable the study to provide an empirical base of the identification of possible problems and the development of appropriate mitigation measures.

In doing so, the study does not claim to provide a universal model and a fundamentally new methodology. Instead, its value is in the application to a specific, policy-relevant case of established analytical tools carefully and in a context-sensitive way. Detailed analysis of this kind is an indispensable bridge between the principles of abstract planning and the realities of day-to-day operations of the infrastructure management and urban development. The Modern Trade Market in the Bandar District cannot be evaluated only through the prism of its economic or architectural qualities, but rather about its ability to fit the transportation system that the area carries and that the transportation system makes sense. With a traffic impact analysis centred in this evaluation, the current study aims to enable more informed, anticipatory and sustainable decision-making processes of regional and urban development.

METHODS

A traffic impact analysis (ANDALALIN) for market development is a crucial document in development planning, as stipulated in the Minister of Transportation Regulation (Kartanto et al., 2024; Meka et al., 2025; Damayanti et al., 2021). ANDALALIN is a prerequisite for development planning, as every development project will inevitably impact traffic in the surrounding area. Therefore, conducting an ANDALALIN study can minimize negative impacts on the transportation system (Handayani et al., 2016; Brata et al., 2023). Data collection in the study is divided into two types: primary and secondary data. Primary data collection is conducted through field surveys to obtain an overview of existing traffic conditions. Primary data collection is conducted directly on-site to obtain important information regarding the performance and condition of traffic and the road network around the research study location (Brusselaers et al. 2022; Ahn et al., 2022; Park et al., 2021; Fattah et al., 2022). Primary data collection is conducted through surveys. Data collection through surveys is carried out by:

Traffic Volume Enumeration Survey

This survey was conducted to obtain traffic volume data for each road segment. This traffic volume data is vital for measuring road performance, as traffic flow is the demand side that will then become the market for traffic management policies to be adopted. The survey was conducted by counting vehicles passing along the road segment. Vehicles can be categorized as public transportation, private vehicles, freight transport, motorcycles, and non-motorized vehicles (Iamtrakul et al., 2025; Tiwari et al., 2016; Kenworthy & Svensson, 2022). Classified traffic enumeration surveys on other road segments were conducted at 10-minute intervals for a period of half an hour. This survey was conducted to determine the traffic volume on each road. Initial calculations were made to find the peak hour (pcu/hour), namely by converting traffic volume data that was still in units of vehicles/hour, then multiplying it by the passenger car equivalent factor (pcu). The passenger car equivalent factor (pcu) value refers to the 2023 PKJI guidelines.

Inventory Survey

Road Sections

This survey is conducted to determine the current condition of the road and its infrastructure. This survey is conducted through direct observation and measurement of each section of the road. Target data obtained from the road inventory survey are: section length, effective lane width, effective shoulder width, sidewalk width, type of pavement, number of lanes, and road type.

Road Facilities

This survey is conducted through direct observation to determine the location and type of infrastructure. The purpose of the infrastructure inventory survey is to determine the level of availability of road and intersection infrastructure for users. This survey data can be used to develop static road and intersection ranking indicators. Target data required from the infrastructure inventory survey are: Terminals, Parking, Bus Stops, Signs, Markings, and Public Street Lighting.

Generation and Attraction Survey

Based on National Regulations or Previous Studies, the determination of the generation and attraction levels is based on nationally determined secondary data or from studies previously conducted in the area. Comparison with Homogeneous Buildings, the determination of the generation and attraction levels is based on survey results or primary data. To obtain the generation and attraction levels, comparisons are made with the characteristics of similar buildings in the study area. The data collection stage is crucial because it is expected that the data collection tools (instruments/formats) used are specific and integrated within the project framework. Researchers will focus on data collection methodologies that have been used or are suitable for projects/programs with similar characteristics. Meanwhile, secondary data collection is obtained from government agencies. The required data can be obtained from: the Regional Development Planning Agency (BAPPEDA), the Central Statistics Agency (BPS), the Public Works Agency (PU), the Transportation Agency (DISHUB), and the Industry and Trade Agency. This secondary data is collected to support the primary data collection and is used for the analysis process.

RESULTS AND DISCUSSION

Based on the development plan, the Modern Trade Market will be implemented in 2025. Details of the development plan are presented in the following table:

Table 1. Data on the Modern Trade Market Development Plan, 2025

No	Description	Size	Unit	Capacity
1	Land Area	34.970	m^2	
2	Building Area	2.018	m^2	
3	Per Kiosk Area	2 x 2	m^2	
4	Number of Floors	2	floors	
5	Number of Kiosks	74	units	
6	Number of Traders	180	persons	
7	Parking Area	1.200	m^2	5 HV, 100 LV, 200 MC
8	Loading and Unloading Area	70	m^2	
9	Vehicle Entry/Exit Access	5	m^2	
10	Corridor Width	2	m	
11	Management Office	60	m^2	
12	Toilet and Bathroom	18	m^2	
13	Toilets (M/F)	8	units	
14	Disabled-Friendly Toilet	2 x 3	m^2	

Source: Department of Industry and Trade, Simalungun Regency, 2024.

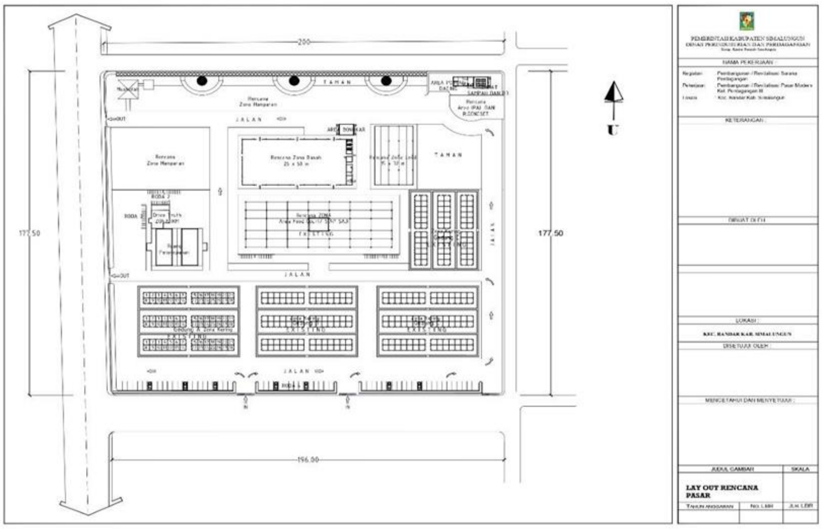

Figure 1. Layout of the Modern Trading Market, 2024

A preliminary survey was then conducted to determine the research locations on roads and intersections for field surveys, as follows:

Affected Road Sections

The road sections affected by the planned construction of the Modern Trading Market in Bandar District are: (1) Pasar Baru Road, Segment 1; (2) Pasar Baru Road, Segment 2; (3) Rajamin Purba Road.

Affected Intersections

The intersection affected by the planned construction of the Modern Trading Market is the 4-way intersection of Jl. Pasar Baru – Jl. Rajamin Purba, which is the intersection that connects the Pasar Baru Road section with the Rajamin Purba Road section.

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Figure 2. Scope of the Impact of Modern Trade Market Development

Vehicle Number Data

Traffic growth can be calculated by understanding the growth in the number of vehicles. Traffic growth is directly proportional to the growth in vehicles. Data on the number of registered vehicles in Bandar District, Simalungun Regency is presented in the following table:

Table 2. Vehicle Number Data in Bandar District

Year	ES	JHS	SHS	Total
2018	11,462	415	310	12,187
2019	11,639	427	322	12,387
2020	11,818	439	334	12,591
2021	12,000	452	347	12,798
2022	12,185	465	360	13,009
2023	12,372	478	374	13,224
2024	12,563	491	388	13,442

Source: BPS Simalungun Regency (Processed data), 2024

SM = Motorcycles, MP = Passenger cars, and KS = Medium vehicles

From the table above, the average growth of two-wheeled vehicles, light vehicles (MP), and heavy vehicles (KS) can also be calculated, as presented in the following table:

Table 3. Average Vehicle Growth (%)

SM	MP	KS
1.54	2.85	3.81

Source: Analysis Results, 2024

Road Section Performance

Road Capacity

Road capacity is the ability of a road section to accommodate the ideal volume per unit of time, expressed in vehicles per hour or passenger car units per hour (pcu/h). Road section inventory data for the study area can be found in the table below.

Table 4. Road Section Inventory Data

No	Street Name	Lane Type	Road Width (m)	Flow Pattern (Direction)	Side Friction	Road Median (m)	Road Shoulder (m)

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1	Jl. Pasar Baru Segment 1	4/2T	14.5	50-50	Medium	2.5	2
2	Jl. Pasar Baru Segment 2	2/2TT	6	50-50	Very High (VH)	-	15
3	Jl. Rajami Purba	2/2TT	4	50-50	Very High (VH)	-	2

Source: Analysis Results, 2024

Several factors influence road section capacity calculations, including basic capacity, lane width adjustment factors, side barriers adjustment factors, direction separation adjustment factors, and city size adjustment factors. For example, Jalan Pasar Baru has a near-urban land use and adjacent market and commercial activities, so the side barriers are considered Very High.

Intersection Performance Analysis

The Modern Trading Market is located near the intersection of Jl. Rajamin Purba and Jl. Pasar Baru. The location of the intersection can be seen in the following image.

Figure 3. Visualization of the Jl. Rajamin Purba - Jl. Pasar Baru Intersection. Approach from the South

Based on peak traffic times on the road sections examined, the traffic flow at the intersection used is the peak traffic flow at each intersection. The traffic conditions at the intersection during these time intervals are shown in the following table.

Table 5. Traffic Flow at the Jl. Rajamin Purba - Jl. Pasar Baru Intersection

Direction	**Approach**	**Vehicle Flow / Hour**		
		MP	JHS	ES
South	Jl. Pasar Baru Segment 2			
	qBKi	14	7	256
	qLRS	2	0	35
	qBKa	8	4	234
North	Jl. Pasar Baru Segment 1			
	qBKi	15	1	71
	qLRS	16	1	77
	qBKa	2	1	13
East	Jl. Rajamin Purba			
	qBKi	18	9	246
	qLRS	13	6	235
	qBKa	6	0	36
West	Jl. Rajamin Purba			

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	qBKi	2	0	12
	qLRS	11	3	187
	qBKa	12	1	156

Source: Analysis Results, 2024

The environmental conditions at this intersection can be categorized as a limited access area with high side barriers. The performance assessment of this unsignalized intersection uses the following performance assessment indicators:

Table 6. Capacity Calculation Approach for Intersection 4 of Jl. Rajamin Purba and Jl. Pasar Baru

Number of Arms Intersections (1)	**Approach Width,**				**m**		**LRP (8)**	**Number of Lanes**		**Intersection Type (11)**
	Minor Road			**Major**	**Road**			**Minor Roads**	**Mayor Street**	
	LA (2)	L_C (3)	LAC (4)	L_B (5)	LD (6)	LBD (7)		(9)	(10)	
4	3	3	3	2	2	2	2,5	2	2	422

Source: Analysis Results, 2024

The table above shows the average approach width at the unsignalized intersection of Jalan Rajamin Purba and Jalan Pasar Baru, which is 2.5 meters. The capacity adjustment factors for the Jalan Rajamin Purba and Jalan Pasar Baru intersection are presented in the following table.

Table 7. Capacity of the Jalan Pasar Baru-Jalan Rajamin Purba Intersection

Basic Capacity	**Traffic Performance**							**Capacity**
	Wide	**Median**	**Size**	**Obstacle**	**Turn**	**Turn**	**Ratio**	
C_0	average Approacher	Mayor Street	City	Side	Left	Right	Minor/Total	C
SMP/hour	FUP	FM	FUK	FHS	FBKi	FBKa	FRmi	SMP/jam
(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
2900	1,0031	1	0,82	0,94	1,4518	1	0,90	2919

Source: Analysis Results, 2024

The table above shows the results of the analysis of intersection capacity adjustment factors, including an average approach width of 1.0031, a median for major/main roads of 1, and a city size based on population of 0.82. Side obstructions of 0.94, a left-turn adjustment of 1.4518, a right-turn adjustment of 1, and a minor road ratio of 0.90. Therefore, the capacity of this intersection is 2,919 SMP/hour.

Table 8. Traffic Performance at the Pasar Baru-Rajamin Purba Intersection

Traffic Flow	**Traffic Performance**						
	Degrees	**Delays**	**Delays**	**Delays**	**Delays**	**Delays**	**Opportunity**
Traffic Flow	Saturation	Traffic	Traffic	Traffic	Geometri	intersection	Queue
qTOT		intersection	Mayor Street	Mayor Street	intersection		
SMP/hour	D_J	TLL	TLLma	TLLmi	T_G	$T=T_{LL}+T_G$	P_a
(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
1700	0,5824	5,2978	4,6777	6,0889	4,1336	9,4315	30,5697

Source: Analysis Results, 2024

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A DJ value of 0.85 is often used as a threshold. Minister of Public Works and Public Housing Regulation Number 5 of 2023 uses this value as a performance threshold. If a road segment has a DJ value ≤0.85, the segment is considered to be performing well. A DJ value >0.85 indicates that the road segment is performing well and needs to consider increasing segment capacity, such as adding lanes or implementing traffic management to prevent existing traffic flow from causing a DJ value greater than 0.85. The analysis results show that the degree of saturation (DJ) at the intersection of Jl. Rajamin Purba-Jl. Pasar Baru is 0.5824, indicating that the intersection is considered to be performing well.

Current Traffic Performance Demonstration in 2024

Current performance needs to be analyzed to identify traffic conditions and determine potential impact management measures for the Modern Trade Market development. The traffic load analysis results will determine the performance of each road segment, intersection performance, and road network performance for the current (existing) condition, as shown in the table below.

Table 9. Existing Road Section Performance in 2024

No.	Road Segment	Total Capacity (pcu/hour)	Volume (pcu/hour)	V/C Ratio	Free Flow Speed MP (km/h)	Density (pcu/km)
1	Jl. Pasar Baru Segment 1	3,158	257	0.08	56.00	5
2	Jl. Pasar Baru Segment 2	1,906	1,057	0.55	31.94	33
4	Jl. Rajamin Purba	1,227	1,060	0.86	26.62	40

Source: Analysis Results, 2024

Based on the table above, information on existing traffic performance in 2024, when the Modern Trade Market Revitalization Development Plan had not yet been completed, shows that the road segment with the highest V/C ratio was Jalan Rajamin Purba, with a V/C ratio of 0.86, a free-flow speed of 26.62 km/h, and a density of 45 pcu/km.

The Rise and Pull of Travel

Analysis of the trip generation model derived from the Modern Trading Market based on analogy with visit data from previously operating Modern Trading Markets. Based on the vehicle entry and exit data at the Modern Trading Market surveyed, the number of incoming vehicle visits is shown in the following table.

Table 10. Trip Generation and Attraction Data

Information	Go out				Enter	
	MP	KS	SM	MP	KS	SM
Human Resources	1	0	7	1	0	4
Traders	1	1	5	2	1	5
Visitors	7	2	87	8	3	75
Total	9	3	99	11	4	84
	111				**99**	

Source: Analysis Results, 2024.

Road performance can be seen from its V/C ratio. The V/C value is one of the Level of Service Indicators (ITP) that serves as an evaluation of traffic performance. The ITP value is determined based on the quantitative V/C value, travel speed, and other factors determined based on qualitative values such as driver freedom to choose speed and vehicle delay values. By considering the network system applicable to each road segment and the traffic flow for each reviewed road segment, the results obtained regarding the performance value and the magnitude of traffic flow for each segment are summarized as outlined in the following table:

Table 11. ITP Values for Reviewed Sections during Peak Hours (Existing Conditions)

No.	Road Section Name	VC Ratio	ITP
1	Jl. Pasar Baru Segmen 1	0,08	B
2	Jl. Pasar Baru Segmen 2	0,55	D
3	Jl. Rajamin Purba	0,86	D

Source: Analysis Results, 2024.

Referring to Minister of Transportation Regulation No. PM 96 of 2015 concerning Traffic Management and Engineering, which states, "The desired level of service on road sections in the primary collector road network system, in accordance with their function, is for arterial and primary collector roads. The service level is at least B (stable flow, but operating speed begins to be limited by traffic conditions and drivers are restricted in choosing their speed), and for secondary arterial/collector roads, at least C, and for secondary local/neighborhood roads, at least D." These traffic conditions represent the current conditions at the time of the study, when the Modern Trade Market Development had not yet begun. This traffic assignment was used to compare the model used with current conditions. To facilitate the road transportation network modeling process, the initial step is to code the road network by assigning a number/code to each node and each direction of traffic flow on the original road sections directly affected. The current code of the road network around the study location can be seen in the following figure:

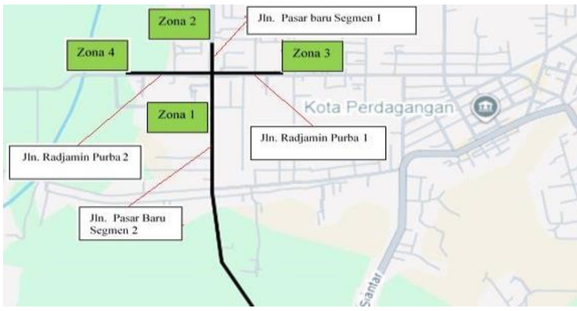

Figure 4. Road Network Coding During Construction Period
Source: Analysis Results, 2024

Road Network Performance Analysis for the Next 5 (Five) Years

Analysis of Trip Distribution After Construction for the Next 5 Years Without Management

At this stage, forecasting of existing traffic conditions for the next 5 years with construction is carried out, using the analogy method, referring to similar studies and correlating with traffic growth data in Bandar District, calculated based on the average annual vehicle growth in Bandar District, as follows:

Table 12. Traffic Growth

SM	MP	KS	Average
1,54 %	2,85 %	3,81 %	2,73 %

Source: Analysis Results, 2024

Traffic volume in the planned year will be calculated based on traffic volume forecasts with a Demand Compound Factor trendline using the following formula:

$Pt = Po (1 + r) n$

Where:

Pt = Final year of calculation

Po = Base year of calculation N = Difference between Pt and Po

r = Percentage increase

In the analysis of the planning year, several parameters used are as follows: (1) No construction activity occurs; (2) Increased traffic growth on road sections with constant annual analysis; (3) The road network loading calculated at this stage is traffic growth for up to 5 (five) years; (4) The analysis is conducted in accordance with the existing transportation infrastructure conditions, meaning there are no additional transportation infrastructure facilities in the study area (during the analysis period), except during the recommendation analysis or impact management phase; (5) The indicators used to calculate the level of service for road sections are speed and the V/C ratio, while the indicator for calculating the level of service at intersections is delay; (6) The level of service for roads and intersections is determined based on the Indonesian Road Capacity Guidelines (PKJI) and Minister of Transportation Regulation Number PM 96 of 2015 concerning Guidelines for the Implementation of Traffic Management and Engineering Activities. After estimating the number of trip generation and attraction, the next step is to distribute this volume to the traffic network in the study area. The following is the distribution of trips over the next 5 years without these management measures.

Table 13. Distribution of Trips in the Next 5 Years Without Management At Peak Peak Hour (pcu/hour)

SM	MP	KS	Average
1,54 %	2,85 %	3,81 %	2,73 %

Source: Analysis Results, 2024

During operational hours, the highest number of trips during peak hours was 2,409 SMP/hour. The largest generation was from Zone 3, with 796 SMP/hour, while the largest draw was from Zone 3, with 801 SMP/hour. This stage explains how to simulate road segment and network performance over the next 5 years without treatment. From the results of the traffic loading, road segment and network performance can also be analyzed based on the results of the survey. The following is an analysis for the next 5 years without treatment.

Table 14. Predicted Operational Road Section Performance for the Next 5 Years Without Treatment.

No.	Road Segment	Capacity (pcu/hour)	Volume (pcu/hour)	V/C Ratio	Speed (km/h)	Density (veh/km)	LOS
1	Jl. Pasar Baru Segment 2	1,906	1,286	0.67	46.70	27.54	D
2	Jl. Pasar Baru Segment 1	3,158	338	0.11	51.20	6.59	B
3	Jl. Rajamin Purba Segment 1	1,227	1,293	1.05	45.52	28.40	F
4	Jl. Rajamin Purba Segment 2	1,227	1,217	0.99	46.27	26.31	F
	Average			**0.71**	**47.42**	**22.21**	**E**

Table 15. Road Network Performance in the Next 5 Years Without Treatment

Description	Value
Average Density (veh/km)	22.21
Average Trip Length (kilometers)	3.50
Travel Time (minutes)	4.60

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Average Speed (km/h)	0
Average V/C Ratio	0.71
Level of Service (LOS)	E

Source: Analysis Results, 2024

The road network performance results show an average density of 22.21 vehicles/km, an average trip length of 3.50 kilometers with an average travel time of 4.60 minutes, an average speed of 46.45 km/h, an average VCR of 0.35, and an average LOS of E.

Comparative Analysis of Traffic Performance and Road Network

Based on the analysis results, comparisons can be made between traffic and road network performance for each observation year. The following is a comparison of traffic and road network performance.

Comparison of VC Ratio of Highest Busy Hours

Table 16. Comparison of VC Ratios for Highest Peak Hours from 2024 to 2030

N0.	Road Section Name				VCR			
			2024		2025		2030	
		Existing	Construction (Do Nothing)	Construction (Do Something)	Operational (Do Nothing)	Operational (Do Something)	Operational (Do Nothing)	Operational (Do Something)
1	Jl. Pasar Baru Segmen 2	0,55	0,60	0,57	0,57	0,56	0,67	0,59
2	Jl. Pasar Baru Segmen 1	0,08	0,09	0,08	0,09	0,08	0,11	0,09
3	Jl. Rajamin Purba Segmen 1	0,86	0,93	0,88	0,89	0,87	1,05	0,92
4	Jl. Rajamin Purba Segmen 2	0,86	0,91	0,88	0,88	0,87	0,99	0,90

Source: Analysis Results, 2024

Table 16 presents a longitudinal comparison of volume-to-capacity (V/C) ratios for the main road segments affected by the Modern Trade Market development under different scenarios and time horizons, namely existing conditions in 2024, construction and early operation in 2025, and the five-year operational projection in 2030. This table is particularly important because the V/C ratio is a fundamental indicator of traffic stress and directly reflects the extent to which each road segment approaches or exceeds its functional capacity. A first and immediately visible pattern is the strong differentiation in performance trajectories between Pasar Baru segments and Rajamin Purba segments. Pasar Baru Segment 1 consistently exhibits very low V/C ratios across all scenarios and years, remaining in the range of 0.08 to 0.11. This indicates that this segment operates with a very large residual capacity and is structurally insensitive to both the construction and operation of the market. Even in the 2030 operational "do nothing" scenario, the V/C ratio remains only 0.11, which is far below any critical threshold. This confirms that Pasar Baru Segment 1 functions primarily as a local access road rather than as a strategic carrier of through or market-oriented traffic flows.

Pasar Baru Segment 2 shows a different but still relatively stable pattern. Its V/C ratio increases from 0.55 under existing conditions in 2024 to 0.67 in the 2030 operational "do

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nothing" scenario. Although this represents a clear upward trend, the segment still remains below the commonly accepted critical threshold of 0.85. This indicates that, while the segment is affected by the development and by general traffic growth, it does not experience structural overload. The modest difference between the "do nothing" and "do something" scenarios in 2030 (0.67 versus 0.59) also suggests that mitigation measures on this segment produce only incremental improvements, because the segment is not the main structural bottleneck of the system. In contrast, the behavior of the Rajamin Purba segments reveals a fundamentally different and much more critical dynamic. Under existing conditions in 2024, both segments already operate at a V/C ratio of 0.86, which places them very close to the upper limit of stable operation. This means that even before the market development, Rajamin Purba is already a structurally stressed corridor. During the construction and early operational phases in 2025, the V/C ratios fluctuate around 0.88 to 0.93 in the "do nothing" scenario, indicating that the corridor is already operating in a condition of chronic near-saturation.

The most critical result appears in the 2030 operational "do nothing" scenario, where Rajamin Purba Segment 1 reaches a V/C ratio of 1.05 and Segment 2 reaches 0.99. A V/C ratio above 1.0 indicates that demand exceeds capacity, which means that congestion is no longer episodic or peak-hour limited, but becomes structurally embedded in daily operation. This marks a qualitative shift from unstable but still manageable traffic flow to a condition of systemic breakdown. In this state, queues are no longer able to dissipate fully, delays become highly variable, and the reliability of the corridor collapses. The comparison between the "do nothing" and "do something" scenarios is also highly revealing. In 2030, mitigation measures reduce the V/C ratio on Rajamin Purba Segment 1 from 1.05 to 0.92, and on Segment 2 from 0.99 to 0.90. While this represents a significant improvement, it is important to note that even with intervention, the corridor remains close to critical saturation. This indicates that mitigation measures can delay and soften the crisis, but do not fully eliminate the structural pressure caused by the combination of market-induced traffic and background growth.

Comparison of Road Performance During Peak Rush Hours

Table 17. Comparison of Road Performance During Peak Rush Hours from 2024 to 2030

N0	**Road Section Name**				**Road Performance**			
			2024		**2025**		**2030**	
		Existing	**Construction (Do Nothing)**	**Construction (Do Something)**	**Operational (Do Nothing)**	**Operational (Do Something)**	**Operational (Do Nothing)**	**Operational (Do Something)**
1	Jl. Pasar Baru Segmen 2	D	D	D	E	D	D	D
2	Jl. Pasar Baru Segmen 1	B	B	B	B	B	B	B
3	Jl. Rajamin Purba Segmen 1	D	E	D	E	E	F	E
4	Jl. Rajamin Purba Segmen 2	D	E	D	E	E	F	E

Source: Analysis Results, 2024

Table 17 enhances quantitative V/C analysis by converting the traffic conditions to Level of Service (LOS) categories; in this way, alternative interpretations of road performance is provided, which is more operational and user-friendly. Whereas V/C ratios measure the level of saturation, LOS categories capture the nature of traffic movement, comfort to the driver, stability and delay rates. Pasar Baru Segment1 is outstanding in terms of its performance, which has always held LOSB in all years and situations. It means that there are no deviations in the flow, speed of operation is high compared with the capacity, freedom of drivers in the choice of speed and maneuvers is high. In line with this, the findings support the conclusion of Table 16 which held that Pasar Baru Segment 1 is structurally strong and mostly inaccessible to the development of both the market and long-term traffic growth.

Pasar Baru Segment 2 is slightly sensitive but it is within a reasonable performance range. Its LOS is usually D in most of the situations and momentarily E in the 2025 and 2030 operational cases of do nothing. Importantly, in the worst the segment will not degenerate to LOS F. This implies that congestion and lower manoeuvrability are experienced, but the flow of traffic is essentially stable and does not degenerate into forced or breakdown flow conditions. The re-LOS D at the do something situation in both 2025 and 2030 shows how comparatively small interventions can be used to maintain decent performance on this segment. Once more the most important and policy-oriented tendency is observed on the Rajamin Purba segments. The two segments already have a stable flow in 2024 at LOS D, which means that it is an unstable flow with delays evident and only manoeuvrability is limited. For the performance in 2025 in the case of do nothing, we have a performance of LOS E which is the operation is close to capacity with minimal freedom of movement and is highly sensitive to disruption. This is a warning condition where the system is fully operational, only it is very lowly resilient.

Under the 2030 operational scenario of doing nothing, the two Rajamin -Purba segments arrive at LOS F, or forced flow. This is the most important level of service, where the conditions are stop and go and queues are unstable and travel time is very unreliable. This is where congestion is no longer an inconvenience but transforms into an organizational limitation on movement and accessibility in the space. The do something scenario suggests that the performance will recover to LOS E in 2030 in part. Although this is a definite improvement to LOS F, it is still a network that is running at the functional threshold. This proves that there should be mitigation and that it is effective enough, but not enough to put the operating conditions on the roster in the long-term.

Structural Transformation of Road Network Performance Following Market Development

As seen in the current research project, the emergence of the Modern Trade Market in the Bandar District does not simply raise the volume of traffic in linear proportion, but brings structural change in the nature of operations of the road network within the locality. This is most pronounced in the changed nature of Jalan Rajamin Purba which changes in terms of a near-saturated position under the existing circumstances to a critical overloaded node in the five-year operation scenario where the V/C ratios are wide above 1.0. This is more of a systemic change in network functionality as opposed to a peripheral operational disruption, and this trend is widely reported in the literature of land-use and transport interaction (Zhong et al., 2017; Krehl et al., 2016; Zhu & Sun, 2017). Transport networks are also conceptualized as interactive systems whereby the perturbation in one of the key activities nodes may reorganize traffic allocation among various links (Meijers et al., 2018; Soczówka et al., 2020). In this instance, the Modern Trade Market presents an effective activity centre that reorganizes the travel trends in the district. Whereas Pasar Baru Segment 1 and Segment 2 remain within rather stable service levels, Rajamin Purba experiences a disproportionate amount of new traffic demand due to its use as an interconnecting route. This finding proves the thesis that the effects of traffic brought about by commercial developments are usually not evenly spread but rather focused on strategically located links (Zhao et al., 2022; Liu et al., 2022).

Most importantly, the results show that network stress is not dictated by the absolute increase of traffic only, but by the hierarchical position and structural location of every road segment. RajaminPurba is a collector-distributor highway, and these connections are especially likely to be responsive to land-use density (Padma et al., 2020; Yayat et al., 2016). Conversely, Pasar -Baru Segment 1 is more of a local access service, thus the reason as to why its performance remains relative steady even with the projected growth. Such a distinction confirms the idea that road operation and network location are more significant than pure geometric capacity to end up on the long-term performance results (Onokala & Olajide, 2020; Tzonevska, 2023). The structural character of such change also demonstrates the shortcomings of short term, segment based, evaluation techniques. Though not all the road segments can meet the minimum performance criteria in the initial years of operation, the five-year forecast shows the evident shift towards chronic overload on a key route.

This has been witnessed in many urban settings that have taken new commercial or service centres in into networks, which are already at functional limits (Fraedrich et al., 2019; Grote et al., 2016; Wangai et al., 2020). Regarding system resilience, a network where only one strategic route has been used to its limit becomes very susceptible to disruptions, such as minor accidents, roadside operations, or interim constructions (Namazi et al., 2019; Chen & Englund, 2015). It indicates that RajaminPurba is heading the way to such a weak position. When this state is achieved, congestion stops being a peak-hour event and turns into a regular structural aspect of daily functioning, a tendency that is much debated in the congestion and network vulnerability literature (Igondova et al., 2016; Brown & Van Kamp, 2017). The geographical structure of the movement within the district is also redesigned spatially by the market development that forms a strong central attraction point.

This effect is consistent with the results that large activity centres have the tendency to restructure urban mobility patterns around them which could often surpass the adaptive capacity of current networks (Zhong et al., 2017; Liu et al., 2022). In that regard, the case of Bandar District should not be perceived as a singular technical issue but a rather common expression of the more general structural conflict between land-use intensification and transport system capacity (Banzhaf et al., 2017; Wagner & de, 2019). Lastly, the research proves that the establishment of the Modern Trade Market causes a structural change of the network performance rather than a quantitative one of the rise of traffic. This change is typified by the development of a critical bottleneck, loss of system resilience and an evident course towards a chronic congestion, which is entirely aligned to the known theories of land-use and transport interaction.

Corridor-Specific Saturation, Network Vulnerability, and the Logic of Induced Concentration

One of the key results of the current study is that the distribution of the impact of congestion is highly uneven across the road network. The heaviness of the traffic caused by the Modern Trade Market is also not distributed equally to the neighboring road lengths; it is concentrated mostly in Jalan Rajamin Purba. This concentration coincides with the idea of the induced concentration expressed by many researchers, where the center of the emergent activity attracts traffic volumes and directs them to the most strategically essential directions (Zhao et al., 2022; Zhong et al., 2017; Krehl et al., 2016). In the transport network theory, some links will necessarily play a dominant role due to their interconnectedness and cohesiveness (Meijers et al., 2018). In the Bandar District, the same role is played by Rajamin Purba. Before the development of the market, the corridor was already running close to the functional capacity, which can be seen in the fact that the velocity-to-congestion ratios were close to critical levels. In turn, the new demand imposed by the market does not create a new issue but instead triggers and exacerbates an existing structural weakness: a trend that is often reported in the research on traffic impact (Padma et al., 2020; Yayat et al., 2016; Wangai et al., 2020).

So, Rajamin Purba is expected to go into oversaturation in the five-year period, but other segments will be relatively stable. This trend is characteristic of networks where congestion initially occurs and is most acute in intersections of strategic meaning and limited capacity (Igondova et al., 2016; Grote et al., 2016). When such vital connections fail, the effects extend outside direct localities, and complex movement chains that rely on them become unstable (Namazi et al., 2019; Chen & Englund, 2015). In turn, network vulnerability is a critical concept in understanding these results. A vulnerable network does not have necessarily all links with high load, but it is characterized by the fact that a small number of critical links can largely affect overall performance when they fail (Brown & Van, 2017; Musa et al., 2023). The estimated performance indicators of the Rajamin Purba suggests that the Bandar District network is moving towards such a set up. Furthermore, the saturation with corridors often leads to the development of secondary complications, such as steering traffic to local streets, increased levels of safety risks, or even inter-user conflicts, which shows in many cases of urban settings (Aljohani & Thompson, 2016; Fattah et al., 2022; Tiwari et al., 2016). These secondary effects are not explicitly modeled in this study, but the level of projected saturation is a strong indication that they may take place.

Equity and accessibility perspective indicates that when the congestion is concentrated at Rajamin Purba it means that the external costs of the development process are experienced not only by the users of the market but the entire community. This is a classic example of the existing and problematic issue of congestion as a negative externality in the urban transport systems (Onokala & Olajide, 2020; Kenworthy & Svensson, 2022). Importantly, this trend cannot be explained only by geometrical limitations or design principles. Rather it is an expression of a greater discrepancy between land-use intensity and network structure. The creation of a high-intensity commercial activity along a route which already serves a strategic connective purpose creates cumulative pressure which cannot be reduced through short operational adjustments in itself (Wagner & de Vries, 2019; Kalfas et al., 2023). Thus, the case of the Bandar District is one of the typical but severe planning dilemmas. Whilst locating key activity centers may seem economically sound in the short, locating them along major corridors will often result in transport inefficiencies over the long term and deteriorating service provision, which is effectively reported throughout the urban transport and land-use integration literature (Banzhaf et al., 2017; Fraedrich et al., 2019).

Implications for Traffic Impact Governance and Long-Term Urban Mobility Management

This study implies much beyond its technical results, which are the governance of traffic-impact and long-term urban mobility management. One of the key findings is that the analysis of traffic impact cannot be regarded as a formal prerequisite to development permission, but it is a strategic tool that allows predicting and controlling the structural effects of the change in land-use (Yayat et al., 2016; Kartanto et al., 2024; Brata et al., 2023). In the case under consideration, the five-year forecast shows that the worst effects are not always regulated during the first years of the work, but can be revealed in the form of the aggregate effect of the increase in traffic and the limiting conditions of the structural network. The point is supported by previous studies which have shown that short-term measures often fail to capture the risks of congestion in the long-term (Padma et al., 2020; Wangai et al., 2020; Musa et al., 2023). The development-control policy implications are at hand. When the approval of projects is mainly based on the state of affairs in the first year or close to the year-end conditions, then the planning authorities will automatically allow developments that will orient the network to eventual failure at a later date but inevitable. The case of the Bandar District shows the necessity to integrate both medium- and long-term scenarios into the process of evaluation of ANDALALIN, which is also stressed in the Indonesian practice-based research (Yayat et al., 2016; Kartanto et al., 2024).

The findings also demonstrate that the mitigation measures should be envisioned at the network level, and not just site-access level. Minor traffic -engineering is not expected to be enough given the performance that is projected by Rajamin Purba. In its stead, it might be necessary to implement more strategic interventions, like the capacity improvement, the redistribution of traffic, or the functional restructuring of the road hierarchy, which is more in line with recommendations typically suggested in the literature on sustainable transport-management (Bagloee et al., 2016; Musa et al., 2023; Park et al., 2021). The other important implication is related to the incorporation of transport planning and spatial planning. It has been demonstrated in many works that introduction of transport considerations after the major land-use decisions have been undertaken is reactive, and, therefore, suboptimal in terms of impact mitigation (Banzhaf et al., 2017; Wagner & de, 2019; Kalfas et al., 2023). The current research offers tangible empirical evidence of this argument demonstrating the extent to which the location and magnitude of the market development creates structural stress which would have been predicted at an earlier planning level.

The fact that in the Indonesian setting, ANDALALIN is supposedly a control tool, which, in this case, highlights the need to reinforced the strategic position of the tool in determining the development patterns, as opposed to addressing the outcomes of the latter (Yayat et al., 2016; Kartanto et al., 2024). These long-term mobility implications cannot be undermined. Not only is a corridor with Level of Service F congested, but it is also unreliable, unpredictable, and socially expensive (Fattah et al., 2022; Brown & Van, 2017). In the long run, these circumstances may deteriorate the accessibility of urban areas, economic performance, and the quality of life. This research has shown that the effects of the Modern Trade Market on traffic are not a one-time problem of operations, but a long-term urban-mobility problem. The analysis provides a strong empirical foundation in changing reactive traffic management into proactive and combined land-use and transport governance.

CONCLUSION

Based on the analysis results that have been conducted, it can be concluded that the analysis of the traffic impact of the Modern Trade Market Development has an impact on traffic performance around the location, especially on Jalan Rajamin Purba, Bandar District, Simalungun Regency, North Sumatra Province. Other traffic impacts that occur are disruption to traffic safety due to the potential for accident conflicts and disruption to traffic flow due to the movement of operating buildings. In addition to the impacts caused by operating buildings, during the construction period there is the potential for an increase in accidents. The potential for accidents is formed due to the access for vehicles to enter and exit and during the construction period, namely during the transportation of materials.

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