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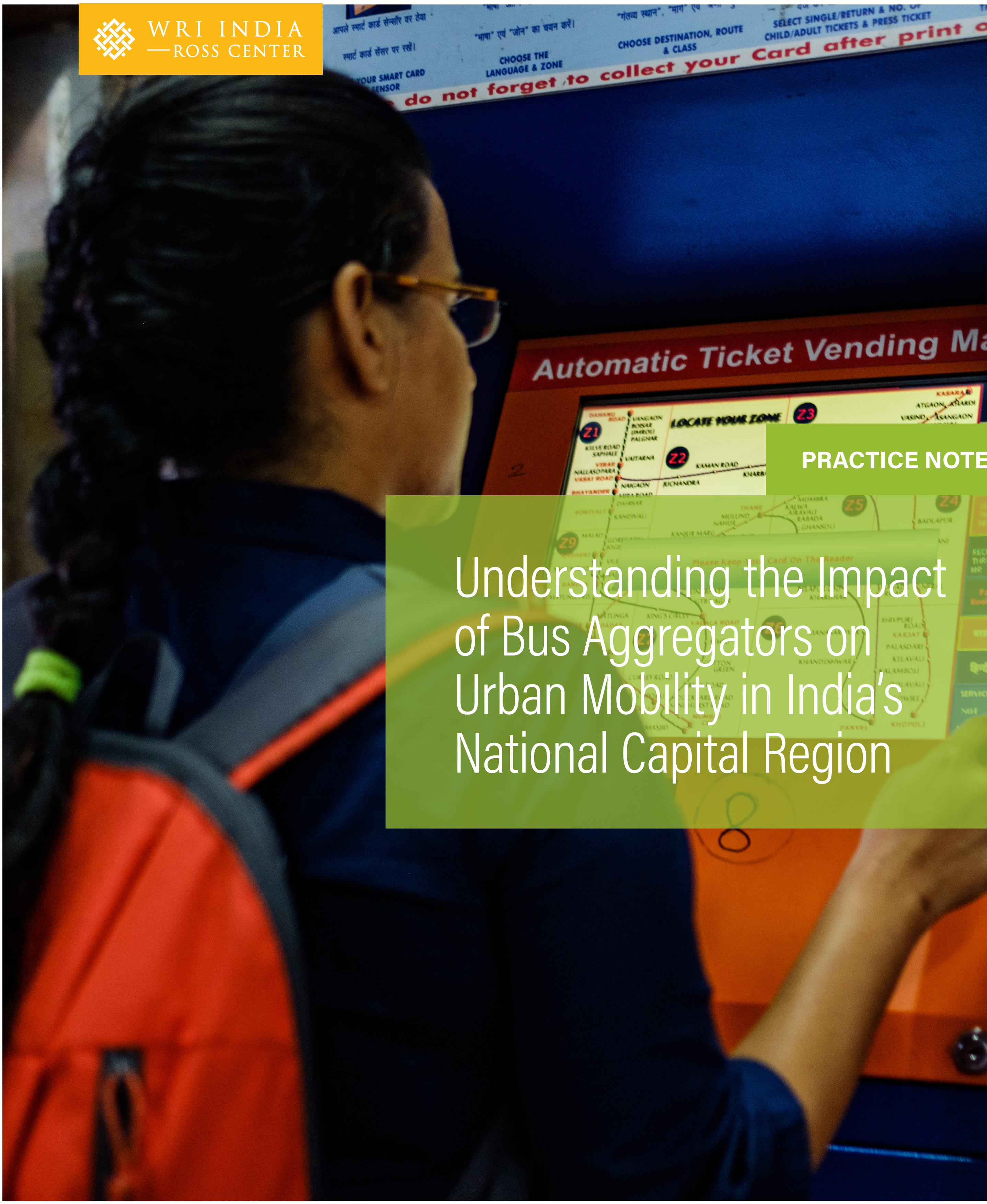

PRACTICE NOTE

Understanding the Impact of Bus Aggregators on Urban Mobility in India's National Capital Region

New Urban Mobility alliance

Practice notes provide rapid analysis of experiences related to a particular project. The analysis and recommendations are limited to the specific context presented in the note and should not be construed to apply more broadly.

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CONTENTS

Authors
Jyot Chadha
Ojas Shetty
Srikanth Shastry

Layout
Billie Kanfer

January 2020

1. EXECUTIVE SUMMARY

HIGHLIGHTS

- Demand-responsive bus transportation start-ups are increasingly providing additional mobility choices to young, urban office commuters in India whose work trips are "very long trips," typically longer than 30 kilometers each way.
- Known in India as bus aggregators, these new entrants are considered disruptive by regulatory authorities and public transit agencies, which have historically dominated the sector.
- An intercept survey of a sample of Shuttl's users, a key bus aggregator operating in India's National Capital Region (Delhi-NCR), finds that commuters primarily shifted to Shuttl services from private cars (51 percent) and other car-based modes (16 percent), and the metro (29 percent), while few shifted from public buses (2 percent).
- This suggests that in dense agglomerations with dispersed business districts like Delhi-NCR, bus aggregator services may better cater to the office commuter market segment than traditional choices of private vehicles or fixed-route transit.
- The findings also highlight the potential for bus aggregators to improve air quality and reduce congestion if a significant shift from private cars continues to take place.
- Considering this potential, the authors suggest the opportunity to re-examine the needs of different market segments and consider how public goals might be served by permitting new entrants and reforming regulatory frameworks to focus on performance metrics.

1.2 BACKGROUND

Demand-responsive bus services provided by technology-led mobility companies are a recent entry into the transportation ecosystem in cities across the world. Known as bus aggregators in India, these companies emerged on the heels of on-demand taxi companies, such as Uber and Ola in India, and microtransit companies, such as Kutsuplus in Helsinki, and Chariot and Bridj in the United States. In 2015 alone, over a dozen companies launched bus aggregator services across metropolitan cities in India.

Capitalizing on limited mobility options in newly developed areas of expanding cities, these companies primarily offer services on routes where commuters have few public transportation options and poor last-mile connectivity. Bus aggregators largely cater to daily peak-hour home-office-home trips for commuters who live in residential hubs that are a significant distance from the large business parks in which they work (usually greater than 30 kilometers each way, also defined as "very long trips"(Kumar and Tiwari 2019).

However, bus aggregators frequently face issues with regulators and public transit agencies. Part of the reason for this standoff is the notion that these services provide unfair competition to public transit and siphon off customers from the transit system's most profitable routes. Part of it is also the novelty of the bus aggregator business model and a lack of understanding of its impact.

This practice note evaluates the environmental impact of a leading bus aggregator operating in India's National Capital Region (Delhi-NCR). More specifically, it asks whether Shuttl's services have helped mitigate urban transportation emissions and thereby reduced the environmental costs for Delhi-NCR.

1.3 ABOUT THIS PRACTICE NOTE

This practice note presents the results from analysis of primary data collected by the authors and operating data shared by Shuttl for its services in Delhi-NCR. This study looks to address the following questions:

- Who uses Shuttl's services, and how did they travel before its introduction?
- What is Shuttl's impact on emissions?
- What is Shuttl's impact on congestion?

Our evaluation framework is anchored in a set of environmental cost indicators corresponding to levels of air pollution, CO_2 emissions, and on-road congestion. Shuttl's environmental cost is then compared with their commuters' alternative mode choice(s) (obtained via a stated-preference intercept survey) to quantify the net benefits to the city from such models.

We draw on our analysis to highlight the potential of bus aggregator services in improving air quality and reducing on-road congestion for metropolitan cities. Our analysis finds that Shuttl's operations in Delhi-NCR have a positive impact on mobility in the region by reducing the number of private cars used to commute to work during the three peak hours, thereby reducing congestion and emissions of criteria pollutants and CO_2. This publication could help policymakers consider the potential benefits of the model while drafting state-specific motor vehicle rules and mobility schemes. Specifically, evidence from this study might contribute to ongoing policy and regulatory conversations about the integration of new mobility services in cities while sparking further research on bus aggregator models as the aggregators scale their businesses.

1.4 KEY FINDINGS

Findings from our research suggest that Shuttl has had a positive impact on the environment in Delhi-NCR, as it reduces emissions of CO_2 (by 14,022 tons/year) and criteria pollutants (PM2.5, NOx, CO, VOC). Our findings illustrate how convenient, quality, and responsive bus operations can shift people from car-based modes to more efficient modes. In Shuttl's case, 67 percent of surveyed users shifted from car-based modes. Extrapolating this to the entire customer base of Shuttl also implies a reduction in congestion by potentially removing 4,312 passenger car units (PCUs) from Delhi-NCR roads each day during morning and evening peak hours.

Contrary to prevailing rhetoric, our analysis shows that the socioeconomic segment and type of trips that Shuttl targets are not the same as the public bus service in Delhi: Less than 2 percent of the surveyed sample shifted from public buses. Commuters that routinely use Shuttl's services are less likely to use public buses in the first place. Bus aggregators and public buses can therefore coexist, possibly by offering different types of services for different market segments and trip types across routes, as also explored by Canales et al. (2017). However, Shuttl does compete with Delhi metro trips because 29 percent of the surveyed sample shifted from the metro.

Further, Shuttl is not for low-income commuters. Using the service requires a smartphone and the ability to pay higher fares compared to public transit. The company's services target high-income customers with monthly incomes that range between 20,000 and 60,000 Indian rupees (INRs) as compared to Delhi's per capita income of 20,796 Indian rupees (Shan-E-Alam et al. 2018). These customers work in white-collar jobs, and their commute is almost four times longer than the average commute of 10.86 km (RITES 2010) in the National Capital Region. Notwithstanding the specific market segment and trip types to which such models cater, evidence from this study suggests that there are many positives to the bus aggregation model that warrant appropriate steps by transit agencies and policymakers to explore and manage this growing sector.

This practice note presents the findings of an impact study of a single bus aggregator service, Shuttl, in one region, Delhi-NCR. The impact of the operations of similar models in other cities is yet to be determined. Future research could address these questions: What is the financial sustainability of bus aggregator models in Indian cities? Does the use of bus aggregator services for trips to work influence a user's mode choice for leisure or other trips? By providing connectivity to areas on the peripheries of cities, do such models induce sprawl? Or, do they support increasingly dispersed employment and land development in rapidly growing cities before public transit services can catch up? How can cities integrate these demand-responsive bus services with the existing public transit ecosystem?

This practice note is structured in the following manner: We first describe the bus aggregator model globally and in India in Section 2, while also providing an introduction to Shuttl's services. Next, in Section 3, we describe our research design and the methodology employed to analyze Shuttl's operations data and deploy our stated preference intercept survey aboard Shuttl buses. Section 4 presents our analysis of the socioeconomic background of Shuttl's commuter base, the commuters' travel preferences, and the environmental impact of Shuttl's operations. We end with Section 5, which presents our conclusions and poses further questions that are ripe for exploration.

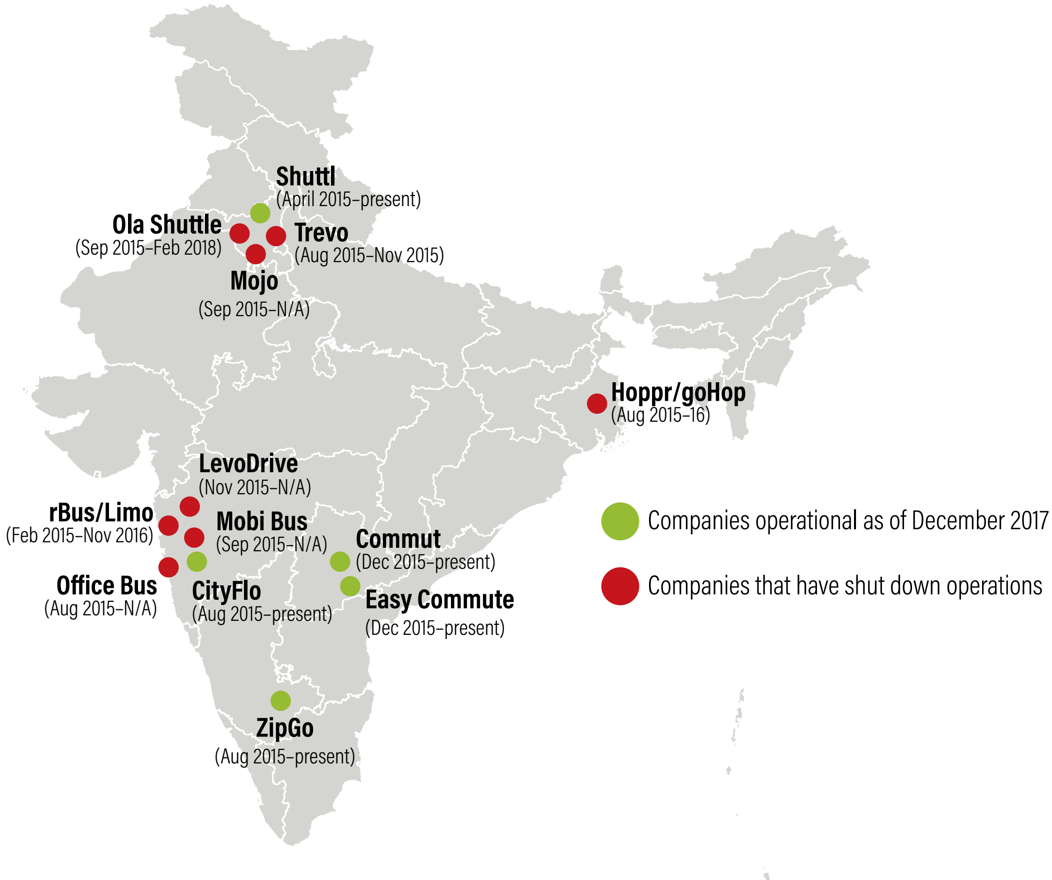
2. INTRODUCTION

The rapid growth of on-demand taxi companies and the influx of venture capital funding for mobility businesses has coincided with entrepreneurs experimenting with different forms of shared transportation services in Indian cities. Market tracking firm Tracxn estimates that the highest number of on-demand transportation and related companies in India was for those founded in 2015—142 companies, up from just 26 founded in 2012 (Sarkar and Shukla 2016). The same period also saw an increase in transportation-related investments from US $8.08 million to $992.75 million (Sarkar and Shukla 2016). This experimentation has included on-demand hailing of auto-rickshaws, motorbike taxis, and carpool options via a smartphone app. It was only a matter of time before mobility startups began to explore the potential of on-demand models in the bus segment. The momentum of demand-responsive bus businesses reached full steam in India with the launch of 13 companies in 2015 alone, as depicted in Figure 1. The reasons for the sudden influx of on-demand bus businesses may trace to trends emerging globally at the time and local on-the-ground realities of increasingly challenging commuting experiences in India.

From a global perspective, Kutsuplus, the first known demand-responsive minibus service, was launched by the Helsinki Regional Transport Authority in 2013 but was shut down in 2015 for lack of funding. Inspired by Kutsuplus, several private enterprises, such as Chariot, Leap, Loup, Bridj, and Via, began offering demand-responsive bus and minibus services in the United States in 2015. Susan Shaheen et al. (2015) define these services as microtransit—privately operated shared transportation systems that can have fixed routes and schedules, as well as flexible routes and on-demand scheduling where the vehicles used generally include vans and buses. Also in 2015, Uber began offering shared rides on fixed routes—a move that many hailed as, best put by the *Guardian*, "a very small bus" (Hern 2015). The interest in innovating in mass transit and public transit models is exemplified by the over 430 start-ups globally (according to AngelList[1] as of March 2018) that have self-selected their industry as "public transportation."

In 2016,[2] the authors interviewed six out of seven founders of demand-responsive bus start-ups in India. These founders indicated that they saw an opportunity to offer a superior shared transportation experience to commuters who could afford more than public transportation but could not afford a taxi or private vehicle. These entrepreneurs expressed the view that public bus infrastructure was crumbling and that without good alternatives, commuters would shift to private vehicles when their income supported the shift. Research does bear out some of these claims. According to Kharola and Tiwari (2008), public bus services often require improvements in reliability, fleet availability, speed, and cost management to meet acceptable levels of service. These factors, along with the social responsibility that these organizations are mandated to shoulder through low fares and a high rate of taxes, contribute to the poor financial performance of public buses. This has resulted in the requirement of huge subsidies to support operations and procure vehicles (Kharola and Tiwari 2008). In 2017, the International Association of Public Transport estimated that India would need an additional 220,000 buses to meet the growing travel demand over the years 2018 to 2021 (UITP 2017). The current shortage results in several neighborhoods going under-served by public transportation networks.

FIGURE 1 Demand-Responsive Bus Companies Founded in India in 2015



Sources: Paul 2015; Sachitanand 2015; Sarkar and Shukla 2016; PTI 2018; Paul et al. 2018; and Interviews with Bus Aggregator Companies (2016).

Enterprises that launched demand-responsive bus services in India since 2015 have capitalized on cities characterized by limited connectivity to large commercial and residential hubs in their peripheries. Routes offered often have few public transportation options, are characterized by poor last-mile connectivity, and largely cater to the daily morning and evening peak-hour work trips. Such services are also offered by privately run chartered buses providing point-to-point travel for employees of large corporations. These organized conveyance services (OCS) represented an estimated INR 150-200 crore ($37–$50 million) industry in 2008 (Singh, Koehler, and Agarwal 2008), but continue to be characterized by low quality of service and a disregard for customer satisfaction. Compared to OCS, demand-responsive bus companies provide a higher quality of service and do not cater only to a single employer.[3] Rather, they are also customer-facing, allowing anyone to book a seat.

Known in India as bus aggregators, on-demand shuttles, and app-based buses, these companies crowd-source routes from customers via their apps and then contract with individual owners or owners of small fleets of buses to operate on these routes. The period of these contracts can range from fairly short time periods, such as three months, to longer-term contracts, such as three years. The size of the vehicle deployed and the frequency of service is determined by the volume of customer requests and adjusted on a weekly or monthly basis as needed. Once services are running on a desired route, customers log into the app, which aggregates all the seats available for a certain origin–destination trip, and make single or season-based bookings in real time or in advance of the trip.

Although many private companies launched services in 2015, a fair number have terminated operations, as depicted in Figure 1 above. For instance, Trevo in Delhi (Paul 2015) and rBus/LimpApp in Mumbai (Paul et al. 2018) shut down services in under a year, while on-demand taxi giant Ola's shuttle bus services discontinued after three and half years (PTI 2018). While the reasons for these terminations are unclear and require further research, the authors pose that critical factors could include the inability to raise the funding required, the high cost of running operations, and frequent fines and bans by city authorities.

In 2017, the authors collaborated with Shuttl, one of the largest bus aggregator services operating in Delhi-NCR, to conduct an environmental impact study of the company's services in the region. Based on operating data shared by Shuttl, and a primary stated-preference intercept survey of a sample of its users, this study answers the following questions:

- Who uses Shuttl's services, and how did they travel before its introduction?
- What is Shuttl's impact on emissions?
- What is Shuttl's impact on congestion?

Evidence from this study is expected to enrich the ongoing policy and regulatory conversations regarding the integration of new mobility services in India (NITI Aayog, Rocky Mountain Institute, and Observer Research Foundation 2018) while sparking further research on bus aggregator models.

2.1 GLOBAL BUS AGGREGATOR LANDSCAPE

The first known demand-responsive minibus service, known as Kutsuplus, was launched by the Helsinki Regional Transport Authority (HSL) in 2013. Active from 2013 to 2015, the Kutsuplus trial became a pioneer in setting up an automated real-time scalable demand-responsive transportation service that optimized routes and added value to operational efficiency. Operating just 15 vehicles across downtown Helsinki, "it offered an increasingly flexible and personal form of public transport, enabling door-to-door connectivity, while competing with the private car in terms of time usage and economy" (Rissanen 2016). It achieved high levels of customer satisfaction, potentially significant environmental benefits, reduced passenger kilometers by car, and exhibited potential for long-term change in the city's urban fabric (Mäkinen et al. 2015). Despite the small fleet, Kutsuplus passenger numbers kept increasing, and reports by HSL indicate that it was well on its way to becoming economically viable. However, local municipalities were unable to procure government funding to grow the fleet, and subsequently HSL was forced to shut Kutsuplus operations down in November 2015. (Rissanen 2016).

Inspired by Kutsuplus, several private enterprises began offering Kutsuplus-type services in the United States in 2015 (Frost and Sullivan 2016). These services are defined as microtransit, with two variants of the model emerging in the North American context: fixed routes and schedules on which "customers make requests for new crowd-sourced routes," and flexible routes with on-demand scheduling (Shaheen et al. 2015). Services such as Chariot in San Francisco and Boston-based Bridj were able to operate small fleets and service 700 to 1,000 riders per day. However, Bridj (and a number of other companies such as Loup and Leap Transit) shut down operations in 2016 (Berrebi 2017). Chariot has since been acquired by Ford (Etherington 2016) and Bridj by Transit Systems for launch of services in Sydney, Australia (Martin 2017).

Recognizing the potential of microtransit services in adding capacity and filling gaps in public transportation (Canales et al. 2017), several transit agencies in the United States launched their own microtransit pilots in partnership with private companies in 2016. The recently released report "Uprooted: Exploring Microtransit in the United States," by the Eno Centre for Transportation (Westervelt et al. 2018) documents three cases of transit agencies partnering with private enterprises to run microtransit services on a pilot basis: Kansas City Transit Authority and Bridj; Santa Clara Valley Transit Authority and RideCell; and Alameda–Contra Costa Transit Authority and DemandTrans. While each of the pilots identified different use cases—daily work commute, last-mile service, and optimization of a low-demand public bus route, respectively—not one could achieve the projected scale. Kansas City and Bridj could only manage about 11 rides per day before terminating the year-long pilot, amounting to a cost of $1,000 per ride to the public agency. Santa Clara and RideCell managed to provide 41 rides per day, but the pilot was discontinued for want of funding. The Alameda–Contra Costa and DemandTrans pilot achieved a considerable portion of the objectives it set out to achieve and was still ongoing at the time of publication of the report. Based on interviews with project teams working on the pilots, the report concludes by providing recommendations for transit agencies to consider when piloting microtransit services in their respective jurisdictions.

Bus aggregators' businesses launched in cities in the Asian subcontinent, on the other hand, have been growing with great speed due to inadequate public transit and high population densities (Frost and Sullivan 2016). Three categories of players have emerged: private enterprises (for example, Shuttl in India and GrabCoach in Singapore), government-led operations (for example, Beeline in Singapore), and services by on-demand taxi companies (for example, Didi Chuxing's Didi Bus in China). In these regions, the "fixed route and schedule" model remains predominant (Frost and Sullivan 2016).

Early research in the Indonesian market suggests that the impact of such models may be different in urban areas in developing economies. Based on demand analysis for a potential microtransit service in the Jakarta Metropolitan Area, Kawaguchi, Yuma, and Danno (2017) estimate that a metropolitan-wide microtransit system could not only reduce vehicle kilometers traveled (VKT), but also reduce congestion and still be profitable in the long run. However, given that demand-responsive bus services are a new entrant into the mobility ecosystem worldwide, there is a dearth of research on such models, particularly in developing countries. The lack of research is also partly due to the difficulty in procuring data from the private companies that operate these models. This paper begins to address this gap by focusing on studying the impact of one bus aggregator service: Shuttl in Delhi-NCR.

2.2 BUS AGGREGATOR LANDSCAPE IN INDIA

As defined earlier, bus aggregators are companies that crowd-source routes from customers via their apps and then contract with individual owners or owners of small fleets of buses to operate on these routes when a minimum demand is reached. These companies are also referred to as app-based buses and on-demand shuttles.

Bus aggregators offer customer-centric and demand-responsive services—from crowdsourcing customer demand in order to frequently re-design routes and schedules to providing an "Uber-style" app interface allowing customers to book a seat, pay online, rate their experience, receive updates on estimated time of arrival, and track their bus in real time. The foundation of the model rests on using buses to provide the comfort, convenience, and reliability of an on-demand taxi at a lower price point.

Financial backing from the venture capital industry (Agarwal 2017), has enabled bus aggregators to grow and build traction with customers (Overdorf 2016). As of May 2018, seven key players continued to operate in Delhi-NCR, Jaipur, Kolkata, Mumbai, Bengaluru, and Hyderabad. However, eight companies had also discontinued operations. Based on publicly available information, the largest player was Shuttl, which offered 20,000 passenger trips a day in Delhi-NCR in 2017 (John 2017) as depicted in Table 1.

TABLE 1 Snapshot of Bus Aggregators in India as of March 2019

COMPANY	LAUNCH DATE	CITY OF LAUNCH	TOTAL FUNDING	FUNDERS	OPERATING STATUS	OPERATING DETAILS
MeriBus.in	Nov 2013	Delhi-NCR	-	-	Operations in Delhi-NCR	Routes: 26 Daily bookings: 250+ Fleet size: 60
rBus/ Limo	Feb 2015 (Sachitanand 2015)	Mumbai	$1m	India Quotient, People Group, India Equity Partners (Mehta 2015)	Discontinued in Nov 2016 (Paul et al. 2018)	-
Shuttl	Apr 2015	Delhi-NCR	$20m (Dec 2015) $3.1m (Jun 2015) $11m (Jul 2018) (Verma 2018) $7.23m (Mar 2019) (Kashyap 2019)	Sequoia Capital, Sequoia Capital India (SCI), AdvantEdge Partners, Lightspeed Venture Partners, Times Internet, Amazon India, Dentsu Ventures	Operations in Delhi-NCR, Kolkata, Hyderabad, Pune, Mumbai, and Chennai	Operating details for Delhi: Routes: 140 Daily bookings: 35,000 Fleet size: 500+
Trevo	Aug 2015	Delhi-NCR	-	-	Discontinued in Nov 2015 (Paul 2015)	-
Office Bus	Aug 2015	Mumbai	-	-	Discontinued	-
ZipGo	Aug 2015	Bengaluru	Undisclosed funding round (Apr 2017) (Merises 2017)	Ventureast Fund Advisors, Omidiyar Network, Orios Venture Partners, Innoven Capital	Operations in Mumbai, Delhi-NCR, Bengaluru, Hyderabad, Jaipur	-
CityFlo	Aug 2015	Mumbai	$750k (Nov 2015) (Ghosh 2015) Undisclosed funding round (Apr 2017)	IDG Ventures, Founder of Purple Bus	Operations in Mumbai	Routes: 8 Daily bookings: 300 Fleet size: 18
Mojo	Sept 2015	Delhi-NCR	-	-	Discontinued bus aggregator services	-
Hoppr/ goHop	Aug 2015 (Ganguly 2015)	Kolkata	-	-	Discontinued	-
MobiBus	Sept 2015	Mumbai	-	-	Discontinued	-

TABLE 1 Snapshot of Bus Aggregators in India as of March 2019 (Cont'd)

COMPANY	LAUNCH DATE	CITY OF LAUNCH	TOTAL FUNDING	FUNDERS	OPERATING STATUS	OPERATING DETAILS
Ola Shuttle	Sept 2015	Delhi-NCR	Undisclosed funding from Ola Cabs	Ola Cabs (ANI Technologies)	Discontinued in Feb 2018 (PTI 2018)	-
LevoDrive	Nov 2015	Mumbai	-	-	Discontinued	-
Commut	Dec 2015	Hyderabad	$200k (Apr 2016) $200k (2017)	50K Ventures (Kanth 2016), Shell Foundation	Company was acquired by Careem and their Hyderabad operations were acquired by Shuttl in September 2018 (Martin 2018)	-
Easy Commute	Dec 2015	Hyderabad	-	-	Operations in Hyderabad	Routes: 40 Daily bookings: 500 Fleet size: 95
Kruze	Apr 2016	Mumbai	-	-	Operations in Mumbai	Routes: 7 Daily bookings: NA Fleet size: NA

Sources: Sachitanand 2015; Mehta 2015; Paul 2015; Ganguly 2015; Ghosh 2015; Kanth 2016; Sarkar and Shukla 2016; Agarwal 2017; Merisis Advisors 2017; Paul et al. 2018; PTI 2018; Verma 2018; Martin 2018; Kashyap 2019; www.crunchbase.com; interview with founder of Purple Bus; interviews with bus aggregator companies.

Since the launch of these bus aggregator companies in India, the legal status of their operations has been highly contested, largely because of the notion that they compete with public buses and because the kind of service and trips they provide have not been clearly defined in Indian transportation policy. Government crackdowns began in 2015 and sporadically continued with vehicles being impounded in Bengaluru (Bharadwaj and Bhat 2015), Delhi-NCR (Shrangi 2017), and Mumbai (Korde 2016).

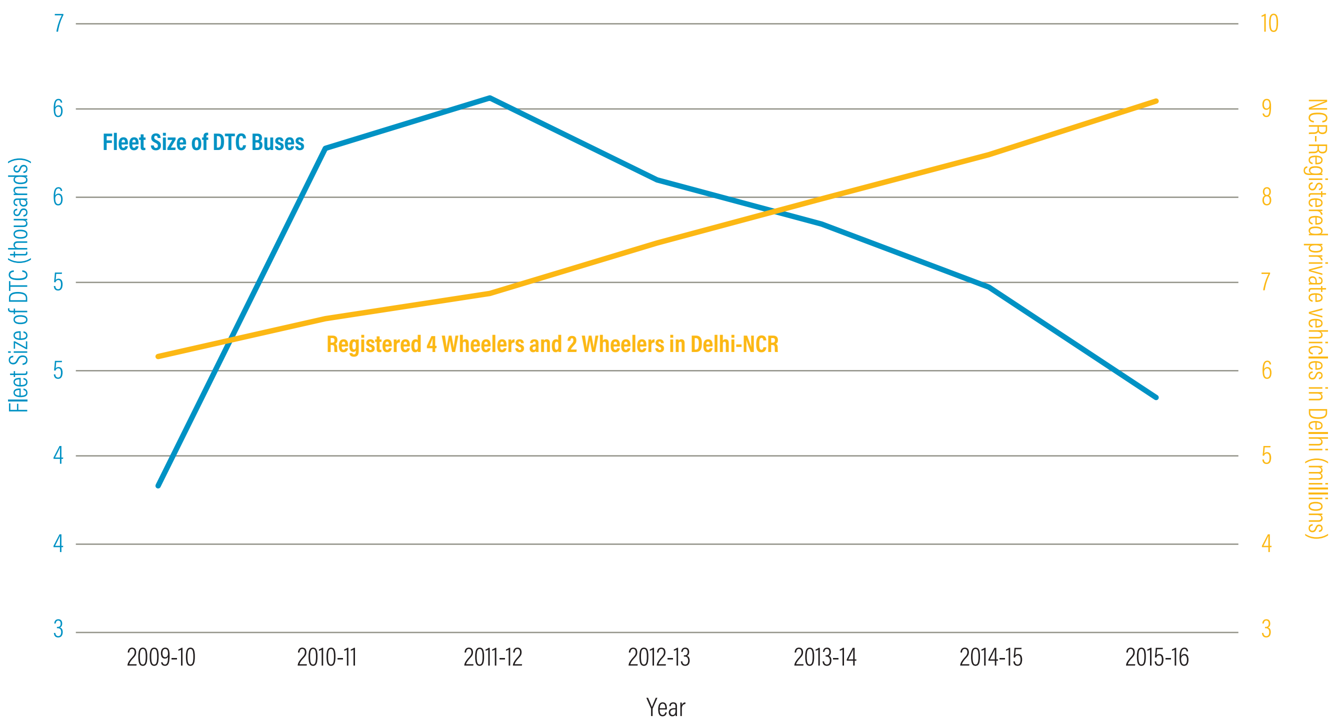
The major points of contention have revolved around the type of permit and existing monopoly rights of the state. The Indian Motor Vehicles (MV) Act (Parliament of India 1988), specifies two types of commercial permits for passenger transportation: stage carriage and contract carriage permits. A stage carriage permit allows the pick-up and drop-off of passengers en route, whereas a contract carriage permit allows the provision of point-to-point transportation. The MV Act and The Road Transport Corporation (RTC) Act (Parliament of India 1950) recognize the state as the monopoly operator of stage carriage buses on public roads. While the state can award stage carriage permits to private operators, these partnerships have typically been structured around the operation of fixed routes and schedules. Bus aggregators with their dynamic routes and schedules do not fit the existing procurement model. Hence, most operate their services with a contract carriage permit and are perceived as violating its provisions as they have multiple pick-up and drop-off points, characteristic of stage carriage operations.

In a series of multi-stakeholder meetings organized by World Resources Institute India, city regulators and public transit agencies voiced concerns that bus aggregators provide unfair competition and siphon customers off their most profitable routes (Ramprasad 2015). This affects their fare revenues and ability to service less profitable routes. On the other hand, bus aggregators maintained that their higher price point per ticket put them in competition with privately driven cars and taxis. They also suggested that public bus systems did not offer a high level of quality and that, without other options, users would shift to private vehicles when feasible.

In April 2016, the Transport Ministry of the Delhi state government proposed the "App-based Premium Bus Services Scheme" for the Delhi-NCR region, to address the lack of higher-end bus services which the ministry believed could encourage private vehicle users to shift to mass transportation (Government of the National Capital Territory of Delhi 2016; Sharma 2016). This was also at a time when the number of buses operated by the Delhi Transport Corporation (DTC) (Kumar et al. 2016) was falling drastically, while registrations of two-wheelers and private cars continued to rise. Figure 2 demonstrates a 48 percent increase in car and motorcycle registrations between 2009–10 and 2015–16 against the trend of decreasing DTC fleet size between 2011–12 and 2015–16 (Kumar et al. 2016; Central Statistics Office 2017b).

During this period, the Delhi metro was catering to 2.6 million passenger trips a day (DMRC and TERI 2016), but commuters traveling from one satellite city to the other had to travel into Delhi and switch lines, resulting in high travel times and multiple interchanges. Bus aggregators successfully launched services by targeting commuters traveling from residences in Noida, Ghaziabad, and

FIGURE 2 Trends in Private Motor Vehicle Registrations and Public Bus Fleet Strengths in Delhi

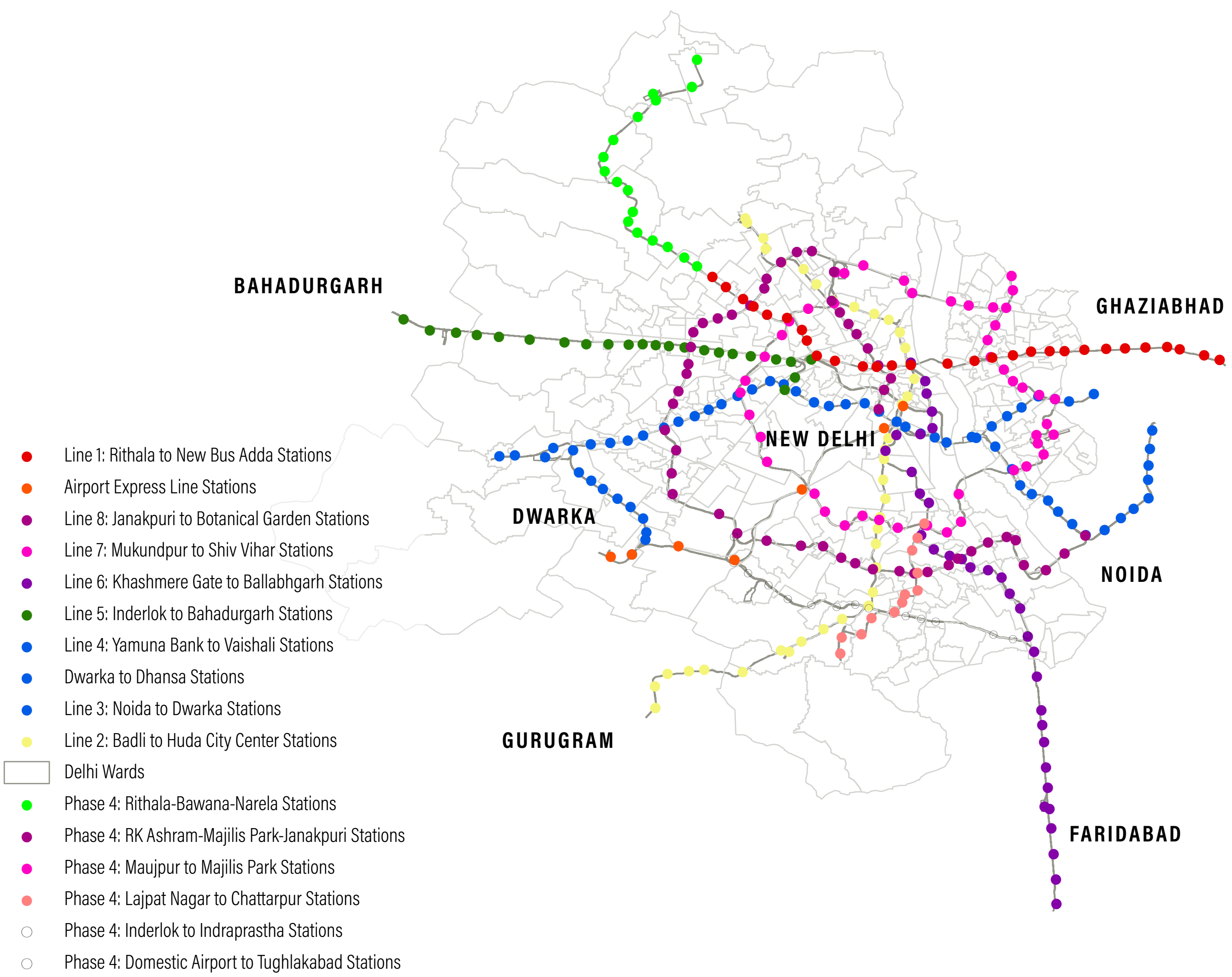


Sources: Kumar et al. 2016; Central Statistics Office 2017b.

Faridabad to offices in Gurugram by offering bus routes that could avoid going into Delhi, thereby significantly reducing travel time. However, the Delhi Metro has been executing plans to substantially expand its capacity and network. Figure 3 below depicts Delhi Metro's operational lines (Phase I, Phase II, and a portion of Phase III) and lines under construction (remainder sections of Phase III and Phase IV), which will launch in 2020 and 2025 (NDTV 2018). The launch of these new lines is set to considerably reduce travel times between satellite cities (Nag 2018), and that may affect the ridership of bus aggregator services in Delhi-NCR going forward.

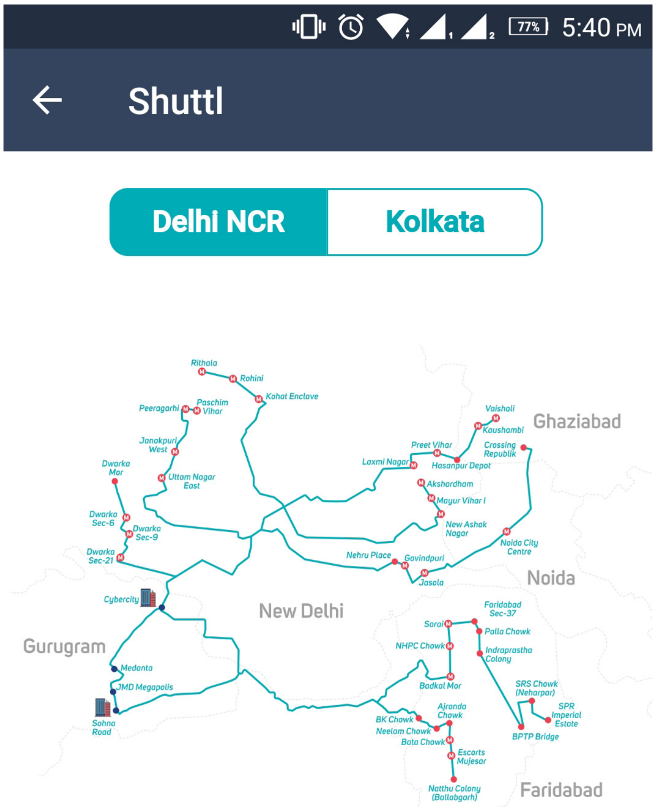
The proposed App-based Premium Bus Services Scheme for Delhi-NCR of 2016 would have authorized bus aggregators and provided a framework to enable and regulate them, but it was met with criticism that was based on rhetoric rather than empirical research. The central government made allegations against the state of corruption to benefit private companies, resulting in the scheme's withdrawal (The Indian Express 2016; Hindustan Times 2016). In December 2017, the Delhi state government once again started a stakeholder consultation process to develop a framework to regulate bus aggregators (Anand 2017), but little progress has been made since then.

FIGURE 3 Network Map of Delhi Metro Rail Corporation's Transportation System



Source: DMRC 2017.

FIGURE 4 Screenshot of Shuttl App Depicting Available Routes in Delhi-NCR as of February 2018



Source: Shuttl app.

2.3 INTRODUCTION TO SHUTTL

Founded in 2015, Shuttl is one of the largest bus aggregators in India. The company raised $23 million across three rounds of funding in 2015 (Mallya 2015). After launching its first bus routes in the Gurugram in April 2015, Shuttl grew quickly to offer rides across the rest of the Delhi-NCR, connecting residents of Noida, Delhi, Faridabad, and Ghaziabad to offices in Gurugram (Shrivastava 2016). Figure 4 provides a visual depiction of Shuttl's routes in Delhi-NCR as of February 2018.

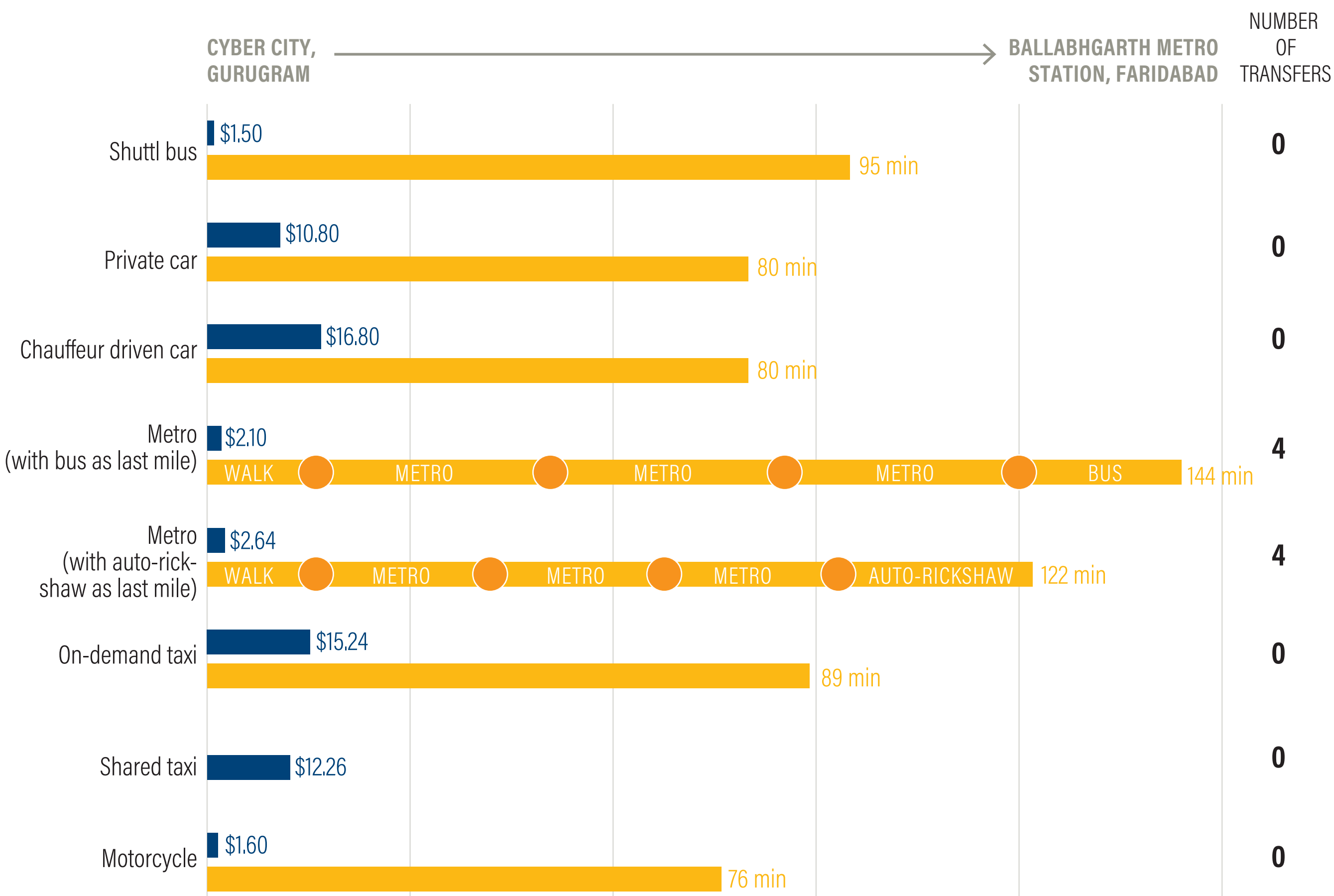
In January 2017, within just six months of launching services, Shuttl completed 1 million passenger rides (Shuttl 2016), and by March 2017, the company was providing 20,000 trips a day. With its expansion into Jaipur and Kolkata in January 2018, Shuttl was providing 35,000 trips a day. By 2019, Shuttl was operating in Delhi-NCR, Kolkata, Jaipur, Hyderabad, Chennai, and Pune.

Shuttl offers long-distance intra-city bus rides targeting office-to-home commuters whose work trips are classified as "very long trips", that is longer than 30 km (Kumar and Tiwari 2019). The average trip length of a Shuttl user is 40 km, almost four times the average commute of 10.86 km (RITES 2010) in Delhi's NCR. In 2017, the company piloted shorter rides to address last-mile connectivity challenges from metro stations to office parks in Gurugram. However, this service was discontinued within a few months. Most of the company's bus services are consumer facing, allowing any commuter with the Shuttl app to book a seat on a bus. A smaller part of the business focused on providing services that are exclusive to employees of large companies. As of January 2018, the company was operating 70 consumer-facing routes in the morning (carrying passengers from origin to destination) and 70 consumer-facing routes in the evening (carrying passengers from destination to origin) in Delhi-NCR.[4] Although both morning and evening routes each corresponded to one origin-destination pair, they were dynamic in nature, having different lengths and catering to different boarding and alighting points, depending on customer requests.

To book a seat on a bus, passengers enter the origin and destination of their journey on the company's app or website. The app identifies suitable bus routes and provides a list of scheduled departures and boarding points. Commuters select a bus corresponding to their desired schedule and purchase a seat via the in-app digital wallet. Once the payment is made, users receive details of the bus and its driver, a link to track the real-time location of the bus, and its estimated time of arrival. On boarding the bus, the passenger's ticket is validated through an on-board device using a QR Code or Customer Identification Number (CIN). For a step-by-step illustration of the process that a commuter would follow on Shuttl's app to book a seat, pay for the ticket or season pass, and board the bus, see Appendix A.

Shuttl leverages the extensive penetration of smartphones among its target audience to get live feedback from the market—from in-app route requests to ratings of the company's service, vehicles, and drivers. This allows Shuttl to determine patterns in demand for routes and timings. Once a minimum threshold of demand has been

Figure 5 Fare and Commute Time Comparison for an Individual Working in Cyber City, Gurugram, and Traveling Home with Ballabhghar Metro Station, Faridabad, as a Proxy for the Individual's Final Destination



Notes:

1. Commute time estimates:
   a. Estimates for Shuttl, private car, chauffeur-driven car, metro, public bus, auto-rickshaw, and motorcycle were obtained every half hour from Google Maps during the evening peak hours on March 14, 2018, and averaged out to arrive at the travel time estimate. For private car and motorcycle, time to park was not included, hence the travel time estimate can be considered conservative. For on-demand taxi, the travel time estimate was obtained from Google Maps whereas the waiting time until the taxi arrived was obtained from the Ola and Uber app.
   b. Estimates for shared taxi rides are not available, as they are recalculated as more passengers are added to the ride.
   c. The time taken to walk the first mile has been included for metro trips as this estimate was provided by Google Maps. It has not been included for Shuttl, private car, chauffeur-driven car, motorcycle, on-demand taxi, and shared taxi as all these modes are available near the entry of the Cyber City hub.
2. For private cars and chauffeur-driven cars, the cost of a trip is represented as an average of cost incurred with diesel and petrol as fuel (ratio assumed as 50:50), depreciation, and equated monthly installments (EMI) on a loan.
3. For motorcycles, the cost of the trip considers depreciation and EMI on a loan.
4. Fuel efficiency estimates for all vehicles were obtained via Goel and Guttikunda (2015).
5. For on-demand taxi and shared taxis, the cost of trip is represented as an average of Ola and Uber fares at every half hour mark during evening peak hours on March 14, 2018. The estimates include surged prices.
6. No public bus options were available for the selected origin destination during the time of this study. Therefore, the cost of trip and time taken for the trip for a combination of public modes (metro + bus/auto-rickshaw) were calculated and are represented here.
7. To give a cost estimate of a bus only trip, the cost of trip was calculated considering a trip with DTC and Gurugram Metropolitan City Bus Ltd. bus services (operational only after September 2017), which included changing three buses and walking 500 meters at both the first and last mile. Travel time for such a trip is unknown, given uncertain waiting times and traffic congestion.
8. Transfers were counted as the number of times a commuter had to shift from one mode or vehicle to another.

Source: WRI research with data collected during peak hours on March 14, 2018, from a combination of Google Maps, Uber app, Ola app, and Shuttl app.

demonstrated, Shuttl is set up to rapidly add new routes, adjust existing ones, and change the capacity or frequency of buses deployed. Shuttl does not own the vehicles that operate on its platform, instead entering into contracts with individual owners and owners of small fleets of buses of varying sizes, from smaller 9-seater vans to 27-seater mini-buses to 54-seater large-format buses. At the time of the intercept survey, Shuttl's entire fleet was air-conditioned and its contracts with bus owners ranged from three months to three years. The risk-benefit of entering into such contracts from the perspective of bus owners operating on the Shuttl platform is a question to be further explored. However, interviews with 25 bus owners on Shuttl's platform suggests that they provided inter-city tourist services prior to joining the platform. As a tourist vehicle, their operations used to be characterized by intermittent and seasonal demand, as opposed to the fixed contracts that they have entered into with Shuttl.

Shuttl's key offering to customers is a scheduled service for work trips with the convenience of a fixed seat in an air-conditioned bus at a reasonable price. As of March 2017, Shuttl's rates were 25 percent higher than air-conditioned buses run by DTC for a comparable trip. However, Shuttl's rates were 28 percent lower than the Delhi Metro fare for a trip of the same distance. Similarly, a ticket on Shuttl was cheaper than the fuel cost incurred while driving a private car and significantly cheaper than booking an on-demand taxi or a shared taxi. Figure 5 provides a comparative overview of fares and commute times for an individual working at Cyber City in Gurugram, a corporate park with many offices, traveling 40 kilometers to reach home with Ballabhghar Metro Station as a proxy for the individual's destination.

3. RESEARCH DESIGN AND METHODOLOGY

Adapted from a study of the social, environmental, and economic impacts of Bus Rapid Transit systems in four cities (Carrigan et al. 2013), the methodological framework to evaluate the environmental impact of Shuttl is anchored in a specific set of environmental cost indicators corresponding to levels of air pollution and CO_2 emissions. Shuttl's environmental costs were compared with its commuters' alternative mode choice(s) to determine the net benefits to the city from the model. The research design deployed two component methodological tools: a spreadsheet-based emissions model to estimate the emissions of criteria pollutants and greenhouse gases and a stated-preference intercept survey with a sample of Shuttl's daily users to understand Shuttl's commuter base and commuters' alternative mode choices.

3.1 AIR POLLUTANTS AND CO_2 EMISSIONS ESTIMATES

To estimate the level of criteria pollutants (PM2.5, NO_X, CO, VOC) and greenhouse gases (CO_2) generated by Shuttl, data on Shuttl's fleet and daily trips were obtained from the company. The dataset comprised entries corresponding to each vehicle, its vintage, fuel type (compressed natural gas [CNG] or diesel), seating capacity, VKT per day, and the average daily bookings as of March 2017.

On-road emissions were quantified based on numbers of vehicles, VKT per day, and fuel consumed per day for each class of vehicle. To assign appropriate on-road fuel economy values sourced from Goel and Guttikunda (2015), vehicles were categorized into two broad classes: buses with more than 26 seats and light commercial vehicles with up to 26 seats. Emission factors for each fuel type were identified from secondary sources on energy released as a result of combustion of various fuel types for the Indian transportation sector (Waldron and Kapshe 2006; IPCC 2018; Aggarwal and Jain 2016b; Engineering ToolBox 2005). Due to a lack of adequate sources for the CNG-based emission factor for PM2.5, it was assumed to be equivalent to the emission factor for industrial use of CNG (Reddy and Venkatraman 2002).

Assuming daily average VKT, the number of daily bookings and average vehicle occupancy remaining constant for all working days in a year (assumed as 300), emission estimate figures were extrapolated for the year by multiplying fuel consumed by each vehicle in Shuttl's fleet with emission factors (for each respective pollutant). Final emission estimates and savings were calculated per passenger kilometer traveled via Shuttl as compared to respondent's prior mode, captured through an intercept survey per the equation given below.

$$Emissions_{\,per\ pollutant} = \sum Fuel\ Consumed_{\,by\ each\ vehicle} * Emission\ Factor_{\,per\ pollutant} * 300$$

$$where\ Fuel\ Consumed = {}^{Daily\ VKT_{\,per\ class\ of\ vehicle}}/_{Fuel\ Economy_{\,per\ class\ of\ vehicle}}$$

3.2 INTERCEPT SURVEY

To generate emission estimates for alternative modes, the daily ridership of Shuttl was split up by alternative mode-share obtained from an intercept survey of commuters that depended on the platform for daily travel. This allowed for the estimation of VKT for each of the alternative modes. Official government sources and secondary research were used to source data on operations (Guttikunda and Calori 2013; Transport Research Wing 2016; Sharma et al. 2014) and occupancy ratios for different modes (Aggarwal and Jain 2016a; Tiwari 2002; S.K. Singh 2004). Public buses in Delhi-NCR were assumed to be operating on CNG even though the Haryana Road Transport Corporation and Uttar Pradesh Road Transport Corporation buses, which also service the region, operate on diesel. Because in comparison to CNG, diesel-based emission factors are higher for CO_2 and criteria pollutants other than NOx, the results for emissions from public buses represented in this paper are likely to be an underestimation of real-world conditions.[5] The emission estimate figures for alternative modes were then compared to Shuttl's emission estimates to arrive at the change in pollutant levels as a result of Shuttl's operations.

The intercept surveys (see Appendix B) were administered by an independent agency, under contract by the authors, to interview Shuttl's users on board their buses over a period of 10 days in May and June 2017. Prior to administering the survey, a pilot was conducted aboard a few buses operating on one morning route and one evening route chosen at random to refine the design of the questionnaire and survey protocol. The questionnaire was designed in English and administered by the agency's surveyors, who were fluent in both English and Hindi.

3.2.1 Route Sampling

At the time of the survey, the company operated 32 customer-facing or B2C (business-to-consumer) routes, or 64 morning and evening trips, that were characterized by the following aspects:

- Eighty-three percent of morning and evening trips were over 30 kilometers each in length. The average length of passenger trips was 43.4 kilometers, with a standard deviation of 15.3 kilometers and minimum and maximum trip lengths at 14.9 kilometers and 89.1 kilometers, respectively.
- Seventy-seven percent of Shuttl's ridership came from routes that originated in North-West Delhi, South-West Delhi, Noida, Ghaziabad, and Faridabad and connected commuters to offices in Gurugram.
- The largest ridership, 22 percent, was attributed to routes connecting Faridabad to Gurugram.

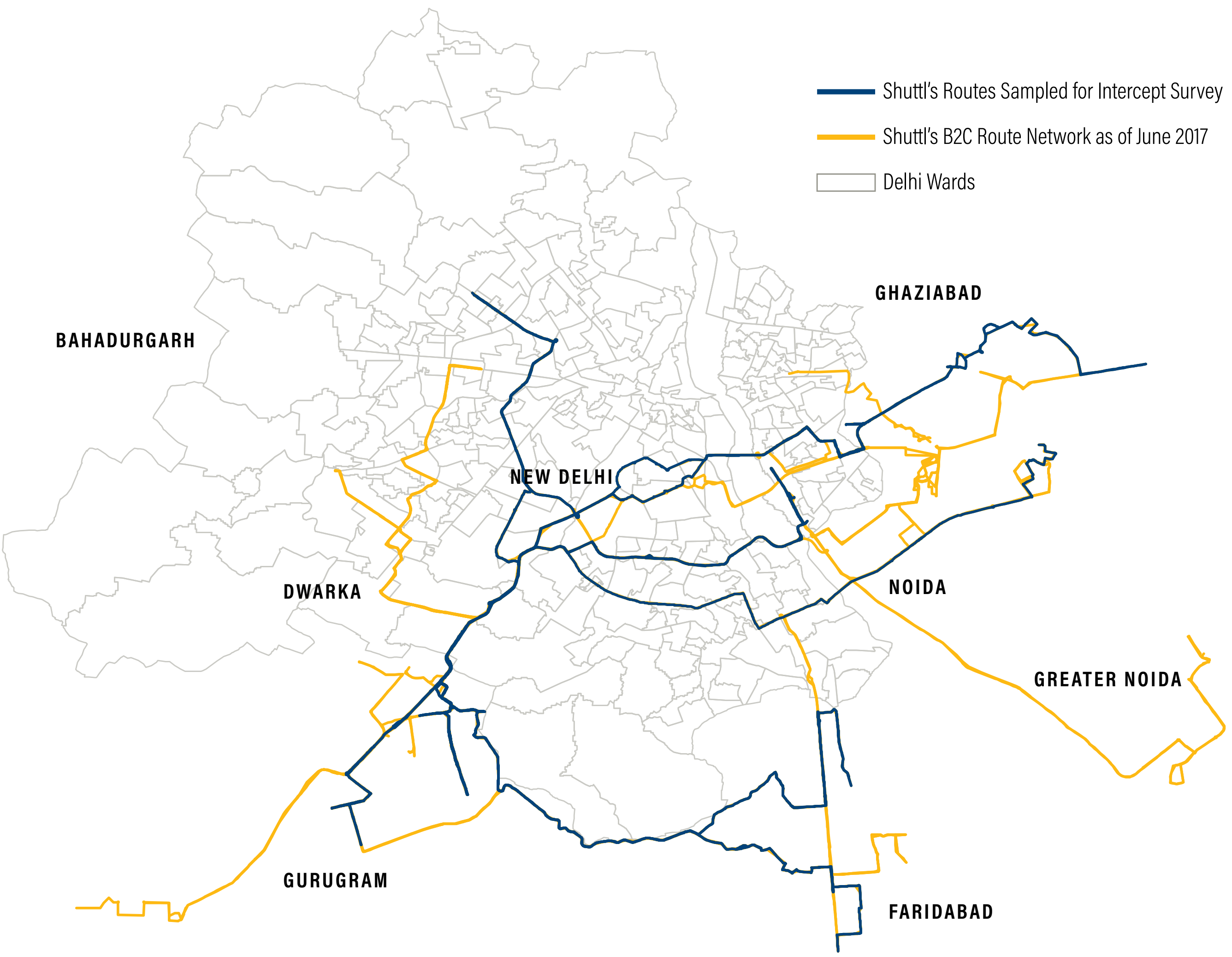
- Twenty-three percent of the company's ridership used routes that were in test or experimental mode connecting Greater Noida to Gurugram or within Gurugram itself.

Our intercept surveys were administered during the morning and evening trips on 6 of the company's 32 routes, which were selected to ensure their representativeness as follows:

- We excluded all experimental routes between Greater Noida and Gurugram and within Gurugram.
- We discarded all routes with morning or evening trips under 30 kilometers.
- One route was chosen at random with its origin in North-West Delhi, South-West Delhi, Noida, or Ghaziabad; and two routes were chosen with an origin in Faridabad, given its larger contribution to ridership. Different routes were chosen at random on different days during the period of the survey.

Figure 6 is a map of the sampled routes (blue) superimposed on Shuttl's B2C routes (orange), and Table 2 lists the sampled routes, their distances, and the proportion of ridership across the network that they represent.

FIGURE 6 Map Depicting the Sampling of Routes Chosen for the Intercept Survey



Source: Shuttl 2017.

TABLE 2 List of Routes Sampled for Intercept Survey

SAMPLED ROUTES	MORNING TRIP[a]	TRIP LENGTH (KM)	EVENING TRIP[a]	TRIP LENGTH (KM)[b]	STARTING SUBREGION/ CLUSTER	% OF SHUTTL RIDERSHIP	PUBLIC TRANSPORTATION OPTIONS[c]	NO. OF TRANSFERS
Route 1	Start 1 – End 1	60.40	End 1 – Start 1	60.90	Ghaziabad - Gurugram	20%	Trip could be made on the Delhi Metro Magenta Line, transfer to the Yellow Line, and transfer to the Rapid Metro	3
Route 2	Start 2 – End 2	49.54	End 2 – Start 2	49.30	Noida - Gurugram	5%	Trip could be made on DTC Bus No. 8, transfer to the Magenta Line, and transfer to the Yellow Line	2
Route 3	Start 3 – End 3	43.17	End 3 – Start 3	41.66	North West Delhi - Gurugram	16%	Trip could be made on DTC Bus No. 990, transfer to the Delhi Metro Pink Line, transfer to the Yellow Line, transfer to the Rapid Metro	3
Route 4	Start 4 – End 4	32.09	End 4 – Start 4	29.89	South West Delhi – Gurugram	14%	Trip could be made on the Delhi Metro Blue Line, transfer to the Yellow Line, transfer to the Rapid Metro	2
Route 5	Start 5 – End 5	47.12	End 5 – Start 5	46.65	Faridabad - Gurugram	22%	Trip could be made on the Delhi Metro Violet Line, transfer to the Magenta Line, transfer to the Yellow Line, transfer to the Rapid Metro	3
Route 6	Start 6 – End 6	42.54	End 6 – Start 6	42.54	Faridabad - Gurugram	22%	Trip could be made on the Delhi Metro Violet Line, transfer to the Yellow Line, transfer to the Rapid Metro	2

Notes:

1. Starting and ending points of sampled routes have been anonymized at the request of the company.
2. For the purposes of this study, the first and last mile were considered to have been walked for Shuttl, public bus, and metro. This is plausible for Shuttl's trips into Gurugram, as the drop-off points are located within 500 meters of the entry of major offices. However, trips to Gurugram via public transportation likely had a motorized last mile as many office locations are, at the very least, five kilometers away from the last metro stop in Gurugram. Our study did not provide data on how the trip from or to the commuter's residence was completed when using Shuttl, public bus, or metro. These are limitations of the study.
3. Public transportation options for the sampled origin–destination pairs were obtained via Google Maps.

Source: WRI India Analysis of Shuttl's Operations, May 2017.

3.2.2 User Sampling

As corroborated by our survey, the population of Shuttl's users is largely homogeneous; that is, young and educated professionals who own and operate a smartphone to book Shuttl's services. At the time of the survey, Shuttl catered to more than 12,000 unique users across 19,000 passenger trips per day. At a 95 percent level of confidence and 5 percent margin of error, the required representative sample size was 373. The survey covered a total of 423 respondents (accounting for 3.4 percent of total unique daily users) across six routes as described in the previous section. Seventy percent of the total population of Shuttl's users were men, and 30 percent were women. Efforts were made to reflect this distribution in the sample as well. A female surveyor was recruited to request responses from commuters who were women.

Since Shuttl operates services only on weekdays, the surveys were also conducted on weekdays. To obtain a representative sample across both morning and evening home-office-home commutes, 50 percent of the surveys were administered in the morning between 6 and 11 a.m., and 50 percent in the evening between 4 and 8 p.m. To eliminate a respondent's bias in answering the questionnaire, every third commuter in the bus was approached to fill out the survey. Prior to administering the survey, commuters were informed by Shuttl about this exercise which resulted in low refusal rates. The survey comprised 20 questions: Seven focused on user demographics, seven covered usage of Shuttl's services and the respondent's alternative mode choice had Shuttl not existed, and the remainder solicited a comparison of the user's experience between Shuttl and the commuter's alternative mode across parameters such as travel time, affordability, and gender balance. For this study, assuming that other conditions such as job, residential location, time of travel, and so on, remained constant, the alternative mode was treated as the commuters' prior mode. This assumption was corroborated by a prior-mode survey, administered by Shuttl that had similar results. The determination of prior mode choices also helped estimate Shuttl's impact on road space and congestion.

However, given constraints of budget and time and the fact that commute distances in Delhi-NCR are quite large, surveyors were deployed on six of Shuttl's B2C routes, thereby introducing certain limitations to the study.

3.3 LIMITATIONS OF THE STUDY

First, administering the survey on selective routes affects prior mode-share as it may differ for commuters from one route to the other depending on the availability of modes connecting those origin–destination pairs at different departure times. To cite an example from the sample, on the Ballabhgarh to Cyber City route, 68 percent of respondents stated that they would have taken their private cars if Shuttl did not operate on that route, 14 percent would have taken the Delhi metro, and 8 percent would have used an on-demand taxi. However, on the Crossing Republic to Golf Course Road route, 67 percent of respondents would have taken the metro, and only 17 percent would have taken their private cars. These proportions could vary across other routes not selected in the sample and therefore have an impact on both emission and congestion estimates.

Second, intercept surveys are by design time-bound (5–10 minutes) and therefore have implications for the type of people who would respond to them adequately. This was accounted for by conducting the surveys on board the bus, thereby confining the interviewee. In an effort to reflect the female-to-male ratio of Shuttl's user population in the sample, the subsamples of men and women were smaller than 373, resulting in larger confidence intervals for responses stratified by gender, which is a limitation of this sampling methodology.

Third, and perhaps most important, due to limitations of time and length of the intercept survey, information on mode used for first and last mile could not be adequately captured. The authors have been conservative and assumed that the first and last mile were walked for Shuttl, public bus, and metro. According to Shuttl, its buses drop most commuters within 500 meters of their office, making it plausible that this leg of the journey was walked when Shuttl was used. However, most office locations to which Shuttl provides transportation are, at a minimum, 5 kilometers away from the last metro stop in Gurugram. This has likely led to an underestimation of emissions for trips to Gurugram made via public transportation and, therefore, conservative estimates of Shuttl's emissions benefits. Our study also did not provide data on how the trip from or to the commuter's residence was completed when using Shuttl, public bus, or metro.

Despite these limitations, insights gained from this analysis have the potential to inform regulators and transit authorities of the value, impact, and limitations of bus aggregation services in Delhi-NCR, and these insights could support them in developing appropriate permits and regulations for these operators.

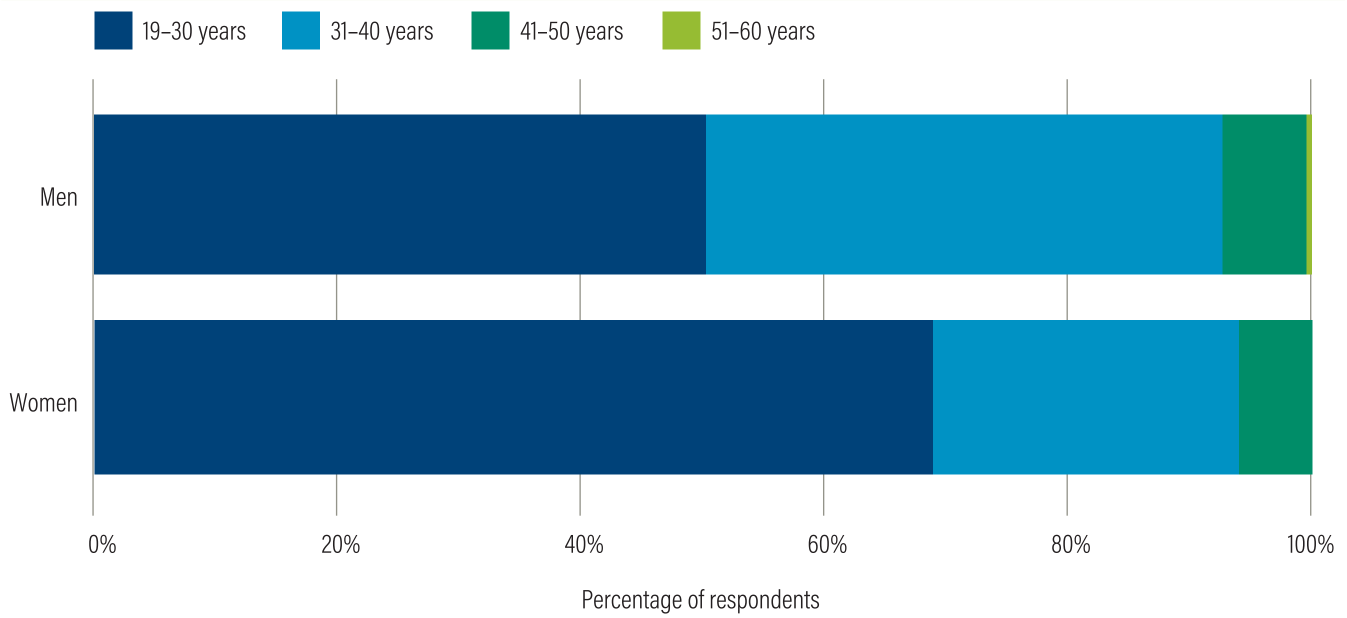
4. FINDINGS AND ANALYSIS

In this section, the authors discuss the findings from the intercept survey and the analysis of Shuttl's operations data. The findings and analysis are geared toward answering the research questions set out in the beginning of the study and focus on the socioeconomic background of Shuttl's commuter base, the commuters' alternative mode of travel in the absence of Shuttl's services (treated as prior mode), reasons for shifting to Shuttl's services, experiences of traveling via Shuttl compared to the prior modes, and the environmental impact of Shuttl's operations.

4.1 SAMPLE PROFILE

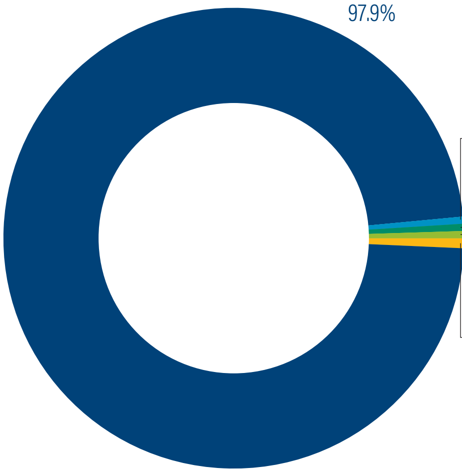
The sample of Shuttl's users surveyed were educated professionals largely between 19 and 40 years of age with disposable incomes that enable the purchase of at least one motorized vehicle. Ninety-three percent of respondents were between 19 and 40 years of age with a majority (56 percent) between 19 and 30 years of age. Of the survey respondents, 68 percent were men and 32 percent women, which corresponds to the female-to-male ratio of the population of Shuttl's users. Women between the ages of 19 and 30 made up 69 percent of the female respondents, as opposed to 50 percent of men from the same age group (Figure 7). Only 25 percent of women were aged between 31 and 40 years, as opposed to 42 percent of men. Ninety-eight percent of all respondents had secured graduate or post-graduate degrees and worked for private companies (see Figure 8).

FIGURE 7 Responses to Questions about Respondent's Age and Gender (n=423; n_{men}=284; n_{women}=138)



Source: WRI India Shuttl User Survey, May 2017.

FIGURE 8 Responses to Questions about Respondent's Education and Profession (n=423)



Source: WRI India Shuttl User Survey, May 2017.

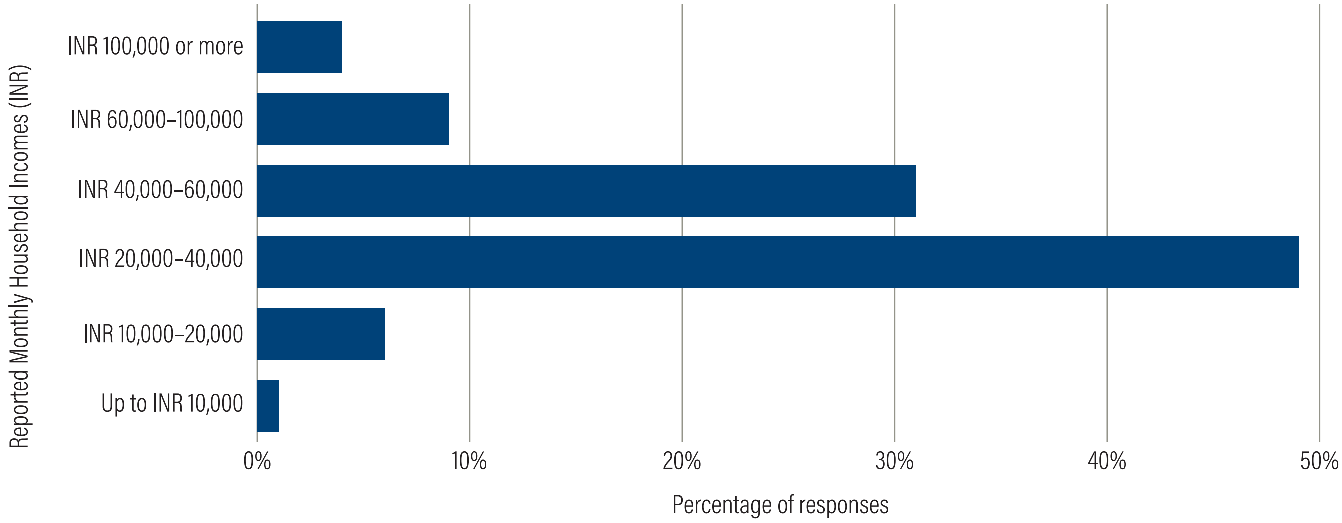
Eighty percent reported monthly household incomes between 20,000 and 60,000 Indian rupees; that is, $308–$923 (Figure 9). Six percent of the sampled users reported monthly household incomes between 10,000 and 20,000 Indian rupees ($141–$282), the lowest income band among all surveyed users. Four percent of sampled users were from the highest income bracket identified in the survey; that is, a monthly household income of 100,000 Indian rupees ($1,410) or more. If we assume mid-range values as representative of real monthly incomes, median household income across the sample is 22,500 Indian rupees, which is 8 percent more than the per capita state income at the time; that is, 20,796 Indian rupees (Shan-E-Alam et al. 2018). In addition, the high ownership of a motorized vehicle across the sample (86 percent of households owned at least one car, and 45 percent owned at least one two-wheeler) indicates a certain degree of disposable income.

Clearly, Shuttl is not for low-income groups or users of feature phones. Requiring a smartphone to book a seat and the high fare (as compared to public buses) excludes many from accessing this service. This is corroborated by the demographic profile of respondents: young, highly educated, and technology-savvy professionals with incomes from the middle percentile enabling ownership of a smartphone and a personal vehicle.

4.2 PRIOR MODE OF TRAVEL AND REASONS FOR SHIFTING

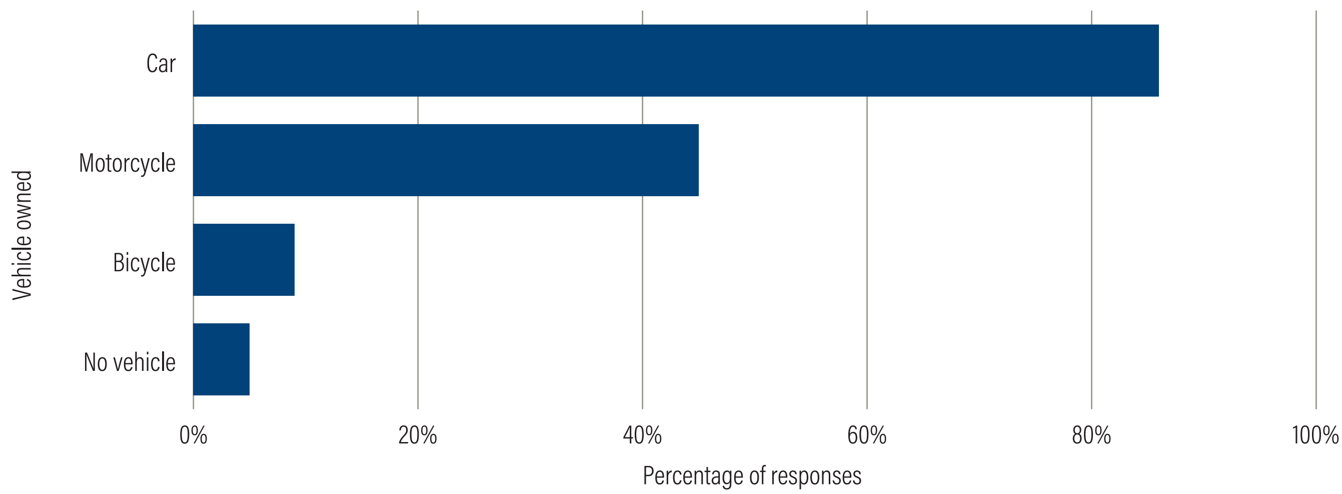
A clear majority of respondents (51 percent) would have driven to work in their private cars if Shuttl were not available (Figure 11). The second-largest shift was seen from users who would take the metro (29 percent). Further studies are needed to shed light on whether the shift from

FIGURE 9 Responses to Questions about Respondent's Monthly Household Income (n=423)



Source: WRI India Shuttl User Survey, May 2017.

FIGURE 10 Responses to Questions about Respondent's Vehicle Ownership at the Household Level (n=422)



Note: Figures add up to more than 100% because some households owned multiple types of vehicles.
Source: WRI India Shuttl User Survey, May 2017.

personalized modes to Shuttl is higher for populations that live on routes without access to the Delhi metro. Aside from the 51 percent that opted for private cars, another 16 percent opted for other car-based transportation, including on-demand taxis (9.2 percent), shared taxis (3.8 percent), carpool arrangements (2.4 percent), and taxis provided by employers (0.2 percent).

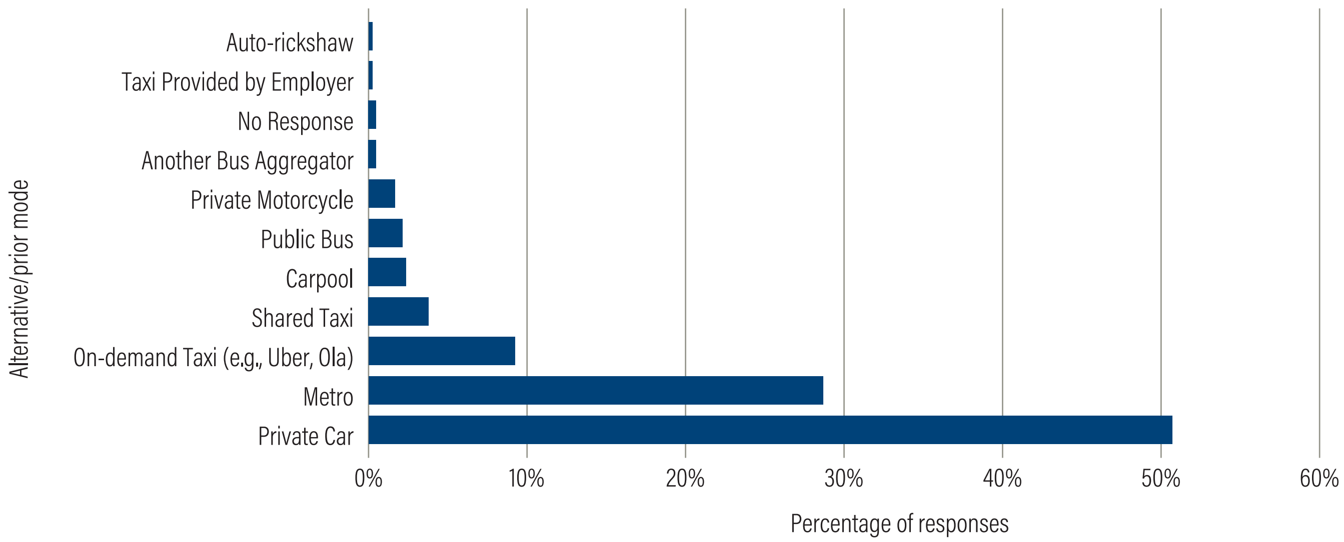
The survey showed that 99.5 percent of respondents would have made the trip irrespective of Shuttl's availability, suggesting that Shuttl does not induce new trips but rather encourages a positive shift, primarily from car-based modes (67 percent).

Interestingly, only 2 percent of respondents stated that they would have taken a public bus, suggesting that Shuttl does not necessarily compete with public bus services in Delhi-NCR. This contradicts the existing rhetoric that bus aggregators siphon off riders from public bus operators.

Shuttl's operations in Delhi-NCR illustrate how convenient, quality, and responsive bus operations can shift commuters from car-based transportation to a more efficient mode and not necessarily compete with other mass transit modes.

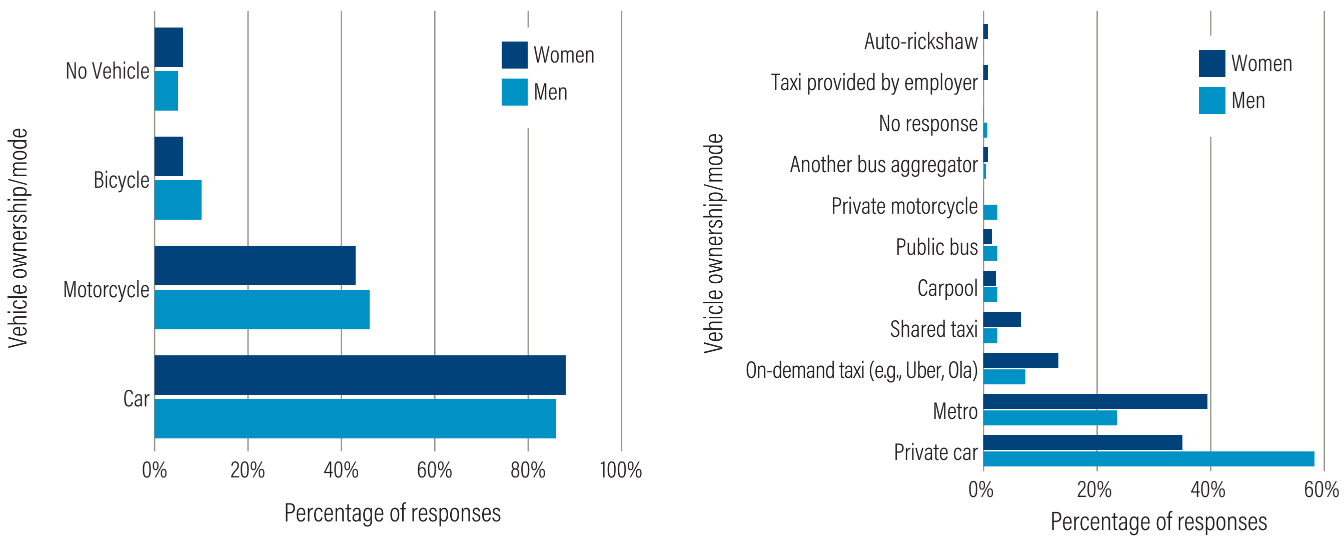
However, Shuttl does compete with metro services in Delhi-NCR since 29 percent of respondents identified the metro as their prior mode. It is also interesting to note that, despite high vehicle ownership at the household level, for many women the Delhi metro remained the preferred alternative as shown in Figure 12.

FIGURE 11 Responses to "If Shuttl Did Not Exist, How Would You Make This Trip?" (n=422)



Source: WRI India Shuttl User Survey, May 2017.

FIGURE 12 Responses to Questions about Vehicle Ownership at the Household Level and Prior Mode Disaggregated by Gender (n_{men}=285; n_{women}=137)

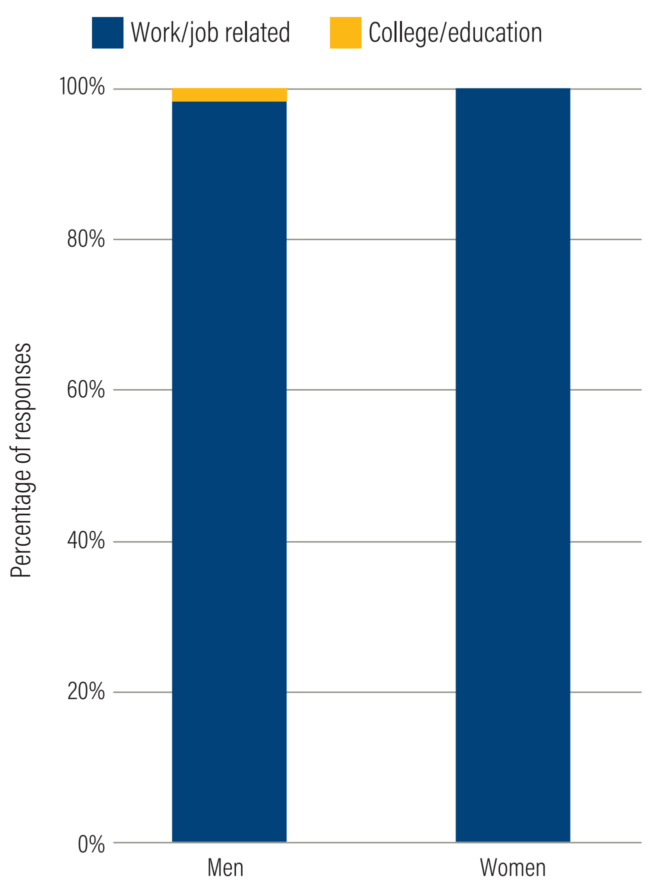


Note: In the chart at left, figures add up to more than 100% because some households owned multiple types of vehicles.
Source: WRI India Shuttl User Survey, May 2017.

While the purpose for using Shuttl was for home-office-home trips (Figure 13), the primary reason for making the shift to Shuttl for work trips was reported as reduced travel time by 38 percent of respondents (Figure 14). This was followed by safety (23 percent), affordability (17 percent), and assured seating (17 percent).

Furthermore, of the 38 percent of respondents who selected "reduced travel time" as their main reason for shifting to Shuttl, 70 percent reported that they would have driven their private cars to work, and 23 percent reported that they would have taken the metro, as shown in Figure 15.

FIGURE 13 Responses to Questions about Respondent's Purpose for Using Shuttl (n_{men}=286; n_{women}=137)

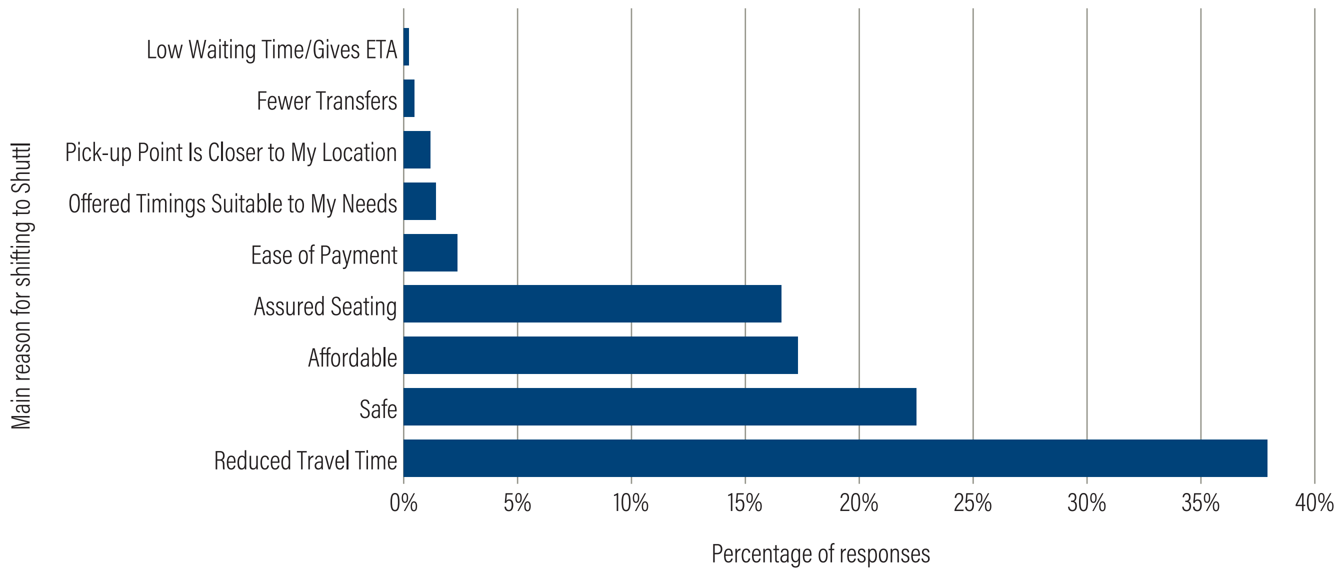


Source: WRI India Shuttl User Survey, May 2017.

However, when the authors compared reported time spent on Shuttl versus time spent on their prior mode by those stating "reduced travel time" as their main reason for the shift, many discrepancies emerged. Our analysis indicates that only 14 percent of respondents actually spent less time traveling after shifting to Shuttl. Most commuters reporting "reduced travel time" actually spent more time (41 percent) or experienced no change (44 percent), as seen in Figure 16. This discrepancy may suggest a perception of reduced travel time rather than an actual reduction in time spent traveling. This could be attributed to an individual's interactions with immediate environmental features (Parthasarathi et al. 2013) such as assured seating and a lack of crowding in the Shuttl bus, the provision of real time information (Avineri and Prashker 2006), or even the pain of driving long distances through peak-hour traffic (interviews with industry experts). It may also stem from a methodological limitation resulting in a limited ability to capture how the first and last mile was conducted for prior trips made by public transportation. This portion of the trip may well be responsible for the perceived difference in travel time.

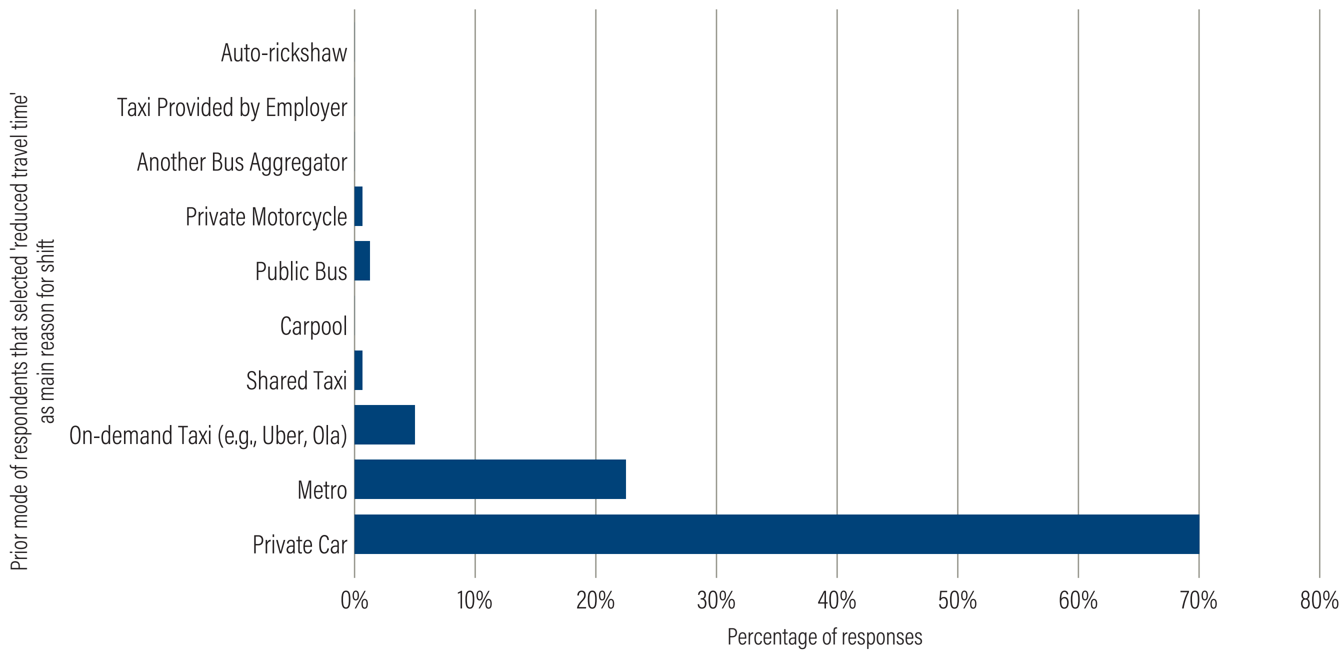
For the most part—that is, across the sample—respondents shifting from private cars reported having experienced shorter or no change in journey time (44 percent and 48 percent, respectively) (Figure 17). Commuters using on-demand taxi services saved time (59 percent). Although the survey had very few respondents shifting from the following modes, commuters that previously used auto-rickshaws (100 percent), carpool (90 percent), shared taxi (88 percent), motorcycles (86 percent), and buses (67 percent) also saved time by shifting to Shuttl. Respondents choosing metro as their prior mode had a mixed experience; people with time savings (37 percent) and a loss of time (36 percent) were comparable.

FIGURE 14 Responses to Questions about Respondent's Main Reason for Shifting to Shuttl (n=422)



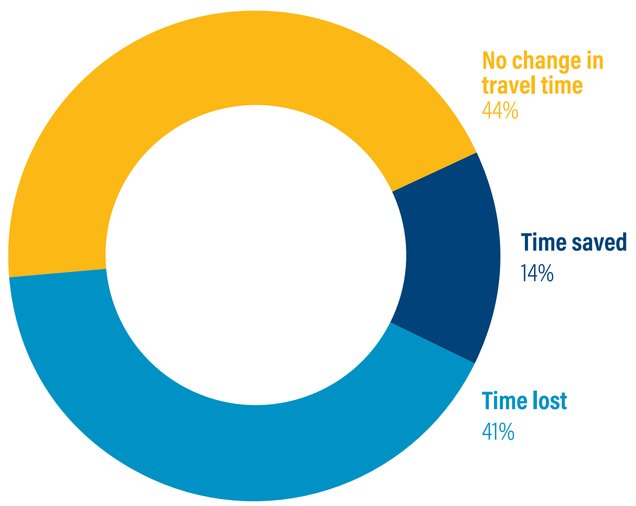
Source: WRI India Shuttl User Survey, May 2017.

FIGURE 15 Prior Mode of Travel of Respondents That Chose "Reduced Travel Time" as Their Main Reason for Shifting to Shuttl (n=160)



Source: WRI India Shuttl User Survey, May 2017.

FIGURE 16 Reported Difference in Travel Time for Shuttl and Prior Modes for Respondents Stating "Reduced Travel Time" as Main Reason for Shifting to Shuttl (n=160)

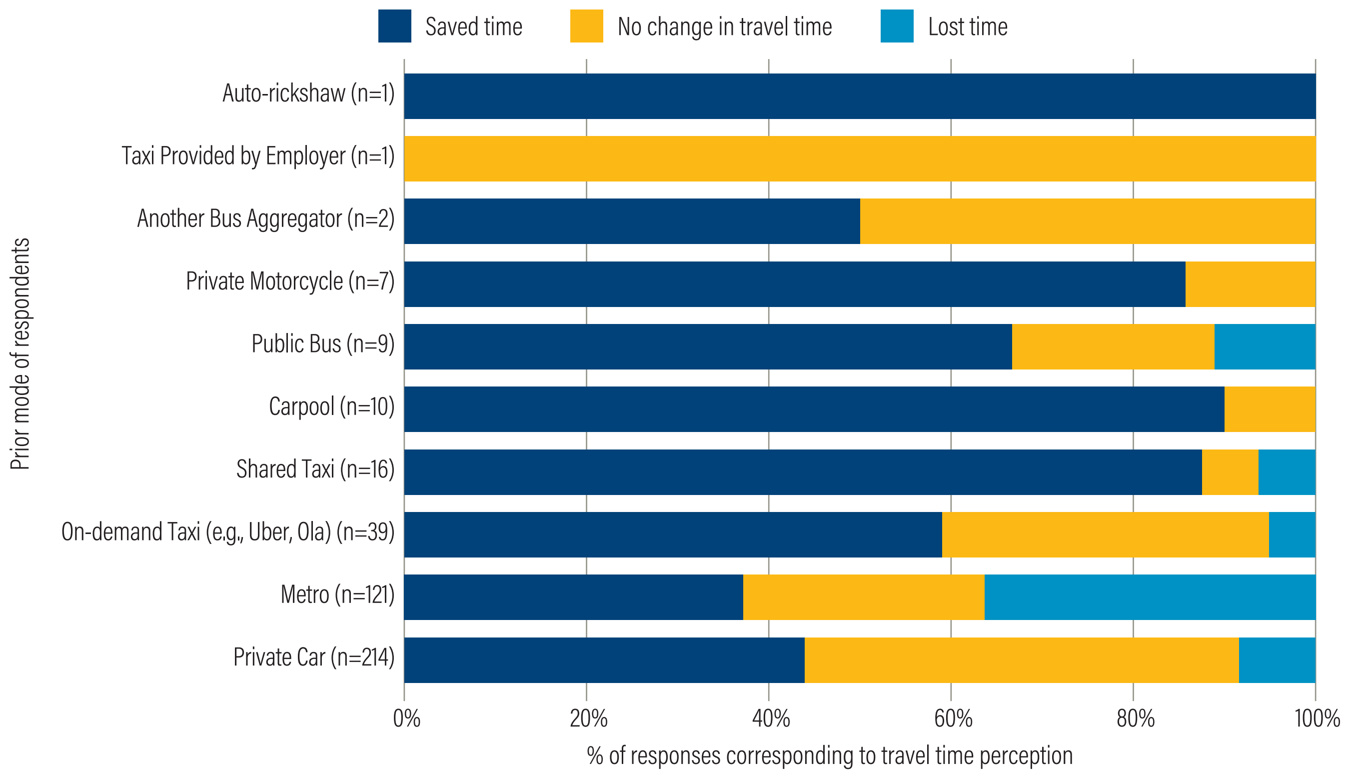


Source: WRI India Shuttl User Survey, May 2017.

4.3 USER EXPERIENCE

Questions comparing experiences of traveling by Shuttl versus prior modes yielded mixed responses (Figure 18). Prior mode was marked as more "punctual" by respondents whose prior mode was metro (60 percent), private car (71 percent), motorcycle (57 percent), on-demand taxis (46 percent), and auto-rickshaw (100 percent). This can be expected from modes with dedicated lanes and those that allow users flexibility in selection of trip times (Tiwari 2002). On the other hand, Shuttl was marked more punctual by 56 percent, 70 percent, and 50 percent of the respondents whose prior mode was public bus, carpool, and shared taxi, respectively. This response may be explained by characteristics such as the lack of real-time location data of the vehicle (Chanchani et al. 2015), multiple stages in the journey, and unanticipated detours to pick up additional passengers characteristic of carpool and shared taxi rides.

FIGURE 17 Difference in Responses to "Time Spent Traveling via Shuttl" and "Time Spent Traveling via Prior Mode" (n = 422). Responses Have Been Categorized by Prior Mode



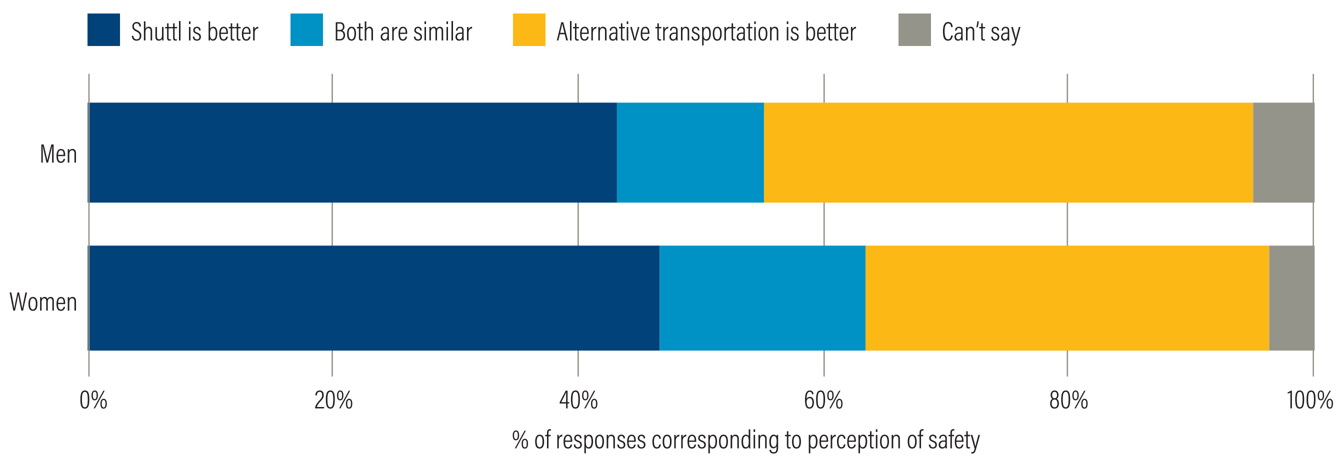
Source: WRI India Shuttl User Survey, May 2017.

FIGURE 18 Responses to Comparisons of Shuttl and Prior Mode (n = 422). Responses Are Categorized by Prior Mode. Numbers in Green Indicate Most Chosen Option

PRIOR MODE	PUNCTUALITY				VEHICLE CONDITION				SAFE DRIVING			
	SHUTTL IS BETTER	BOTH ARE SIMILAR	ALTERNATIVE IS BETTER	CANNOT SAY	SHUTTL IS BETTER	BOTH ARE SIMILAR	ALTERNATIVE IS BETTER	CANNOT SAY	SHUTTL IS BETTER	BOTH ARE SIMILAR	ALTERNATIVE IS BETTER	CANNOT SAY
Private Car (n=214)	21%	7%	**71%**	-	33%	7%	**60%**	-	37%	8%	**54%**	-
Metro (n=121)	30%	9%	**60%**	1%	39%	15%	**46%**	-	25%	19%	**54%**	2%
On-demand Taxi (n=39)	26%	26%	**46%**	3%	21%	31%	**49%**	-	33%	**54%**	13%	-
Shared Taxi (n=16)	**50%**	13%	38%	-	**50%**	19%	31%	-	**50%**	44%	6%	-
Carpool (n=10)	**70%**	-	30%	-	**50%**	10%	30%	10%	**60%**	40%	-	-
Public Bus (n=9)	**56%**	22%	22%	-	**78%**	11%	11%	-	**67%**	22%	11%	-
Private Motorcycle (n=7)	29%	14%	**57%**	-	**71%**	0%	14%	14%	**71%**	14%	14%	-
Another Bus Aggregator (n=2)	-	**100%**	-	-	-	**50%**	**50%**	-	-	**100%**	-	-
Taxi Provided by Employer (n=1)	-	0%	-	**100%**	-	-	**100%**	-	-	**100%**	-	-
Auto-rickshaw (n=1)	-	-	**100%**	-	-	**100%**	-	-	-	**100%**	-	-

Source: WRI India Shuttl User Survey, May 2017.

FIGURE 19 Perception of Safety of Shuttl as Compared to Prior Mode(s) (n_{men}=285; n_{women}=137)



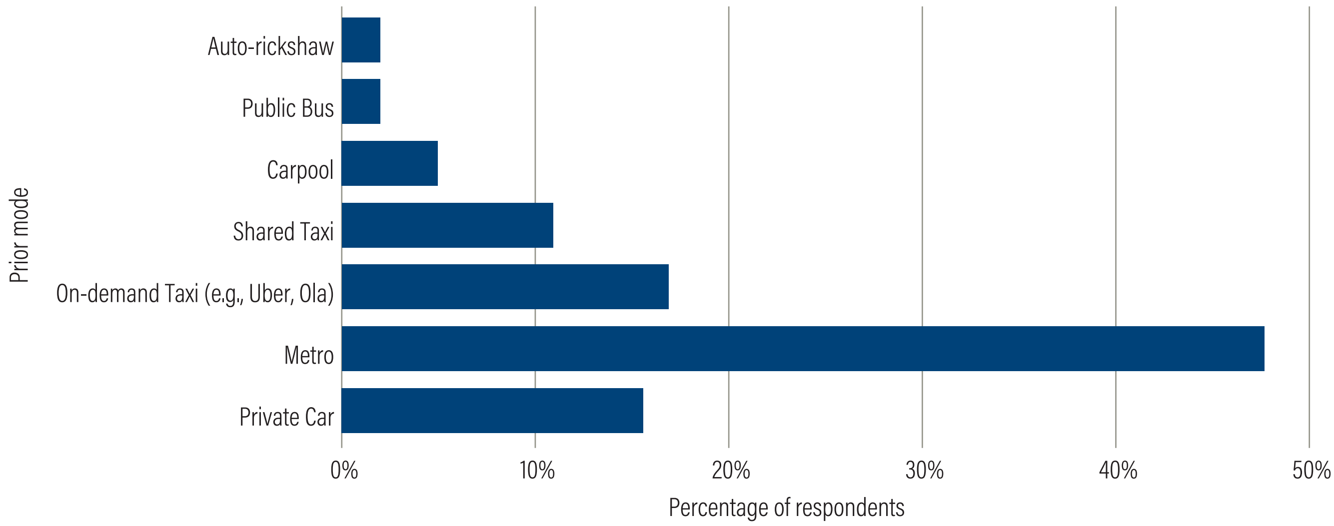
Source: WRI India Shuttl User Survey, May 2017.

Responses to vehicle condition and quality of driving follow the same trend as responses to punctuality. The notable exception is respondents whose prior mode was a private motorcycle as they identified Shuttl's vehicles to be in better condition and safer than their motorcycles.

When it came to safety for women commuters, 47 percent of women respondents reported feeling safer traveling by Shuttl than their prior mode(s) (Figure 19). Of these women, a majority (48 percent) came from the metro, followed by on-demand taxi (17 percent), and private car (16 percent) (Figure 20).

It is also important to note the responses of commuters that shifted to Shuttl from on-demand taxis. When asked to compare experiences, more commuters thought that Shuttl offered a safer experience for women in terms of the behavior of the driver and a better institutional mechanism of grievance redressal as compared to on-demand taxis. However, they ranked on-demand taxis as having better

FIGURE 20 Prior Mode of Women Who Reported Feeling Safer Traveling by Shuttl (n=65)



Source: WRI India Shuttl User Survey, May 2017.

FIGURE 21 Perception of Safety of Shuttl as Compared to Prior Mode(s) (n_{men}=285; n_{women}=137)

SAFETY	SHUTTL IS BETTER	ON-DEMAND TAXI IS BETTER	BOTH ARE SIMILAR	CAN'T SAY
Driver Behavior	**44%**	28%	28%	-
Grievance Redressal	**41%**	31%	23%	5%
Safety for Women	**59%**	-	28%	13%
Safety Features	26%	**41%**	28%	5%

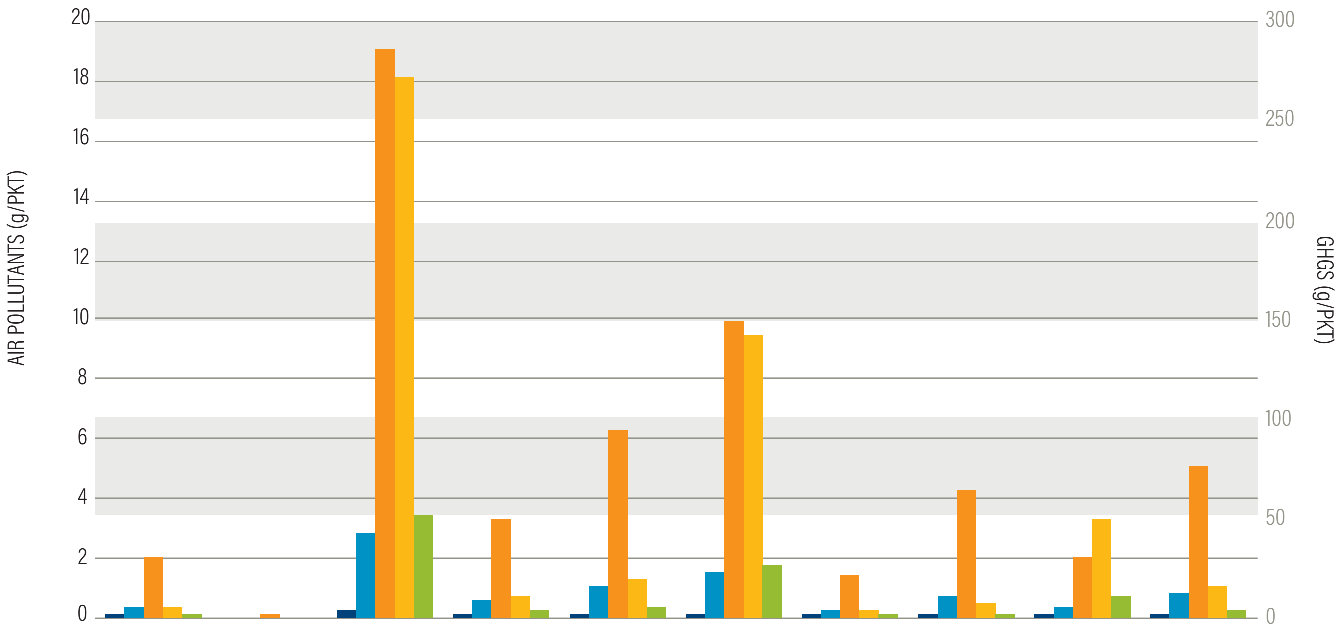
Source: WRI India Shuttl User Survey, May 2017.

safety features, such as the panic button (Figure 21). This contradiction must be studied further, but it raises the question: Do larger vehicles and the presence of other passengers increase the perception of safety? These data points can inform the ongoing debate about how bus-based travel can compete with on-demand taxis on commuter experience.

4.4 IMPACT ON EMISSIONS

Figure 22 shows the comparison of emissions from using Shuttl against each prior mode for every kilometer that a passenger travels (PKT). While auto-rickshaws, public buses, and private motorcycles produce less PM2.5 compared to Shuttl, in comparison to all car-based modes, Shuttl produces 1/10th (or less) of PM2.5 per PKT. Shuttl

FIGURE 22 Emissions of Shuttl Compared to Emissions of Prior Mode(s) (in Grams per PKT)



	SHUTTL	METRO	PRIVATE CAR	TAXI PROVIDED BY EMPLOYER	ON-DEMAND TAXI (E.G., UBER, OLA)	CARPOOL	PUBLIC BUS	AUTO-RICKSHAW	PRIVATE MOTORCYCLE	SHARED TAXI
PM2.5	0.01		0.17	0.05	0.10	0.09	0.00	0.01	0.00	0.08
NO_x	0.32		2.77	0.53	1.00	1.45	0.23	0.68	0.25	0.82
CO	0.25		18.04	0.67	1.25	9.43	0.15	0.45	3.31	1.02
VOC	0.02		3.41	0.13	0.25	1.78	0.00	0.01	0.62	0.20
CO_2	29.81	0.18	284.49	48.29	92.74	148.71	21.12	63.12.	28.67	75.88

Notes: The following assumptions inform this analysis:

1. Average trip length for prior modes = average trip length of Shuttl's vehicle trips = 40 km.
2. First and last mile was considered to be walked for trips made via Shuttl, public bus, and metro. For Shuttl trips to Gurugram, the last mile was likely walked as Shuttl drop-off points are located at the entry of major offices. However, trips to Gurugram via public transportation likely had a motorized last mile as major office locations are not easily walkable from transit hubs, resulting in higher emissions than reported here. For trips from commuter residences, our study did not provide data on how the last mile was completed for Shuttl, public bus, or metro. This is a limitation of this study, as noted in the methodology section.
3. The ratio of petrol to diesel cars in Delhi-NCR was 50:50.
4. Shared taxis, on-demand taxis, and taxi provided by employer (or employee transport vehicles) operate on diesel.
5. CNG emission factor for PM2.5 = PM2.5 factor from industrial use of CNG.

Source: WRI India Analysis of Shuttl's Operations, May 2017.

produces an amount of CO that is equivalent to a public bus (0.2 grams/PKT), which is much less than other modes. On the other hand, for NO_X, Shuttl performs poorly, compared to a public bus and private motorcycle, but favorably when compared to all other modes. Similarly, for CO_2, Shuttl produces more (29.8 grams/PKT) only when compared to a public bus (21.1 grams/PKT) and private motorcycle (28.7 grams/PKT). For all other modes, Shuttl's performance is far superior, particularly against a private car, which produces almost 10 times as much CO_2/PKT.

Given the assumptions built into the spreadsheet model and the responses to the commuter survey, during the calendar year 2017, the scale of Shuttl's operations is estimated to have avoided the emission of 14,022 tons of CO_2/year—a 70 percent reduction compared to alternative modes that would have been used (Figure 23). Other than motorcycles, public bus, and the metro, Shuttl compares favorably with every other mode.

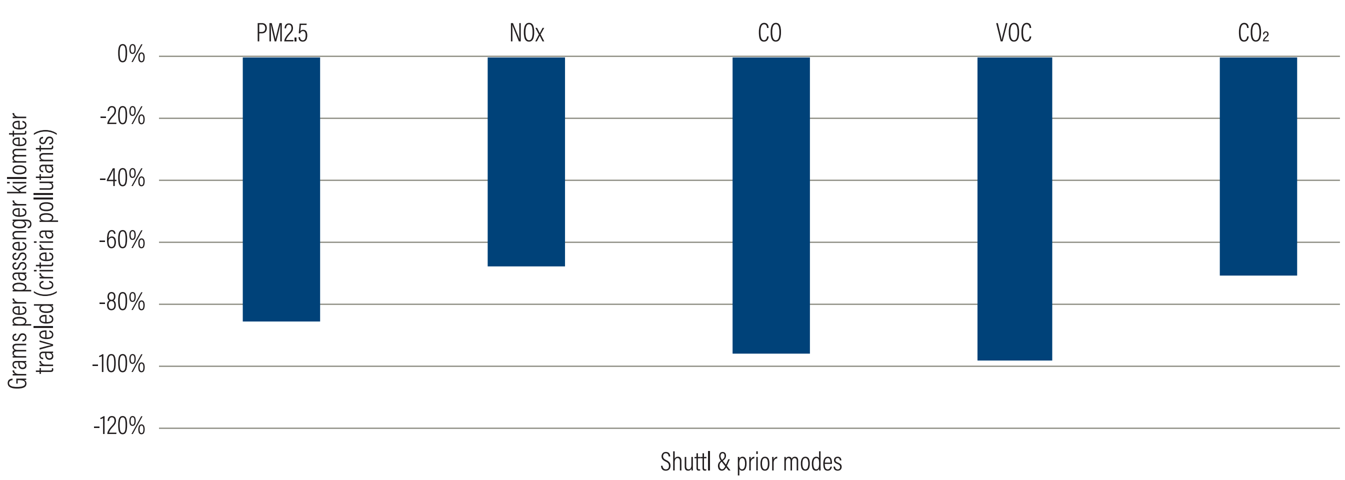
All buses operating in Delhi are mandated to operate on CNG. Shuttl has a mix of CNG (82 percent) and diesel (18 percent) buses. This is because Shuttl also operates between Gurugram and Faridabad, which are part of neighboring states, and is not required to operate CNG buses on that route. It is possible that if all buses on Shuttl were CNG, the impact of Shuttl's operations on emissions could improve further.

This study does not estimate air pollutants for the metro system; while it is true that PM and other pollutants are emitted at the source of electricity generation, the study boundary is limited to the NCR region, and within this region, the metro does not emit any local pollutants.

4.5 IMPACT ON CONGESTION

By shifting commuters from a less efficient mode (car-based) to a more efficient mode (on average 21-seaters), Shuttl has managed to remove an estimated 4,312 vehicle equivalents (PCUs or passenger car units) off the road for the peak three hours in Delhi-NCR each day (see Table 3). In a region characterized by congestion, increasing private vehicle registration, and poor air quality, shifting people from space-inefficient vehicles like cars and taxis to space-efficient vehicles like buses reduces congestion and is a significant step in the right direction. This partially corroborates the findings of the demand analysis conducted by Kawaguchi et al. (2018) for Jakarta where they estimated that a potential microtransit service could significantly reduce congestion in the city by offering more passenger kilometers per vehicle kilometers. However, it must be noted that, if private bus services are allowed to proliferate unchecked, particularly in cities without public mass transportation options, they could contribute to on-road congestion, as illustrated by the case of *matatus* in Nairobi, Kenya (Klopp 2017).

FIGURE 23 Aggregate Reduction in Emissions of Air Pollutants and CO_2 as a Result of Shuttl (Tons per Year)



Source: WRI India Analysis of Shuttl's Operations, May 2017.

TABLE 3 Passenger Car Units Potentially Removed from the Road per Day Due to Shuttl

MODE	VEHICLE TYPE	AVERAGE OCCUPANCY	NO. OF VEHICLES	PCU FACTOR	PCU EQUIVALENT
Prior Mode	Private Car	1.15	4,248	1	4,248
	On-demand Taxi (e.g., Uber, Ola)	1.18	495	1	495
	Shared Taxi	2.2	166	1	166
	Carpool	2.2	104	1	104
	Private Motorcycle	1.5	107	0.5	54
	Taxi Provided by Employer	4.0	6	1	6
	Auto-rickshaw	1.76	13	1	13
	Total (A)	-	**5,139**	-	**5,086**
Shuttl	LCV	11.17	180	1.5	270
	Bus	29.61	168	3	504
	Total (B)	-	**348**	-	**774**
Net Reduction in Congestion: PCUs off the road (per day) = (A) - (B)					**4,312**

Source: WRI India Analysis of Shuttl's Operations, May 2017; Occupancy estimates from Singh 2004; Sharma et al. 2014; IUT and CSTEP 2015; Aggarwal and Jain 2016; Transport Research Wing 2016; and industry interviews.

5. CONCLUSION

Privately operated bus-based transportation has a long legacy in India. But these services are typically characterized by extremely low quality and a widespread disregard for customer satisfaction. Combining technology to improve customer interaction, demand-responsive routing, and better reliability with higher levels of service, bus-aggregators are looking to transform this sector. But they constantly face regulatory issues, possibly due to their novelty and possibly due to the perception that they compete with state-run public transportation services.

This study, while based on the operations of a single company, suggests otherwise in Delhi-NCR. Primary data collected through intercept surveys with a sample of users of the bus aggregator Shuttl suggest that it is predominantly former car-based commuters (67 percent) that have shifted to the service. This contributes to the potential removal of 4,312 passenger car equivalents (PCUs) from Delhi's roads every day. The analysis of Shuttl's operations data shows that Shuttl avoids 14,022 tons of CO^2 per year at its current scale of operations. On a per passenger-km basis, Shuttl also compares favorably on most pollutants with most other modes that commuters would have employed for travel. In aggregate, Shuttl produces only 15 percent of PM2.5 emissions, 32 percent of NOx, 4 percent of CO, 2 percent of VOC, and only 30 percent of CO_2 that would have been emitted by vehicles that it takes off the road. These estimates suggest that Shuttl (and possibly similar aggregator services) might be good for the environment, largely because it encourages commuters to shift away from less efficient car-based modes to buses.

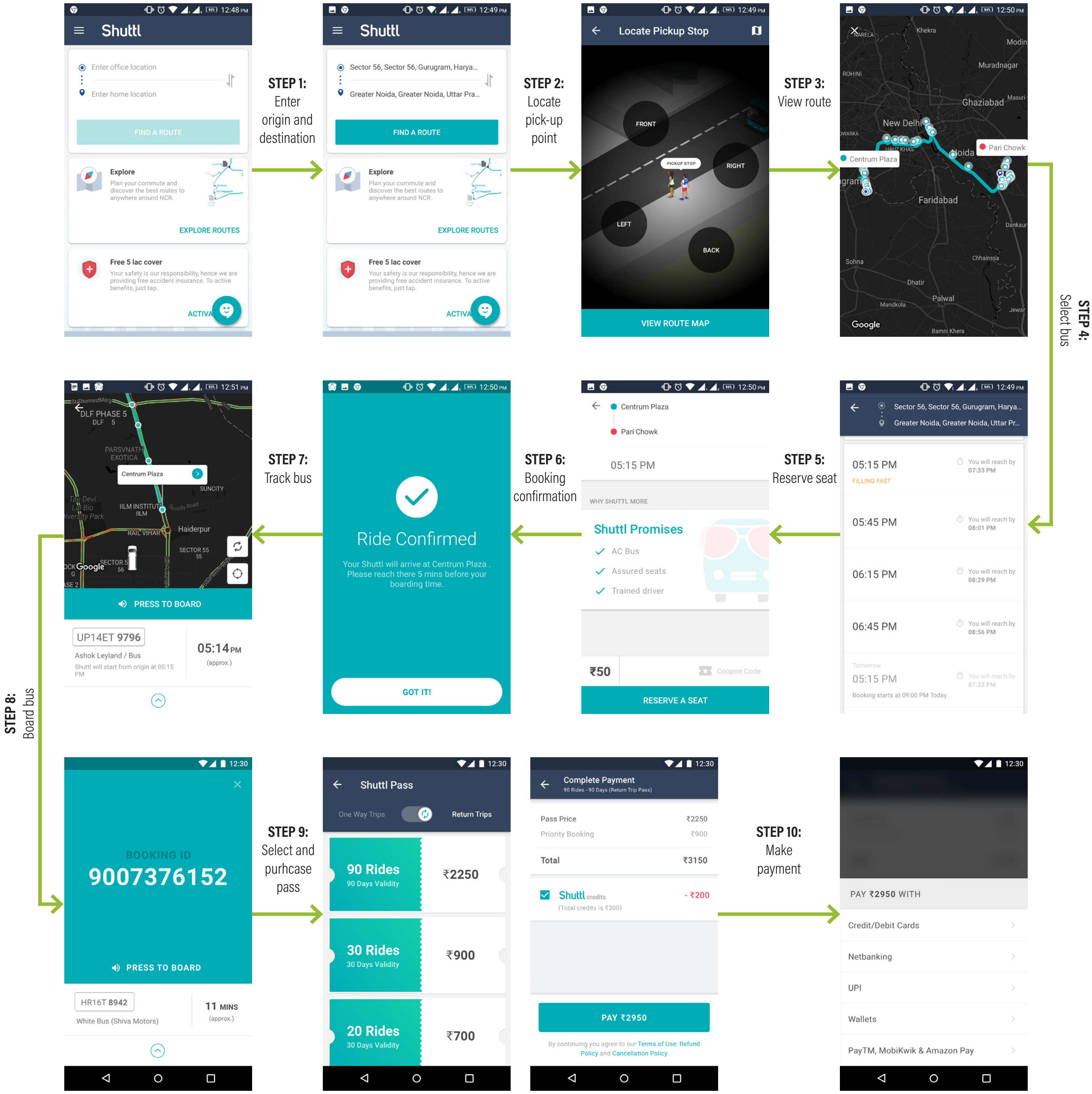
When comparing Shuttl commuters' experience with their prior mode of travel, a couple of interesting themes emerge: First, while travel time savings was reported as the top reason for commuters to shift to Shuttl (38 percent), a large percentage did not save time or experienced no change in travel time (47 percent and 37 percent, respectively) based on reported time spent in Shuttl versus their prior mode. This may be explained by a difference in perception of travel time on Shuttl as compared to their prior mode. Another possible explanation may lie in how commuters make their first and last mile trips when using Shuttl versus their prior mode, which is a question for further study. Second, a large majority of respondents thought that safety for women commuters on Shuttl was better when compared to on-demand taxis, despite better safety features on the latter. Do larger vehicles (in comparison to cars) and the presence of other passengers, particularly women, increase the perception of safety? Such questions can be critical for cities as they consider planning and regulating the transportation options available in their jurisdictions.

The public bus case is interesting. While the dominant rhetoric is that bus aggregators siphon off customers from public bus services, this study finds that only 2 percent of the sample of respondents would have traveled by public bus services in Delhi-NCR if Shuttl were unavailable. This suggests that Shuttl does not necessarily compete with public bus agencies and that bus aggregators and public transit can coexist. It would appear that bus aggregators have introduced a reliable new commuting choice for this particular segment of commuters. By combining demand response scheduling with high quality of service (assured seats, air-conditioned buses, etc.) they attract passengers largely from private cars. For many states and cities grappling with insufficient finances to augment public transportation services, these privately provided mass transit options could be a boon. While bus aggregators serve a particular segment of society today, public administrators could study their success and try to integrate them into the city's mobility ecosystem; possibly by offering different types of services for different routes and market segments.

Differentiated services are not a new concept: Public bus operators such as Bengaluru Metropolitan Transport Corporation (BMTC) have provided higher levels of service to commuters (at a higher price than regular services) successfully. While in Bengaluru, BMTC has a long legacy of operations, in those areas of the NCR where very few public buses ply, opportunities exist for partnership models that provide lasting societal benefits (Canales et al. 2017). Partnerships with privately provided mass transit vendors is not new to Delhi. The Delhi Integrated Multi Modal Transit System (DIMTS) Limited has been issuing stage carriage contracts for fixed-route, fixed-schedule services to private bus companies under its "Cluster Bus Scheme" since 2010. Today DIMTS operates more than 1,675 cluster buses across Delhi and is set to add more to its fleet but continues to have a poor track record with respect to safety (Roy 2019). However, unlike cluster buses that operate on fixed routes with fixed stops, bus aggregators deploy demand-responsive routing with dynamic stops and therefore would need to be regulated differently. Cities and transit agencies would need to think differently about what different commuter segments want and the quality of bus-based transportation services that they can access.

This study is a first of its kind in India and focuses specifically on the environmental impact of the operations of one bus aggregator by studying data from a sample of its passengers in one urban agglomeration, Delhi-NCR. The results from this study suggest that these emerging models could potentially contribute net positive benefits, but their current scale of operations is insufficient to make predictive generalizations. However, this study can inform the current debate on bus aggregators and provide an evidence base for better policymaking. But these models need to be studied further. The bus aggregators' fare is much higher than what low-income commuters can afford, and their economic impact must be understood. As bus aggregator companies continue to scale up, how would they affect land-use and rental prices in areas where they provide connectivity? By improving connectivity, would they induce sprawl? Does the use of bus aggregator services for work commutes influence the choice of mode for other trips? Additionally, what agreements might be possible for the shared use of curb space and bus stops between the city and bus aggregators? What is the financial sustainability of such models? Should cities consider integrating these demand-responsive services with the existing public mass transit ecosystem? Further research into these questions would build knowledge of these models and could help us better evaluate their impact.

APPENDIX A. THE PROCESS OF BOOKING A SEAT AND BOARDING A SHUTTL BUS



Source: Shuttl App.

APPENDIX B. INTERCEPT SURVEY

1. Route:

No of Seats: No of Men in Bus: No of Women in Bus:

DEMOGRAPHICS

2. Gender: (Check any one)

☐ Male
☐ Female
☐ Third Gender

3. Age: (Check any one)

☐ Under 18
☐ 18 – 30
☐ 31 – 40
☐ 41 - 50
☐ 51 - 60
☐ 60 and over

4. Level of Education: (Check any one)

☐ Primary School
☐ Secondary School (10th Pass)
☐ Intermediate (12th Pass)
☐ Undergraduate
☐ Postgraduate/Diploma
☐ No Schooling

5. What is your occupation? (Check any one)

☐ Government employee
☐ Private company employee
☐ Business owner
☐ Self-employed
☐ Student
☐ Housewife
☐ Retired
☐ Unemployed/Unoccupied

6. What is your monthly household income (INR)? (Check any one)

☐ Up to 10, 000
☐ 10, 000 – 20, 000
☐ 20, 000 – 40, 000
☐ 40, 000 – 60, 000
☐ 60, 000 – 100,000
☐ 100,000 or more

7. Which of the following vehicles are owned by your household? (Check all that apply)

☐ Scooter/Motorcycle
☐ Car
☐ Bicycle
☐ Other (Please specify) _______________ (blank field for entry)

8. How many times do you use the vehicle in a week? (Check any one)

☐ **SCOOTER/MOTORCYCLE**

☐ Daily
☐ 2-3 times a week
☐ Once a week
☐ Less than once a week
☐ Do not use at all

☐ **CAR**

☐ Daily ☐ Less than once a week
☐ 2-3 times a week ☐ Do not use at all
☐ Once a week

☐ **BICYCLE**

☐ Daily ☐ Less than once a week
☐ 2-3 times a week ☐ Do not use at all
☐ Once a week

☐ **OTHER** ____________________

☐ Daily ☐ Less than once a week
☐ 2-3 times a week ☐ Do not use at all
☐ Once a week

9. Email ID: ________________________________ *(If respondent wants to be informed about the results of this survey)*

TRIP DETAILS

10. In a regular week, how many trips do you make using Shuttl? (Check any one)

☐ 10 trips or more a week ☐ 2 – 4 trips a week
☐ 5 – 9 trips a week ☐ 1 or 2 trips a week

11. For what purpose do you use Shuttl? (Check more than one option if applicable)

☐ Work/job-related ☐ Household errands
☐ College/education ☐ Caregiving errands
☐ Leisure/shopping/social visit ☐ Other (Specify): ________________________

12.1. Enter Pick-up Point: __________________________________ (blank field for entry)

12.2. Enter Drop-off Point: _________________________________ (blank field for entry)

13. For which trip(s) do you usually use Shuttl? (Check any one)

☐ One-way trip (either to work or to home)
☐ Round trip

13.1. If you answered, "One-way trip" above, why so? (Check any one)

☐ Timings are not suitable ☐ Takes too long to reach
☐ Feel unsafe ☐ Other (Specify): ________________ (blank field for entry)
☐ Round trip is expensive

MODE SHIFT

14. When you use Shuttl, what is the: (blank field for numerical entry)

14.1. Distance to pick-up point or time taken to reach pick-up point: ___________Km

14.2. Time spent waiting for vehicle: ___________Min./Hours

14.3. Time spent traveling: ___________Min./Hours

14.4. Distance to destination from drop-off point: ___________Km

14.5. Cost of trip: ___________Rs

15. If Shuttl did not exist, would you have made this trip? (Check any one)

☐ Yes

☐ No

15.1 If No, why would you not have made this trip? (Check the most relevant option)

☐ No other transportation option exists

☐ Existing transportation options are unsafe

☐ Existing transportation options are expensive

☐ Existing transportation options take too long to reach

☐ Existing transportation option require multiple transfers

☐ Other (Please specify) ___________________________

15.2a. If Yes, how would you have made this trip? (Check the most relevant option)

☐ Metro

☐ Public bus

☐ Private car

☐ Private motorcycle

☐ Office provided cab

☐ Carpool

☐ App-based cab

☐ Auto-rickshaw

☐ Shared taxi/Cabpool

☐ Other __________________________

15.2b. For this alternative transportation option, what is the: (blank field for numerical entry)

15.2.1. Distance to pick-up point or time taken to reach pick-up point: ___________Km

15.2.2. Time spent waiting for vehicle: ___________Min./Hours

15.2.3. Time spent traveling: ___________Min./Hours

15.2.4. Distance to destination from drop-off point: ___________Km

15.2.5. Cost of trip: ___________Rs

16.1. What is your most important reason for using Shuttl? (Check any one)

REASONS	RANK
☐ Affordable	
☐ Reduced travel time	
☐ Safe	
☐ Assured seating	
☐ Ease of payment	
☐ Offered timings suitable to my needs	
☐ Pick-up point is closer to my location	
☐ Fewer transfers	
☐ Low waiting time/gives estimated time of arrival	
☐ Other (please specify) ____________________________	

16.2. What is your second most important reason for using Shuttl? (Check any one)

REASONS	RANK
☐ Affordable	
☐ Reduced travel time	
☐ Safe	
☐ Assured seating	
☐ Ease of payment	
☐ Offered timings suitable to my needs	
☐ Pick-up point is closer to my location	
☐ Fewer transfers	
☐ Low waiting time/gives estimated time of arrival	
☐ Other (please specify) ____________________________	

16.3. What is your third most important reason for using Shuttl? (Check any one)

REASONS	RANK
☐ Affordable	
☐ Reduced travel time	
☐ Safe	
☐ Assured seating	
☐ Ease of payment	

REASONS	RANK
☐ Offered timings suitable to my needs	
☐ Pick-up point is closer to my location	
☐ Fewer transfers	
☐ Low waiting time/gives estimated time of arrival	
☐ Other (please specify) ____________________________	

17. Comparing Shuttl with your alternative transport option (Q15.1), which would you rate higher in terms of the following performance indicators? (Check any one against each parameter)

	Shuttl is better	Alternative transportation is better	Both are similar	Cannot say	Not applicable
17.1. Punctuality					
17.2. Physical condition of vehicle					
17.3. Safe driving					
17.4. Security against theft					
17.5. Safety for women regarding harassment					
17.6. Behavior of drivers and other staff					
17.6. Behavior of other passengers					
17.7. Presence of other women passengers					
17.8. Availability of safety features: panic button, GPS tracking, etc.					
17.9. Mechanism to address grievances and complaints					

ADDITIONAL QUESTIONS

18. Do you think women face issues concerning their safety and security while commuting in NCR? (Check any one)

☐ Yes
☐ No
☐ Maybe
☐ Cannot say

19. Have you witnessed or do you know any women that have faced the following issues while commuting in NCR? (Check all that apply)

☐ Harassment
☐ Assault
☐ Inappropriate behavior
☐ Inappropriate contact
☐ Being followed

ENDNOTES

1. AngelList is an online database of start-ups set up for the purpose of assisting startups to raise early stage funding. As start-ups are allowed to create their own profiles on the website, the size of the database changes frequently. All details about the start-ups in the database are self-reported.

2. In 2016, WRI India ran a business accelerator called New Mobility Accelerator and received entries by several bus aggregator companies. In the application form and subsequent pitch sessions for the accelerator, these companies had elaborated on their business models and the challenges they were looking to solve.

3. In addition to their consumer-facing product line, some bus aggregators also offer employee transportation services to large employers, which is known as a B2B (business-to-business) model. Customer-facing models are known as B2C (business-to-consumer) models.

4. The authors decided against terming these as circular routes because of the dynamic nature of both morning and evening components of each O–D pair. Further, 70 percent of the population of Shuttl's users engaged with Shuttl for both morning and evening trips, while 30 percent engaged Shuttl only for one-way trips. The authors chose to not term these routes as circular routes also to properly account for the 30 percent that did not use the service for a round trip.

5. The Gurugram Metropolitan City Bus Limited (GMCBL) also operates buses that serve passengers in the Gurugram Metropolitan Area. Although active as a special-purpose vehicle since April 2017, the agency was officially incorporated only on September 5, 2017 (Admin 2019), several months after data were obtained for this study and the intercept survey was conducted with a sample of Shuttl's users. However, GMCBL operates only CNG buses, adding to the strength of the authors' assumptions.

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ACKNOWLEDGMENTS

We are pleased to acknowledge our institutional strategic partners, who provide core funding to WRI: Netherlands Ministry of Foreign Affairs, Royal Danish Ministry of Foreign Affairs, and Swedish International Development Cooperation Agency.

The authors would like to thank Suhas Khullar and Sunny Sharma from Shuttl for sharing data on operations and facilitating the survey. A special thanks to Sonal Karia from WRI for facilitating the data-sharing agreement process. The authors are grateful for key inputs on the environmental analysis provided by Umang Jain, Dario Hidalgo, Vivek Adhia, and Chirag Gajjar. The authors would also like to thank the brilliant external and internal reviewers: Shivanand Swamy, Onesimo Flores, Ashwin Sabapathy, Anjali Mahendra, Robin King, Amit Bhatt, Madhav Pai, Jaya Dhindaw, OP Agarwal, and Laura Malaguzzi. A special thanks is extended to Raj Bhagat and Janhavi Mane for their assistance in generating the maps used in this practice note. Finally, thanks to Zainab Kakal, Vishal Ramprasad, Sahana Goswami, and Divya Kottadiel for their insightful remarks.

ABOUT THE AUTHORS

Jyot Chadha is a senior manager with the New Urban Mobility alliance, which is housed at WRI Ross Center for Sustainable Cities.

Ojas Shetty is an Associate with WRI India's Sustainable Cities & Transport Practice.

Srikanth Shastry has been a consultant with WRI Ross Center.

ABOUT NUMO

NUMO is a global alliance that channels tech-based disruptions in urban transport to create joyful cities where sustainable and just mobility is the new normal. Founded in 2019 as an outgrowth of the Shared Mobility Principles for Livable Cities, NUMO convenes diverse allies and leverages the momentum of significant revolutions in mobility to target urban issues — including equity, labor, governance, safety and data privacy — impacted by the shifting transportation landscape. NUMO is hosted by WRI Ross Center for Sustainable Cities. For more information, visit www.numo.global.

ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

WORLD
RESOURCES
INSTITUTE

10 G STREET NE
SUITE 800
WASHINGTON, DC 20002, USA
+1 (202) 729-7600
WWW.WRI.ORG

ISBN 978-1-56973-933-1