Why is my bus suddenly so crowded? Spillover effects of the discontinuation of three-in-one policy in Jakarta

Joshua Paundra a,*, Jan van Dalen a, Laurens Rook b, Wolfgang Ketter a,c

a Rotterdam School of Management, Erasmus University, The Netherlands
b Faculty of Technology, Policy and Management, Delft University of Technology, The Netherlands
c Faculty of Management, Economics, and Social Sciences, University of Cologne, Germany

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ABSTRACT

We assess the case of the abrupt discontinuation of the three-in-one policy, a high-occupancy vehicle (HOV) restriction, in Jakarta, with the objective of mapping potential interdependencies in the transportation system. Statistical investigation of the passenger volume in the bus rapid transit (BRT) system in the whole city before and after the policy change revealed a significant increase in the number of passengers during peak hours, especially in the evening period. The extent of the increase, however, depended on whether the area had been subject to the initial policy restriction. The case of sudden discontinuation of the three-in-one policy in Jakarta illustrates how a change in policy aimed at a single transportation mode may spill over to alternative transportation modes. The importance of acknowledging the systemic nature of urban transportation systems when altering policies intended to discourage the use of a single transportation mode within the larger transportation network is discussed.

1. Introduction

INRIX Global Traffic Scorecard (2018) reported that commuters in large cities spend up to 102 unproductive hours driving on congested roads every year. Particularly, the use of single occupancy private cars (SOV) has been identified as a major contributor to traffic congestion. Thus, city governments worldwide have implemented various transportation policies aimed at reducing SOV usage and eventually minimizing congestion (Hanna et al., 2017). High occupancy vehicle (HOV) restrictions specifically force private vehicle users to travel with two or more passengers, when accessing a reserved high-occupancy lane or entering a particular restricted area in the city (cf. Dahlgren, 1998). However, the effectiveness of these HOV policies in reducing traffic congestion has been questioned (Li, 2001). Restricting entrance to a lane or an area has been observed to actually worsen traffic in the unrestricted lanes and areas (Fuhs and Obenberger, 2002). Also, traffic congestion in the general lanes must be large, with a substantially lower travel time in HOV lanes, for HOV policies to be successful (Dahlgren, 1998). Even though HOV policies do not necessarily reduce overall traffic congestion, they remain a popular policy intervention to combat traffic congestion among policy makers in many cities worldwide.

Pros and cons of HOV and other driving restrictions to combat traffic congestion have been discussed extensively (e.g. Fontes et al., 2014; Wang et al., 2014; Hanna et al., 2017), but their potential impact on alternative transportation modes remains largely overlooked. Some exceptions include Liu et al. (2016) who surveyed Chinese commuters’ attitudes to public transportation following license-plate based restriction implementation, and Zhang et al. (2019) who considered the long-term effect of car restriction policy on the annual number of users of public transportation. However, to our knowledge, the real-life short-term change in public transportation demand has not been studied thus far. This is surprising, for spillover effects of HOV policies possibly exert a direct short-term influence on the usage of public transportation. In this study, we therefore explore the consequences of the abrupt discontinuation of an HOV policy in Jakarta, Indonesia, to map out the impact of this policy change on the number of public transportation passengers. The case of HOV policy discontinuation in Jakarta is highly relevant for two reasons. First, Jakarta is a megacity with over 10 million inhabitants, plus another 20 million inhabitants living in surrounding areas (World Bank, 2015), and the city is severely affected by traffic congestion (Burke et al., 2017). Many governments in developing cities are faced with similar problems of managing their cities’ under-developed transportation systems and the growing urban mobility needs. Jakarta’s case is therefore relevant to other cities in anticipating...
the potential spillover effects of policy change. Second, there is a lack of research on policy discontinuation and its implications for urban mobility (with the exception of Hanna et al., 2017). The Jakarta city government introduced a HOV policy restricting cars with fewer than three passengers, coined the “three-in-one” by local residents, from entering the central business district during peak hours in 2004. The government discontinued this policy on 5 April 2016, due to negative social implications associated with this policy. Theoretically, two main scenarios related to spillover effects of the three-in-one discontinuation on public transportation can be expected. First, the policy discontinuation may cause public transportation users to switch to their private cars, as they can again reach the workplace with their own vehicles without having to travel with carpooling passengers. This should especially occur if commuters are non-competitive public transportation users, and they have the option to choose between their private vehicle and public transportation. Indications of this switch can be observed from the increase of citywide traffic congestion following the policy discontinuation (Hanna et al., 2017). In this scenario, a reduction of the number of public transportation passengers can be expected. Second, travellers that used to carpool with a vehicle owner, but do not own a private vehicle themselves, may be forced to consider alternative modes for their trip when the car owner, in the absence of the HOV measure, is no longer required to take carpoolers on the daily commute. These travellers will turn to public transportation instead, since they do not have other options. This scenario would predict an increase of the number of public transportation passengers. We investigate which of these two scenarios has a stronger influence by analyzing the three-in-one discontinuation impact on the passenger volume of the main public transportation service in Jakarta, the Transjakarta Bus Rapid Transit (BRT).

This paper is structured as follows. In Section 2, we describe the background of the HOV policy, its applications, and the nature of the BRT system in Jakarta. Next, we discuss the data collection in Section 3, and present our analyses in Section 4. We conclude our study with a discussion of the policy implications of our findings.

2. Case of three-in-one discontinuation in Jakarta

2.1. Three-in-One policy

HOV policies were introduced in the year 1969 in several cities in the U.S. as a way to experiment with exclusive bus lanes. Over time, the bus lanes were converted into HOV lanes for private vehicles with more than one passenger (Fuhs and Obenberger, 2002). In the 1970s, HOV lanes for private vehicles were introduced in Washington, New York, and California (Hanna et al., 2017). Thanks to these experiments, HOV lanes started to gain popularity in the U.S. and elsewhere as a travel demand management measure that contributed to a more efficient use of road facilities (Stamos et al., 2012). Typically, the HOV policy requires a minimum number of passengers in a vehicle. Most implementations require two or more passengers (which is labeled HOV2). The high-occupancy toll (HOT) restriction is a variant of the traditional HOV policy, by allowing lower-occupancy vehicles to travel on HOV lanes for a fee (Li, 2001; Abulibdeh and Zaidan, 2018). A recent trend has been to grant exceptions to more sustainable vehicles to use HOV lanes as a way to promote clean-fuel vehicles (Shewmake and Jarvis, 2014).

The restriction of having multiple persons in a single vehicle means that, in theory, the utilization of the limited urban road capacity can be improved upon (Fuhs and Obenberger, 2002). It also promotes the use of alternative transportation modes like carpooling, and it helps to reduce the energy intensity of transport (Javid et al., 2017). However, the alleged contributions of HOV policy to the reduction of traffic congestion, travel time, and emissions have frequently been challenged (Wang, 2011). First, HOV lanes have lower utilization in comparison to general lanes as only a small portion of commuters tend to carpool (Li, 2001; Hanna et al., 2017). Second, reductions in the already limited road capacity are observed, because usually a general-purpose lane that was open to all commuters is converted into a HOV lane, causing even more severe congestion. Some have argued that while HOV lanes provide faster travel times, the time differential between the HOV and the general purpose lanes is minimal and insignificant (Kwon and Varaiya, 2008). Still, others claim that HOV lanes offer substantial travel time reductions in some cases and, more importantly, provide higher travel time reliability for HOV drivers (Fontes et al., 2014; Samimi et al., 2016).

In Jakarta, the HOV policy was introduced in January 2004. The policy was implemented following the Jakarta Provincial Governor’s Decision No. 4014 of 2003, and subsequently adjusted in Jakarta Provincial Governor’s Regulation No. 110 of 2012. The policy required a minimum of three people per vehicle in order to be permitted to use the road segments (HOV 3+), thus popularly referred to as “three-in-one” policy. Unlike many other cities worldwide, Jakarta’s three-in-one policy restricted entrance to the central business district area, in Jalan Sudirman and Jalan Thamrin, for vehicles with fewer than three passengers during peak hours: the restriction applied to the morning and afternoon peak hours period, from 07.00 to 10.00 and from 16.30 to 19.00 on work days. Fig. 1 shows the area and road segments that were affected by the three-in-one policy in Jakarta.

A major consideration for the three-in-one discontinuation was the unwanted social impact of the policy that encouraged drivers to use “jockey” services. The jockey joined a car with fewer than three passengers for a fee of IDR 20,000 to 30,000 (roughly equal to 1.40 to 2.10 US Dollar). Many jockeys brought babies and children, possibly hired, to join them in offering the service, raising concerns on children’s well-being (Detikcom, 2016; CNN Indonesia, 2016). Fig. 2 depicts a typical situation related to the jockey service in Jakarta during the period of the three-in-one policy. On 13 May 2016, Jakarta officials decided to discontinue the three-in-one policy by Jakarta Provincial Governor’s Regulation No. 13 of 2016 primarily because of this practice. Prior to the formal discontinuation, the Jakarta government announced a trial period of the policy discontinuation between 5 and 13 April 2016, which was then extended to 13 May 2016, after which the HOV3 + restriction was permanently lifted.

2.2. Bus rapid transit system in Jakarta

Bus rapid transit (BRT) is a form of mass transit that aims to combine the reliability of rail services with the flexibility and low costs of bus services (Deng and Nelson, 2011). One of the earliest BRT systems was implemented in Curitiba, Brazil in 1973 (Hidalgo and Grafieaux, 2008). BRT systems gained popularity worldwide in the late 1990s, when the majority of these systems were introduced (Cervero, 2013). BRT systems have been implemented not only in developed countries, but also in developing countries, such as in China, South Africa, India, and Indonesia. In total, BRT systems are available in 168 cities worldwide, carrying more than 33 million passengers per day (BRTdata, 2018).

For various reasons, policy makers in large cities often perceive BRT as an attractive public transportation alternative to private vehicles. First, BRT systems can be implemented with low investments (Hensher, 2007; Satiennam et al., 2016; Rizelio and Arslan, 2020) and operational costs (Márquez et al., 2018). They are four to twenty times less expensive to implement than a light rapid transit system, and ten to a hundred times cheaper to realize than a metro system (Wirasinghe et al., 2013). The lower investments and operational costs also mean lower ticket prices, which makes BRT systems attractive to consumers. City governments sometimes subsidize ticket prices to further improve BRT usage among commuters. Second, BRT systems can be built relatively fast and be incrementally expanded, as they make use of the existing road infrastructure with only minor adaptations (Nikitas and Karlsson, 2015). Moreover, the fast implementation is attractive for political
leaders as it can be realized within a single term of office (Hidalgo and Carrigan, 2010). Next, the introduction of BRT systems is known to have a positive impact on the environment (Bel and Holst, 2018; Abbasi et al., 2020). Finally, these systems have a high reliability, especially in comparison to conventional bus services, as BRT systems often include a dedicated lane for operation (the so-called “busway”). The busway limits BRT’s exposure to traffic conditions and enhances performance (Wirasinghe et al., 2013; Mavi et al., 2018; Ishaq and Cats, 2020).

The BRT system has also been criticized. The dedicated busway reduces the road capacity, especially when implemented in existing road networks (Susilo et al., 2007; Nikitas and Karlsson, 2015). In terms of comfort, BRT systems are often overcrowded, more so than traditional rail-based transportation systems (Thilakaratne et al., 2011). Overcrowding in general leads to users’ dissatisfaction, as it may reduce the service quality of public transportation (Haywood et al., 2017), increase discomfort, and causes delays (Tirachini et al., 2017). These criticisms of BRT systems are a challenge for city governments.

Jakarta’s BRT system, known as Transjakarta, was designed after the TransMilenio in Bogota, Colombia, that was established in the year 2000 (Transjakarta, 2018). Transjakarta was officially launched on 1 February 2004 with a 12.9-kilometer line from the Blok M bus terminal to Kota railway station. This line serves the main central business district in Jakarta located in Jalan Sudirman and Jalan Thamrin. By 2016, Transjakarta operated twelve lines and served 123.7 million passengers (BPS Jakarta, 2017). Table 1 lists the twelve main lines of Transjakarta.
services and their characteristics. The system is currently the longest in the world, covering over 230 km in length citywide. Transjakarta charges a fixed price for a journey in the system, which costs IDR 3500 (0.25 US Dollar). A reduced fee of IDR 2000 (roughly around 0.14 US Dollar) applies for rides between 05:00 and 07:00 A.M.

The initial implementation of Transjakarta was deemed a success. A survey in the first month of Transjakarta operation indicated that 20% of surveyed BRT passengers were former private vehicle users, and the service reduced the travel time for bus passengers by 59 min over the length of the 12.9 km route (Ernst, 2005). However, subsequent operations had operational consequences for the Transjakarta service and for the city as a whole. On the one hand, the three-in-one discontinuation has had operational consequences for the Transjakarta service and for the city as a whole. For the second and third lines, we allow the system's capacity to grow over the entire five-month period. In particular, we remove days with zero passengers from our sample, which seemed to be due to misreporting; these were present on January 1, February 8, March 9, March 25, May 1, May 5, May 6, and May 22.

3. Data, measures, and empirical strategy

To investigate the impact of the discontinuation of the three-in-one policy in Jakarta on the demand for BRT services, we make use of data provided by PT. Transjakarta, the provincial government-owned company that manages Jakarta’s BRT system. The data contain the hourly passenger volume entering a station in the particular line for the period starting from 1 January to 31 May 2016. During the period of the study, Transjakarta service did not record the number of exiting passengers. In total, there are 43,776 observations of the passenger demand per hour for the twelve lines over the stated period.

As the three-in-one policy was only effective during the working days, we excluded time periods during weekends and public holidays. In Indonesia, eight public holidays fell within the five-month period: January 1, February 8, March 9, March 25, May 1, May 5, May 6, and May 22. Further, we excluded the time period between 23:00 and 04:59, as most of the lines did not operate during these hours (they typically stop operations by 23:00). We also removed hours with zero passengers counts, which seemed to be due to misreporting; these were present on the following days: January 28, January 29, February 9, March 7, March 14, and March 28. The final data set contains 21,934 observations of the passenger demand per hour for the twelve lines over the stated period.

3.2. Description of variables

3.2.1. ThreeInOne

The discontinuation of the HOV3 + policy was recorded as an indicator variable, assigning the value zero to the time before the discontinuation from January 1 to April 4, 2016, and the value one to the time after the discontinuation from April 5 to May 31, 2016. Overall, there are 13,510 hourly periods with value zero and 8424 hourly periods with value one.

3.2.2. HOV_time

The peak travel periods lie between 07:00 and 10:00 and 16:00 – 19:00, and are represented with an indicator variable that has the value zero for all time periods outside of these peak hours, and the value one during the peak hours. In total, we have 7305 hourly periods during the peak hour period, and 14,629 hourly periods outside the peak hour period.

3.3. Empirical strategy

Our empirical strategy is based on a difference-in-difference approach that aims to tease out the effect of the three-in-one discontinuation by controlling for possibly unobserved characteristics (cf., Chevalier and Mayzlin, 2006). Such an empirical approach has been used in studying transport policy changes (e.g., Li et al., 2012; Ge et al., 2017; Bayle and Palacios, 2017). We made use of the off-peak hour periods as our counterfactual observations, as these were not part of the three-in-one restriction, but were useful in capturing the specific
characteristics of each line on each day of the week. Furthermore, by focusing on the difference between the relative demand of hourly passengers in peak and off-peak hours, the potential normal increase in passenger volume over time could be accounted for. All analyses consider the fixed effect of line and weekday. As our panel data are unbalanced due to holidays and misreporting, the use of the fixed effect model is appropriate and known to give consistent estimates (Bel and Hoist, 2018). For each line $i$ and hour $t$, the passenger volume is related to the mentioned variables in the following manner:

$$\text{PassengerVolume}_{it} = \alpha + \sum_{l=1}^{L} \alpha_{il} d_{li} + \sum_{w=1}^{W} \alpha_{lw} d_{lw} + \beta_{1} \text{ThreeInOne}_{it} + \beta_{2} \text{HOV}_{timeit} + \beta_{3} \text{ThreeInOne}_{it} \times \text{HOV}_{timeit} + \theta \text{Trend} + \epsilon_{it}$$ (1)

where $\alpha_{il}$ represents the fixed effects of line $l=1, \ldots, L$ and $\alpha_{lw}$ refers to the fixed effects of the weekday $w=1, \ldots, W$; $\beta_{1}$ is the effect of the discontinuation of the HOV3+ policy, $\beta_{2}$ is the effect of peak hour period, and $\beta_{3}$ refers to the effect of the interaction term of ThreeInOne $X$ HOV$_{timeit}$, which captures the additional increase in the passenger volume due to the policy discontinuation; $\text{Trend}$ represents the time trend on a daily basis; $\epsilon_{it}$ is an independently distributed disturbance term. Passenger volume is measured in absolute number of passengers as well as the log-transformed number of passengers.

4. Results

The subsequent analysis of passenger volumes in Jakarta surrounding the date of the Three-in-one policy lifting contains three parts: (1) a descriptive analysis of passenger volumes over time; (2) a difference in difference analysis of the consequences for passenger volumes of the policy lifting; and (3) a complementary analysis of the passenger volumes per BRT line in order to explore the potentially differentiated impact of the policy.

4.1. Descriptive results

Fig. 3 shows the average hourly count of passengers per day for all lines combined over time, separated for peak and off-peak hour periods. The average number of passengers per hour per line is 1489. Before the policy discontinuation, the difference between the hourly average number of passengers between peak and off-peak hour periods amounts to 677, which increases to 789, after the discontinuation of HOV3 + restriction. The graph also shows that on the day after the discontinuation, there was a marked increase of the average hourly passengers count in the peak hour period, from 1969 passengers (on April 4) to 2052 passengers (on April 6). Meanwhile, the average hourly count of passengers in the off-peak hour periods hardly seems to have been affected on this day.

Substantial differences are observed between the hourly average numbers of passengers per line, ranging from 200 passengers per hour in Line 12 to around 5500 passengers per hour in Line 1. Peaks occur right after the discontinuation of the three-in-one policy, especially in Lines 1, 2, 4, 5, 9, and 11, and only apply to the average number of passengers during peak hour periods, not to the off-peak hour periods, as shown in Fig. 4. These observations suggest the potential impact of policy discontinuation, especially during peak period.

4.2. Difference-in-Difference model

The impact of the discontinuation of the three-in-one policy on the number of BRT passengers is further analyzed with model (1). Main interest is in the interaction between ThreeInOne and HOV$_{time}$, which provides the change in passenger volume on top of the normal increase in passenger volume over time. Table 2 summarizes the estimation results obtained for various versions of this models, separate for the nominal and log-transformed passenger volumes.

The specified model (1) with the interaction term and Time trend (specification (3) in Table 2 Panel A) is significant with an $R$-squared of 0.591 ($F = 1,666.526, p < 0.01$). The significant main effect of HOV$_{time}$ indicates that 675.603 more passengers were transported in peak hour periods than in off-peak hour periods ($\beta = 675.603$, s.e. = 190.916, $p < 0.001$). ThreeInOne is not significant ($\beta = -5.370$, s.e. = 14.266, $p = 0.707$), whereas Time trend is ($\beta = 0.919$, s.e. = 0.184, $p < 0.001$),
indicating that there is an increase of one passenger per hour per line in each day during the period of analysis. The interaction term ThreeInOne: HOV_time is significant (β = 0.174, s.e. = 0.106, p < 0.004 and β = 0.188, s.e. = 0.03, p < 0.01, respectively). These results show that the highest increase in passenger volume is observed during the evening peak period, which is in line with the results in Hanna et al. (2017).

A further refinement of the model based on time split is implemented to assess the varying impact of policy discontinuation at different times of the day. The BRT service hours of a day were split into five time periods: (1) Morning (05.00 – 06.59), (2) AM Peak (07.00 – 09.59), (3) Midday (10.00 – 15.59), (4) PM Peak (16.00 – 18.59), and (5) Evening (19.00 – 22.59); the morning period is used as reference. Specification (5) in Table 2 Panel A and B present the results of the analysis based on these five splits of time period for nominal and log-transformed passenger volumes models, respectively. The estimation results again show, that our variables of interest, i.e., the interaction of ThreeInOne with time periods, are significant. First, the impact of policy discontinuation on passenger volumes during MidDay (ThreeInOne:MidDay) is positive and significant for both nominal and log-transformed passenger volumes (β = 30.885, s.e. = 13.016, p = 0.018 and β = 0.085, p < 0.01, respectively). The impact of policy discontinuation in the afternoon peak period (ThreeInOne:HOVpm) is also significant in both models (β = 210.316, s.e. = 63.893, p = 0.01, and β = 0.188, s.e. = 0.03, p < 0.01, respectively). Meanwhile, the impact of policy discontinuation in the morning peak period (ThreeInOne:HOVam) and evening non-peak period (ThreeInOne: Evening) are observed to be significant for the log-transformed passenger volumes only (β = 0.137, s.e. = 0.04, p = 0.004 and β = 0.174, s.e. = 0.027, p < 0.001, respectively), but not for the nominal passenger volumes (β = 23.823, s.e. = 14.705, p = 0.106, and β = 42.808, s.e. = 28.767, p = 0.137, respectively). These results show that also with a more granular time period split, the impact of policy discontinuation on passenger volumes, especially during the afternoon HOV period, remains consistent with what was observed in the morning.
Table 2
Estimation results of various variants of model (1) for the nominal passenger volume and log-transformed passenger volume.

<table>
<thead>
<tr>
<th>Panel (A): Passenger volume</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>Panel (B): Log passenger volume</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
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<tr>
<td>Constant</td>
<td>3,546.91**</td>
<td>3,322.28***</td>
<td>3,276.20***</td>
<td>3,276.22***</td>
<td>3,084.054***</td>
<td>7.958***</td>
<td>7.781***</td>
<td>7.760***</td>
<td>7.760***</td>
<td>8.448***</td>
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<td>(18.596)</td>
<td>(81.039)</td>
<td>(87.431)</td>
<td>(87.407)</td>
<td>(201.315)</td>
<td>(0.018)</td>
<td>(0.023)</td>
<td>(0.026)</td>
<td>(0.026)</td>
<td>(0.110)</td>
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<tr>
<td>ThreeInOne</td>
<td>94.506**</td>
<td>64.091***</td>
<td>5.370</td>
<td>5.652</td>
<td>31.707 **</td>
<td>0.118**</td>
<td>0.109**</td>
<td>0.078**</td>
<td>0.078**</td>
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<td>(18.126)</td>
<td>(12.391)</td>
<td>(14.266)</td>
<td>(14.437)</td>
<td>(25.203)</td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.024)</td>
<td>(0.024)</td>
<td>(0.026)</td>
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<tr>
<td>HOV_time</td>
<td>675.567**</td>
<td>675.603**</td>
<td>7.958**</td>
<td>7.781**</td>
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<td>(190.911)</td>
<td>(190.916)</td>
<td>(0.018)</td>
<td>(0.023)</td>
<td>(0.026)</td>
<td>(0.110)</td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.024)</td>
<td>(0.024)</td>
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<tr>
<td>HOVam</td>
<td>590.753***</td>
<td>521.369***</td>
<td>0.919**</td>
<td>0.922**</td>
<td>0.903**</td>
<td>0.0004</td>
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<td>(111.995)</td>
<td>(164.340)</td>
<td>(14.016)</td>
<td>(14.016)</td>
<td>(14.016)</td>
<td>(0.010)</td>
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<tr>
<td>ThreeInOne: HOVpm</td>
<td>30.885**</td>
<td>30.885**</td>
<td>0.056**</td>
<td>0.056**</td>
<td>0.056**</td>
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<td>(13.016)</td>
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<td>HOVam</td>
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<td>51.626***</td>
<td>0.182**</td>
<td>0.182**</td>
<td>0.182**</td>
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<td>(190.911)</td>
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<td>ThreeInOne: MidDay</td>
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<td>42.808**</td>
<td>0.056**</td>
<td>0.056**</td>
<td>0.056**</td>
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<td>(28.767)</td>
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<tr>
<td>$R^2$</td>
<td>0.508</td>
<td>0.508</td>
<td>0.508</td>
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<td>0.508</td>
<td>0.508</td>
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<td>Adjusted $R^2$</td>
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<tr>
<td>Residual Std.</td>
<td>817.124 (df = 21917)</td>
<td>745.096 (df = 21915)</td>
<td>744.801 (df = 21914)</td>
<td>741.066 (df = 21912)</td>
<td>673.291 (df = 21908)</td>
<td>673.291 (df = 21908)</td>
<td>673.291 (df = 21908)</td>
<td>673.291 (df = 21908)</td>
<td>673.291 (df = 21908)</td>
<td>673.291 (df = 21908)</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>21917</td>
<td>21915</td>
<td>21914</td>
<td>21912</td>
<td>21908</td>
<td>21908</td>
<td>21908</td>
<td>21908</td>
<td>21908</td>
<td>21908</td>
<td></td>
</tr>
<tr>
<td>$F$ Statistic</td>
<td>1,412.282** (df = 21; 21917)</td>
<td>1,756.704** (df = 21; 21915)</td>
<td>1,666.526** (df = 21; 21914)</td>
<td>1,533.690** (df = 21; 21912)</td>
<td>1,746.221** (df = 21; 21908)</td>
<td>1,746.221** (df = 21; 21908)</td>
<td>1,746.221** (df = 21; 21908)</td>
<td>1,746.221** (df = 21; 21908)</td>
<td>1,746.221** (df = 21; 21908)</td>
<td>1,746.221** (df = 21; 21908)</td>
<td></td>
</tr>
</tbody>
</table>

Note: *p < 0.1, **p < 0.05, ***p < 0.01; Clustered standard error based on Line; models that include the interaction of Time trend with ThreeInOne and HOV_time were considered, but proved to be statistically indistinguishable from specification (4) and (5) based on a partial F tests, while added interaction terms suffers from multicollinearity.
previous – coarser – time split models.

4.3. Per line analyses

The network of BRT lines in Jakarta covers substantial areas of the city, which provides an opportunity to further explore the impact of the HOV3 + discontinuation on each of the separate lines. Also, the parameter stability of specification (5) in Table 2 Panel A and Panel B is rejected based on Chow test \( (F(154, 21754) = 117.51, p < 0.001 \) and \( (154, 21754) = 29.27, p < 0.001 \) for nominal and log-transformed specifications, respectively), which points at structural differences between the various transit lines. The estimation results for specifications (5) per line of BRT are presented in Table 3, panel A gives the results for the nominal passenger volumes and panel B for the log-transformed volumes.

The impact of the policy discontinuation is especially observed in the afternoon peak period, as shown by the positive interaction term \( \text{ThreeInOne:HOVpm} \) which is significant for all lines, except for Line 11. Meanwhile, the impact of the policy discontinuation varies per line in the morning peak period: the effect of \( \text{ThreeInOne:HOVam} \) is significantly negative for Lines 1, 8, 10, and 12, significantly positive for Lines 2, 3, 5, 7, 9, and 11, and non-significant for Lines 4 and 6. For the non-peak periods, the impact of the policy discontinuation on passenger volumes during midday and in the evening, as expressed in the interaction terms \( \text{ThreeInOne:MidDay} \) and \( \text{ThreeInOne:Evening} \), shows a similar pattern. The impact is positive and significant for Lines 1, 2, 4, 5, 6, and negative and significant for Lines 10 and 11, but not significant for Line 3, 7, 8, and 9. Meanwhile, for Line 12, the impact of policy discontinuation is negative, but only marginally significant, in the evening (\( \text{ThreeInOne:Evening} \)), and not significant during midday (\( \text{ThreeInOne:MidDay} \)). Similar patterns can be observed for the policy discontinuation impact on log-transformed passenger volumes, especially for those lines that serve commuters, such as Line 1, 6, and 9, and for the afternoon peak period. Overall, the policy discontinuation, therefore, seems to have had a citywide effect, albeit to varying degrees depending on the line and the period of the day.

5. Policy implications

The present research investigated the consequences of the sudden discontinuation of a high-occupancy vehicle policy on public transportation use in Jakarta. The impact of the three-in-one discontinuation on traffic congestion has been studied before (cf. Hanna et al., 2017), but hardly any research thus far has focused on the spillover effects of such car-oriented policy changes on public transportation. We observed a significant spillover effect of the three-in-one discontinuation on the use of public transportation in Jakarta. Clearly, the abrupt policy discontinuation transferred a large number of passengers to the BRT service. This switch in commuting behavior was probably caused by former carpoolers that could no longer join in private vehicles, and needed to look for alternative transportation modes, especially in the evening period. It seems that the variation in the time of leaving the office at the end of the day, which is not as strict as the starting office hours for many, contributed to the high evening period demand for BRT service. Overall, the number of people that switched to the BRT service as a result of the three-in-one discontinuation seemed to be higher than the number of BRT passengers that may have switched to private vehicles.

Our study emphasizes the need for policy makers to reckon with the interconnectedness of the transportation network in metropolitan areas when developing, discontinuing, and managing transition between various policies. A decision that is specifically proposed to solve issues with single transportation modes, such as single-occupancy private cars, can spill over to other transportation modes, and not always in a positive manner. Extant transportation research has shown that spillover effects are observed in relation to transportation mode choices due to policy change (e.g., Liu et al., 2016; Zhang et al., 2019; Hanna et al., 2017; Kaida and Kaida, 2015). The three-in-one discontinuation in Jakarta illustrates that such a change puts a sudden high pressure on the BRT system. It seems that the drop in occupancy of car travel directly translates into an increase in demand for BRT service. Failing to account for spillover effects in the development of transport policy can lead to dissatisfaction of commuters about the public transportation services, which may have unwanted consequences for their willingness to use public transportation services in the future. In our case, the three-in-one discontinuation was part of the transition from an occupancy-based to a number-plate based vehicle restriction. While the absence of policy restrictions was temporary, there was still a need to carefully manage the sudden change in transportation policy in order to maintain the service level of public transportation services.

The spillover effects of the abrupt policy change may be severe for public transportation companies, such as Transjakarta, especially if they have no knowledge of this change in advance. It is well-documented that BRT services worldwide have been coping with overcrowding (Wirasinghe et al., 2013), and Transjakarta faced the similar problem. The sudden additional pressure following the increased number of passengers might have further increased such overcrowding instances, reducing Transjakarta’s ability to attract private vehicle users to switch to public transportation. Commuters under such circumstances typically attempt to revert to taking their private cars — assuming they have the option to do so (cf. Abou-Zeid and Ben-Akiva, 2012). Yet, the three-in-one discontinuation could also serve as an opportunity for Transjakarta and the city government to attract commuters to public transportation. Contextual changes due to policy change can cause commuters to re-evaluate their commuting habit and consider using other transportation alternatives than their own vehicles (Verplanken et al., 2008). If Transjakarta manages the newly established situation well, it may attract commuters to be loyal public transportation users. This would be beneficial to the city in the long run. Therefore, city governments should ensure that the implications of policy changes, even those seemingly unrelated to local transportation companies, are made known well in advance to prepare all stakeholders for the potential spillover effects. Coordination between the city government and local public transportation companies is critical in encouraging people to switch to public transportation services during policy change.

Operationally, Transjakarta needs to deal with a large concentration of passengers during the evening peak period. Our analysis provides some pointers on how to do so. For instance, for BRT Line 1, we observed an increase of around 875.7 passengers per hour in the evening peak period due to this policy change. This increase translates into approximately 11 fully loaded additional buses per hour during the evening peak period. Extra or prolonged bus services (Dell’Olio et al., 2011) can be scheduled accordingly, so as to manage the increase in gap between the peak and the normal period of use. It is also necessary to predict such an increase or decrease in passengers, and provide this information (cf. Zhang et al., 2017; Márquez et al., 2018) to enable commuters in order to avoid the peak period, thus alleviating high peak demand.

Our study of the three-in-one discontinuation in Jakarta provides support for the presence of spillover effects of a car-centered policy change on public transportation (cf. Liu et al., 2016; Zhang et al., 2019). Future research could further explore the interrelatedness of metropolitan transportation networks under such circumstances for a wider array of transportation modes or for other locations. In addition, it would be interesting to delve into the implications of such policy changes at the more detailed level, i.e., particularly at the bus-occupancy level or the bus station crowdedness level. Unfortunately, our data were at the aggregate line level — hence not suitable for capturing the implications of this policy change at such a fine level of granularity. Moreover, our data could only capture the count of entries per hour period and as a result, it was not possible to construct the precise route chosen by passengers. It would be particularly interesting for future research to gain access to the routes that passengers took from point of departure to point of arrival in case of the discontinuation or implementation of citywide
Table 3

Estimation results per line for nominal, non-transformed and log-transformed models.

<table>
<thead>
<tr>
<th></th>
<th>Panel (A): Passenger volume</th>
<th>Panel (B): Log passenger volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Constant</td>
<td>2,574.8***</td>
<td>1,704.3***</td>
</tr>
<tr>
<td>(201.2)</td>
<td>(66.8)</td>
<td>(74.7)</td>
</tr>
<tr>
<td>ThreeInOne</td>
<td>-164.2</td>
<td>-57.9</td>
</tr>
<tr>
<td>(224.5)</td>
<td>(52.0)</td>
<td>(57.0)</td>
</tr>
<tr>
<td>HOVam</td>
<td>1,231.0***</td>
<td>-352.1***</td>
</tr>
<tr>
<td>(96.6)</td>
<td>(19.1)</td>
<td>(34.0)</td>
</tr>
<tr>
<td>MidDay</td>
<td>-120.7***</td>
<td>-827.5***</td>
</tr>
<tr>
<td>(36.4)</td>
<td>(37.4)</td>
<td>(49.1)</td>
</tr>
<tr>
<td>HOVpm</td>
<td>3,567.6***</td>
<td>-468.0***</td>
</tr>
<tr>
<td>(293.8)</td>
<td>(103.5)</td>
<td>(90.8)</td>
</tr>
<tr>
<td>Evening</td>
<td>-214.7</td>
<td>-1,191.6***</td>
</tr>
<tr>
<td>(156.7)</td>
<td>(67.8)</td>
<td>(83.3)</td>
</tr>
<tr>
<td>Trend</td>
<td>1.8</td>
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<td>(2.9)</td>
<td>(0.6)</td>
<td>(0.5)</td>
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<tr>
<td>ThreeInOne: HOVam</td>
<td>-83.6***</td>
<td>84.5***</td>
</tr>
<tr>
<td>(28.0)</td>
<td>(24.9)</td>
<td>(28.1)</td>
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<tr>
<td>ThreeInOne: MidDay</td>
<td>98.8***</td>
<td>62.4***</td>
</tr>
<tr>
<td>(42.3)</td>
<td>(22.9)</td>
<td>(28.3)</td>
</tr>
<tr>
<td>ThreeInOne: HOVpm</td>
<td>875.7***</td>
<td>168.7***</td>
</tr>
<tr>
<td>(246.4)</td>
<td>(54.2)</td>
<td>(35.7)</td>
</tr>
<tr>
<td>ThreeInOne: Evening</td>
<td>303.8***</td>
<td>92.2***</td>
</tr>
<tr>
<td>(88.3)</td>
<td>(21.8)</td>
<td>(27.1)</td>
</tr>
<tr>
<td>Day of week</td>
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<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
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<td>1,826</td>
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<tr>
<td>$R^2$</td>
<td>0.6</td>
<td>0.7</td>
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</table>

(continued on next page)
transportation policy, as this would allow us to offer custom-made support to BRT service companies regarding how to manage and modify bus allocation strategies (cf. Monterola et al., 2016).

6. Conclusion

Our study showed that the three-in-one policy discontinuation increases the hourly passenger volume of BRT services in Jakarta. The significant spillover effects were found on the hourly demand of BRT services due to this policy change, especially in the evening, because fewer carpooling options were available and passengers needed to opt for the BRT services. It is important for policy makers and BRT companies to consider the potential occurrence of unintentional, yet negative, spillover effects of a sudden transportation policy change on public transportation service quality. With no preparation, a sudden increase in BRT demand could negatively impact the service provided to passengers, and cause reluctance for passengers to use the BRT services in the future. Proper management of spillover effects of a transportation policy change therefore is required.

CRediT authorship contribution statement

**Joshua Paundra:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing. **Jan Dalen:** Conceptualization, Methodology, Formal analysis, Validation, Writing - original draft, Writing - review & editing, Supervision. **Laurens Rook:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Supervision. **Wolfgang Ketter:** Conceptualization, Supervision, Project administration, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The first author of this study acknowledges the financial support from Lembaga Pengelola Dana Pendidikan (LPDP - Indonesia Endowment Fund for Education). The authors thank PT. Transportasi Jakarta (Transjakarta) for providing the data used in this study. The authors also thank reviewers and participants of the 15th World Conference on Transport Research for their feedback, as well as Dr. Antonio Russo for his review of the earlier version of this study.

References


\[Table 3 (continued)\]

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<td>0.03</td>
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<td>0.2</td>
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Note:*p < 0.1, **p < 0.05, ***p < 0.01; Clustered Standard error based on Day of the Week.

**ThreeInOne:** HOVpm 0.2 (0.1) (0.2) (0.1) (0.02) (0.1) (0.1) (0.04) (0.1) (0.04) (0.03) (0.02)

ThreeInOne: Evening 0.4 (0.1) (0.2) (0.05) (0.1) (0.03) (0.1) (0.1) (0.1) (0.1) (0.04) (0.04) (0.03)