Journal of Industrial Engineering and Halal Industries (JIEHIS) *Submitted: 2026-05-10*
P-ISSN 2722-8150, E-ISSN 2722-8142 *Revised: 2026-06-14*
Vol. 7 No. 1 June 2026, Pp 44-53 *Accepted: 2026-06-21*
https://doi.org/10.14421/jiehis.6302 *Online: 2026-06-31*

Behavioral Insights in Traffic Congestion Mitigation in the Special Region of Yogyakarta: Analysis and Modelling of Driver Decision-Making

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Abstract

Traffic congestion in the Special Region of Yogyakarta (DIY) is a complex problem characterised by mixed traffic and manual interactions between road users. This study aims to formulate a conceptual model extending the Theory of Planned Behavior (TPB) to identify the psychological determinants influencing road users' decisions regarding traffic congestion mitigation in DIY. The original TPB model was extended by adding the variables Perceived Cost and Perceived Usefulness. A quantitative approach was adopted through the distribution of a questionnaire survey to drivers in DIY, with the collected data subsequently analysed using structural equation modelling (SEM). The results of the structural model analysis indicate that this model extension successfully explains 56.1% of the variance in drivers' intentions ($R^2 = 0.561$) and 45.0% of the variance in actual congestion mitigation behavior ($R^2 = 0.450$). Of the seven constructs tested, four factors were found to have a significant influence on drivers' decisions: subjective norms, perceived costs, perceived usefulness, and driving intention. Conversely, the constructs of attitude and perceived behavioural control were found to have no significant influence on the intention to mitigate congestion. The main conclusion of this study indicates that decision-making by motorists in DIY is more likely to be driven by moral values (social pressure) and rationality (cost calculations and perceived usefulness) than by personal attitudes or situational control. The practical implications of this study can be utilized by the Regional Government in DIY to design transport intervention policies based on behavioural insights, such as optimising public transport fare incentives and social norm campaigns.

Keywords : Driver Behavior; Traffic Congestion Mitigation; Decision Making; Theory of Planned Behavior; Yogyakarta

INTRODUCTION

Traffic congestion in the Special Region of Yogyakarta (DIY) is no longer merely a matter of infrastructure capacity, but has developed into a manifestation of complex systemic problems arising from thousands of individual decisions made simultaneously by road users. The conventional approach, which has focused on expanding physical infrastructure, is often constrained by limited land availability and high investment costs. On the other hand, traffic management that ignores the "human" factor as the main cause of congestion has proven to be ineffective.

In the last decade, global literature has been dominated by advanced technology-based solutions and automation to address this issue. Yan et al. (2022) demonstrated that the application of Deep Reinforcement Learning (DRL) in autonomous vehicles was able to reduce congestion by up to 60% in simulations. Similarly, Zhang et al. (2024) highlighted how algorithm optimisation in ride-sourcing systems can interact positively with macro traffic flows. However, the application of this purely high-tech approach faces contextual challenges in Yogyakarta. Traffic characteristics in DIY are characterised by mixed traffic (dense interaction between motorcycles and cars) with a low level of automation, so autonomous vehicle solutions are not yet fully relevant for direct adoption without understanding the nuances of current manual driver behavior.

Recent studies emphasise the urgency of behavioural interventions in mitigating traffic congestion. Li et al. (2025), through the development of the Theory of Planned Behavior (TPB), found that drivers' habits have strong inertia that can hinder behavioural change, such as the decision to switch to shared modes of transport. This finding is reinforced by Varotto et al. (2022), who provide insight that any technological intervention, such as Adaptive Cruise Control, can trigger behavioural adaptation that is not always linear, where drivers tend to accelerate their vehicles faster even though a safe distance is maintained. This indicates that congestion mitigation in DIY requires a human-centric approach that understands the decision-making architecture of local drivers.

Although Rossetti et al. (2002) and Ozbay et al. (2002) have laid the foundations for agent-based modelling (BDI Agents) to simulate driver route learning, and Kaura & Georgakis (2019) have used clustering for traveller profiling, there is a clear research gap. Most recent studies focus on technology adoption in developed countries or fleet operational optimisation, and few have comprehensively modelled driver decision-making in the context of mixed traffic in cultural cities such as Yogyakarta.

Therefore, this study aims to fill this gap by combining psychological frameworks and industrial engineering decision analysis. In the context of this research, decision analysis in industrial engineering refers to the application of a systematic approach to support the decision-making process through the measurement and modelling of behavioral variables, costs, benefits and operational constraints. The psychological framework employed is the TPB, which has been adapted by adding the variables of perceived cost and perceived usefulness to explain drivers' intentions and behavior. Furthermore, these factors are not only analyzed to understand behavior, but are also integrated into a decision model that serves as the basis for the formulation of transport policy. Consequently, this approach enables the identification of dominant factors, the classification of driver groups, and the prioritization of the most appropriate interventions to be implemented. Consequently, this research is not only focused on understanding the psychological aspects of drivers, but also on utilizing the results of the analysis as a foundation for designing more effective operational systems and policies.

METHODS

Each variable has indicators that are formulated into statements within a research instrument in the form of a questionnaire. The questionnaire used was adapted and adopted from previous studies and comprised 25 statements covering all variables. All statements were originally in English and were subsequently translated into Indonesian. The statements from the questionnaire were modified into 26 statements based on the theoretical framework of the questionnaire in the previous study.

The researchers asked participants about their history of traffic congestion mitigation through the following questions:

1. How many motor vehicles (motorcycles and cars) does your family own or use on a regular basis?
2. Are you the primary driver of this vehicle or one of these vehicles (motorcycle or car)?
3. How often do you usually travel by motorcycle or car as the driver?
4. How often do you travel by motorcycle or car as a passenger?
5. Do you drive your own vehicle or someone else's?
6. How often do you travel by local bus (Trans Jogja or Teman Bus)?
7. If you rarely or never travel by local bus (Trans Jogja or Teman Bus), what are your main reasons for not using this mode of transportation?
8. How often do you usually travel within the Special Region of Yogyakarta by taxi or rental/online vehicle? (This includes app-based services such as Gojek, Grab, and Maxim, as well as conventional taxis.)
9. What type of online service do you use most often?

Next, the author compiled a list of assessment statements related to traffic congestion mitigation behaviors using 7 variables and 26 indicators, as shown in the following table.

Table 1. Variables and indicators used (Pratama & Dicinta, 2026)

Variable	Indicators	
Attitude	ATT1	I am confident that my efforts to help reduce traffic congestion will make travel more comfortable for everyone.
	ATT2	In my opinion, changing driving habits to reduce traffic congestion is a wise move.
	ATT3	Making adjustments to your trip (such as finding an alternative route or changing your departure time) is a sensible way to work around traffic congestion.
	ATT4	I believe that measures to reduce traffic congestion are very beneficial for the smooth flow of traffic in the Special Region of Yogyakarta.
Subjective Norm	SN1	The opinions of those closest to me (such as family or friends) influence my decision on how to travel to avoid traffic jams.
	SN2	The experiences and opinions of the general public have influenced my interest in trying alternative modes of transportation (such as buses or online motorcycle taxis/taxis).
	SN3	Government policies (such as parking management or the provision of public transportation) influence my decision to give up my private motor vehicle.

Variable	Indicators	
Perceived Behavioral Control	PBC1	I feel capable and confident that I can change my travel habits (for example, leaving earlier, taking the Trans Jogja, or taking back roads) to get around traffic jams.
	PBC2	In my opinion, the ways to avoid traffic jams (such as finding alternative routes or using public transportation) are quite easy and practical for me to do on a daily basis.
	PBC3	I feel I have the freedom to choose the mode of transportation that best suits my needs and is most comfortable for me when the roads are congested.
Perceived Cost	PC1	Changing my travel habits to avoid traffic jams (such as biking) has proven to reduce my daily expenses, especially gas costs.
	PC2	In my opinion, switching to alternative modes of transportation (such as public transit or carpooling) is much more cost-effective than constantly using a private motor vehicle.
	PC3	If the costs associated with owning a private motor vehicle (such as rising gas prices and parking fees) are becoming increasingly expensive, switching to public transportation is the best solution for saving money and reducing traffic congestion at the same time.
	PC4	For me, using public transportation isn't just about saving money—it also makes getting around easier without having to worry about parking fees and vehicle maintenance.
Perceived Usefulness	PU1	Switching to alternative modes of transportation (such as buses or ride-hailing services) really saves me time and energy, especially when traffic is extremely heavy and driving my own vehicle is a real hassle.
	PU2	Taking advantage of the various modes of transportation available (such as Trans Jogja or carpooling) is very helpful for me in reaching my destination more efficiently.
	PU3	Making adjustments to my commute (for example, using a navigation or map app, finding back roads, or changing my departure time) has proven to make my daily commute smoother and less stressful.
Intention	INT1	Going forward, I plan to start or continue adopting travel habits that can help reduce traffic congestion (for example: taking public transportation, biking, or carpooling).
	INT2	I plan to encourage my family and friends to use alternative modes of transportation to help reduce traffic congestion.
	INT3	If public transportation facilities in the Special Region of Yogyakarta (such as bus stops, routes, and safety) become more adequate, I intend to make them my primary choice over private motor vehicles.
	INT4	I intend to gradually reduce my reliance on private motor vehicles and switch to public transportation, provided that travel times and service are reliable.
Traffic Congestion Mitigation Behavior	TCM1	I am willing to switch to public transportation or non-motorized vehicles for short trips (< 5 km) in order to reduce traffic congestion.
	TCM2	If there are safe dedicated lanes available, I prefer to use active modes of transportation (walking or biking) rather than private motor vehicles.
	TCM3	I am considering using public transportation if the parking fees for private motor vehicles in the city center are raised.
	TCM4	I actively adjust my departure times (leaving earlier or coming home later) to avoid rush hour traffic.
	TCM5	When the main route is congested, I immediately look for and take an alternate route, even if it's a bit longer.

Validity and reliability tests were then carried out on the questionnaire design to ensure that the indicators measured were appropriate and consistent, as the compilation of the questionnaire was akin to creating new statements. The research began with a two-stage pilot study involving 36 respondents from the DIY who met the questionnaire criteria. Based on the results of the first stage of evaluation, one statement item was added to the attitude indicator, bringing the total to 26 items. In the second stage, the validity and reliability of these 26 items were tested using the One-Sample Kolmogorov-Smirnov Test for an initial normality test. The results indicated that the data were normally distributed (Sig. 0.200), and all items were deemed valid and reliable (Cronbach's Alpha > 0.6), meaning no statements were removed.

One-Sample Kolmogorov-Smirnov Test

			Unstandardized Residual
N			36
Normal Parameters[a,b]	Mean		.0000000
	Std. Deviation		2.71303304
Most Extreme Differences	Absolute		.097
	Positive		.062
	Negative		-.097
Test Statistic			.097
Asymp. Sig. (2-tailed)[c]			.200[d]
Monte Carlo Sig. (2-tailed)[e]	Sig.		.519
	99% Confidence Interval	Lower Bound	.506
		Upper Bound	.532

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

d. This is a lower bound of the true significance.

e. Lilliefors' method based on 10000 Monte Carlo samples with starting seed 2000000.

Figure 1. One-Sample Kolmogorov-Smirnov Test (Pratama & Dicinta, 2026)

Reliability Statistics

Cronbach's Alpha	N of Items
.956	25

Figure 2. Reliability Test (Pratama & Dicinta, 2026)

Next, the main data collection was conducted online via Google Forms from March to April 2026, with the survey distributed through social media platforms such as WhatsApp, Instagram, X (Twitter), and Facebook. Eligible participants in this study are residents who meet the following criteria: aged 17–64, own a private motor vehicle (motorcycle and/or car), and have resided in the Special Region of Yogyakarta for at least the past year.

From the initial target of 260 respondents, the researcher successfully collected 456 data points, which were then filtered down to 445 after removing invalid raw inputs. This data was then cleaned of outliers or random entries through two stages: manually using Microsoft Excel formulas (reducing the data to 332 entries) and using boxplot graphs in SPSS 27 software, resulting in a total of 303 final data points ready for analysis.

In the final stage, the 303 data points that passed the selection were retested for normality using the One-Sample Kolmogorov-Smirnov Test. The test results showed a significance value of less than 0.05, indicating that the data were not normally distributed. Consequently, the researcher decided to employ the Mann-Whitney test in the subsequent descriptive statistical analysis, as this method is suitable for comparing two independent groups in data that are not normally distributed.

RESULT AND DISCUSSION

This study analysed the descriptive profiles of 303 motorcyclists and car drivers in the Special Region of Yogyakarta based on six personal characteristics to examine their influence on congestion mitigation variables using the Mann-Whitney test. By gender, female participants (158 people) were found to have higher Subjective Norms scores than males (145 people), indicating greater social pressure regarding the consequences of failing to mitigate traffic congestion. Regarding age, the 25–29 age group (the largest category) showed significantly higher Perceived Behavioural Control scores compared to the 60–64 age group (the smallest category), indicating that younger people feel it is easier to undertake traffic congestion mitigation.

Meanwhile, in terms of educational background, Bachelor's degree holders (the largest category) had significantly higher scores for Intention (active willingness and motivation) in planning traffic congestion mitigation compared to primary school graduates (the smallest category). Based on place of residence, a comparison between Gunung Kidul Regency (the largest group) and Yogyakarta City (the smallest group) revealed significant differences across four variables simultaneously: Attitudes, Subjective Norms, Perceived Cost, and Perceived Usefulness. Participants from Gunung Kidul assessed mitigation efforts more positively due to the limited local facilities, felt greater social pressure due to the culture of rural solidarity, felt that transport costs were more burdensome due to the low minimum wage, and perceived greater practical benefits due to their daily commuting routines between regions. Finally, testing on the employment aspect (dominated by private sector employees) and the monthly income aspect (dominated by the range of Rp3,000,001.00 – Rp5,000,000.00) showed results that did not exhibit statistically significant differences across all research variables.

The researchers also asked participants about their history of traffic congestion mitigation through the following questions:

How many motorised vehicles (motorbikes and cars) does your family own or use regularly?
Are you the main driver of these vehicles (motorbikes or cars)?
How often do you usually travel by motorbike or car as the driver?
How often do you travel by motorbike or car as a passenger?
Do you drive your own vehicle or someone else's?
How often do you travel using local buses (Trans Jogja or Teman Bus)?
If you very rarely or never travel by local bus (Trans Jogja or Teman Bus), what are your main reasons for not using this mode of transport? (Select up to 3 main reasons.)
How often do you usually travel within the Special Region of Yogyakarta by taxi or hire/online vehicle? (including app-based services such as Gojek, Grab, Maxim, or conventional taxis.)
Which type of online service do you use most frequently?

The majority of residents in the Special Region of Yogyakarta own at least one or two motor vehicles, 75% of which are privately owned. This high level of ownership makes private vehicles the preferred mode of transport, with 65% of participants being the primary drivers of motorcycles and 47% of them travelling daily due to their busy schedules. The ease of driving, flexibility, and high mobility are the main reasons why people are reluctant to be mere passengers. This phenomenon correlates directly with the low interest in public transport, evidenced by the fact that 59% of participants have never used a local bus. There are three main operational issues with buses that have been highlighted: bus stops being too far from residential areas without temporary parking facilities (25%); unpredictable waiting times due to buses having to share lanes and getting stuck in traffic with other vehicles (20%); and impractical bus routes, as they currently only cover the areas of Yogyakarta City, Sleman, and Bantul (20%).

Similar conditions apply to alternative public transport modes such as taxis and online/offline motorbike taxis, with 47% of participants stating they use them very rarely (less than once a week or only on occasional occasions). When forced to use such services, the public still tends to prefer online motorbike taxi options. This further reinforces the strong perception among residents that motorcycles remain the most comfortable, flexible, and mobile means of transport to support their daily activities compared to other modes of transport.

PLS-SEM Data Analysis

The data analysis technique using the Partial Least Squares (PLS)-based Structural Equation Modelling (SEM) method involves two stages: the evaluation of the outer model and the inner model. Following the evaluation process, hypothesis testing is carried out. The model constructed comprises seven latent variables with 42 indicators. Figure 2 shows the PLS-SEM model constructed using SmartPLS 3 software.

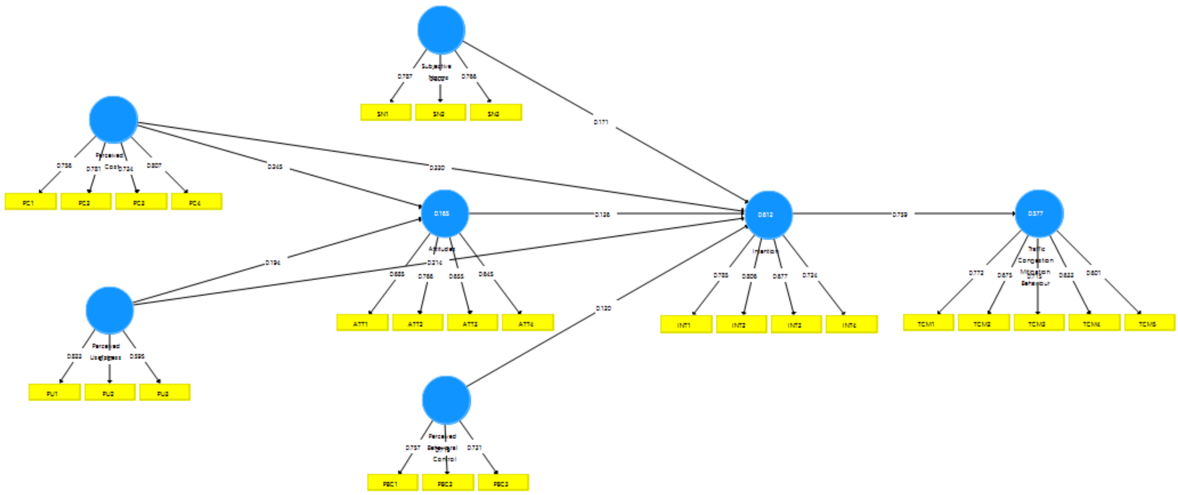

Figure 3. PLS-SEM Model (Pratama & Dicinta, 2026)

An evaluation of the measurement model (outer model) was conducted to verify the validity and reliability of the research instrument. In the first stage of the convergent validity test, eight indicators (ATT1, ATT3, ATT4, INT3, PU3, TCM2, TCM4, TCM5) and one additional indicator identified in the second test (INT4) were found to have outer loadings below 0.7. After these eight invalid items were eliminated, the final model retained 18 indicators, all of which met the criteria of an outer loading > 0.7 and an Average Variance Extracted (AVE) > 0.5, indicating high convergent validity. Furthermore, tests of discriminant validity using the cross-loading and Fornell-Larcker criteria showed that each indicator had the highest correlation with its own variable compared to other constructs, thus confirming their validity. The internal consistency reliability test was also met, as all latent variables produced composite reliability (CR) values above the threshold of 0.70.

Once the outer model was satisfied, a structural model (inner model) evaluation was conducted to examine the predictive ability of the relationships between variables. The results of the multicollinearity test showed a Variance Inflation Factor (VIF) < 5 for all variables, meaning the model was free from multicollinearity issues. In the assessment of the coefficient of determination (R^2), the intention variable had a moderate level of accuracy, whilst attitudes and traffic congestion mitigation behavior had weak values; however, these indices were deemed sufficiently adequate for the discipline of consumer behavior ($R^2 > 0.20$). Furthermore, the predictive relevance test (Q^2) for these three variables yielded values > 0, proving that the model possesses good predictive relevance for the endogenous latent variables.

Through hypothesis testing using PLS Bootstrapping by comparing the T-statistic value against the T-table (1.96) at the 0.05 level, five positive and significant causal relationships were identified. These relationships include the influence of perceived cost on attitudes and intention, the influence of perceived usefulness on intention, the influence of subjective norms on intention, and the influence of intention, which contributes most significantly to traffic congestion mitigation behavior. Conversely, there were three hypothesised relationships found to have no statistically significant influence, namely the influence of perceived usefulness on attitudes, and the influence of attitudes and perceived behavioural control on intention.

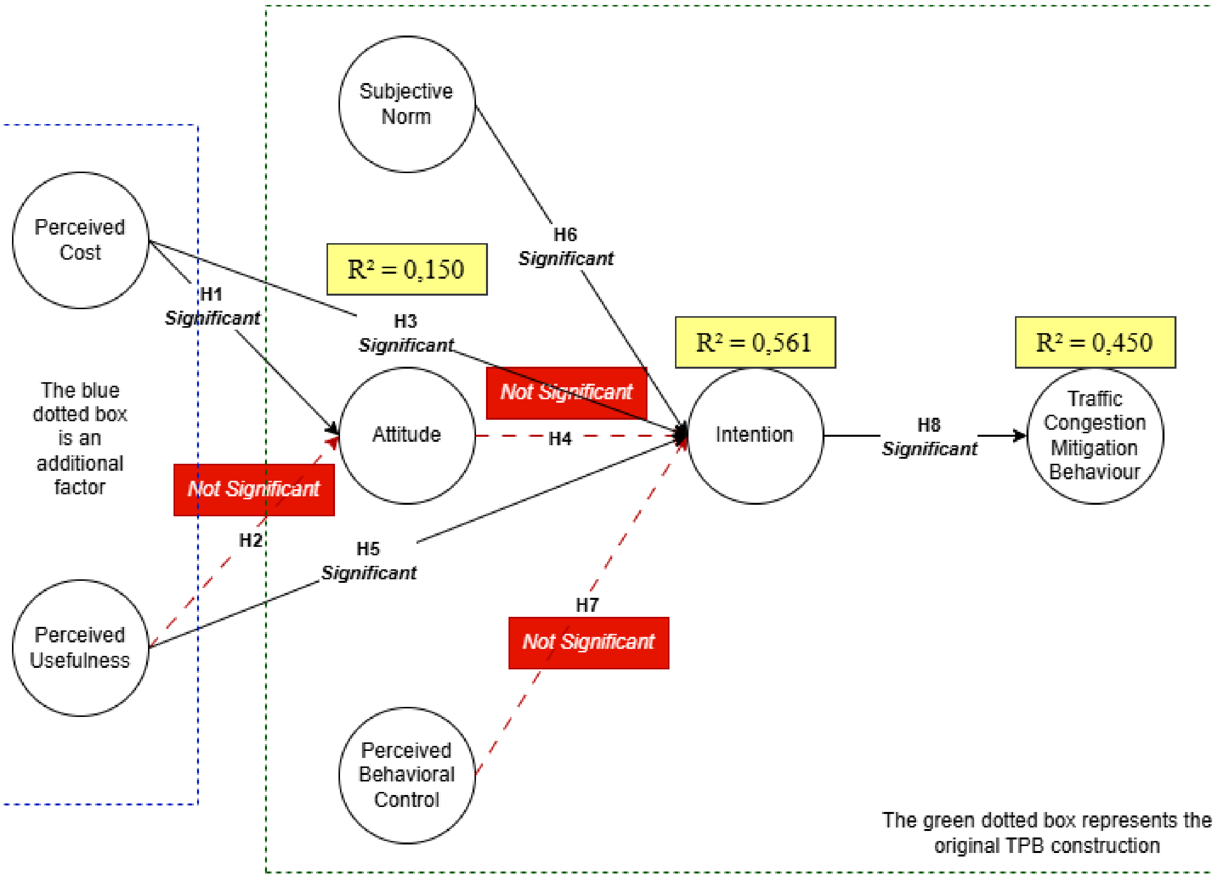

Figure 4. Final Model of Traffic Congestion Mitigation Behavior in the Special Region of Yogyakarta (Pratama & Dicinta, 2026)

Unlike the study by Kaura & Georgakis (2019), which used only two clusters, this study employed Non-Hierarchical Cluster Analysis (K-Means) via SPSS 27 to generate seven unique clusters based on the combination of scores from seven determining variables. The results of the significance test showed that all instruments were valid (sig. < 0.05) in distinguishing respondent characteristics, with the number of participants varying across each group, ranging from the smallest cluster comprising 11 people to the largest cluster comprising 91 people.

These seven clusters were then categorised into two main behavioural groups. The first is the Adaptive Drivers Group (easily accepting of mitigation measures), which includes the Rational-Optimistic type (convinced of the benefits of change), the Conformist type (compliant due to social/environmental pressure), the Passive Intender type (currently only discussing the issue without taking action), and the Proactive type (already actively practising congestion mitigation). The second is the Resistant Driver Group (difficult to accept mitigation), which includes the Calculative-Economic type (highly sensitive to costs and effort), the Situationally Constrained type (feeling resigned due to a lack of alternative routes), and the Sceptical-Apathetic type (indifferent and self-centred). Ultimately, this mapping of driver characteristics serves as the basis for humane and efficient transport policy interventions aimed at optimising urban logistics. In the context of the DIY community, this effective and stress-free mobility aligns with the principle of 'halalan thayyiban', as it eliminates the harm caused by the waste of time and energy on the roads, which in turn can enhance the productivity and overall quality of life of residents.

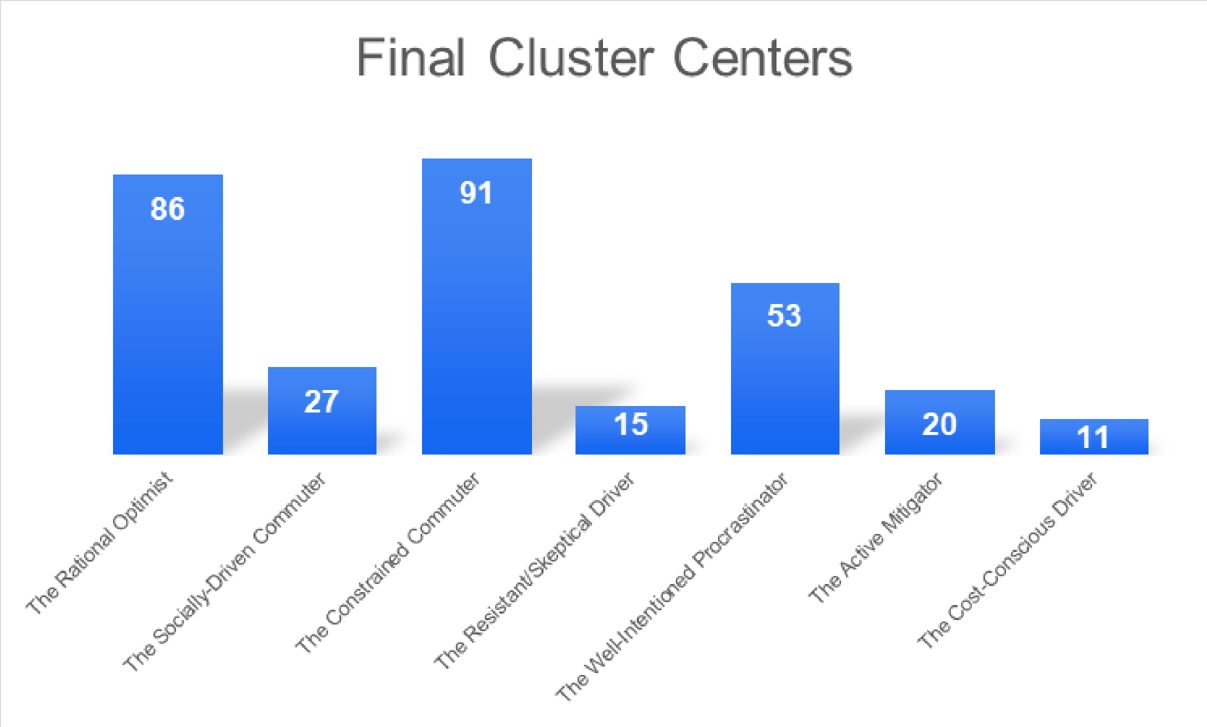

Figure 5. Motorcycle Riders in the Special Region of Yogyakarta (Pratama & Dicinta, 2026)

CONCLUSION

As a concrete proposal for improvement (re-design) based on macro-ergonomics, the Provincial Government of DIY needs to integrate human (passengers), organisational (transport operators) and technological elements by providing integrated Park-and-Ride facilities in urban fringe areas (such as the Sleman-Bantul boundary and the Gunung Kidul commuter corridor). This step directly addresses the operational challenges of the current transport system, where 25% of the public are reluctant to use buses due to the remote location of bus stops without adequate vehicle parking facilities.

Given that the Perceived Cost variable has been shown to have a significant influence on the formation of drivers' behavioural intentions, this macro-ergonomic intervention must be managed using a transparent Cost-Benefit Analysis (CBA) approach from the consumer's perspective, particularly for drivers of the Calculative-Economic type. Structurally, this system is implemented via a single-payment gateway architecture based on an app, where the cost of private vehicle parking at the border already includes (bundles) a TransJogja ticket. Based on cost-benefit analysis, the disincentive policy of high progressive parking tariffs in the city centre can have its subsidy redirected to reduce the operational costs of this Park-and-Ride scheme.

With this macro-level intervention, the rational calculations of cost-sensitive commuters (nglaju) due to the constraints of the minimum wage will shift naturally. Drivers will see that the economic benefits (fuel savings and the elimination of city parking fees) far outweigh the cognitive and financial costs of switching modes. This user-centred redesign of the transport system not only alleviates physical congestion but also optimises social welfare and urban logistics efficiency in line with the essence of halalan thoyyiban.

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