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# *TRANSPORT DEMAND MANAGEMENT STRATEGY PRIORITY ASSESSMENT BASED ON EXPERT JUDGMENT*

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***ABSTRACT***
*The main problem of transportation is the very high growth of vehicles causing congestion, resulting in various derivative impacts such as pollution, fuel waste, time value, and other environmental problems. This problem can be solved by Transportation Demand Management (TDM). TDM is a combination of various strategies, which strategy should be chosen whose priority depends on the conditions of each region. This research was conducted in a medium-scale city by determining the priority of TDM using the Analytical Hierarchy Process (AHP) tool. The final result of the judgment is the priority weight of the TDM strategy that will be applied with a CR value of < 10%, namely the pull strategy. This strategy is represented by improving public transport services and infrastructure (especially the integration of public transport services). This study shows that the strategy group with a high AHP Consensus Index (ACI) score means a high consensus among experts.*
***Keywords***: *Analytical Hierarchy Process, Judgment, Medium City, Priority, Strategy, Transportation Demand Management*

## 1. Introduction

The city of Yogyakarta is a medium-urban area with relatively high growth of motorized vehicles (4-6% per year) (Kresnanto, 2019). The number of vehicles entering the city from the hinterland area also make higher growth of motorized vehicles (*Urban Sprawl Dan Kemacetan Di Yogyakarta | Balairungpress*, 2018). Those conditions make Yogyakarta City experience high traffic density and contribute to environmental problems (Eriksson et al., 2008). Recorded in 2020, the average volume capacity ratio (VCR) has reached 0.75 (Kresnanto, 2021a). This ratio means that more and more roads are experiencing congestion. Congestion will result in various negative impacts, ranging from air/noise pollution, waste of fuel, and loss of time value (Anggarani et al., 2016; CIE, 2006; Dargay et al., 2007; Nugmanova et al., 2019; Yang et al., 2016). One of the solutions to the condition is by balancing supply and demand. Supply in a road network that serves traffic flow will undoubtedly be complicated to increase its capacity because it is an urban area. Thus, the best way to balance supply and demand is to reduce the amount of demand. This method/method is known as Transport Demand Management (TDM). The city of Yogyakarta needs TDM as a solution and its implementation.

TDM is a series of policies/strategies aimed at transport efficiency (supporting sustainable transportation) by reducing the use of private vehicles and prioritizing the use of transit, walking and non-motorized mode or vehicles that are more environmentally friendly. (Broaddus et al., 2009; *Chapter 32: Transportation Demand Management (TDM)*, 2010; Habibian & Kermanshah, 2011; Nygaard Nelson, 2008). The results of the literature search show that in general the TDM strategy is divided into two policy strategies, push-strategy and pull-strategy. Pull-strategy encourage use of non-car modes by making them attractive to car users; these policies include transit-oriented development, road reclamation and bus rapid transit development. In contrast, a push-strategy is one that discourages car use by making it less attractive; this policy includes toll roads, parking fees and guard fees (Habibian & Kermanshah, 2011). According to Kresnanto (2021b), there are 15 types of push strategies and 11 types of pull strategies that can be implemented as part of TDM. The number of these strategies requires an assessment of the priority strategies that can be implemented. Thus, the main problem in implementing TDM is which strategy is considered the most effective that can be implemented in a particular area/city (in this study, Yogyakarta City) to overcome congestion problems due to an imbalance between supply and demand.

The effectiveness of TDM in overcoming urban transportation problems has been proven in several countries (Islam & Saaty, 2010; Nygaard Nelson, 2008). However, the choice of prioritized strategy should be studied more deeply (Bylinko, 2020). Prior research stated that many strategies might be implemented, such as improving public transport, raising the tax, subsidizing renewable fuel, improving the facilities for cyclists and pedestrians, road charging, increasing the parking price, and land use management (Eriksson et al., 2008; Nugmanova et al., 2019). However, it is necessary to know the priority of the TDM strategy that will be implemented. The TDM strategy priorities that will be implemented can be used as a reference for policymakers so that TDM can run effectively. Thus this research aims to determine which priority TDM policy strategies will be implemented in the City of Yogyakarta.

Determining the priority of the TDM strategy to be implemented in the City of Yogyakarta will be analyzed with an analytical tool, namely the Analytical Hierarchy Process (AHP). AHP is a decision-making method based on experts' opinions included in the Multiple-Criteria-Decision-Making (MCDM) method (De Brito & Evers, 2016). AHP is used in this study as a tool because AHP has been widely used for priority analysis of transportation solving strategies in general (Ahmed et al., 2017; Moslem & Duleba, 2017; Podvezko et al., 2014), even those specific to TDM strategy priorities (Alkharabsheh et al., 2019; Pradana, 2012).

## 2. Literature Review

### Yogyakarta as A Medium City

Yogyakarta is a medium city based on the definition of a medium city (*OECD Regions and Cities at a Glance 2020*, 2020). Urban population by city size is determined by population density and commuting patterns; this better reflects cities' economic function and administrative boundaries. Urban areas in OECD countries are classified as: large metropolitan areas if they have a population of 1.5 million or more; metropolitan areas if their population is between 500,000 and 1.5 million; medium-size urban areas if their population is between 200,000 and 500,000; and small urban areas if their population is between 50,000 and 200,000. This indicator is measured as a percentage of the national population (*OECD Regions and Cities at a Glance 2020*, 2020). According to the OECD, the city of Yogyakarta is a medium-sized city that is already very densely populated because the current population is 438,761 people (*BPS Provinsi D.I. Yogyakarta*, 2020), almost in the category of a metropolitan area.

### Transportation Demand Management

Transportation/Travel Demand Management (TDM) has become more popular since discussing how to provide alternatives to travel, either self-driving or sharing a vehicle with various time-based travel destinations, to improve trip reliability (*Transportation Demand Management | Organizing and Planning for Operations - FHWA Office of Operations*, 2022). TDM also means to do two things: 1) prioritize efficient travel modes (which consume less road space per passenger kilometre); and 2) diverting travel by inefficient modes to off-peak periods to reduce congestion (*Chapter 32: Transportation Demand Management (TDM)*, 2010). Recent research on travel management directly addresses push and pull measures to ensure efficiency in traffic capacity (Nugmanova et al., 2019) but mention that measures are not the only solution to manage traffic congestion. Push and pull measures also should combine with another way, such as increasing road capacity.

TDM maximizes the efficiency of the urban transportation system by limiting the unnecessary use of private vehicles. Then we discuss a push strategy to encourage more effective, healthy and friendly modes of transportation. Furthermore, we mention the second as a pull strategy, which addresses making environmentally-friendly modes, such as public transportation, walking, cycling, and another choice of travel modes (Habibian & Kermanshah, 2011). Based on the discussion above, TDM can define as an effort to provide efficient alternative modes of travel and divert travel demand to use these efficient modes of travel to overcome congestion and the impact of congestion.

**Important Issue of TDM Strategy Implementation**

Several issues related to the implementation of TDM are: (1) Where has TDM proven successful?; (2) How to determine the best TDM strategy in the situation of the study area?; and (3) Do you need more than one TDM strategy? (Nygaard Nelson, 2008).

Where has TDM proven successful? The best experience of TDM in other countries that have been successfully recorded is in Bellevue, Washington, a city with an area of 97.14 km2, which has succeeded in reducing > 30% of private vehicle use by implementing TDM from 1990-2000). London applies Single Occupant Vehicle (SOV) Pricing by charging a vehicle with only one passenger (driver only) when entering the city. This strategy can increase the use of public transport reduce accidents and pollution (Nygaard Nelson, 2008). However, specific strategies - establishing congestion pricing, parking management, developing compact mixed-use, and providing high-capacity Public Transport (AU) services - have repeatedly succeeded in reducing travel demand and shifting travel from single-passenger vehicles to more advanced modes.

Implementing the use of public transit can significantly reduce congestion (more than 45% on some roads (Li & Guo, 2016). One person who switches from travelling 20 miles alone by car to available public transport can reduce their annual CO2 emissions by 20 pounds per day, or more than 48,000 pounds in a year. That equates to a 10% reduction in all greenhouse gases produced by a household with two adults two cars (KCATA, 2023). A study in Vietnam stated that the public, in general, responded positively that public transport was a strategy to reduce congestion and pollution (Le & Trinh, 2016).

On average, a driving vehicle releases about 0.96 - 1.1 pounds of CO2 per mile, while riding a bicycle does not. The success of the program to use bicycles as transportation, in addition to providing adequate facilities, also requires the strength of leaders in its implementation (Karanikola et al., 2018); cycling is also a means of reducing pollution that is harmful to health (Tainio et al., 2016) and can reduce congestion by up to 4% of research results in Washington (Hamilton & Wichman, 2018).

Road pricing can significantly reduce congestion by 20-25% and is predicted to reduce vehicle trips by 30% (Mattsson, 2008). Several researchers have also carried out studies on the success of various TDM strategies in various countries to overcome transportation problems (Kusumantoro et al., 2009).

How to determine the best TDM strategy in the situation of the study area? The strategies adopted will depend on the overall objectives and desired outcomes. The TDM strategy that will be carried out depends on the conditions of each region that will implement it. Do you need more than one TDM strategy? It is challenging to determine the effectiveness of either strategy, and TDM works best when complementary strategies are packaged together (e.g., improved bus service combined with subsidized transit tickets) (Nygaard Nelson, 2008).

Many strategies are part of TDM (Broaddus et al., 2009; *Chapter 32: Transportation Demand Management (TDM)*, 2010; Mittal & Biswas, 2019; Southern California Association of Governments, 2019), is stated that TDM is a series of strategies such as the promotion of alternative modes of transportation, financial and time incentives, dissemination of information and marketing to promote these modes, and support services using alternative modes (US department of Transportation, 1994). Because of the many strategies in TDM, the question is which strategy is the most effective (single strategy) or which combination of strategies can best solve the problem of traffic congestion? (Nygaard Nelson, 2008). There is no effective TDM implementation with only one strategy (Thomas et al., 2020). There must be a combination of strategies in TDM. A combination of several TDM strategies can be more effective up to 10% (United States. Department of Transportation, 2020). In addition to the combination of strategies, strategic priorities must also be determined that must be carried out according to the area’s conditions to be applied TDM because each goal and area of specific TDM implementation will have different priorities for the TDM strategy (Nygaard Nelson, 2008). One of the tools to determine priorities is the Analytical Hierarchy Process (AHP), a non-linear framework for addressing complex semi-structured decision-making problems. AHP is a scaling method for deriving priorities (weights) for a set of options/scenarios based on their importance, which is one of the Multicriteria Decision Making (MCDM) methods (Saaty, 1980, 1990, 2008). Multicriteria

Analysis is applicable at the micro-scale, where all the stakeholders can be easily individuated and consulted and can express informed opinions on their priorities (Beria et al., 2012).

**AHP as A Tool to Priorities TDM Strategy**

AHP has been used for decision-making analysis on various transportation issues, from policy level to implementation (Baric & Starcevic, 2015; Nalmpantis et al., 2019). Including AHP is used in determining the priority of the TDM strategy. However, it is still only for a few strategies, such as (1) prioritizing the TDM strategy from 3 strategies (public transportation, non-motorized improvement, and Alternative Work Schedules) in Bandung (Pradana, 2012); (2) case study in Iran (Soltani & Namdarian, 2012) carried out the priority weighting of the TDM strategy from practical, social, economic, and environmental factors, (3) case study in Zagreb a big city with a population of almost 1 million people, using five main criteria in TDM priority (Šimunović et al., 2013)

## 3. Research Methods

This study uses AHP to determine the priority of TDM strategy with a case study of Yogyakarta City, one of the medium-sized cities in Indonesia. The methodological stage will follow as (i) building the hierarchy, (ii) weighting the indicators by pairwise comparison, and (iii) calculating the final value for the alternatives (Saaty, 1990). AHP relies on three main principles: a) the decomposition of the decision space into its fundamental elements, b) the comparative judgments, and c) the synthesis of priorities (Saaty, 2005). The study begins by listing alternative TDM strategies from four northern works of literature (AbuLibdeh, 2017; Broaddus et al., 2009; Nygaard Nelson, 2008; Thomas et al., 2020) and several supporting works of literature. From the list of alternative strategies, strategies that might be applied in Yogyakarta were selected. After the alternative strategy is selected, a priority assessment is carried out by the expert using AHP. The AHP process uses the AHP-OS software, a free web-based AHP solution that supports the decision-making process (Goepel, 2018). It can be accessed viahttps://bpmsg.com/ahp/.

The AHP steps are as in Fig. 1., starting from determining the goal, making alternative structures to the smallest level, pairwise comparison by experts, and calculating the eigenvalues of alternative criteria. Eigen Value is the weight of the influence of alternative strategies on achieving goals. The consistency of expert judgment is measured by the Consistency Ratio (CR), which must be less than 0.1 (10%). The AHP implementation procedure in assessing the priority of the AHP strategy will be based on the AHP method from several previous researchers (Fitriastuti & Kresnanto, 2021; Saaty, 1980, 1990, 2008).

The respondent selection, which consists of experts, considers the disparity between experts and non-expert, especially if we need specific opinions on transportation expertise. Prior research stated that experts more have psychological, social and institutional factors (Whitmarsh et al., 2009), different types of information processing (Xenias & Whitmarsh, 2013) and the way of developing reasoning (Weber, 2010). The two types of reasoning, experiential reasoning, which is affective, automatic and rapid, given mainly by non-expert, and analytic reasoning, which is more deliberative, conscious, and cognitive-based, hopefully, given by the experts. So, the participants in this study are experts because we need analytical reasoning to develop the study result. The respondents' scope is the experts from an academic background (lecturer, transportation experts) and civil servants who have duties in transportation (Dinas Perhubungan Kota Yogyakarta).

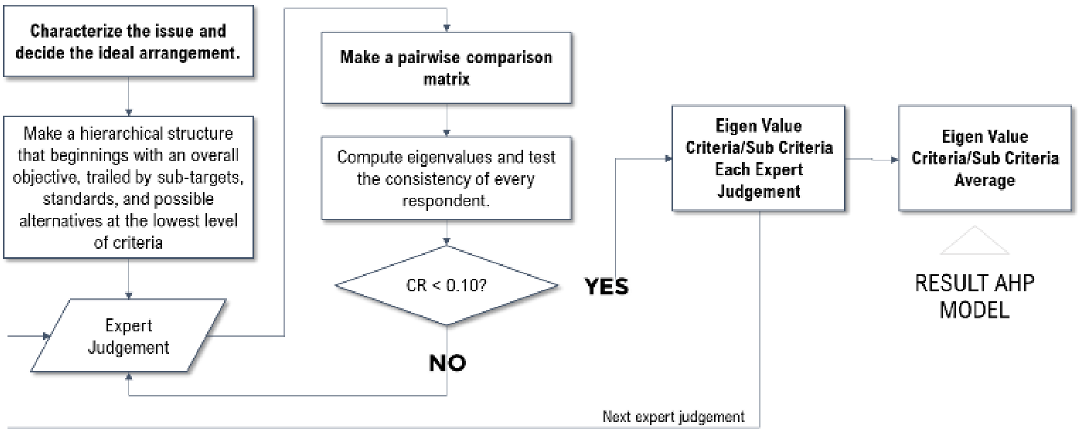


Fig 1. Research design - AHP steps

Another indicator to assess the results of the AHP is the AHP consensus indicator (ACI). The ACI is used to measure group consensus (approximate agreement on exit priorities between participants). The range for this indicator is 0% to 100%. Zero per cent is not a consensus at all; 100% is a complete consensus. This indicator is derived from Shannon's concept of diversity based on alpha and beta entropy (Goepel, 2018). It is a measure of priority uniformity among participants and can also be interpreted as a measure of overlap between group member priorities (*AHP Group Consensus Indicator – How to Understand and Interpret? – BPMSG*, 2020).

ACI falls into three categories: low, medium and high. Assign the following percentages to these categories:

- Very low: Less than 50%
- Low consensus: 50% to 65%
- Medium consensus: 65% to 75%
- High consensus: 75% to 85%
- Very high consensus: Value of over 85%

If is less than 50%, there is virtually no consensus within the group and there is a high degree of variety of judgment. Scores in the 80% to 90% range indicate high priority overlap and a good match in group member ratings

## 4. Results and Discussions

### TDM Strategy

The results of the literature reviews show that, in general, the TDM strategy is divided into two policy strategies, namely push strategy and pull strategy (Broaddus et al., 2009). Transport policies could be implemented successfully if the community has perceived fairness effectiveness and does not restrict freedom (Xenias & Whitmarsh, 2013). Pull policies encourage behaviour change by providing and improving alternatives (Schuitema et al., 2010), such as using non-car modes by making them attractive to car users. These policies include transit-oriented development, road reclamation, and bus rapid transit development. In contrast, a push policy, which prohibits or constrain behaviours [47], discourages car use by making it less attractive; this policy includes taxes, toll roads, parking fees, and guard fees (Habibian & Kermanshah, 2011). Then the two major groups of strategies are divided into implementing strategies, as shown in Fig 2.

### AHP Result

The final result of the analysis using AHP is the weight of the influence/priority of a strategy/alternative strategy to achieve the goal. This weight is indicated by the eigenvalue results from the expert assessment (pairwise comparison judgment). The experts who assessed the alternative strategies provided were 11 experts from academia, regulators (government), and transportation business actors. Of the 11 experts who conducted the AHP assessment, there were seven whose CR was more than 10%, so the results of this assessment could not be used, namely Part (Participants) 2, 3, 6, 7, 9, 10, 11. The AHP assessment results from all participants can be seen in table 1, and the result of the AHP assessment of participants that CR under 10% can be seen in table 2.

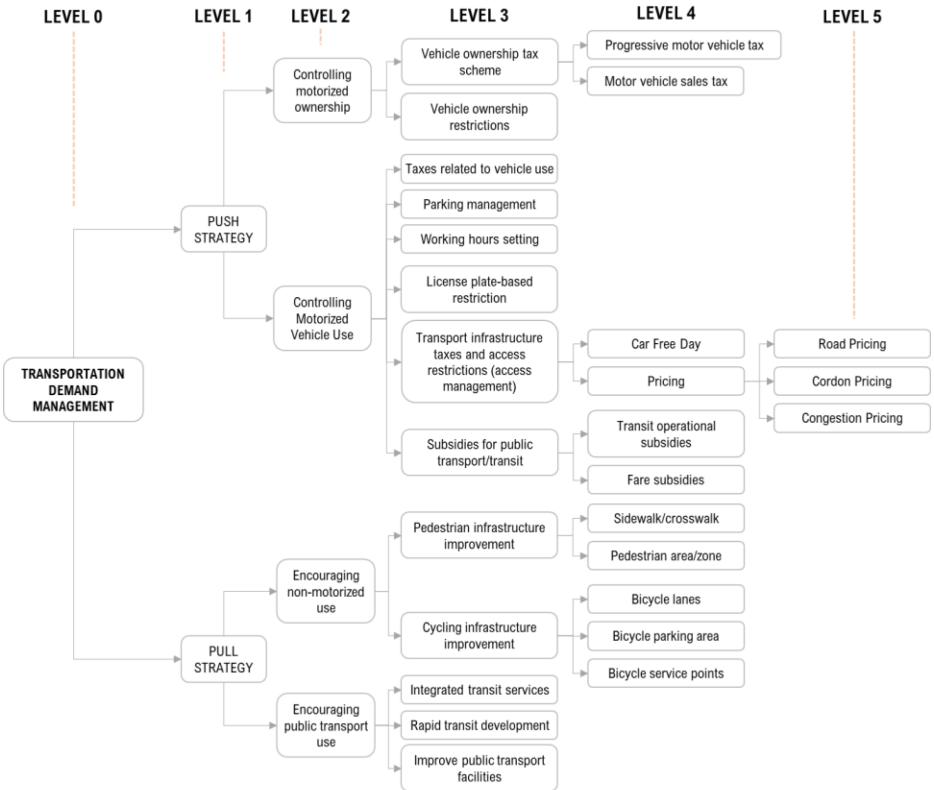


Fig 2. TDM strategy based on literature review
Sources: (AbuLibdeh, 2017; Broaddus et al., 2009; Nygaard Nelson, 2008; Thomas et al., 2020)

Table 1 - AHP result from all participants

| TDM Strategy | Participant | | | | | | | | | | | Group result |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Part 1 | Part 2 | Part 3 | Part 4 | Part 5 | Part 6 | Part 7 | Part 8 | Part 9 | Part 10 | Part 11 | |
| **Progressive motor vehicle tax** | 1.10% | 11.10% | 8.00% | 11.10% | 9.40% | 2.90% | 0.90% | 58.60% | 0.70% | 11.20% | 4.40% | **10.10%** |
| **Motor vehicle sales tax** | 0.10% | 11.10% | 1.10% | 5.60% | 9.40% | 8.70% | 0.10% | 8.40% | 0.40% | 11.20% | 4.40% | **4.80%** |
| **Vehicle ownership permit** | 0.20% | 22.20% | 1.80% | 5.60% | 18.80% | 2.30% | 0.20% | 9.60% | 4.40% | 2.50% | 1.20% | **4.70%** |
| **Fuel tax** | 1.30% | 2.50% | 0.70% | 4.60% | 1.90% | 2.20% | 0.90% | 1.80% | 0.90% | 8.50% | 2.00% | **3.60%** |
| **Road Pricing** | 0.00% | 0.20% | 0.00% | 0.10% | 0.30% | 0.70% | 0.50% | 0.00% | 0.10% | 1.20% | 2.10% | **0.60%** |
| **Cordon Pricing** | 0.10% | 0.10% | 0.00% | 0.10% | 0.10% | 0.30% | 0.10% | 0.00% | 0.20% | 5.10% | 6.20% | **0.50%** |
| **Congestion Pricing** | 0.00% | 0.10% | 0.10% | 0.10% | 0.10% | 2.50% | 0.10% | 0.00% | 0.10% | 0.30% | 0.70% | **0.40%** |
| **License Plate Restriction** | 0.40% | 5.40% | 0.10% | 0.50% | 1.20% | 1.20% | 3.40% | 0.10% | 0.60% | 0.40% | 3.10% | **1.90%** |
| **Parking management** | 0.30% | 0.90% | 0.10% | 2.10% | 0.50% | 4.20% | 0.70% | 0.40% | 1.20% | 0.60% | 5.40% | **1.50%** |
| **Car Free Day** | 0.00% | 1.50% | 0.00% | 1.00% | 0.20% | 10.30% | 0.30% | 0.30% | 1.10% | 1.50% | 0.90% | **1.30%** |
| **Working hours setting** | 2.90% | 7.40% | 0.20% | 1.80% | 1.50% | 7.90% | 0.30% | 2.70% | 2.80% | 2.50% | 3.30% | **3.70%** |
| **Fare subsidies** | 5.40% | 19.80% | 0.20% | 0.40% | 3.30% | 6.70% | 3.10% | 2.80% | 1.00% | 2.50% | 8.20% | **5.70%** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Transit operational subsidies** | 0.70% | 6.60% | 0.20% | 0.40% | 3.30% | 33.40% | 0.40% | 2.80% | 3.10% | 2.50% | 8.20% | **4.50%** |
| **Sidewalk/Crosswalk** | 1.00% | 0.70% | 12.20% | 8.30% | 4.70% | 1.70% | 3.70% | 0.80% | 11.70% | 1.20% | 3.60% | **5.00%** |
| **Pedestrian Area** | 6.70% | 0.10% | 2.40% | 8.30% | 1.60% | 0.30% | 0.70% | 0.10% | 3.90% | 11.20% | 0.60% | **2.30%** |
| **Bicycle lanes** | 0.80% | 0.50% | 8.50% | 9.80% | 1.20% | 0.20% | 1.80% | 0.70% | 3.30% | 5.90% | 2.90% | **2.70%** |
| **Bicycle Parking Area** | 0.20% | 0.20% | 4.10% | 5.40% | 0.60% | 0.40% | 1.80% | 0.10% | 1.20% | 5.90% | 1.00% | **1.30%** |
| **Bicycle service points** | 0.10% | 0.10% | 2.00% | 1.50% | 0.30% | 0.10% | 0.90% | 0.20% | 0.70% | 0.70% | 0.30% | **0.50%** |
| **Integrated transit services (schedule, fare)** | 53.70% | 5.30% | 34.60% | 18.00% | 6.50% | 9.50% | 49.20% | 5.40% | 34.20% | 8.30% | 27.30% | **24.60%** |
| **Rapid transit development (bus lanes, bus priority at the junction)** | 6.50% | 1.40% | 14.50% | 5.40% | 27.40% | 1.10% | 9.40% | 0.90% | 16.40% | 8.30% | 10.40% | **8.80%** |
| **Improve public transport facilities (station, bus stop, etc)** | 18.60% | 2.80% | 9.20% | 9.90% | 7.70% | 3.30% | 21.50% | 4.40% | 11.90% | 8.30% | 4.00% | **11.30%** |
| **$CR_{max}$** | 9.80% | 45.50% | 14.10% | 1.00% | 7.00% | 30.80% | 22.70% | 8.50% | 14.10% | 58.50% | 30.80% | **0.70%** |

Table 2 - AHP results from participants with CR < 10%

| TDM Strategy | Participant | | | | Group result |
|---|---|---|---|---|---|
| | Part 1 | Part 4 | Part 5 | Part 8 | |
| Progressive motor vehicle tax | 1.10% | 11.10% | 9.40% | 58.60% | 16.10% |
| Motor vehicle sales tax | 0.10% | 5.60% | 9.40% | 8.40% | 4.80% |
| Vehicle ownership permit | 0.20% | 5.60% | 18.80% | 9.60% | 5.80% |
| Fuel tax | 1.30% | 4.60% | 1.90% | 1.80% | 3.80% |
| Road Pricing | 0.00% | 0.10% | 0.30% | 0.00% | 0.10% |
| Cordon Pricing | 0.10% | 0.10% | 0.10% | 0.00% | 0.10% |
| Congestion Pricing | 0.00% | 0.10% | 0.10% | 0.00% | 0.10% |
| License Plate Restriction | 0.40% | 0.50% | 1.20% | 0.10% | 0.90% |
| Parking management | 0.30% | 2.10% | 0.50% | 0.40% | 1.10% |
| Car Free Day | 0.00% | 1.00% | 0.20% | 0.30% | 0.50% |
| Working hours setting | 2.90% | 1.80% | 1.50% | 2.70% | 4.00% |
| Fare subsidies | 5.40% | 0.40% | 3.30% | 2.80% | 4.30% |
| Transit operational subsidies | 0.70% | 0.40% | 3.30% | 2.80% | 2.60% |
| Sidewalk/Crosswalk | 1.00% | 8.30% | 4.70% | 0.80% | 4.20% |
| Pedestrian Area | 6.70% | 8.30% | 1.60% | 0.10% | 3.30% |
| Bicycle lanes | 0.80% | 9.80% | 1.20% | 0.70% | 2.40% |
| Bicycle Parking Area | 0.20% | 5.40% | 0.60% | 0.10% | 0.70% |
| Bicycle service points | 0.10% | 1.50% | 0.30% | 0.20% | 0.40% |
| Integrated transit services (schedule, fare) | 53.70% | 18.00% | 6.50% | 5.40% | 21.70% |
| Rapid transit development (bus lanes, bus priority at the junction) | 6.50% | 5.40% | 27.40% | 0.90% | 8.70% |
| Improve public transport facilities (station, bus stop, etc) | 18.60% | 9.90% | 7.70% | 4.40% | 14.30% |
| | 9.80% | 1.00% | 7.00% | 8.50% | 3.10% |

Based on the result of AHP that CR < 10%, the assessment at level 1 (top-level), Pull Strategy weights 55.8%, meaning that according to experts, this strategy should take precedence over Pull Strategy with a total of 15.8% points (Fig 3). Assessment at level 2, the experts prefer the strategy of encouraging the use of public transportation as a feasible strategy to be implemented with a weight of 80.2% (Fig 3). This result indicates that encouraging public transport quality in better strategies is still the main priority, especially for local government. In line with several previous studies that improving the quality of public transport services is one of the TDM strategies that can reduce congestion due to the shift from using private vehicles to using public transportation. The modal selection simulation conducted by Abdulkareem et al. (2020) shows that 48.3% of users will switch to public transportation if the travel time is shorter. Application simulations in Kuwait also prove that public transportation can reduce fuel consumption by up to 46% (reducing congestion) (AlKheder, 2021). Inadequate investment to improve public transport also results in an increase in the growth of private vehicles and has an impact on congestion (Fulponi, 2023). Several research results show that public transportation is the most reliable TDM strategy for overcoming congestion, as well as the results of this AHP study showing similar results.

However, the one big issue of improving public transport efficiency that should be addressed in developing policies is attracting new users, which must consider the community economically and psychologically (Belwal & Belwal, 2010; Moslem & Çelikbilek, 2020; Nalmpantis et al., 2019). Even though making good perspectives in public transport socially and psychologically in Indonesia’s culture is hard to do, the behavioural intention to using the public transport that still follows the influencer people is the facts found here. It means that the systematic movement on the community to develop the choice of using public transport is a must be a priority program while improving the public transport facilities. The systematic movement must follow sufficient public acceptability for better strategy implementation (Eriksson et al., 2008).

Of course, the weight on this strategy will affect the weight on the strategy at the level below it. The top three final results of the alternative weights (level 3), the integration of public transport services dominates the weight of 21.7%, the progressive motor vehicle tax (16.1%), and improve public transport facilities (station, bus stop, etc.) (14.3). The complete weighted AHP results show in Fig. 3.

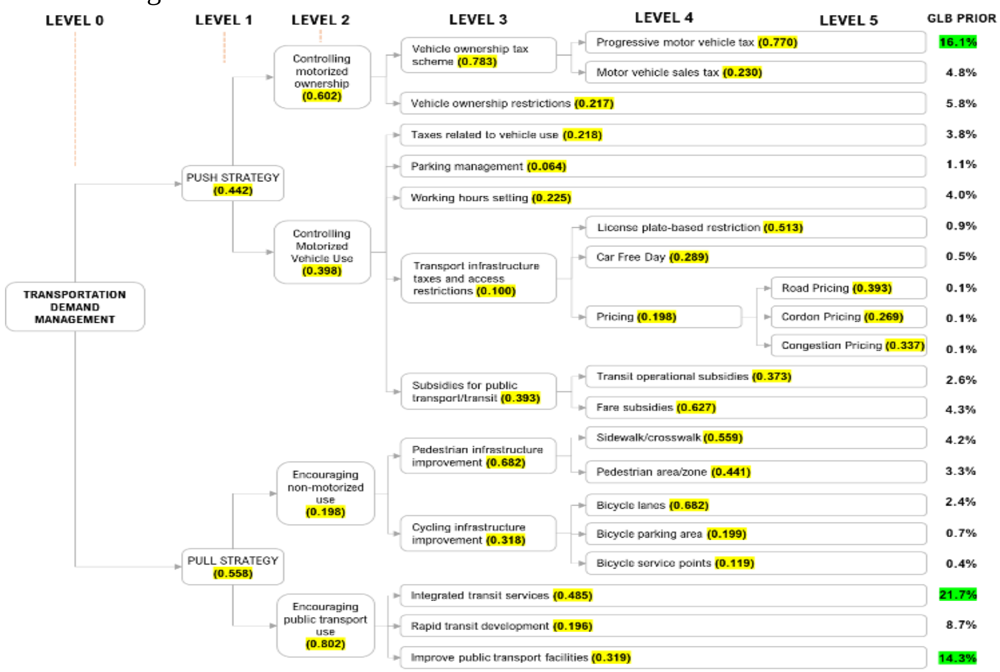


Fig 3. AHP Weighting Results of Interests Between TDM Strategies

The results of the AHP assessment demonstrated that TDM would indeed succeed by prioritizing the pull strategy, but it must also balance with the push strategy. The push strategy evidences this conclusion at level 3, which is relatively high. Implementing a combination strategy also suggested by several researchers to increase public acceptability (Eriksson et al., 2008; Steg & Schuitema, 2007). The combination of TDM policy implementation must also be a balanced policy between push and pull strategies so that TDM goals can be achieved properly (He et al., 2009; Wang et al., 2022). One of the keys to the successful implementation of TDM is community behavior factors related to motivation, norms and personal intentions (Eriksson et al., 2010). Even the implementation of TDM without a combination of coercive policies will not succeed in effectively reducing private vehicle use (Gärling & Schuitema, 2007).

The results of the ACI assessment at the top level (level 1) in the pull strategy group showed that the expert had high uniformity with an ACI value of 79.1% (high consensus). In contrast, in the push strategy group, the expert had a diversity of assessments. It was indicated by the ACI value of 43.4% (very low consensus). Other strategic groups that get the ACI in the high category are control of motorized vehicle owners (80.1%), vehicle ownership tax schemes (78.1%), subsidies for public transport (78.9%), encouraging the use of non-motorized vehicles (80.4%), and cycling infrastructure improvement (90.8%). The hierarchy of strategies and ACI values in each group can be seen in Fig. 4.

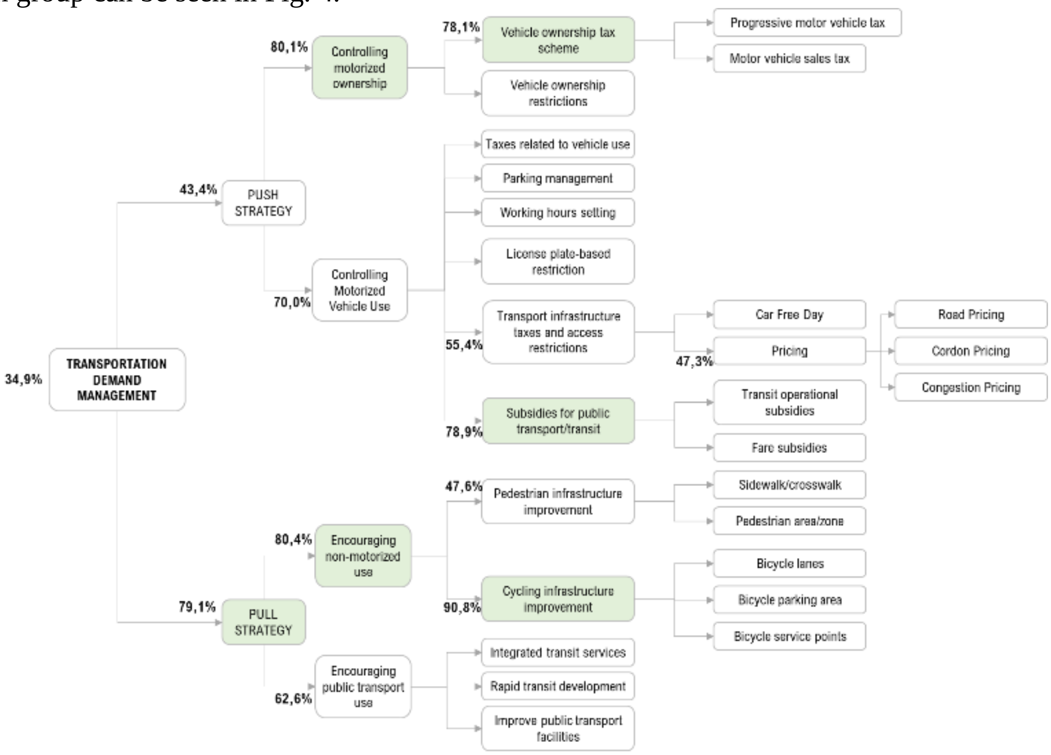


Fig 4. ACI in AHP group.

## 5. Conclusion

The conclusion from experts' opinions through the AHP assessment is that a pull strategy in the form of improving public transport services and infrastructure (especially the integration of public transport services) is one part of a reliable TDM strategy to overcome transportation problems. This strategy should be accompanied by a push strategy policy to implement the motor vehicle tax scheme so that the TDM policy can run well. However, there are also differences of expert opinion regarding the effectiveness of TDM in a push strategy which is judged by its ACI value. Strategies that get uniformity of assessment by experts are control of motorized vehicle owners, vehicle ownership tax schemes, subsidies for public transport, encouraging the use of non-motorized vehicles, and cycling infrastructure improvement. The results of previous research also show that there are other factors that influence the success of TDM including coercive policies (Gärling & Schuitema, 2007; Steg & Schuitema, 2007), a balance of push and pull strategies (He et al., 2009; Wang et al., 2022), as well as characteristics of people's behavior that need attention (Eriksson et al., 2010).

Practically, the results of this study can be used by stakeholders to determine the TDM strategy to be implemented in overcoming urban congestion. The next theoretical implication is the need to measure public acceptance of TDM strategy implementation by using public policy acceptance theory or other theories.

## References

Abdulkareem, M. N., Yazid, M. R. M., Alsaidi, L. R., & Borhan, M. N. (2020). Traffic congestion: Shift from private car to public transportation. *Civil Engineering Journal*

*(Iran)*, *6*(8), 1547–1554. https://doi.org/10.28991/cej-2020-03091566

AbuLibdeh, A. (2017). Traffic Congestion Pricing: Methodologies and Equity Implications. *Urban Transport Systems*, *January 2017*. https://doi.org/10.5772/66569

Ahmed, S., Vedagiri, P., & Krishna Rao, K. V. (2017). Prioritization of pavement maintenance sections using objective based Analytic Hierarchy Process. *International Journal of Pavement Research and Technology*, *10*(2), 158–170. https://doi.org/10.1016/J.IJPRT.2017.01.001

*AHP Group Consensus Indicator – how to understand and interpret? – BPMSG*. (2020). https://bpmsg.com/ahp-group-consensus-indicator-how-to-understand/

Alkharabsheh, A., Moslem, S., & Duleba, S. (2019). Evaluating passenger demand for development of the urban transport system by an AHP model with the real-world application of Amman. *Applied Sciences (Switzerland)*, *9*(22). https://doi.org/10.3390/app9224759

AlKheder, S. (2021). Promoting public transport as a strategy to reduce GHG emissions from private vehicles in Kuwait. *Environmental Challenges*, *3*(March), 100075. https://doi.org/10.1016/j.envc.2021.100075

Anggarani, D., Rahardjo, M., & Nurjazuli, N. (2016). Hubungan Kepadatan Lalu Lintas Dengan Konsentrasi Cohb Pada Masyarakat Berisiko Tinggi Di Sepanjang Jalan Nasional Kota Semarang. *Jurnal Kesehatan Masyarakat (e-Journal)*, *4*(2), 139–148.

Baric, D., & Starcevic, M. (2015). Implementation of Analytic Hierarchy Process in Solving Transport Problems. *International Journal of the Analytic Hierarchy Process*, *7*(2). https://doi.org/10.13033/ijahp.v7i2.251

Belwal, R., & Belwal, S. (2010). Public Transportation Services in Oman: A Study of Public Perceptions. *Journal of Public Transportation*, *13*(4), 1–21. https://doi.org/10.5038/2375-0901.13.4.1

Beria, P., Maltese, I., & Mariotti, I. (2012). Multicriteria versus Cost Benefit Analysis: A comparative perspective in the assessment of sustainable mobility. *European Transport Research Review*, *4*(3), 137–152. https://doi.org/10.1007/s12544-012-0074-9

*BPS Provinsi D.I. Yogyakarta*. (2020). https://yogyakarta.bps.go.id/indicator/12/133/1/jumlah-penduduk-menurut-kabupaten-kota-di-d-i-yogyakarta-.html

Broaddus, A., Litman, T., & Menon, G. (2009). Transportation Demand Management: Training Document. *Transportation in the New Millenium*, *0*(0), 1–118.

Bylinko, L. (2020). The practical importance of transport demand management policy. *Transport Problems*, *15*(4), 191–201. https://doi.org/10.21307/TP-2020-059

*Chapter 32: Transportation Demand Management (TDM)*. (2010). https://brtguide.itdp.org/branch/master/guide/transportation-demand-management-tdm/

CIE. (2006). Business costs of traffic congestion. *Context*, *August*.

Dargay, J., Gately, D., & Sommer, M. (2007). Vehicle Ownership and Income Growth, World wide: 1960--2030. *The Energy Journal*, *28*(4), 1–32.

De Brito, M. M., & Evers, M. (2016). Multi-criteria decision-making for flood risk management: A survey of the current state of the art. *Natural Hazards and Earth System Sciences*, *16*(4), 1019–1033. https://doi.org/10.5194/nhess-16-1019-2016

Eriksson, L., Garvill, J., & Nordlund, A. M. (2008). Acceptability of single and combined transport policy measures: The importance of environmental and policy specific beliefs. *Transportation Research Part A: Policy and Practice*, *42*(8), 1117–1128. https://doi.org/10.1016/j.tra.2008.03.006

Eriksson, L., Nordlund, A. M., & Garvill, J. (2010). Expected car use reduction in response to structural travel demand management measures. *Transportation Research Part F: Traffic Psychology and Behaviour*, *13*(5), 329–342. https://doi.org/10.1016/J.TRF.2010.06.001

Fitriastuti, F., & Kresnanto, N. C. (2021). Measurement of user interest in public transport performance variables using ahp. In *Lecture Notes in Civil Engineering* (Vol. 132). https://doi.org/10.1007/978-981-33-6311-3_86

Fulponi, J. I. (2023). Traffic congestion in Buenos Aires: diagnosis and public policy recommendations for a more sustainable city. *Transportation Research Procedia*, *69*(2022), 21–28. https://doi.org/10.1016/j.trpro.2023.02.140

Gärling, T., & Schuitema, G. (2007). Travel demand management targeting reduced private car use: Effectiveness, public acceptability and political feasibility. *Journal of Social Issues*, *63*(1), 139–153. https://doi.org/10.1111/J.1540-4560.2007.00500.X

Goepel, K. (2018). Implementation of an Online software tool for the Analytic Hierarchy Process (AHP-OS). *International Journal of the Analytic Hierarchy Process*, *10*(3), 469–487. https://doi.org/10.13033/ijahp.v10i3.590

Habibian, M., & Kermanshah, M. (2011). Exploring the role of transportation demand management policies' interactions. *Scientia Iranica*, *18*(5), 1037–1044. https://doi.org/10.1016/J.SCIENT.2011.09.005

Hamilton, T. L., & Wichman, C. J. (2018). Bicycle infrastructure and traffic congestion: Evidence from DC's Capital Bikeshare. *Journal of Environmental Economics and Management*, *87*, 72–93. https://doi.org/10.1016/j.jeem.2017.03.007

He, J. W., Zeng, Z. X., & Li, Z. H. (2009). An analysis on effectiveness of transportation demand management in Beijing. *Jiaotong Yunshu Xitong Gongcheng Yu Xinxi/ Journal of Transportation Systems Engineering and Information Technology*, *9*(6), 114–119. https://doi.org/10.1016/s1570-6672(08)60091-4

Islam, R., & Saaty, T. L. (2010). The Analytic Hierarchy Process in the Transportation Sector. In *Multiple Criteria Decision Making for Sustainable Energy and Transportation Systems* (Vol. 634, pp. 79–91). Springer. https://doi.org/10.1007/978-3-642-04045-0

Karanikola, P., Panagopoulos, T., Tampakis, S., & Tsantopoulos, G. (2018). Cycling as a smart and green mode of transport in small touristic cities. *Sustainability (Switzerland)*, *10*(1), 1–18. https://doi.org/10.3390/su10010268

KCATA. (2023). *Environmental Benefits of Public Transit*. https://www.kcata.org/about_kcata/entries/environmental_benefits_of_public_transit

Kresnanto, N. C. (2019). Model of relationship between car ownership growth and economic growth in Java. *IOP Conference Series: Materials Science and Engineering*, *650*(1), 0–8. https://doi.org/10.1088/1757-899X/650/1/012047

Kresnanto, N. C. (2021a). *Laporan Teknis Studi Manajemen Lalu Lintas Kawasan Heritage Kranggan Yogyakarta*. https://www.researchgate.net/publication/322756028_Laporan_Teknis_Studi_Manajemen_Lalu_Lintas_Kawasan_Heritage_Kranggan_Yogyakarta

Kresnanto, N. C. (2021b). *Transport Demand Management (TDM) Kota Yogyakarta*. https://www.researchgate.net/publication/364383292_Transport_Demand_Management_TDM_Kota_Yogyakarta

Kusumantoro, I. P., Martha, E., & Kipuw, D. (2009). Level of Effectiveness of the Implementation of Transport Demand Management (TDM) Strategy in Indonesian Cities. *Proceedings of the Eastern Asia Society for Transportation Studies*, *7*.

Le, T. P. L., & Trinh, T. A. (2016). Encouraging public transport use to reduce traffic congestion and air pollutant: A case study of Ho Chi Minh City, Vietnam. *Procedia Engineering*, *142*, 236–243. https://doi.org/10.1016/j.proeng.2016.02.037

Li, R., & Guo, M. (2016). Effects of odd–even traffic restriction on travel speed and traffic volume: Evidence from Beijing Olympic Games. *Journal of Traffic and Transportation Engineering (English Edition)*, *3*(1), 71–81. https://doi.org/10.1016/j.jtte.2016.01.002

Mattsson, L. G. (2008). Road pricing: Consequences for traffic, congestion and location. *Advances in Spatial Science*, *55*, 29–48. https://doi.org/10.1007/978-3-540-77150-0_3

Mittal, S., & Biswas, A. (2019). Exploring transportation demand management as a strategy to decongest Indian cities and improve mobility. *International Review for Spatial Planning and Sustainable Development*, *7*(4), 185–211. https://doi.org/10.14246/irspsda.7.4_185

Moslem, S., & Çelikbilek, Y. (2020). An integrated grey AHP-MOORA model for ameliorating public transport service quality. *European Transport Research Review*, *12*(1), 1–13. https://doi.org/10.1186/s12544-020-00455-1

Moslem, S., & Duleba, S. (2017). *Analytic Hierarchy Process Evaluation of Public Transport System in Budapest, Hungary*. 660–665.

Nalmpantis, D., Roukouni, A., Genitsaris, E., Stamelou, A., & Naniopoulos, A. (2019). Evaluation of innovative ideas for Public Transport proposed by citizens using Multi-

Criteria Decision Analysis (MCDA). *European Transport Research Review*, *11*(1). https://doi.org/10.1186/s12544-019-0356-6
Nugmanova, A., Arndt, W. H., Hossain, M. A., & Kim, J. R. (2019). Effectiveness of ring roads in reducing traffic congestion in cities for long run: Big Almaty ring road case study. *Sustainability (Switzerland)*, *11*(18). https://doi.org/10.3390/su11184973
Nygaard Nelson. (2008). 7 Best Practices in Transportation Demand Management. *Transportation*, *3*(Transportation Demand Management), 28. http://www.seattle.gov/transportation/docs/ump/07 SEATTLE Best Practices in Transportation Demand Management.pdf
*OECD Regions and Cities at a Glance 2020*. (2020). https://doi.org/10.1787/26173212
Podvezko, V., Sivilevicius, H., & Podviezko, A. (2014). Scientific applications of the AHP method in transport problems. *Archives of Transport*, *29*(1), 47–54. https://doi.org/10.5604/08669546.1146966
Pradana, F. (2012). Penggunaan Metode Analytic Hierarchy Process (AHP) Dalam Kajian Strategi Transportation Demand 124 Management (TDM) (Studi Kasus Kota Bandung). *Teknika: Jurnal Sains Dan Teknologi*, *8*(2), 124. https://doi.org/10.36055/tjst.v9i2.6693
Saaty, T. L. (1980). *The Analytic Hierarchy Process*. McGra w-Hill.
Saaty, T. L. (1990). How to make a decision: The Analytic Hierarchy Process. In *European Journal of Operational Research* (Vol. 48, pp. 9–26). https://doi.org/10.1016/0377-2217(90)90057-I
Saaty, T. L. (2005). The analytic hierarchy and analytic network processes for the measurement of intangible criteria and for decision-making. In *International Series in Operations Research and Management Science* (78th ed., Vol. 78, pp. 345–405). Springer New York LLC. https://doi.org/10.1007/978-1-4939-3094-4_10
Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International Journal of Services Sciences*, *1*(1), 83. https://doi.org/10.1504/IJSSCI.2008.017590
Schuitema, G., Steg, L., & Rothengatter, J. A. (2010). The acceptability, personal outcome expectations, and expected effects of transport pricing policies. *Journal of Environmental Psychology*, *30*(4), 587–593. https://doi.org/10.1016/j.jenvp.2010.05.002
Šimunović, L., Brčić, D., & Sadić, H. (2013). Choice of an Optimal Management Strategy of Transport Demand Using Multi-Criteria Analysis: City of Zagreb Case Study. *International Journal for Traffic and Transport Engineering*, *3*(1), 54–63. https://doi.org/10.7708/ijtte.2013.3(1).05
Soltani, A., & Namdarian, A. (2012). Feasibility Of Transport Demand Management Through A Bottom-Up Planning Approach. *Theoretical And Empirical Researches in Urban Management*, *7*(4), 63–72.
Southern California Association of Governments. (2019). *Transportation Demand Management Strategic: Plan dan Final Report* (Issue August).
Steg, L., & Schuitema, G. (2007). Behavioural Responses To Transport Pricing: A Theoretical Analysis. *Threats from Car Traffic to the Quality of Urban Life*, 347–366. https://doi.org/10.1108/9780080481449-019
Tainio, M., de Nazelle, A. J., Götschi, T., Kahlmeier, S., Rojas-Rueda, D., Nieuwenhuijsen, M. J., de Sá, T. H., Kelly, P., & Woodcock, J. (2016). Can air pollution negate the health benefits of cycling and walking? *Preventive Medicine*, *87*, 233–236. https://doi.org/10.1016/J.YPMED.2016.02.002
Thomas, F., Carran-Fletcher, A., Joseph, C., & Philbin, S. (2020). *Travel demand management: strategies and outcomes* (Issue April). www.nzta.govt.nz
*Transportation Demand Management | Organizing and Planning for Operations - FHWA Office of Operations*. (2022). https://ops.fhwa.dot.gov/plan4ops/trans_demand.htm#ftn1
United States. Department of Transportation. (2020). *Integrating Demand Management into the Transportation Planning Process: A Desk Reference - Chapter 10. Known Effectiveness of TDM Strategies - FHWA Office of Operations*. https://ops.fhwa.dot.gov/publications/fhwahop12035/chap10.htm
*Urban Sprawl dan Kemacetan di Yogyakarta | Balairungpress*. (2018). https://www.balairungpress.com/2018/03/urban-sprawl-dan-kemacetan-di-yogyakarta/

US department of Transportation. (1994). Overview of Travel Demand Management Measures. *Reports on Travel Demand Management (TDM) Provided by the Federal Highway Administration and the Federal Transit Administration*, 21.

Wang, Y., Geng, K., May, A. D., & Zhou, H. (2022). The impact of traffic demand management policy mix on commuter travel choices. *Transport Policy*, *117*, 74–87. https://doi.org/10.1016/J.TRANPOL.2022.01.002

Weber, E. U. (2010). What shapes perceptions of climate change? *Wiley Interdisciplinary Reviews: Climate Change*, *1*(3), 332–342. https://doi.org/10.1002/wcc.41

Whitmarsh, L., Swartling, Å. G., & Jäger, J. (2009). Participation of experts and non-experts in a sustainability assessment of mobility. *Environmental Policy and Governance*, *19*(4), 232–250. https://doi.org/10.1002/eet.513

Xenias, D., & Whitmarsh, L. (2013). Dimensions and determinants of expert and public attitudes to sustainable transport policies and technologies. *Transportation Research Part A: Policy and Practice*, *48*, 75–85. https://doi.org/10.1016/j.tra.2012.10.007

Yang, J., Liu, A., Qin, P., & Linn, J. (2016). The Effect of Owning a Car on Travel Behavior: Evidence from the Beijing License Plate Lottery. In *SSRN*. https://doi.org/10.2139/ssrn.2789824.