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Eiji Yamada and Yi Jiang

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JICA Ogata Sadako Research Institute for Peace and Development, Japan International Cooperation Agency (JICA)
10-5 Ichigaya Honmura-cho, Shinjuku-ku, Tokyo, 162-8433, JAPAN
TEL: +81-3-3269-3374
FAX: +81-3-3269-2054

The Impact of Dhaka Mass Rapid Transit on Road Congestion

Eiji Yamada* and Yi Jiang†

Abstract

The Dhaka Mass Rapid Transit (MRT) is the first rail-based urban mass transit system in Bangladesh and was expected to reduce the severe traffic congestion in Dhaka. This study examines the impact of the introduction of Dhaka MRT Line 6 on road congestion. We employ a two-group event study evaluation design, comprising a multiple-period version of the difference-in-difference. Instead of using survey-based travel time data, we measure the speed of vehicles using super-frequent real-time travel data derived from Google Maps. The results from the quasi-experimental analyses show a substantially large impact of increasing vehicle speed along the treatment corridor that hosts the MRT Line 6 viaduct. Vehicle speeds responded immediately to the gradual expansions of the MRT operational hours and stations. However, our analysis also suggests that this additional traffic capacity may be gradually saturated by the induced travel demand along the corridor served by the MRT, providing an empirical case supporting the fundamental law of road congestion.

Keywords: Urban Transport, Travel Time, Mass Rapid Transit, Congestion.
JEL Codes: R41, R42, L92

* Senior Research Fellow, JICA Ogata Sadako Research Institute for Peace and Development, Tokyo, Japan & Senior Representative, JICA Bangladesh Office, Dhaka, Bangladesh.
† Principal Economist, Economic Research and Development Impact Department, Asian Development Bank

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1. Introduction

Dhaka, the capital city of Bangladesh and home to approximately 20 million people, is one of the most congested cities in the world. According to the Asian Development Bank (2019), Dhaka ranks fourth among Asian cities with populations above five million in terms of traffic congestion, following megacities such as Metro Manila, Kuala Lumpur, and Yangon. According to the latest Traffic Index by Numbeo, Dhaka is the fifth worst city on the global aggregate index and the second worst in terms of travel time and dissatisfaction after Lagos, Nigeria.[1] This slow mobility incurs significant costs, with residents of Dhaka spending 19 percent of their income on commuting trips—the highest among the cities in developing Asia (Asian Development Bank, 2019). In addition to the direct cost of transport services, the economic burden of time lost due to congestion is sizable. According to Haider and Papri (2021), the average commuter in Dhaka loses one working hour per day, or USD 4.21 (USD 1010.76 per year), based on 2016 estimates. Considering that the GNI per capita in 2016 was USD 1410, this represents a significant economic burden.

Under these circumstances, the Mass Rapid Transit (MRT) in Dhaka has been a long-awaited project that addresses the worsening traffic situation. Almost two decades after its conception in the World Bank's master plan, the first of six planned urban railways—MRT Line 6—started commercial operations on December 29, 2022. As the first modern transit system, MRT Line 6 has quickly gained popularity among residents, reaching more than 300,000 passenger trips per day within a year of its inauguration, even though the operation has yet to achieve its full scale.[2]

In general, whether newly constructed urban transport systems can reduce traffic congestion remains an empirical question. While it might seem clear that the introduction of new public transit creates additional capacities to accommodate larger traffic volumes, the question of whether commuters will switch from vehicle traffic to public transit depends on many factors, such as the alignment of the MRT within the urban traffic system, commuter fares, and feeder infrastructure to facilitate access to the MRT stations. Some studies have reached negative conclusions on the economic benefit of urban subways that require substantial investment (Winston and Maheshri, 2007), while others have quantified the relatively limited congestion-easing effects of MRT systems (Gu et al., 2021). The case of Dhaka Metro provides an excellent opportunity to examine the congestion-easing effect of MRT in the context of densely populated developing cities with high vehicle traffic.

This paper presents the results of a quantitative evaluation of the impact of the MRT Line 6 opening on road traffic congestion. The main dataset used for the analysis is the real-time travel data generated by Google Maps. We make use of a dataset collected by the ADB since late 2019, based on the method of data collection proposed by Akbar et al. (2023), which constructed a rich

[1] https://www.numbeo.com/traffic/rankings.jsp

[2] See Section 3 for the operational situation. As of the endpoint of this study, June 2024, MRT Line 6 still operates only 6 days a week, does not operate during the early morning or late at night, and the headway is 8 minutes even at the peak hours, two times longer than the planned peak hour headway.

time series of the real-time traffic across Dhaka's urban area.[3] The data contains around 100,000 simulated trips per day across a randomly distributed set of O-D (origin-destination) pairs of locations scattered over Dhaka (defined by the commuting area). Our study period starts at the beginning of 2022, when the major construction work of the MRT Line 6 that affected road traffic finished, and ends in June 2024, just before the unexpected political turmoil in Bangladesh in July 2024 that led to the collapse of the government and disrupted MRT operations. As Widita et al. (2023) note, using real-time data available through web-based platforms like Google Maps can overcome the classic problem of data constraints in evaluating urban transit programs.

We estimate the impact of Dhaka MRT Line 6 on congestion by employing a quasi-experimental method, a difference-in-difference (DID) approach with many time periods, sometimes referred to as "two group event studies" (Freedman et al., 2023). We set the road corridor that runs under the viaduct of MRT Line 6 as the "treatment" while designating road corridors planned for future MRT lines as the "control." Namely, we examine the corridors along the future MRT Lines 1, 2, and 4 as the control area. Since we limit our sample trips starting and ending within the immediate neighborhood of the treatment and the control corridors, our estimates of the impact should be regarded as a localized effect of the MRT on congestion. To the best of our knowledge, Widita et al. (2023) is the first study to evaluate the impact of public transit on congestion using travel data from Google Maps. Ours departs from this method by utilizing a much more intensively collected dataset that covers an extended timeframe before and after the MRT opening and a larger geographical diversity of the O-D pairs. The dataset enables us to confirm the parallel pre-trend between treatment and control, as well as observe the evolving impact of the MRT over time.

The remaining sections of this paper proceed as follows. After the literature review in Section 2, Section 3 summarizes the history of MRT development in Dhaka. The data we use in the analyses is explained in Section 4. Section 5 details our empirical strategy, and 6 presents the results of the estimations and the discussion. Section 7 offers our conclusions and ideas for future research.

2. Literature

This paper examines the literature on the benefit of urban transit development in the context of developing countries. Instead of focusing solely on the direct impacts, such as vehicle speed and congestion, economists tend to examine the socio-economic impacts of urban public transit development. An emerging strand of studies utilizes granular urban household-level data before and after urban transit construction to calibrate quantitative spatial equilibrium models that quantify the overall welfare gains and distributional impact (Tsivanidis, 2023). Some of these studies focus on specific change channels, such as formalization of employment (Zárate, 2022), crime

[3] The dataset was initially collected for Asian Development Bank (2019), then the team has continued the collection to date.

reduction(Khanna et al., 2022), or female labor participation (Velásquez, 2023).[4] Moreover, the urban railway transit system may have a positive, complementary impact on welfare by enabling more flexible land use policies (Chen et al., 2024).

From the perspective of policymakers and the local public, however, the first-order objectives of urban transit in developing countries are easing traffic congestion and reducing air pollution. This paper focuses on the former in the context of a densely populated megacity in developing Asia. The literature on the congestion-easing effect of urban rail transit has concentrated unevenly on the cases of developed countries, especially in regard to US cities (Widita et al., 2023). Among the limited examples from developing countries, Yang et al. (2018) examined the short-run effect of the opening of subways in Beijing in reducing vehicle congestion. Employing the regression-discontinuity design approach for the city-wide daily index of vehicle speed in Beijing, they conclude that the opening of subways caused an immediate reduction of delay times by 15%. In another study, Gu et al. (2021) used the data from the Baidu Maps to measure the congestion-easing impact of opening 45 subways across China. Their difference- in-difference estimates demonstrate that the launch of the subway line increased the rush-hour vehicle speed on nearby roads by about 4% over one year.

To our knowledge, Widita et al. (2023) and Widita (2024) are the only studies that examine the congestion-easing effect of urban rail transit in developing countries outside China. The former examined the short-run (a few months) traffic-easing effect of the MRT Jakarta, which was inaugurated in 2019, finding that vehicle speed along the road corridor hosting the MRT increased by 7.9 km per hour (about 30%) compared to the corridors parallel to the MRT corridor. The latter focuses on the medium-term impact. Their results show that the congestion-easing effect persisted six months after the opening of the MRT Jakarta, reducing the delay by 40%.[5] While both of these studies on Jakarta utilize simulated trip data from Google Maps, they employ the two-period (before-after) DID without a pre-trend check. In addition, since the currently operating MRT Jakarta is located in relatively less-congested areas—where the average speed of vehicles was already 23 km per hour or above even before the opening of the MRT—these studies may not be readily applicable to more highly congested cities like Dhaka or other South Asian cities, as described in Akbar et al. (2023), where the average vehicle speed is closer to 10km per hour during peak hours.

Given the discussion above, the major contributions of the paper are as follows. First, this paper

[4] Martinez et al. (2018) and Seki and Yamada (2020) quantify the impact of urban transit on female labor participation, employing a difference-in-difference program evaluation method.

[5] Gaduh et al. (2022) is another study measuring the impact of urban transit; however, they focused on the Bus Rapid Transit, which is different from the case of MRT in terms of capacity and scale of investment.

adds a new case study of a large city from the developing world to the scarce literature on the direct benefit of urban transit systems. In particular, it provides a unique case study of the newly opened Dhaka MRT Line 6 and its impact on urban traffic in the context of extreme congestion. Second, this paper examines the short-to-medium-term evolution of the congestion-easing impact of MRT, previously explored only by Gu et al. (2021). Our estimates show the diminishing congestion-easing effect of MRT over time, demonstrating the "fundamental law of road congestion" (Duranton and Turner, 2011), where the reduced traffic resulting from the new urban transit is sooner or later offset by increasing traffic demand, including private vehicles and public buses. Duranton and Turner (2011) examine the impact of the increased lane-kilometer of the roads (road capacity) on vehicle-kilometers traveled (VKT, the traffic volume) in the US context and concluded that the traffic volume increases as the road capacity increases, which to some extent offsets the congestion easing by larger road capacity. In this article, we consider that the opening of MRT increases the capacity of existing road corridor by providing an alternative mode to travel. If capacity increases, the speed of vehicle on the corridor can increase (congestion reduces) provided that the traffic volume is constant. From the change in speed after the opening of MRT, we may conjecture how the congestion evolves against the increased capacity by the MRT.

3. The Dhaka MRT System and its Development

The concept of developing MRTs in Dhaka originated in 2005 with the Strategic Transport Plan for Dhaka, a report issued by the Government of Bangladesh with financial support from the World Bank. The plan proposed three rail-based MRTs in addition to three lines of Bus Rapid Transit (BRT). The government faced significant delays in moving the plan forward until the Japan International Cooperation Agency (JICA) provided support to complete a Feasibility Study for the construction of the MRT Line 6 in 2011, which was selected as the first line to be constructed. Through a subsequent series of studies, including urban transportation master plans—mainly supported by JICA—the Government of Bangladesh developed a comprehensive plan for the MRT system in Dhaka, consisting of six urban railways, either underground or elevated, with potential extensions to further suburbs in the future. Figure 1 shows the current plan of the MRT system by Dhaka Mass Transit Company Limited (DMTCL), a publicly owned company responsible for developing and operating the Dhaka MRT.[6] Among the six proposed lines, only Line 6 has been completed and is currently under commercial operation. Line 1 and Line 5 North are under construction with financial support from JICA.

Figure 2 shows the location of the MRT Line 6 stations. The line connects the city's populated business and residential areas. The southern end of the Line is Motijheel Station, located in the traditional central business district of Dhaka. Together with nearby stations, such as Bangladesh

[6] https://dmtcl.portal.gov.bd/sites/default/files/files/dmtcl.portal.gov.bd/page/4c09476f_2d25_41a1_803d_78165d28a7a6/2021-09-14-05-59e7616c1542374a2b5c224001d6fff8bb.pdf. Retrieved September 15, 2024.

Secretariat (serving government institutions) and Dhaka University, the area attracts employees and students commuting from the residential areas located in the northern part of the city.[7]Other key stations, such as Karwan Bazar and Farmgate, are centers of Dhaka's commercial activity, providing access to large markets, hotels, and commercial buildings.

Based on the Feasibility Study above, financial support from the Japanese ODA (Official Development Assistance) Loan was provided through JICA for the construction of the MRT Line 6 from 2013. Designed as an elevated railway, with a 13m-high viaduct along its entire length, construction started in 2016. As the viaduct extended over the median strips of the major road corridors running from north to south in central Dhaka, the construction of the pillars and the viaduct caused congestion.[8] After six years of construction, the viaduct of the entire section was completed on January 27, 2022.[9]

Following the installation of system and equipment on the line and stations, the Northern section of the MRT, from Uttara North to Agargaon—Phase I—was inaugurated on December 29, 2022. Although Phase I now comprises nine stations, only Uttara North and Agargaon stations were opened initially, and the hours of operation were limited to mornings only. Subsequently, the Metro Rail Authority gradually opened the remaining stations while extending its operational hours. By May 31, 2023, all stations in the Phase I section were operational and operating hours were extended to the evenings, with services stopping at 20:00. On November 5, 2023, the southern section, running from Agargaon to Motijheel (Phase II Section) commenced operations. The operational stations were limited only to Farmgate, Bangladesh Secretariat, and Motijheel, while the other stations in between started opening gradually. The Phase II Section also operated in the mornings only at first. After making all the stations in the section operational, the complete MRT Line 6 from Uttara North to Motijheel became operational, with services running daily from 7:00 in the morning till 20:40, except for Fridays. Table 1 summarizes the chronology of this staggered inauguration.

The other MRT lines shown in Figure 1 are either under construction or in planning. Line 1 will run from north to south through the Dhaka city area parallel to MRT Line 6 on its western side. Construction is ongoing for the section connecting Dhaka Airport and Kamalapur (Bangladesh's main central railway station, which will serve the CBD of Dhaka together with Motijheel), with a branch line extending towards the eastern suburbs. The construction of MRT Line 1 started in February 2023 with land development for a depot in Purbachal, located at the end of the branch line in the eastern suburbs, 25 km from the city center of Dhaka. Construction work on the main line from

[7] As of the date of this article, the southern terminal of the MRT Line 6 is Motijheel. However, an extension to the line from Motijheel to Kamalapur, the city's central railway station, is now also under construction.
[8] https://www.banglanews24.com/national/news/bd/952145.details. Retrieved September 20,2024.
[9] https://www.thedailystar.net/news/bangladesh/transport/news/dhaka-metro-rail-milestone-last-girder-segment-mrt-6-installed-2948391. Retrieved September 20, 2024.

the airport to Kamalapur Station, which will be underground, has not yet commenced. Another line that has already started construction is the MRT Line 5 North. This line is the first east-west MRT line in Dhaka and will connect major residential areas and business centers in the northern half of Dhaka. The depot land development for Line 5 North started in November 2023 in the western suburbs, around 20km from the city. At the time of writing, no construction work for MRT lines interferes with the road traffic corridors in urban Dhaka. Both Line 1 and Line 5 North are expected to start their commercial operations by the late 2020s.

MRT Line 5 South, Line 2, and Line 4 remain in the planning stages at the time of publication, while construction projects are expected to commence soon. Line 5 South is another East-West line branching off from Line 5 North. Line 2 and Line 4 will serve the southern part of the city. The northern half of Line 2 will run parallel to MRT Line 6 on its western side, then connect Kamalapur Station with residential and industrial areas to the south. Line 4 will run along the corridor connecting Kamalapur Station with the southern densely populated city of Narayanganj. All these lines are expected to be commissioned by the early 2030s.

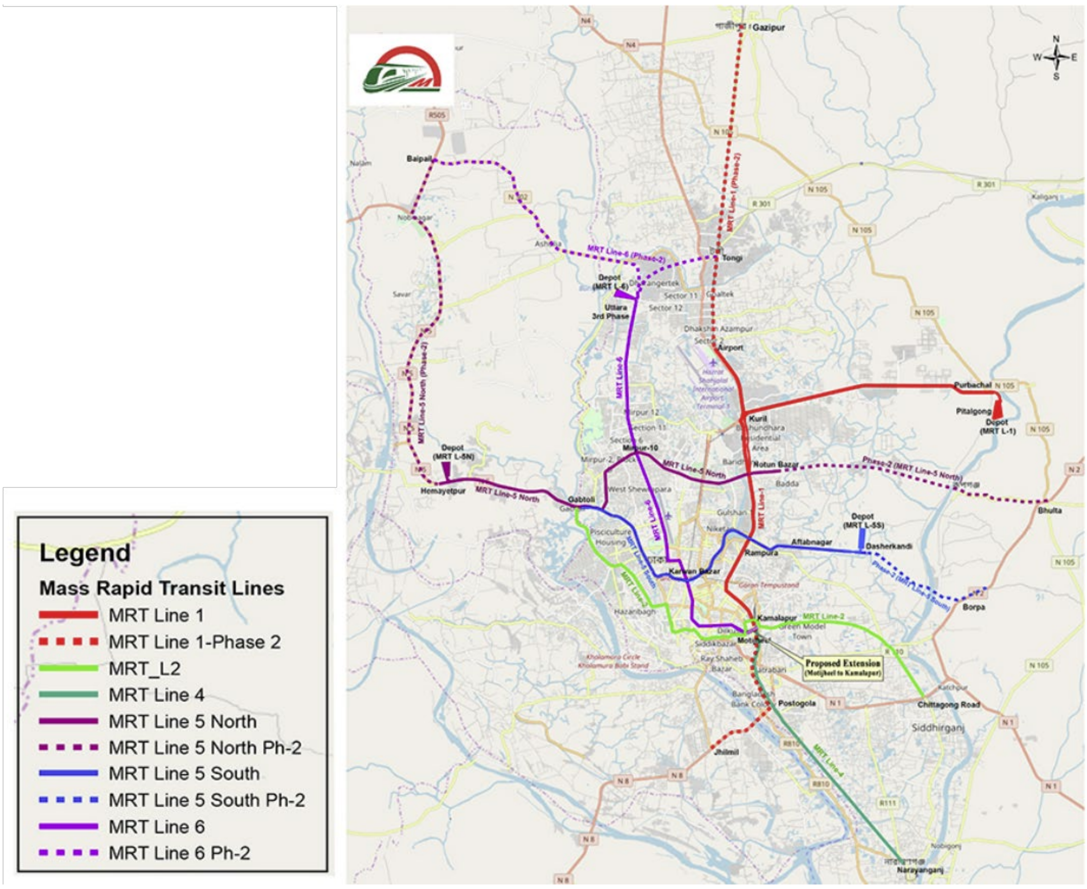

Figure 1: Plan of MRT Lines in Dhaka

Source: DMTCL Web Site

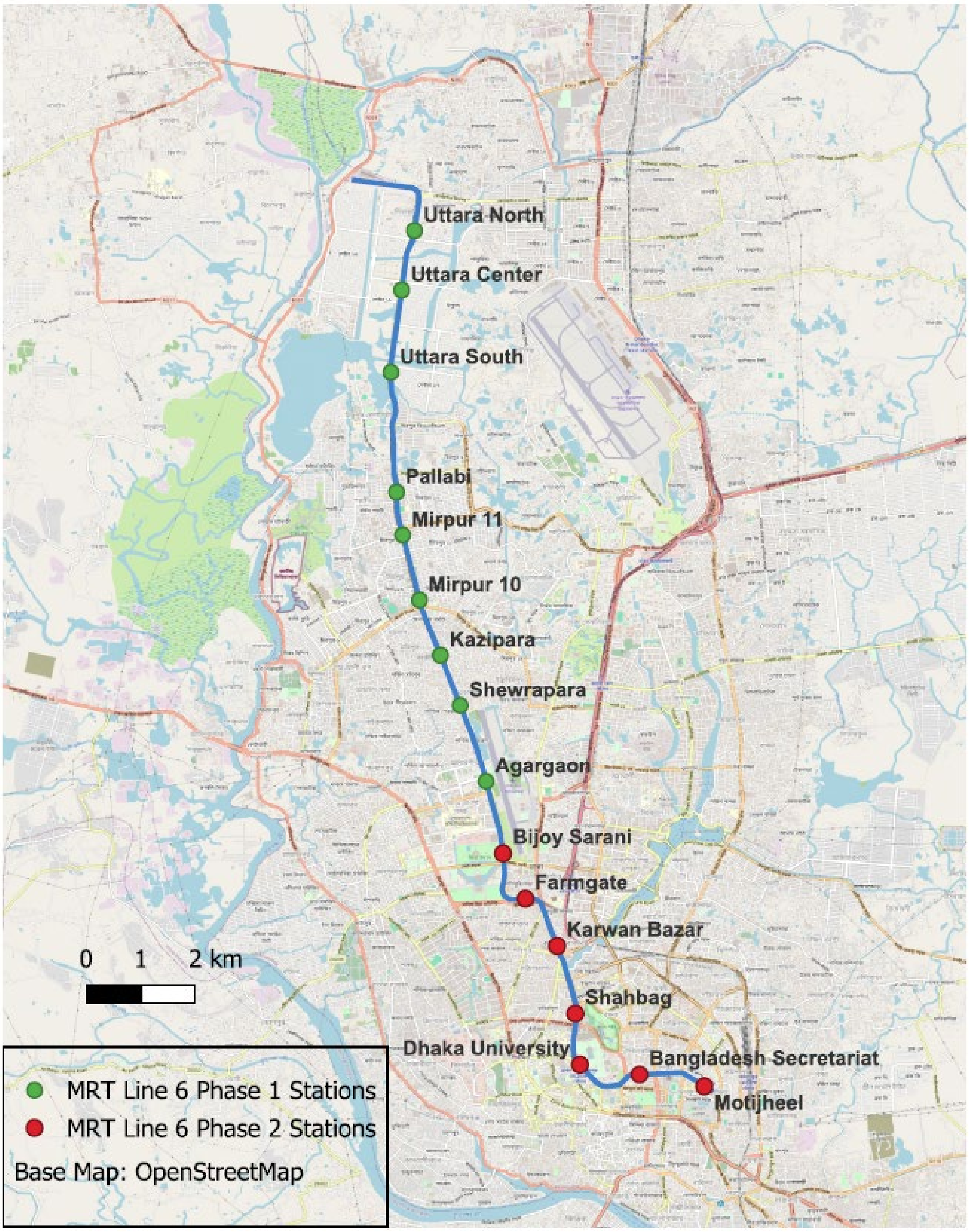

Figure 2: MRT Line 6 Stations Map

Table 1: Phased Opening of the Dhaka MRT Line 6

Phase	Date	Operational Hours	Off day	Stations Added
(1)	Dec 29, 2022	8:00-12:00	Tuesday	Uttara North, Agargaon
(2)	Jan 25, 2023	8:30-12:30	Tuesday	Pallabi
(3)	Feb 18, 2023	8:30-12:30	Tuesday	Uttara Center
(4)	March 1, 2023	8:30-12:30	Tuesday	Mirpur 10
(5)	March 15, 2023	8:30-12:30	Tuesday	Mirpur 11, Kazipara
(6)	March 31, 2023	8:30-12:30	Tuesday	Uttara South, Shewrapara
(7)	April 5, 2023	8:00-14:00	Tuesday	-
(8)	May 31, 2023	8:00-20:00	Friday	-
(9)	July 8, 2023	8:00-20:30	Friday	-
(10)	November 5, 2023	7:30-20:30 7:30-11:30	Friday	- Farmgate, Secretariat, Motijheel
(11)	December 13, 2023	7:30-20:30 7:30-11:30	Friday	- Bijoy Sarani, Dhaka University
(12)	December 31, 2023	7:30-20:30 7:30-11:30	Friday	- Karwan Bazar, Shahbag
(13)	January 20, 2024	7:00-20:40	Friday	(All the stations in the Southern Section started full day operation)
(14)	Mar 27, 2024	7:00-21:40	Friday	-

Source: Authors based on newspapers

4. Data

We use simulated real-time trip data collected by the ADB, as described by Akbar et al. (2023). The data collection comprises three steps: delineating the city extent, defining trips with origins and destinations within the extent, and querying multiple instances of each trip using Google Maps (GM).

4.1 Delineating the extent of Dhaka

The city extent of interest is defined based on commuting zones rather than administrative boundaries. Considering that commuting patterns are dynamic and commuting-based city extents are likely to expand over time, we identify both an "inner" and an "outer" city for data collection. The former represents the current core commuting areas, while the latter acts as a buffer zone around the inner city to accommodate potential urban expansions in the future. In the absence of commuting flow data, we use two layers of the Global Human Settlement Layer (GHSL) version 2016A—which reports conditions circa 2014–15—to delineate city extent. First, contiguous grid cells of about 1 kilometer that are classified as urban in the Settlement Model layer of GHSL are grouped together to form an initial polygon. Then, the polygon is restricted to 38-meter micro-cells that are classified as built-up by the Build layer of GHSL to make the inner city. Third, for the outer city boundaries, we add a 0.05 arc degree (≈5-6 km) buffer around the inner city and subtract water bodies and rugged terrain.[10]

4.2 Defining trips with origins and destinations

Once we have the inner and outer boundaries for Dhaka, we then divide the city into one-kilometer grid cells using the same process as the 1 km squares in the Settlement Model layer of GHSL. A cell falling on the inner-city boundary is classified as “inner-city” only if half or more is within the inner-city boundary. This generates 307 cells for Inner Dhaka and 5,098 for Outer Dhaka. Figure 3 shows the inner and outer city grids for Dhaka and the location of MRT lines.

A trip is defined as a unique origin-destination (OD) pair. Each OD pair corresponds to a pair of 1km cells with a direction of travel. For instance, cell A to cell B and B to A are regarded as two OD pairs or trips. Instead of querying travels for all OD pairs in the city, we focus on three types of OD pairs to contain the data collection burden. The first type, inner matrix trips, includes all directed pairs of 1km cells of the inner Dhaka, that is, 307 × 306 × 2 = 187,884 of them. For each grid cell, an exact location is drawn among the centroids of 38-meter micro-cells that are built up according to GHSL. Centroids that are more intensively built up are more likely to be drawn.

The second type of trip, outer matrix trips, is a random set of cell pairs in both directions, one of which lies in outer Dhaka. Cells with a higher GHSL urban cluster classification are more likely to be selected, and within cells, centroids of micro-cells with higher built-up classification are more likely to be drawn as exact locations. There are 191,456 such trips identified for Dhaka.

The third type of trip consists of cell pairs (in both directions) drawn randomly from the built-up micro-cells, which we refer to as gravity trips following Akbar et al. (2023). There are no cell constraints. However, the resulting straight-line distances between these ODs mimic a truncated normal distribution with a mean of 5 km and a standard deviation of roughly 3 km. We draw 312,896 gravity trips in Dhaka. In total, we have defined 346,118 pairs of endpoints corresponding to 692,236 trips for Dhaka.

4.3 Querying trip instances

Trip instance denotes a simulated trip on Google Maps that is uniquely identified by the trip (OD pair), time-of-day and date. In other words, it is a time-specific trip. To query trip instances, we follow the same approach as Akbar et al. (2023) and draw departure times following the same time-of-day distribution as the US National Household Transportation Survey (NHTS), with a slight oversampling of trip instances at off-peak hours between 9 pm and 6 am to retain statistical power for these hours in the

[10] Ruggedness data comes from Nunn and Puga (2012), who developed the Terrain Ruggedness Index (TRI) globally in 30 arc-second grids. Any terrain with TRI greater than the 99th percentile of TRI among existing GHSL urban clusters in Bangladesh is considered too rugged for development.

analysis.

We program each trip to be simulated at many different times of the day and spread out across different weeks of the year so we ensure that at any time and day, each trip is equally likely to be selected for querying. The rate of querying is controlled such that roughly each trip has one instance queried every week. For instance, there were a total of 35,562,783 trip instances obtained for Dhaka, corresponding to 675,033 trips in 2023, an average of 52.7 instances per trip.[11]

4.4 The study sample

From the entire set of GM-queried simulated trip data, we extract the study sample as follows. First, we set the beginning of the study period to the date 360 days prior to December 29, 2022. This is because before January 2022, construction work for the viaducts and stations of the MRT Line 6 was still underway, and traffic control was implemented on some road sections along the Line 6 alignment to facilitate construction. Since such large-scale construction work was completed by the beginning of January 2022, we can measure the impact of MRT services without mistakenly picking up the impact of the construction work.[12] The end period of the study is set to the end of June 2024. After July 2024, traffic across Dhaka city was frequently and significantly disrupted by political unrest, which began in early July. Protests, road blockages by the police and the army, and multiple general curfews took place during July and early August until the Prime Minister resigned and fled the country. To avoid this period of the "quota-reform movement" and the subsequent "non-cooperation movement," June 2024 provides a suitable endpoint for the analysis.

Out of the original data collected by ADB, which covers an extensive commuting area of Dhaka City, we chose sample trips within the narrow corridors along the alignment of the MRT lines. More specifically, since our primary purpose is to measure the immediate local impact of the MRT Line 6 on traffic congestion, we include trips that originate and end within a 500m buffer of the existing and future MRT lines.[13] We define the treatment as trips within the 500m buffer of the MRT Line 6 alignment. For the control, we take the alignments of the MRT lines that run parallel to Line 6 or in the opposite direction to Line 6, heading southward from the CBD area. Therefore, the MRT Line 1 main section and MRT Line 2 (the northern half) run parallel to the treatment, while the Line 2 southern half and Line 4 run south from the CBD, in the opposite direction to MRT Line 6.

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[11] For some trips, GM did not return results. Thus, the number of trips in the sample is smaller than the total defined.

[12] Minor construction works inside the stations and on the viaduct, such as station interior and equipment, and electrical and telecommunication works on the viaduct continued after January 2022 but these did not significantly interfere with the volume of traffic on the road.

[13] We define buffer as the polygon that has of boundary 500m haversine distance from the middle line of the road that MRT passes/will pass through (either on the viaduct or underground). We use the package "sf" of R for the calculation of the buffer.

In the analysis, we set two definitions for the treatment. The first covers the 500m buffer of the entire section of MRT Line 6, as depicted in Panel (a) of Figure 4. The second takes only the section of the Phase 1 operation of MRT Line 6 as the treatment, shown in Panel (b) of Figure 4. For the treatment definition (a), we measure the impact of MRT Line 6 opening on the trips along the entire corridor of the line, including the southern half of the corridor, which the Phase 1 operation of Line 6 does not cover. The treatment definition (b) only covers the trips within the corridors that Phase 1 runs through, where new station openings and significant expansion of operational hours did not take place after May 31, 2023.

Table 2 shows the summary statistics of the control and two treatment groups, divided into periods before and after the MRT Line 6 initial opening. “Trip Length (m)” is defined as the actual length of the route taken by the trip (the OD pair), while “Haversine Trip Length (m)” is given as the straight line distance between the origin and destination, regardless of the actual route on the road network. For a given directed combination of origin and destination, the former may change over time depending on the congestion, while the latter does not change over time. “Travel Speed (km per hour)” in Table 2 is defined as “Trip Length” divided by “Trip Duration,” while “Effective Speed” is “Haversine Trip Length” divided by “Trip Duration.” Therefore, the “Effective Speed” represents the speed of travel between two locations, unaffected by the route selection. In the analysis, we choose Effective Speed as our primary outcome variable to measure congestion levels. The analysis includes several control variables. "Route Rank" denotes the ordinal position of the route recommended by Google Maps for a trip incident, where the dataset utilizes only the shortest route in terms of estimated travel time.[14] “Road Closure” and “Road Construction” are the binary taking 1 if Google Maps indicates any road closure or construction on the route, respectively. “Ramadan” refers to the periods when Ramadan took place, and “MRT Service Suspension” indicates the dates when the MRT suspended services due to technical or other reasons. “Tuesday before April 5, 2023” is an indicator for Tuesdays before April 5, 2023, until when the MRT Line 6 did not operate even though Tuesday is a weekday. Fridays were excluded from the sample due to their significantly different traffic patterns compared to other days of the week.

Figure 5 depicts the distributions of Effective Speed across hours from 7:00 to 22:00 for each of the treatment and control groups. The left side graph shows the results for the period before the MRT Line 6 opening, while the right side graph shows the same for the period after the opening. It is visually obvious that the mean of Effective Speed is almost the same between the treatment and the control trips before the MRT opening and that the treatment gets faster, especially from the morning to 15:00, after the opening.

[14] For each trip instance, Google Maps provides multiple route options. The dataset utilizes only the shortest route based on estimated travel time. While the route rank may not always directly correlate with travel time, it can potentially reflect certain characteristics of the origin-destination pair.

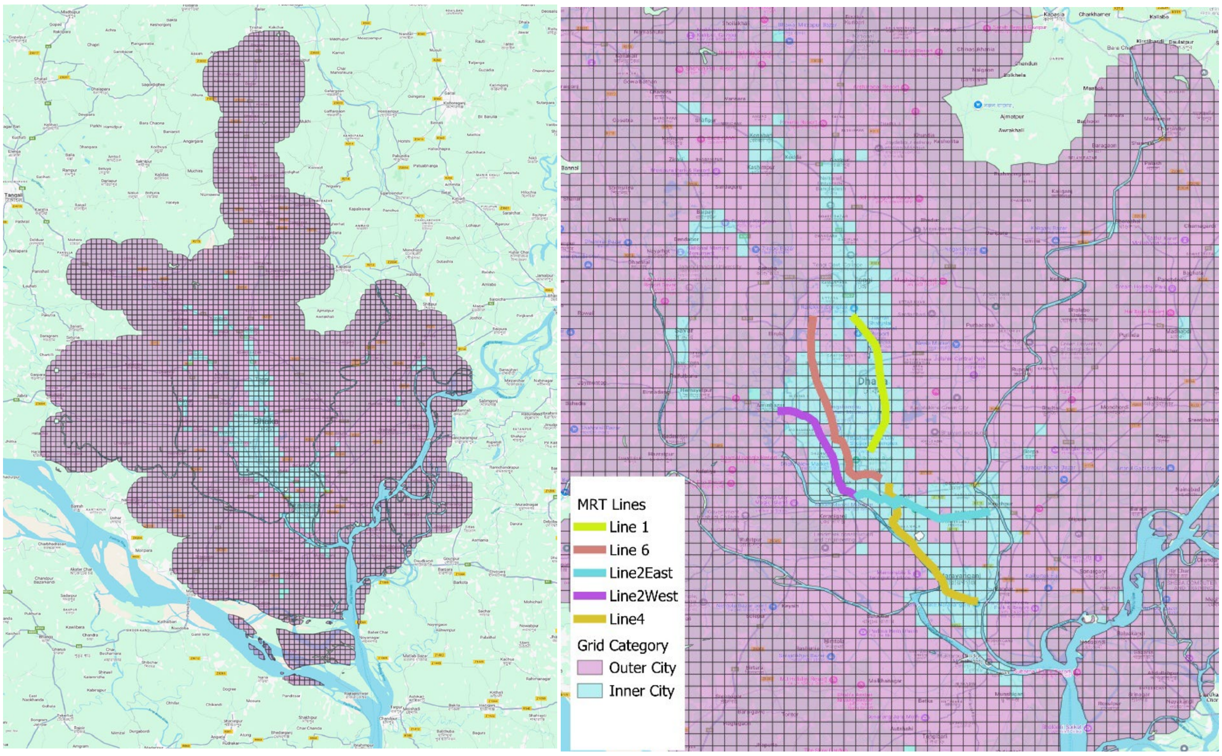
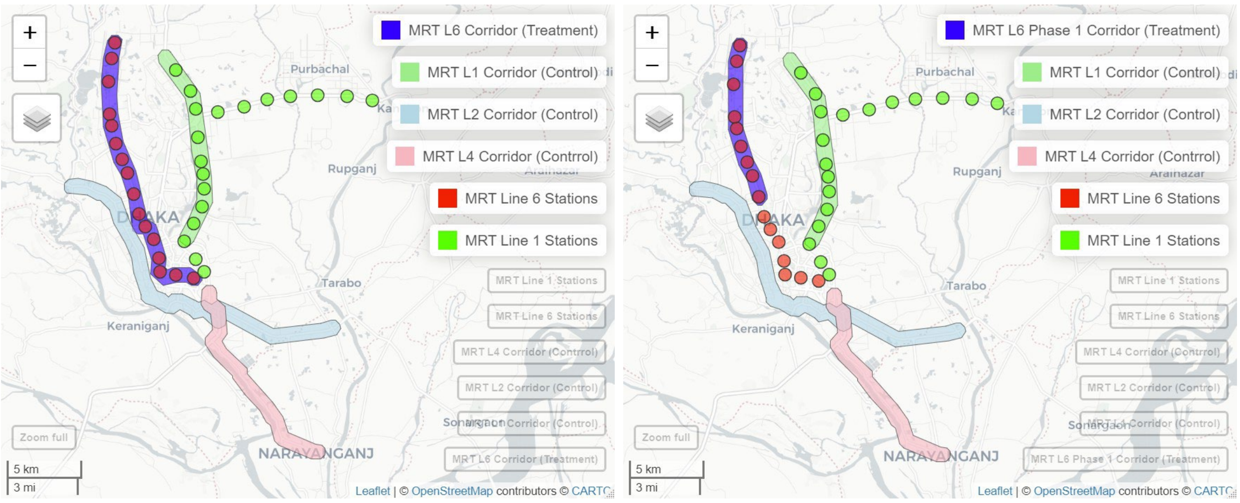


Figure 3: Grids of Inner and Outer City of Dhaka and MRT Lines

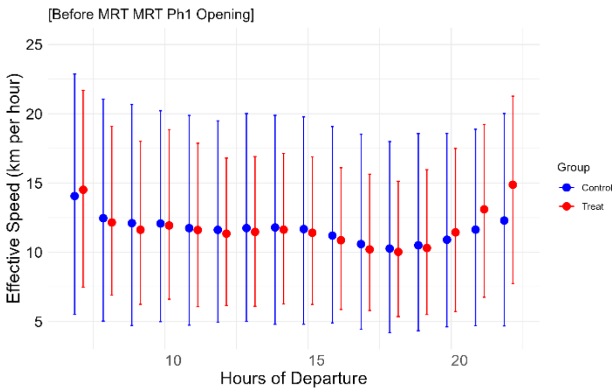


(a) Entire Line 6 as Treatment (b) Only Line 6 Phase 1 as Treatment

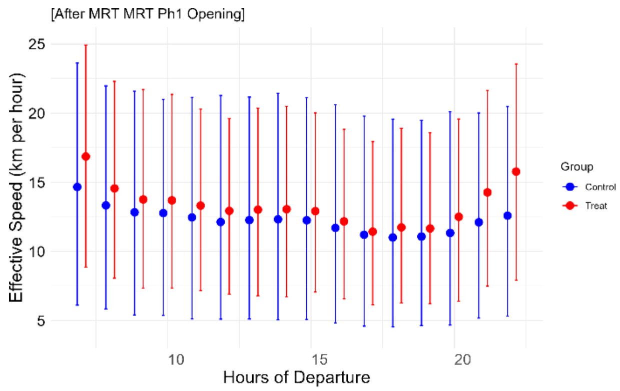
Figure 4: Map of Treatment and Control Corridors

Table 2: Summary Statistics: Buffer=500m, Time=Morning: 8:00–12:00

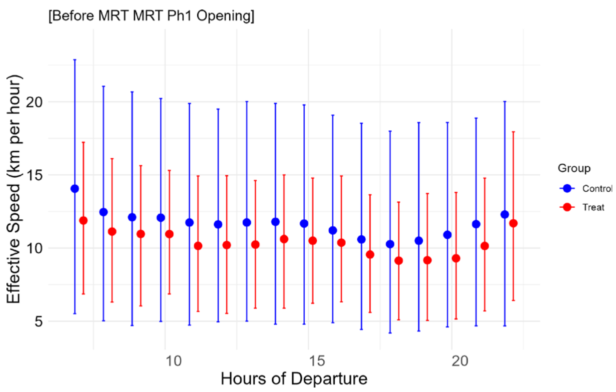
Statistic	Control			Treatment (Line 6 Full)			Treatment (Line 6 Phase 1)		
	N	Mean	St. Dev.	N	Mean	St. Dev.	N	Mean	St. Dev.
Before MRT Opening									
Trip Duration (second)	11828	1203	715	4475	1442	909	1428	891	471
Trip Duration (No Traffic) (second)	11828	927	500	4475	1032	555	1428	756	379
Trip Length (m)	11828	6097	3821	4475	6734	4277	1428	4140	2660
Haversine Trip Length (m)	11828	4033	2816	4475	4763	3205	1428	2699	1624
Travel Speed (km per hour)	11828	18.3	5.10	4475	17.2	4.38	1428	16.5	3.41
Effective Speed (km per hour)	11828	12.1	4.82	4475	11.8	3.62	1428	10.8	2.95
Time per Haversine Distance (second/m)	11828	0.366	0.225	4475	0.337	0.125	1428	0.365	0.1346
Route Rank	11828	1.11	0.348	4475	1.17	0.420	1428	1.2	0.465
Road Closure	11828	0.0408	0.198	4475	0.0880	0.283	1428	0.0469	0.212
Road Construction	11828	7.61e-04	0.02758	4475	8.94e-03	0.09413	1428	0.0098	0.09856
Ramadan	11828	0.0865	0.281	4475	0.0849	0.279	1428	0.0868	0.282
MRT Service Suspension	11828	0.0000	0.000	4475	0.0000	0.000	1428	0	0.000
Tuesday before April 5	11828	0.000	0.000	4475	0.000	0.000	1428	0	0.000
Holidays	11828	0.0626	0.242	4475	0.0615	0.240	1428	0.0469	0.212
After MRT Opening									
Trip Duration (second)	20660	1174	684	7436	1231	734	2350	779	364
Trip Duration (No Traffic) (second)	20660	921	523	7436	892	461	2350	650	286
Trip Length (m)	20660	6323	4017	7436	6483	4151	2350	3984	2063
Haversine Trip Length (m)	20660	4157	2791	7436	4777	3160	2350	2831	1580
Travel Speed (km per hour)	20660	19.4	6.02	7436	19.1	4.83	2350	18.5	4.06
Effective Speed (km per hour)	20660	12.8	5.09	7436	13.8	4.25	2350	13.1	4.11
Time per Haversine Distance (second/m)	20660	0.344	0.223	7436	0.289	0.102	2350	0.303	0.0997
Route Rank	20660	1.12	0.343	7436	1.16	0.402	2350	1.16	0.405
Road Closure	20660	0.0593	0.236	7436	0.0597	0.237	2350	0.014	0.118
Road Construction	20660	4.84e-05	0.00696	7436	4.03e-04	0.02008	2350	0.000426	0.02063
Ramadan	20660	0.1044	0.306	7436	0.1087	0.311	2350	0.0974	0.297
MRT Services Suspension	20660	0.0304	0.172	7436	0.0285	0.166	2350	0.0281	0.165
Tuesday before April 5, 2023	20660	0.205	0.404	7436	0.203	0.402	2350	0.2	0.400
Holidays	20660	0.0696	0.254	7436	0.0668	0.250	2350	0.063	0.243



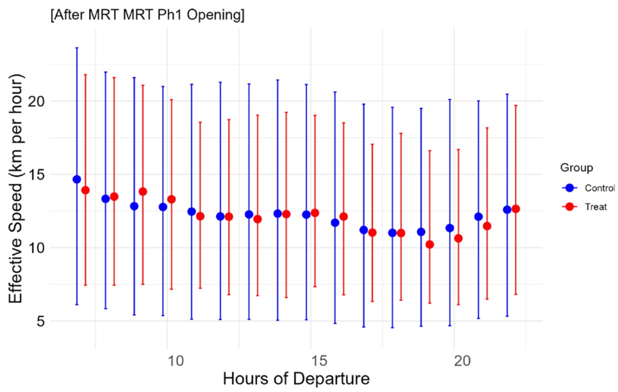
(a)Treat=Full Line 6, Before Opening



(b) Treat=Full Line 6, After Opening



(c) Treat=Line 6 Phase 1, Before Opening



(d) Treat=Line 6 Phase 1, After Opening

Figure 5: The Distribution of Travel Time across Departure Hours

Note: The figures show the mean, 5% and 95% percentiles of the effective speed (defined by the travel time divided by the haversine length of the OD) in kilometers per hour across departure hours from 7:00 in the morning to 22:00 in the evening, comparing the control group and treatment group. The left side figure is for the period before the MRT opening on Dec 29, 2022; the right side figure is for the period after the opening. Treatment is the trip within the 500m buffer of the MRT Line 6 alignment, while the control is the trip within the 500m buffer of the alignments of Line 1, Line 2 and Line 4.

5. Estimation

We employ the estimation method—commonly referred to as "two group event" studies (Freedman et al., 2023). This method involves two groups, namely treatment and control, and multiple time periods. While the MRT Line 6 has expanded its operating stations and hours in many different phases, we do not consider our case suitable for use with staggered DID (Freedman et al., 2023; Callaway and Sant'Anna, 2021), which is designed for the rolling-out of the same treatment across multiple mutually exclusive treatment groups. Importantly, staggered DID assumes that once an individual receives treatment, its status as treated remains unchanged until the end, and it does not receive additional rounds of the rolling-out process.

By contrast, in our case, the same individual (for our case, the OD pair) near the MRT receives multiple waves of service intensification. Most of the alignment of the MRT Line 6 runs alongside one of the main north-south road corridors in the city of Dhaka. The first phase of the operation was initiated on December 29, 2022, with the opening of the station at the northern end (Uttara North) and the midpoint (Agargaon) of the line. After this initial opening, the other stations between these two gradually opened, and the hours of operation were extended, as described in Section 3. The opening of the stations under the second phase happened in a similar manner, namely opening the major stations, including the southern end—Motijheel, together with Farmgate and Secretariat—before the in-between stations were opened.

Given this sequence of service expansion of Line 6, it is difficult to separate the corridor into multiple different treatment groups. Rather, it is more natural to consider that the entire section of the Line 6 corridor is treated by the MRT from the beginning—on December 29, 2022—and that the intensity of treatment in the same corridor had been increased step by step as the new stations in between the terminal stations opened and the operating hours were extended. Therefore, we choose to employ the two group event study rather than the Staggered DID, paying attention to the intensifying treatment that is assumed to confound only onto the treatment group.

As explained in Section 4, we focus on measuring the impact of MRT opening on the trip that starts and ends within the buffer of a short distance (500m) from the MRT alignment. Using the data of the OD trip in the treatment and control corridors covering the period before and after the Dhaka MRT started its operations, we estimate the impact of the MRT Line 6 opening on traffic congestion by employing the difference-in-difference (DID), specified as follows:

$$Y_{it} = \sum_{t=\underline{P}, t \neq -1}^{\bar{P}} \beta_t D_i T_t + \gamma D_i + \delta T_t + \zeta X_{it} + \epsilon_{it} \qquad (1)$$

where Y_{it} is the outcome variable, either travel time or speed, with i and t representing the trip, defined as the pair of origin and destination, and the time period, measured in units of either a month

(30 days) or a quarter (90 days), respectively. D_i refers to the assignment of trip i to either the treatment group or the control group, taking $D_i = 1$ for the treatment group. T_t is the dummy for the period when the departure of an artificial trip was queried from Google Maps.

We define the period starting from December 29, 2022, as zero, when the MRT Line 6 commenced its first commercial operations. Hence, t takes negative integers for the months or quarters preceding the MRT opening, and positive for quarters following the opening. For example, $t = 0$ means the period from December 29, 2022, and $t = -1$ is the period that ends on December 28, 2022. The time index $t \in [\underline{P}, \overline{P}]$ spans from the starting period of the data $\underline{P}$ to the end period of the data.

X_{it} represents a vector of covariates that may be correlated with the outcome variable other than the treatment, including the straight line distance between the origin and destination (OD) of the trip, the time trend, dummies for month (seasonality dummy), a dummy for the Ramadan period, dummies for hour, day of the week, and holidays, a dummy for Tuesdays before April 5, 2023, and a dummy for road closures or road construction.

ϵ_{it} is an error term for which we cluster the standard errors of the estimates into three categories, defined as follows. The first category is the dummies of year-month, to account for the correlation of errors among trips queried closer in the time horizon. The second clustering is taken for each directional pair of the 1km grids where the origin and destination belong, considering that the trips from (and to) the same area may have some correlated errors. Errors of effective speed may also be correlated if the lengths (distances) of trips are similar. Therefore, the third category clusters errors into five groups based on the length of haversine travel distance.[15] Following the convention, we define the term for the coefficient β_{-1} as the reference and drop it from the estimation.

We estimate (1) by the Least Square Dummy Variable estimation. Considering the slow and gradual nature of the service expansion—both in terms of stations and service hours, as explained in Section 3—the interpretation of the estimation requires careful consideration. As explained earlier in this section, we assume that the trips in the treatment group have experienced repeated intensification of the intervention, while the trips in the control group remained unaffected. In the case of MRT Line 6, the same corridor undergoes multiple waves of gradual service intensification, making it difficult for researchers to disentangle the (lagged) impact of the initial opening from those of the gradually intensifying intervention. Therefore, the estimated impact β_t should be interpreted as a confounded impact of the phased intensification of the services.

[15] Distance bands are taken as i) less than 1000m, ii) equal or greater than 1000m but less than 3000m, iii) equal or greater than 3000m but less than 6000m, iv) equal or greater than 6000m but less than 10000m, and v) equal or greater than 10000m.

6. Estimation Results and Discussion

In this section, we present the estimation results. Figure 6 demonstrates the event study graphs showing the results estimates for the morning hour (8:00–12:00) sample, with the treatment group defined as the entire Line 6 corridor. Panel (a) on the left shows the case of a 90-day time window, while panel (b) on the right is for a 30-day time window. Firstly, we can confirm the parallel pre-trend in the two graphs. The estimates for the period prior to the intervention ($t \leq -1$) are not statistically different from zero. This demonstrates that the trend between the treatment group and control group is similar in the absence of the treatment, indicating that use of the two group event study design is appropriate for this analysis.

Panel (a) of Figure 6 shows a clear upward trend of the treatment effect, meaning that the vehicle speed in the treatment corridor has consistently increased since the opening of the MRT. The estimated effect for the first three months (Quarter 0) after the MRT opening is small at around 2.8%, while it increases to around 10% in the 7th to the 9th month (Quarter 2). After the opening of the Phase 2 section for the southern half on November 5, 2023, the positive impact on vehicle speed peaks at around 15% in Quarters 5 and 6 (after the 16th month). In sum, the impact is always positive and significant, and it gets larger along with the gradual expansion of the services. The result remains largely consistent if we change the time window to 30 days from 90 days, as shown in Panel (b) of Figure 6.

Figure 7 shows the results when we define the treatment by the corridor of the Phase 1 section of the MRT Line 6. Unlike the results shown in Figure 6, the impact of the MRT opening on the traffic of the corridor under the Phase 1 is both large and immediate. In Quarter 0 (the initial three months following the opening), estimates of the impact already exceed 10%, as can be seen in Panel (a). We can confirm the immediate large impact even in the first month after the commencement in Panel (b).

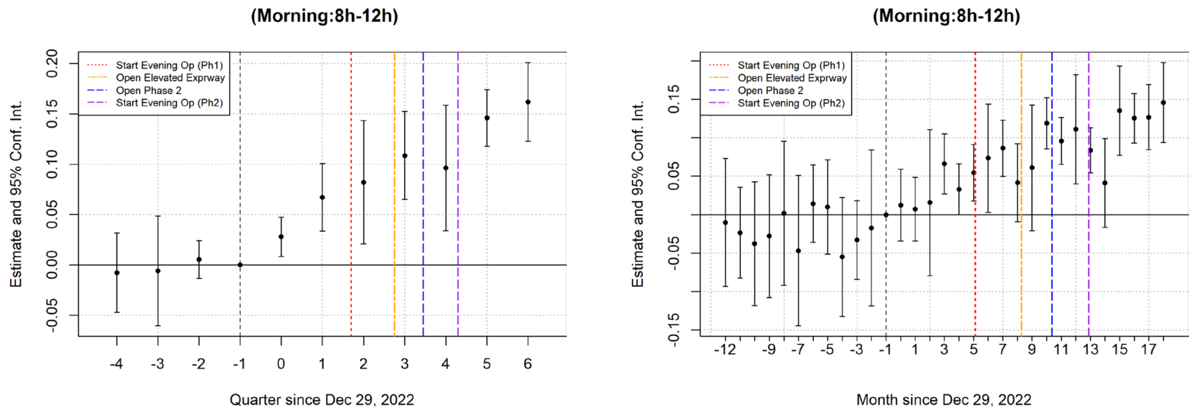
However, notably, the magnitude of the positive impact declines after the opening of Phase 2 on November 5, 2023, even though the impacts remain largely positive and significant. The reason behind this diminishing positive impact may be attributed to the increasing demand for vehicle travel due to the increase in vehicle speed. The MRT might have diverted a part of traffic demand from vehicle-based travel (private car, bus, and others) to the MRT in the short run. This creates more space in the road corridors beneath the MRT, leading to an increase in the speed of vehicle travel. The increased vehicle speed lowers the travel cost of using vehicles along the corridor, thereby attracting additional vehicles to the corridor. Gradually, this increased vehicle demand may offset the initial improvement in travel speed on the Phase I corridor. This likely explains the mechanism behind the declining trend of the impact over time, especially after the opening of Phase 2.

In Appendix Sections A.2 and A.3, we report the results of estimation for the trips that take place in the daytime (12:00–16:00) and in the evening (16:00–20:00). For the daytime, the results are almost comparable with the case in the morning, as both the treatment is defined as the entire section of Line 6 as in Figure A9 and is defined as the Phase 1 section as shown in Figure A11. Notably, when estimated with the treatment defined by the Phase 1 section, the diminishing impact over time is clearly observed.

For the evening, as shown in Figure A10, the pre-trend does not hold when the entire Line 6 section is included as the treatment and a significantly positive impact appears only after the Phase 2 section of Line 6 began evening operations. When the treatment is limited to the case of the Phase 1 corridor only, we observe a short-lived congestion-easing effect. However, this only lasts for a few months after the commencement of evening operations of the Phase 1 section.[16]

Overall, the opening of MRT Line 6 had a positive and significant impact on the vehicle speed along the road corridor that hosts the MRT Line 6. Reflecting the nature of gradual service expansion, the impact became stronger as the service coverage expanded. As shown when the treatment sample was limited to those within the Line 6 Phase 1 section, the positive and significant impact started declining after the service expansion was completed for each respective section. While the impact varied over time, the maximum magnitude of the impact was around 10–13 percentage points in general. This exceeds the across-city average in China found by Gu et al. (2021) and is almost comparable with the findings for Beijing by Yang et al. (2018), but is still substantially lower than the case of Jakarta MRT, presented by Widita et al. (2023) and Widita (2024). The diminishing positive impact in the second setting suggests that the traffic capacity created by the MRT was rapidly saturated by the newly generated travel demand, which may be explained by the "fundamental law of road congestion," as discussed by Duranton and Turner (2011). Further investigation over a longer period of time will be required to examine whether this mechanism actually works as expected.

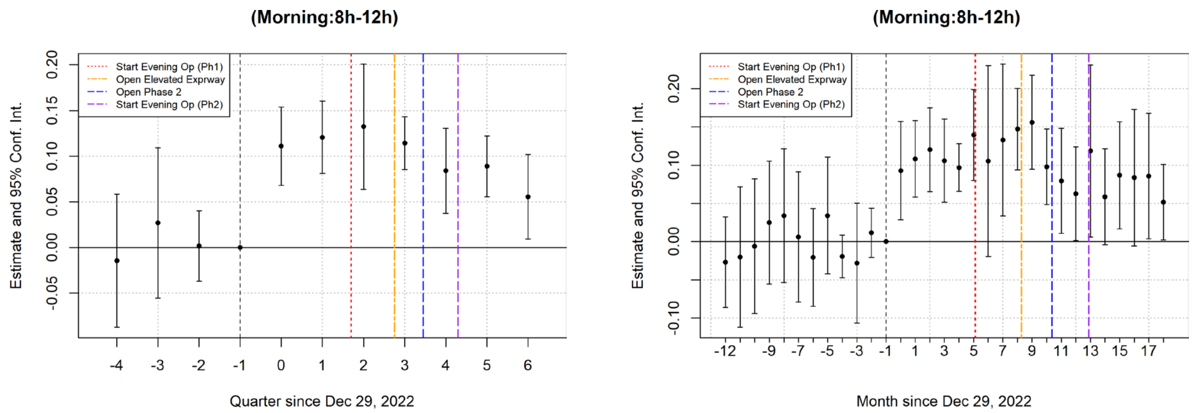
[16] Figure A8 shows the case of estimation in case the buffer to define treatment and control become 1000m instead of 500m.



(a) Time Window = 90 days (b) Time Window = 30 days

Figure 6: Impact of MRT Line 6 on Effective Speed (Treat=Whole Line 6 Corridor)

Note: The figures plot the estimates of β_t at 95% confidence intervals. The vertical red line shows the date (May 31, 2023) when the MRT Line 6 Northern Section launched whole-day operations, the green line shows the date when the Elevated Expressway was inaugurated (September 3, 2023), and the blue line shows the date (November 5, 2023) the whole section of the MRT Line 6 began operations. The period is defined by the quarter for the top figure, and by the month for the bottom figure.



(a) Time Window = 90 days (b) Time Window = 30 days

Figure 7: Impact of MRT Line 6 on Effective Speed (Treat=Only Line 6 Phase 1 Corridor)

Note: The figures plot the estimates of β_t , with their 95% confidence intervals. The dependent variable is log effective speed. The vertical red line shows the date (May 31, 2023) when the MRT Line 6 Northern Section started the whole day operation, the green line is for the date when the Elevated Expressway was inaugurated (September 3, 2023), and the blue line is for the date (November 5, 2023) the whole section of the MRT Line 6 started operation. Period is defined by the quarter for the top figure by the month for the bottom figure.

Table 3: The Impact of MRT on Effective Speed (Morning 8:00-12:00)

	Treat=500m Buffer from Line 6 (Ph 1 & Ph 2)	Treat=500m Buffer from Line 6 (Ph 1)
Dependent Var.:	Log Effective Speed	Log Effective Speed
D x T = -4	-0.0078	-0.0145
	(0.0142)	(0.0263)
D x T = -3	-0.0060	0.0268
	(0.0197)	(0.0296)
D x T = -2	0.0053	0.0016
	(0.0068)	(0.0138)
D x T = 0	0.0279*	0.1110**
	(0.0070)	(0.0154)
D x T = 1	0.0672**	0.1207**
	(0.0121)	(0.0143)
D x T = 2	0.0821*	0.1324**
	(0.0221)	(0.0247)
D x T = 3	0.1086**	0.1143***
	(0.0157)	(0.0104)
D x T = 4	0.0964*	0.0840**
	(0.0224)	(0.0167)
D x T = 5	0.1459***	0.0890**
	(0.0102)	(0.0120)
D x T= 6	0.1619***	0.0556*
	(0.0141)	(0.0167)
Observations	44,399	36,266
R2	0.34367	0.34523
Adj. R2	0.34293	0.34433

Note: The dependent variable is log of effective speed. Standard Errors in the parentheses are clustered at the dummies of the year-month, and the grid pair of the OD, and trip categories by its haversine length. *** p<0.01, ** p<0.05, * p<0.1. The covariates include the trip length category, time trend, dummies for hour, month, the day of week, holiday, Tuesday, road closure, and road construction. For the time dummies, $T = 0$ refers to the quarter (90 days) starting from Dec 29, 2022, the Dhaka MRT started the commercial operation. $T = -4$ indicates the 90 days starting from January 4, 2022, $T = -3$ from April 3, 2022, $T = -2$ from July 2, 2022, $T = -1$ from October 1, 2022, $T = 1$ from March 29, 2023, $T = 2$ from June 27, 2023, $T = 3$ from September 27, 2023, $T = 4$ from December 24, 2023, and $T = 5$ from March 23, 2024, respectively.

7. Conclusion

This paper empirically examines the localized and short-to-mid-term impact of the Dhaka MRT Line 6, the first Mass Rapid Transit in Bangladesh, on road traffic congestion measured by the speed of travel. We use the super-high frequent and geographically dense real-time travel data derived from Google Maps that covers the period from 12 months before the opening until June 2024, 18 months after the opening of the initial section of Line 6. To estimate the impact, we employ the two group event study approach that compares the treatment group against the control group across multiple time periods.

Results of the estimation show that the MRT Line 6 had a significant short-term impact on easing traffic congestion, increasing the speed of journeys by 10 to 15 percent). The positive impact is more immediate when the sample is limited to the corridor opened under Phase 1 of the MRT Line 6. For such cases as constrained treatment of Phase 1, the positive impact on the vehicle speed gradually declined over time after the service expansion was completed for the Phase 1 section. This may suggest that the MRT's positive impact on vehicle speed will be quickly offset by the increased traffic demand in response to the reduced travel cost (i.e., reduced congestion) in the treated corridor.

As the traffic situation of megacities in developing countries worsens, despite the immense cost, constructing rail-based urban transit systems has become an attractive option to address urban problems. This study provides a valuable case study for governments of the countries hosting megacities like Dhaka, which suffer from severe congestion caused by extreme population density and increasing economic activities.

There are some limitations to the analyses presented in this paper. Along with these, we offer some additional suggestions on future directions for research. First, the duration of our study needs to be extended to verify the existence of the mid- to long-term evolution of the impacts. Fortunately, since the data collection using Google Maps is ongoing, this could be undertaken once again after a sufficient volume of data has accumulated. Second, this paper defines the treatment simply as a 500m buffer from the MRT line. Experimenting with different definitions of buffers would be helpful, as well as defining continuous treatment according to the distance instead of dichotomous settings using the distance buffer.

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Abstract (in Japanese)

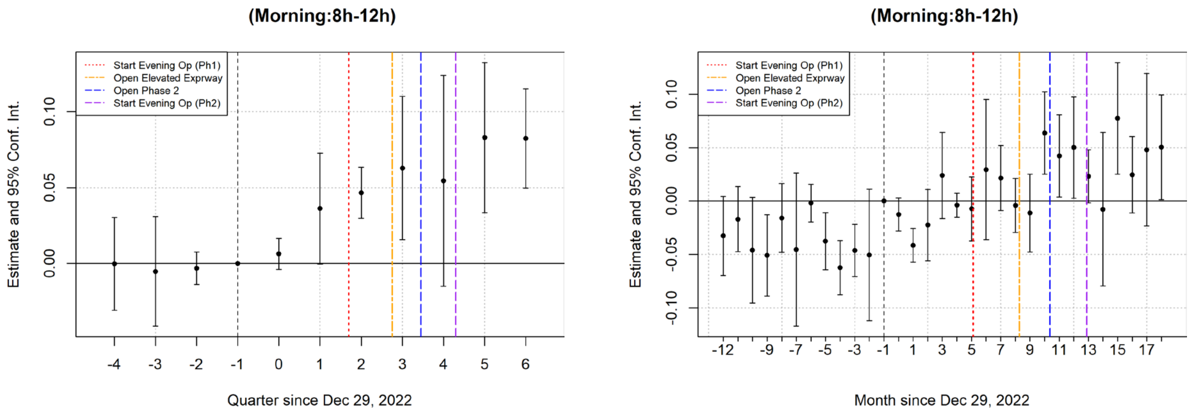
要　約

Dhaka Mass Rapid Transit (MRT) 6号線は、バングラデシュで初めての鉄道ベースの都市大量輸送システムであり、ダッカの深刻な交通渋滞を緩和することが期待されている。本稿は、ダッカ MRT ライン6の導入が交通渋滞を緩和する影響を、「差の差（Difference-in-difference)」の複数期間バージョンである「Two Group Event Studies Design」(Freedman et al., 2023) を使用して検証した。実地調査ベースでの移動時間データの代わりに、Google マップから得られる超高頻度リアルタイムの二地点間移動データを使用して車両の速度に与える影響を推定した。準実験的分析の結果、MRT 6号線が通る回廊やその周辺では、MRT の開通に伴い車両速度が有意に向上する影響が示された。車両速度は、MRT の運行時間および駅の段階的な拡張に即座に反応して増加している。一方で、時間の経過とともに速度上昇の効果は低減しており、MRT によって作り出された交通容量が新たに生み出された交通需要によって徐々に飽和している可能性を示唆している。これは「道路渋滞の基本法則」を裏付ける経験的なケースを提供している。

キーワード： 都市交通、移動時間、大量高速輸送、渋滞

A. Appendix

A.1 Estimates for the treatment and control by 1000m buffers

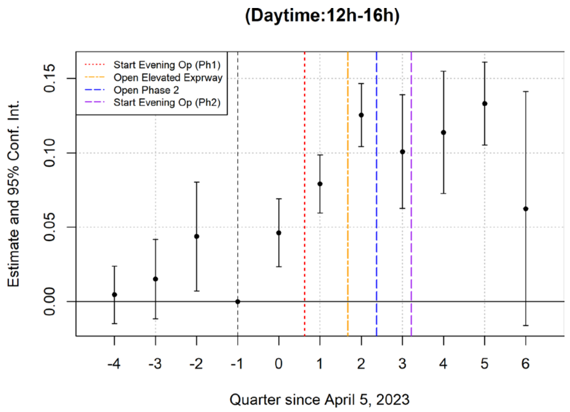


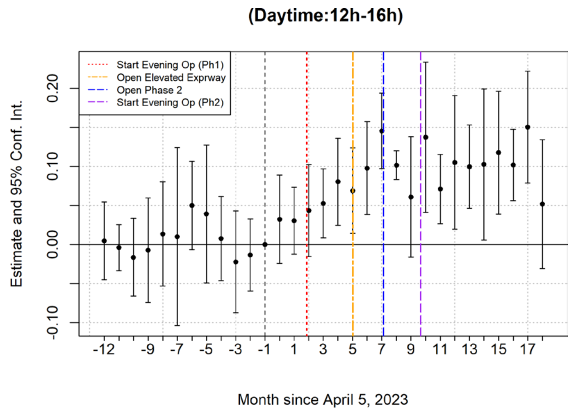
(a) Time Window = 90 days

(b) Time Window = 30 days

Figure A8: Results with 1000m buffers, morning (8:00–12:00)

A.2 Estimates for daytime and evening, treatment & control by 500m buffers; treatment is defined as the entire Line 6 section

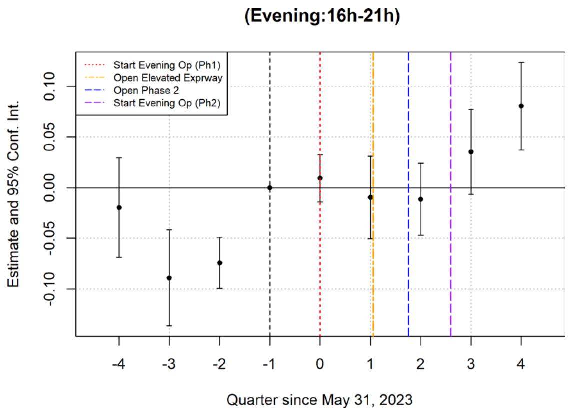


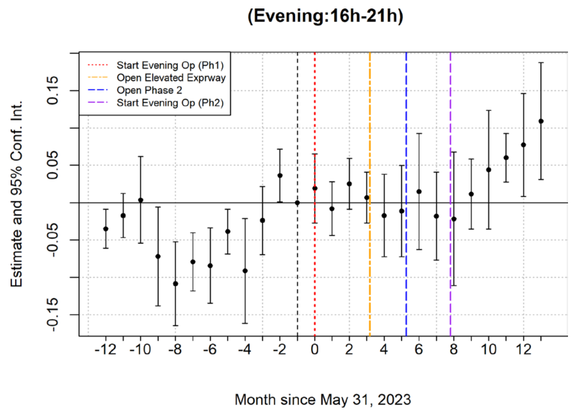


(a) Time Window = 90 days

(b) Time Window = 30 days

Figure A9: Results for the daytime (16:00–20:00), treat = Entire Line 6



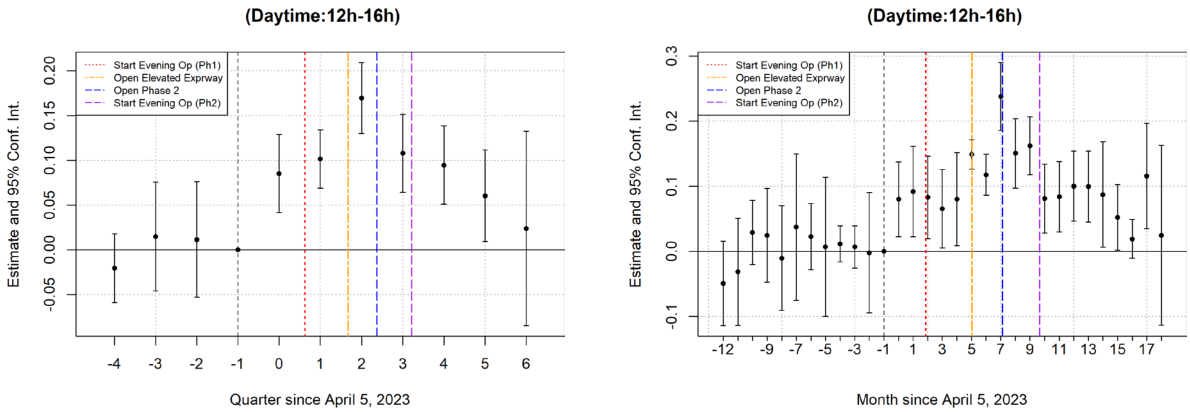


(a) Time Window = 90 days

(b) Time Window = 30 days

Figure A10: Results in the evening (16:00–20:00), treat = Entire Line 6

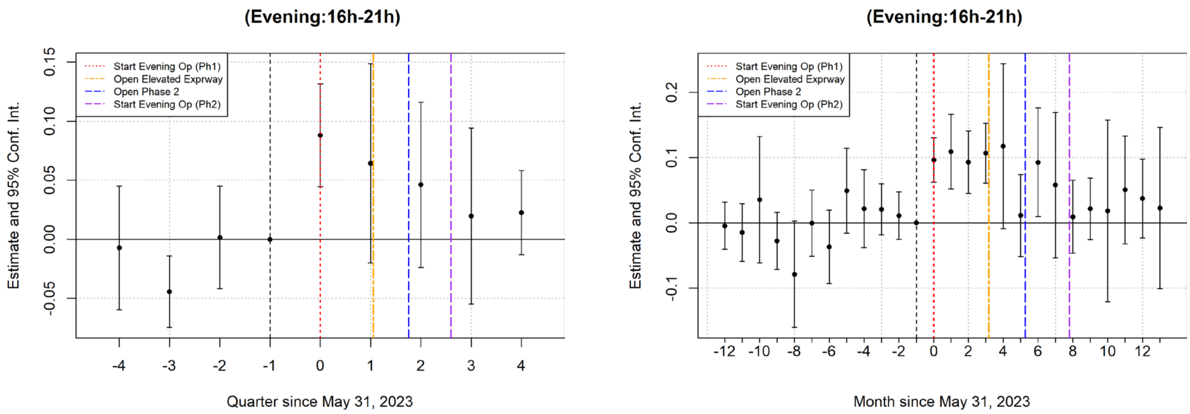
A.3 Estimates for daytime and evening, treatment & control for 500m buffers; treatment is defined as the Phase 1 section of Line 6



(a) Time Window = 90 days

(b) Time Window = 30 days

Figure A11: Results for the daytime (16:00–20:00), treat = only Phase 1



(a) Time Window = 90 days

(b) Time Window = 30days

Figure A12: Results in the evening (16:00–20:00), treat = only Phase 1