Citywide effects of high-occupancy vehicle restrictions: Evidence from "three-in-one" in Jakarta

CITYWIDE EFFECTS OF HIGH-OCCUPANCY VEHICLE RESTRICTIONS: EVIDENCE FROM "3-IN-1" IN JAKARTA

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Abstract

Widespread use of single occupancy cars often leads to traffic congestion. Using anonymized traffic speed data from Android phones collected via Google Maps, we test whether high-occupancy vehicle policies can combat congestion. We study Jakarta's 3-in-1 policy, where all private cars on two major roads needed three or more passengers during peak hours. After the policy was abruptly abandoned in April 2016, delays rose from 2.1 to 3.1 min/km in the morning peak and from 2.8 to 5.3 min/km in the evening peak. The lifting of the policy led to worse traffic throughout the city, even on roads that had never been restricted or at times when restrictions had never been in place. In short, we find that HOV policies can greatly improve traffic conditions.

One Sentence Summary: We show using traffic speed data from Google Maps that removing a high occupancy vehicle policy in Jakarta significantly increased traffic congestion citywide.

Traffic congestion is a scourge of cities everywhere. In U.S. metropolitan areas like New York, Washington, and Atlanta, people spend, on average, over an hour a day commuting to and from work (Census, 2009). In many developing countries, the figures are similar or even worse, with individuals spending on average 50 minutes daily in Mumbai, and over 1.5 hours per day commuting in São Paolo and Rio de Janeiro (*1-2*). In addition to wasted time, traffic congestion may influence urban economic activity, affecting important decisions from where to live to which jobs one would be willing to take. Moreover, it constitutes a substantial cause of health hazards from air pollution (*3*).

A commonly cited reason for congestion is the inefficiency of single-occupancy vehicles, which use a substantial amount of road capacity for each passenger transported. In response, one policy prescription is to restrict certain lanes or roads to vehicles carrying multiple passengers. First begun in the 1970s, so-called "high-occupancy vehicle" (HOV) lanes were introduced in Washington, New York, and California, and have spread throughout metropolitan areas both in the US and, somewhat, internationally (*4*).

Yet, the benefits of HOV restrictions are unclear, with this type of policy remaining quite controversial. The main concern is that HOV lanes are underused (*5-6*). By restricting certain lanes to HOV traffic, these policies reduce the amount of available road space available for regular, single-occupancy traffic. If not enough people are induced to carpool by the existence of the HOV lane, these policies could potentially make traffic worse on the remaining lanes. They may also have spillovers, either positive or negative, on other routes, depending on how drivers change their routes in response to changes in congestion on the HOV lanes. The equilibrium traffic response from implementing the restrictions is difficult to predict theoretically as it depends on the full traffic network and the full network of drivers' origins, destinations, times of departure, and preferences. Indeed, the well-known Braess' Paradox states that adding more roads can actually increase equilibrium congestion (*7*), so what happens is ultimately an empirical question.

We examine this question empirically by analyzing the elimination of perhaps the most extreme HOV restrictions anywhere in the world: the "3-in-1" policy in Jakarta, Indonesia. This is an ideal setting to study traffic congestion policies. With a population of over 30 million, Jakarta is the world's second-largest metropolitan area, second only to Tokyo (*8-9*). Virtually all commuters in the region use the roads in some form or another: the city has no subway or light rail system, and only a limited commuter rail network. Not surprisingly, it has some of the world's worst traffic: a recent study of cities using GPS data found that the typical Jakarta driver experienced an average of 33,240 "stops and starts" in traffic per year, the worst in the world. By this metric, traffic jams in Jakarta are more than twice as severe as the worst-ranking U.S. city, New York, where drivers average only 16,320 stops and starts (*10*).

Under the 3-in-1 policy, first introduced in 1992, and unchanged since 2004, *all* private cars during the morning rush (7:00-10:00AM) and evening rush (4:30-7:00PM) on the main streets of Jakarta's Central Business District were restricted to those carrying at least 3 individuals. This included the 12-lane Jalan Sudirman, the city's main artery and home of the stock exchange, the education ministry, large shopping malls, and numerous corporate headquarters, as well as several other main thoroughfares (see Figure 1). By requiring at least three individuals, the policy was more stringent than the common HOV2+ lane policies.

The policy was not necessarily popular, with many believing that it did little or nothing to help reduce Jakarta's notorious traffic (*11*). While police were posted at the entrances of the 3-in-1 zone and routinely stopped cars in violation, with a maximum fine of Rp. 500,000 (approx. USD 37.5), there was a potential workaround: the policy had led to the development of professional passengers, called "jockeys," who stood by the road near 3-in-1 access points, and provided an additional passenger in exchange for around Rp. 15,000 (USD 1.20). In fact, a single driver in need of two additional passengers could hire a mother and child standing on the side of the road to gain another two bodies (*12*).

In this paper, we study the elimination of the 3-in-1 policy on traffic speeds throughout the city using innovative, high-resolution anonymized data collected via Android phones through Google Maps. On Tuesday March 29, 2016, the Jakarta government unexpectedly announced the abolition of the 3-in-1 restrictions, effective 7 days later. They initially announced a one-week trial; this was then extended for another month and then the policy was permanently scrapped on May 10, 2016. To study the impact of this change, starting two days after the first announcement (Thursday afternoon, March 31), we began collecting real-time data on driving speeds on several main roads in Jakarta – including some roads affected by the 3-in-1 policies, and alternate unaffected routes – by querying the Google Maps API for each route, every 10 minutes, 24 hours per day. This "live" data captures current travel conditions based on real-time reporting of traffic conditions from Android smartphone users, and is intended for real-time navigation.

To study the effects, we rely on two alternative counterfactuals. First, we use pre-period data from the 2-3 days before the policy change took effect. Second, we take advantage of Google's own innovative prediction algorithms by asking Google to predict the expected trip duration, for each route, day of the week and departure time, under typical traffic conditions. These predictions essentially use all of Google's data on average road speeds. We show that both counterfactuals are virtually identical.

We collected data in two phases. Starting on March 31 at 4:40pm local time, approximately 48 hours after the announcement, but 2.5 "weekday" days before the 3-in-1 policy was lifted, we began collecting traffic data in both directions on three main roads (see Figure 1): Jalan Sudirman, Jakarta's main artery and a road subject to the HOV policy, and two alternate roads that run parallel to parts of Jalan Sudirman that were never subject to the HOV policy: Jalan Rasuna Said (another main CBD road with many office towers), and Jalan Tentara Pelajar (an artery leading into the CBD from the southwest). Thus, we have data from both before and after the policy was lifted, as well as the predicted speeds described above. Starting on April 28, 2016, we expanded our dataset to include an additional previously HOV road, Jalan Gatot Subroto, as well as 8 alternate routes that had never been subject to HOV restrictions that were suggested to us by the Jakarta Government Department of Transportation. As with the earlier roads, we also queried the "predicted" business-as-usual data for comparison. More details on the data can be found in the Supplementary Materials (*13*).

The data from before the policy was lifted reveal that traffic is clearly bad. We focus on *delay*, defined as the number of minutes to move one kilometer (i.e., delays are defined as the inverse of speed). Delays averaged 2.8 minutes per km on the former HOV road from 7am – 8pm, and 3.2 and 2.2 minutes per km on the two alternate roads (See Table S1). Certain time intervals have significantly worse congestion, up to 3.6 and 4.4 minutes per km. By comparison, average delay is 0.7 minutes per km (53 mph) on the Los Angeles highways studied in Anderson (*14*). In Delhi, another congested city, delays are 2.6-2.7 minutes per km on average between 8am and 8pm over many routes across the city (*15*).

The pre-data also contains suggestive evidence that the HOV policy was effective in reducing traffic at the restricted times of the day. Specifically, on Jalan Sudirman, the delay is lower during the morning and evening peaks, relative to the mid-day off-peak and the hour after the evening peak, respectively. On the two non-restricted roads, the opposite pattern holds. In fact, Jalan Sudirman traffic was abruptly worse right after the end of the two restricted time periods (Figure S1).

We begin our analysis of the lifting of the policy by comparing traffic right before and after the policy. In Figure 2, we graph the average delay in minutes per kilometer on the weekdays for the former HOV road Jalan Sudirman (Panel A), as well an alternate road (Jalan Rasuna Said) in Panel B; results for an additional alternate road (Jalan Tentara Pelajar) are in Figure S2. We average over both road directions (North and South) since there are strong traffic flows in both directions at both times (disaggregated results are in Figure S3). The dashed-line denotes the pre-period days of March 31st (from 4:40pm onwards), April 1 and April 4, while the solid-line denotes the post-period from April 5th to May 4th. Note that we start by only examining what occurred during the first month after the policy change, in order for our post-period to be as comparable as possible to the pre-period. The concern is that factors—e.g. city-wide changes in school schedules, income, weather, etc.—may eventually change over time. We lift this restriction below to explore what happens over time. Bootstrapped 95 percent confidence bands, bootstrapped pointwise and clustered by date and direction, are shown shaded. For convenience, vertical lines mark the morning and evening peak-hour intervals during which the 3-in-1 policy was in effect during the pre-period.

Traffic clearly increased after the HOV policy was lifted. On the former HOV road (Figure 2, Panel A), we observe traffic increasing in both the morning and evening peak. This could be due to one of two factors: (1) after the abolition of the 3-in-1 policy, the number of car trips increased and there are more cars on the road (e.g., people stopped carpooling, stopped using bus transit, or increased their likelihood of travel to and from the CBD) or (2) the number of cars on the road is the same, but people changed the times of day when they travel, or their routes. Figure

2 shows that (2) is unlikely to play a large role. If anything, we observe an increase in traffic on the former HOV road during non-peak hours (Panel A) – especially after 7pm, when HOV restrictions were never in place. Moreover, we do not observe any changes in traffic on the alternate routes in the morning peak hours and actually observe an *increase* in traffic on the alternate routes in the evening rush hour. This implies that individuals are not just changing their travel time or routes, but rather there is more traffic overall throughout the city.

Table 1 formalizes Figure 2 and allows us to quantify the magnitudes. Specifically, we estimate, separately for each road segment and time period, the following equation:

$$delay_{idh} = \alpha + \beta \cdot post_d + \gamma \cdot north_i + \varepsilon_{idh}$$

where $delay_{idh}$ is the average travel delay in minutes per kilometer for segment i, on date d and for departure time h, $north_i$ is an indicator for whether segment i is northbound, and $post_d$ is an indicator for dates after the lifting. β is the coefficient of interest, providing the difference in average delays after the policy is lifted relative to before. Each column in Table 2 restricts the sample of departure times h. We provide β for both the morning (Column 2) and evening rush hours (Column 4) where 3-in-1 restrictions were in place in the pre-period, as well the non-peak periods (Columns 1, 3, 5 and 6) that were always unrestricted on all roads. Standard errors are clustered by date and direction.

The results in Table 1 echo the graphical findings from Figure 2. Table 1, Panel A shows that traffic is worse on the former HOV road after the policy is lifted. Specifically, we observe a 0.98 minutes/km increase (46 percent increase over the control mean of 2.14 minutes/km) in travel delay during the morning rush hour (significant at the 1 percent level, Column 2) after the policy is lifted and a 2.5 minutes/km (87 percent) increase in the evening rush hour (significant at the 1 percent level, Column 4). This translates into a decline in average morning rush hour speeds from

28 to 19 km/h in the morning and a decline in evening rush hour speeds from 21 to 11 km/h. The resulting speeds after the policy lifting are extremely congested: by comparison, typical *walking* speeds are about 5 km/h.

Even more surprising, the elimination of the HOV restrictions during the morning and evening rush – from 7-10am and 4:30-7pm – also led to increases in congestion at other times of the day when no HOV restrictions were in place in the pre-period. Specifically, traffic delays also increase by 2.0 minutes/km (55 percent) during the hour immediately *after* the evening peak (i.e. from 7-8pm), which was never restricted even during the HOV policy period. Likewise, traffic delay increases by 0.55 minutes/km during the midday period, which was also never restricted. This implies that individuals are not simply substituting away from travelling at other time periods once the 3-in-1 policy is lifted. We do not observe any change in traffic either in the hour before the morning rush hour (Column 1) nor at night (Column 6).

We then turn to examine whether there were any positive or negative spillover effects of the HOV restrictions on *other roads*. One might expect that, after the elimination of the HOV restrictions, congestion should decrease on these alternate routes, as traffic induced to use these routes would substitute back to Sudirman once it became open. Yet we find the opposite: delays on the main alternate route (Jalan Rasuna Said) *also* increase – by around 0.60 minutes/km (14 percent) during the evening commute. Delays also increase during the middle of the day and in the 7-8pm evening period. We find broadly similar effects on Jalan Tentara Pelajar, another alternate route (see Table S2). In short, these spillovers to other time periods and the alternative roads imply an overall negative general equilibrium effect on traffic congestion when the HOV policy is lifted, even at times or on routes that had previously not been affected by the policy.

We next extend the analysis in two ways: we explore (1) what happened to traffic over time, as individuals learned that traffic conditions worsened over time, and (2) what was happening in the rest of the road network. For this analysis, we use the second phase of our data collection, adding another former 3-in-1 road and a larger set of 8 alternate routes suggested by the Jakarta government. For these routes and dates, we do not have comparable pre-policy lifting "live" data; instead, we rely on our second counterfactual, the Google Maps' predicted travel time data. The Supplementary Materials show using a variety of checks that this counterfactual appears reasonable; importantly, due to time-lags and smoothing in their prediction algorithm, this predicted data does not take into account the change in policy.

Figure 3 graphs the live post-data against the predicted traffic data for the extended set of HOV roads (Panel A) and alternate routes (Panel B) for April 28th to June 3rd. Table 2 provides the corresponding regressions. As before, we observe an increase in traffic for both the morning and evening rush hours for the former HOV roads after the policy is lifted—the evening rush hour delay is nearly 70% higher than the predicted delay (Column 4 of Table 2, Panel A). We also observe both an increase in traffic in the non-rush hour times of the former HOV roads (Panel A of Table 2), as well as an increase in traffic on the alternate routes (Panel B of Table 2). In fact, the alternate routes experience an increase in delay from 3.08 to 3.72 min/km (21% increase) in traffic delays in the midday period, an increase from 3.61 to 4.67 min/km (29% increase) in the evening rush hour and an increase from 3.25 to 4.35 min/km (34% increase) in the hour after rush hour.

Examining the effects day-by-day, we find that effect of the policy appears immediately after the policy is lifted and persists over time on both the HOV and alternate roads. Delay drops during the holiday of Lebaran (when many Jakarta residents leave Jakarta to travel to their native regions), and increases again relative to the predicted after the holidays, albeit to a lesser extent (see Figures S4-S5, S10-S12).

There are several potential reasons why eliminating HOV restrictions could lead to a general equilibrium increase in congestion. The most parsimonious explanation is that more people were induced to drive: once people decided to drive during peak hours, they also used their cars at other times of day and on other roads, creating more traffic.

However, other explanations could explain our findings. For example, HOV restrictions may have prevented hyercongestion on the targeted roads. Hypercongested conditions describe a situation where an increase in density of vehicles on the roads decreases average speeds by so much that the total flow of cars over the road actually falls (*16*). If eliminating the HOV restriction resulted in the emergence of hypercongestion on the affected roads, the total amount of volume handled by these roads would have fallen, forcing more traffic onto other roads and worsening speeds throughout the city (see Supplementary Materials for a stylized example.) Another potential reason is through the feeder aspect of the road network: it is possible that some people were trying to get to the now-congested CBD, and the congestion in the CBD spills back to other parts of the network.

Although our data do not allow us to disentangle these hypotheses directly, the fact that we see spillovers on other times of the day, and even on one alternate route that heads away from the CBD, suggests that there may be more cars on the road.

Importantly, the magnitude of the policy impacts is quite remarkable, and significantly larger than other policies documented in the literature. For example, in the 7-8 pm time period – when 3-in-1 was never in effect – we find that eliminating 3-in-1 led to increases of delays of 1.3-2 minutes per kilometer, even on alternate roads. By contrast, estimates are that London Congestion Charge led to a decrease in delay of 0.6 minutes per kilometer (*17*). Anderson (*14*) finds that a public transport strike in Los Angeles leads to an increase of between 0.2 and 0.4 minutes of delay per mile during peak hours on highways throughout the city. Kreindler (*15*) studies the introduction of short-term driving restrictions based on license plate numbers in Delhi, and using similar Google Maps data finds an improvement of around 0.2 minutes per kilometer across the city, and other studies of even-odd restrictions have found small effects due to household behavioral responses (*18*-*19*).

These relatively large effects are even more notable given the challenges of implementing HOV policies in a developing country. In particular, as discussed above, in Jakarta, there was a widespread practice of hiring "jockeys" to serve as extra passengers in order to enter the 3-in-1 restricted areas. Had the widespread use of jockeys compromised the policy, we would expect little or no effect of the lifting. The evidence emphatically rejects this view, as the lifting of 3-in-1 made a large difference to traffic congestion.

In sum, we show that the lifting of Jakarta's 3-in-1 policy not only had effects on traffic on former HOV roads, but had spillovers to alternative roads and time periods. The results therefore suggest that quantity restrictions on severely congested roads can have beneficial spillover effects on traffic throughout the city, whether by potentially eliminating hypercongestion or by getting cars off the road. We cannot decisively say, however, whether the 3-in-1 policy improved welfare. This depends on how commuters with cars value the alternatives to single occupancy cars (e.g. carpooling, taxi, public transport, or not travelling). However, given the extremely high congestion levels, we can infer that the wedge between private and social cost is also high, making it likely that the equilibrium after the lifting is severely inefficient.

REFERENCES

1. J. Baker, R. Basu, M. Cropper, S. Lall, A. Takeuchi, Urban Poverty and Transport: The Case of Mumbai. *World Bank Policy Research Working Paper*. **3693**, (2005).
2. R. H. M. Pereira, T. Schwanen, Commute time in Brazil, 1992-2009: differences between metropolitan areas, by income levels and gender. *IPEA Discussion Paper No. 1813a*, (2013); http://www.ipea.gov.br/portal/images/stories/PDFs/TDs/td_1813a.pdf.
3. C. R. Knittel, D. L. Miller, N. J. Sanders, Caution, Drivers! Children Present: Traffic, Pollution, and Infant Health. *The Review of Economics and Statistics*, **98(2),** 350-366 (2016).
4. C. Fuhs, J. Obenberger, Development of High-Occupancy Vehicle Facilities: Review of National Trends. Transportation Research Board, Issue 1781, Paper No. 02-3922 (2002).
5. J. Dahlgren, High occupancy vehicle lanes: not always more effective than general purpose lanes**.** *Transportation Research Part A: Policy and Practice* **32 (2)**, 99–114 (1998).
6. J. Kwon, P. Varaiya, Effectiveness of California's High Occupancy Vehicle (HOV) system, *Transportation Research Part C* **16**, 98-115 (2008).
7. R. Steinberg, W. I. Zangwill, The Prevalence of Braess' Paradox. *Transportation Science.* **17(3)**, 301 (1983).
8. Indonesian Central Bureau of Statistics (BPS) (2015a), Banten Penduduk Menurut Jenis Kelamin dan Kabupaten/Kota di Provinsi Banten, 2005-2015, http://banten.bps.go.id/linkTableDinamis/view/id/51.
9. Indonesian Central Bureau of Statistics (BPS) (2015b), Satudata Jawa Barat Jumlah Penduduk Kabupaten/ Kota di Jawa Barat Tahun 2010 – 2015, http://pusdalisbang.jabarprov.go.id/pusdalisbang/data-94-Kependudukan.html.
10. Castrol Stop-Start Index, http://www.castrol.com/en_au/australia/car-engine-oil/engine-oil-brands/castrol-magnatec-brand/stop-start-index.html.
11. M. Z. Mochtar, Y. Hino, Principal Issues to Improve the Urban Transport Problems in Jakarta. *Mem. Fac. Eng., Osaka City University* **47**, 31-38 (2006).
12. Jakarta Globe, "Jakarta Jockeys Feel the Squeeze as 3-in-1 Scheme Runs Out of Gas," (Publication October 21, 2012, http://jakartaglobe.id/archive/jakarta-jockeys-feel-the-squeeze-as-3-in-1-scheme-runs-out-of-gas/).
13. Additional Supplementary Materials are available at the Science Web site.
14. M. L. Anderson, Subways, Strikes, and Slowdowns: The Impacts of Public Transit on Traffic Congestion. *American Economic Review* **104(9)**, 2763–2796 (2014).
15. Kreindler, Gabriel, Driving Delhi? Behavioural Responses to Driving Restrictions (July 11, 2016). Available at SSRN: https://ssrn.com/abstract=2966797 .
16. N. Geroliminis, C. F. Daganzo, Existence of urban-scale macroscopic fundamental diagrams: Some experimental findings. *Transportation Research Part B Methodological*. **42(9),** 759–770 (2008).
17. Transport for London (TfL), Central London Congestion charging, Impacts monitoring, Fourth Annual Report, (2006).
18. L.W. Davis, The effect of driving restrictions on air quality in Mexico City. *Journal of Political Economy*. **116(1),** 38-81 (2008).
19. F. Gallego, J.P. Montero, C. Salas, The effect of transport policies on car use: Evidence from Latin American cities. *Journal of Public Economics*. **107**, 47-62 (2013).

REFERENCES FOR SUPPLEMENTARY MATERIALS

20. Jakarta Central Bureau of Statistics (Badan Pusat Statistik Provinsi DKI Jakarta) (2015), *Statistik Transportasi DKI Jakarta Tahun 2009*, Katalog BPS 8301007.31.

21. Indonesian Central Bureau of Statistics (BPS) (2014). Statistics Commuter Jabodetabek.
22. Delhi Metro Rail Corporation (DMRC), Annual Report 2014-2015.
23. MTA facts, http://web.mta.info/nyct/facts/ridership/ridership_sub_annual.htm
24. Y. O. Susilo, T. B. Joewono, W. Santosa, D. Parikesit, A Reflection of Motorization and Public Transport in Jakarta Metropolitan Area. *IATSS Research* **31**(1), 59-68 (2007).
25. Japan International Cooperation Agency (JICA) and Badan Perencanaan Pembangunan Nasional (BAPPENAS), The Study on Integrated Transportation Master Plan for JABODETABEK (Phase II) Final Report, Pacific Consultants International, Almec Corporation, March 2004.
26. Governor of the DKI Jakarta, Decision No. 4104/2003 Penetapan Kawasan Pengendalian Lalu Lintas Dan Kewajiban Mengangkut Paling Sedikit 3 Orang Penumpang Perkendaraan Pada Ruas – Ruas Jalan Tertentu Dipropinsi Daerah Khusus Ibukota Jakarta, (2003).
27. Indonesian Road Traffic and Transport national Law 22/2009.
28. "Gov't vows to end child begging after 4 arrested for beating and drugging exploited children in South Jakarta," see https://coconuts.co/jakarta/news/govt-vows-end-child-begging-after-4-arrested-beating-and-drugging-exploited-children/.
29. Pekan Depan, Ahok Ujicoba Hapus Peraturan 3 in 1 (Next week, Ahok Tests Removing the 3 in 1 Rule) *Poskota News*, Tuesday, March 29, 2016, http://poskotanews.com/2016/03/29/pekan-depan-ahok-ujicoba-hapus-peraturan-3-in-1/.
30. 3-in-1 Removal Trial Extended to Four Weeks, *Tempo*, April 14 2016, http://en.tempo.co/read/news/2016/04/14/057762681/3-in-1-Removal-Trial-Extended-to-Four-Weeks.
31. Dishub DKI Jakarta: Aturan 3 in 1 Dihapus, *Liputan 6*, May 10 2016, http://news.liputan6.com/read/2503360/dishub-dki-jakarta-aturan-3-in-1-dihapus.
32. A.C. Cameron, J. B. Gelbach, and D.L. Miller. Bootstrap-based improvements for inference with clustered errors. *The Review of Economics and Statistics* **90 (3)**, 414-427 (2008).
33. E. T. Verhoef, Time, speeds, flows and densities in static models of road traffic congestion and congestion pricing. *Regional Science and Urban Economics,* **29**, 341–69 (1999).
34. K. A. Small, X. Chu, Hypercongestion, *Journal of Transport Economics and Policy*. **37(3),** 319–52 (2003).
35. E.T. Verhoef, and K.A. Small. Product Differentiation on Roads: Constrained Congestion Pricing with Heterogeneous Users. *Journal of Transport Economics and Policy*. **38(1)**, 127-156 (2004).

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Tables and Figures

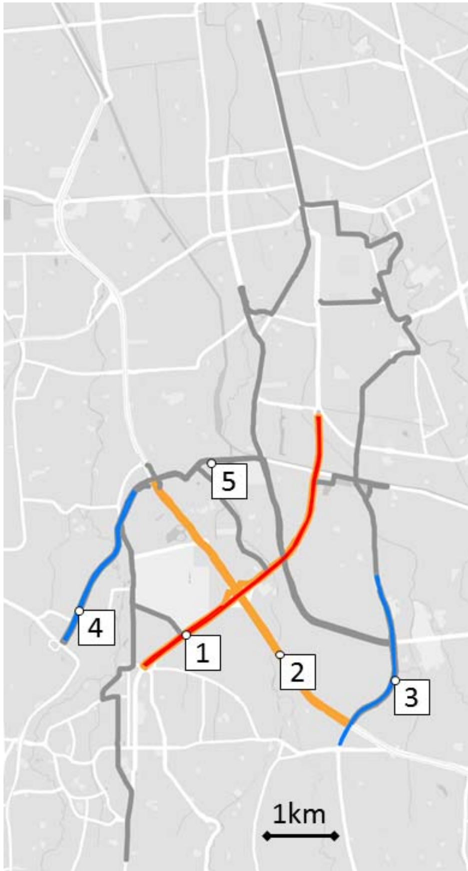

Figure 1.

Routes included in the analysis. (1) Former 3-in-1 road (Jalan Sudirman, red and orange), (2) Former 3-in-1 road (Jalan Gatot Subroto, orange), (3) Unrestricted alternate road (Jalan Rasuna Said, blue), (4) Unrestricted alternate road (Jalan Tentara Pelajar, blue), (5) 8 unrestricted alternate routes from the Jakarta Department of Transport (gray). Routes from the first phase of data collection are drawn with thin lines: 1 (red), 3 (blue), and 4 (blue). Map data ©2017 Google

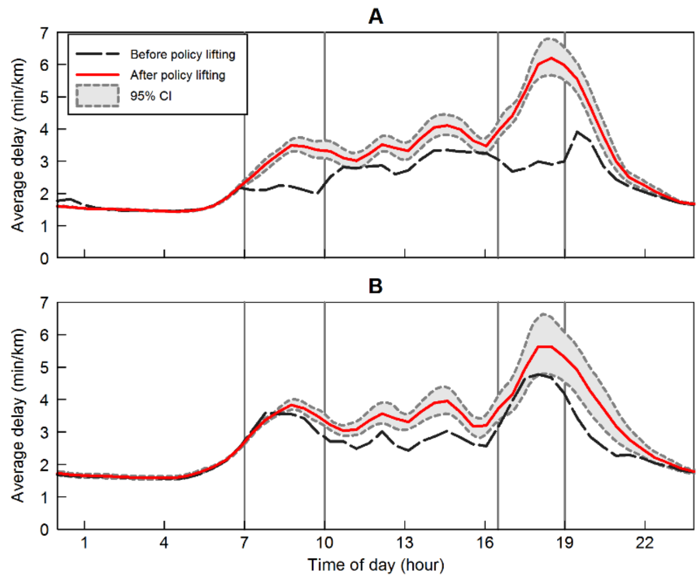

Figure 2.

Impact of 3-in-1 policy lifting. (A) Former 3-in-1 restricted road (Jalan Sudirman) and (B) unrestricted alternate road (Jalan Rasuna Said). The graph shows locally linear regressions (Epanechnikov kernel, 0.2 hour bandwidth) of delay on departure time, before and after the lifting. Uses "live" data pre- and post-lifting. Pre-data from Thursday March 31 (4:40pm onward), Friday April 1 and Monday April 4. Post- data from all weekdays April 5 - May 4. For each departure time, there are two observations per route, corresponding to the two road directions. Pointwise bootstrapped 95% confidence bands around post-data, adjusted for date times road direction clusters (1000 bootstrap iterations).

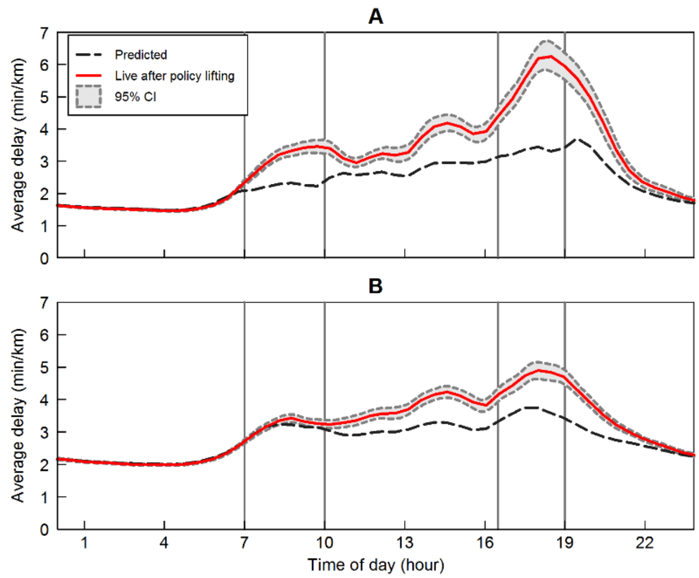

Figure 3.

Impact of 3-in-1 policy lifting on expanded set of routes using “predicted” counterfactual. (A) Both former 3-in-1 restricted roads (Jalan Sudirman and Jalan Gatot Subroto) and (B) 8 unrestricted alternate routes (identified by Jakarta Department of Transportation). Post-data from all weekdays April 28 - June 3. See Figure 2 for further information.

	(1)	(2)	(3)	(4)	(5)	(6)
Time interval	6 - 7 a.m.	7 - 10 a.m.	10 a.m. - 4:30 p.m.	4:30 - 7 p.m.	7 - 8 p.m.	8 p.m. - 6 a.m.
Panel A. Delay on 3-in-1 Road (Jalan Sudirman)						
Policy Lifting	-0.00	0.98***	0.55**	2.48***	1.98***	0.05
	(0.05)	(0.07)	(0.23)	(0.30)	(0.34)	(0.08)
Northbound	0.24***	0.12	-0.98***	-1.48***	-2.01***	-0.08
	(0.01)	(0.12)	(0.16)	(0.26)	(0.36)	(0.05)
Observations	264	792	1,720	670	270	2,656
Control mean	1.92	2.14	2.98	2.84	3.59	1.87
Panel B. Delay on Alternate Road (Jalan Rasuna Said)						
Policy Lifting	0.03	0.13	0.71***	0.60***	1.32***	0.16*
	(0.03)	(0.09)	(0.12)	(0.20)	(0.37)	(0.09)
Northbound	-0.08***	-0.14	-0.80***	-4.24***	-4.03***	-0.77***
	(0.02)	(0.09)	(0.17)	(0.21)	(0.33)	(0.07)
Observations	264	792	1,720	670	270	2,656
Control mean	2.19	3.34	2.71	4.35	3.61	1.89

Table 1.

Impact of 3-in-1 policy lifting on restricted and unrestricted roads. Each column shows the policy impact in a given time of day interval. The outcome variable is delay (min/km) measured using "live" Google Maps API data. The sample is described in Figure 2. The sample in each column is restricted to the departure time interval (open on the right) in the column header. For March 31, data is available for the evening peak onward. Coefficients are from linear regressions of traffic delay (min/km) on post-policy lifting and road direction indicators. Standard errors reported in parentheses are clustered at the date times road direction level. Significance levels given by * P <0.10, ** P<0.05, *** P<0.01

	(1)	(2)	(3)	(4)	(5)	(6)
Time interval	6 - 7 a.m.	7 - 10 a.m.	10 a.m. - 4:30 p.m.	4:30 - 7 p.m.	7 - 8 p.m.	8 p.m. - 6 a.m.
Panel A. Delay on Former 3-in-1 Roads (Jalan Sudirman and Jalan Gatot Subroto)						
Policy Lifting	-0.02	0.88***	0.81***	2.29***	1.98***	0.19***
	(0.02)	(0.08)	(0.10)	(0.19)	(0.21)	(0.04)
Northbound	0.18***	-0.09	-0.21	-0.75**	-1.08***	-0.18***
	(0.03)	(0.11)	(0.15)	(0.29)	(0.35)	(0.05)
Observations	384	1,152	2,494	960	384	3,832
Control mean	1.93	2.23	2.75	3.31	3.63	1.83
Panel B. Delay on Alternate Routes (Identified by Jakarta Department of Transportation)						
Policy Lifting	-0.02*	0.09*	0.64***	1.06***	1.10***	0.11***
	(0.01)	(0.05)	(0.09)	(0.12)	(0.10)	(0.02)
Northbound	0.28***	0.51***	0.71***	0.75***	0.35**	0.20***
	(0.01)	(0.06)	(0.09)	(0.18)	(0.16)	(0.03)
Observations	384	1,152	2,494	960	384	3,832
Control mean	2.41	3.12	3.08	3.61	3.25	2.27

Table 2.

Impact of 3-in-1 policy lifting using “predicted” counterfactual. Each column shows the policy impact in a given time of day interval. The outcome variable is delay (min/km), measured using “live” or “predicted” Google Maps API data. The sample is described in Figure 3. The sample in each column is restricted to the departure time interval (open on the right) in the column header. Coefficients are from linear regressions of traffic delay (min per kilometer) on “live” and road direction indicators. Standard errors reported in parentheses are clustered at the date times road direction level. Significance levels given by * P <0.10, ** P<0.05, *** P<0.01