Shifting from Driving to Riding: a study of the impacts of on-demand cab services on public transit ridership and vehicle ownership in Hyderabad, India

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Abstract

This thesis explores the effects of on-demand cab services, Uber and Ola, on public transit ridership and vehicle ownership in Hyderabad, India. India has grown to be Uber's third largest market in the world but still lacks any comprehensive policies at the federal level to regulate on-demand cab services. These services have risen in popularity and have led to the evolution of new ownership and financial models to help populations afford a car to "drive to work." This research examines the spatial effects of this rising popularity on public transit ridership and vehicle ownership in Hyderabad. This research found that there has been a shift in the proportion of on-demand cabs and cars to all vehicles from 2010 to 2016. This research also found that annual occupancy ratio along bus routes in the city has decreased from 2014 to 2016. This research found that these relationships are localized in the city. This thesis concludes by recommending further studies be carried out to understand the full extent of these effects to effectively incorporate these technologies and plan for the future mobility of city residents.

Glossary

Ride sharing - an arrangement in which a passenger travels in a private vehicle driven by its owner, for free or for a fee, especially as arranged by means of a website or app.

Ride sourcing - TNC platforms have sometimes been called "ridesharing", but transportation experts prefer the term "ridesourcing" to clarify that drivers do not share a destination with their passengers. The term "ridesourcing" means the outsourcing of rides.

Ride – hailing - Transportation from an unlicensed taxi service. Also called a "ride-sharing" service, which is a misnomer when applied to single-fare rides but accurate when referring to the carpool service that companies offer.

TNCs - In 2013, the California Public Utilities Commission defined, for regulation purposes, transportation Network Company as a company that uses an online-enabled platform to connect passengers with drivers using their personal, non-commercial, vehicles.

Cab/ taxi aggregators – Aggregator means a person, who owns and manages a web based software application, and by means of the application and a communication device, enables a potential customer to connect with persons providing service of a particular kind under the brand name or trade name of the aggregator.

*[1]On-demand cab services – the term used to encompass all the variations amongst digitally enabled, platform facilitated cab services.

Sharing economy - refers to a hybrid market model (in between owning and gift giving) of peer-to-peer exchange or peer-to-peer based sharing of access to goods and services. Such transactions are often facilitated via community-based (virtual) online services.

GIS – Geographic Information Systems is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. A geographic information system (GIS) lets one visualize, question, analyze, and interpret data to understand relationships, patterns, and trends.

Stratified Sampling - Stratified sampling refers to the type of sampling method wherein the population is divided into separate groups, called strata. Then, a probability sample (often a simple random sample) is drawn from each group.

*[1] This research employs this term.

List of Tables and Maps

Background

New digital technologies are transforming transportation and urban mobility in cities across the world. Sharing economy platforms are transforming why, where, when, and how people travel to their destinations. These digital technologies have been termed disruptors and have disrupted age old practices and patterns of travel. On-demand cabs or ride-sharing platforms like Uber, Lyft, Gett, and Ola are peer-to-peer ridesharing networks that connect riders in need of a ride with drivers looking for passengers, in real time, through a digital platform that both the riders and the drivers are registered on. These functions are coordinated through a network service (platform), which can instantaneously handle the driver payments and match rides using optimization algorithms. Sometimes, as the term suggests, the drivers pick up multiple passengers and drop them off at various locations and the riders "share a ride," which makes it cheaper for the riders.

Real-time ridesharing services use GIS (Geographic Information Systems) and global positioning system technologies on Internet-enabled "smartphones" to organize ridesharing in real time, just minutes before the trip takes place. Drivers post their trip as they drive, i.e., they make their location, movements, and destination information accessible to the platform, and potential riders request rides right before their desired departure time. Ride-matching software automatically matches riders to drivers with similar trips and notifies each party's smartphone (Nelson & Shahneen, 2012).

In recent years, ride sourcing platforms have turned transportation from a physical infrastructure into an information and informatics-based business. With the increasing number and popularity of such services in cities across the world, and particularly in Indian cities, their impacts on public

transport, mobility, livelihoods of cab drivers, livelihoods of informal transportation drivers, informal economy, environment, safety etc., are being questioned.

These digital platforms offering on-demand cab services are slowly restructuring travel patterns in our cities. By making it cheaper, easier and more convenient to travel, on-demand cab services are enhancing the mobility of residents and making it possible to live farther away from public transit options. These on-demand cab options are also available at all times of the day, whereas in most cities, public transit does not run late in the night or early in the morning. These services are also freeing up parking spaces in most cities (Utley, 2015)

This restructuring of travel patterns and new possibilities are undermining the ability of planners to predict and plan for the future of their cities. By making it possible to live farther away from public transit, on-demand cab services are undermining the power wielded by transit oriented development to steer development in a city. By making it cheaper and more convenient to travel by an on-demand cab, these services are undercutting public transit in cities and are also putting more vehicles on streets. On the other hand, these services are acting as gap-fill measures in outer lying areas which are not served by public transit in most cities. They also provide a means of additional income to drivers and offer cheaper, faster travel alternatives to riders. However, all these new patterns, densities, frequencies, origins, and destinations cannot be studied by planners to be effectively incorporated into their plans as this data generated is proprietary and is inaccessible to planners and city governments.

Transportation planning is only slowly waking up to these developments. The technological transformation of travel behavior brought about by on-demand cab services is something new for planners to consider and accommodate into planning practice. Until now, transportation systems have largely been planned, designed, and managed as physical infrastructure systems. Both supply

and demand were treated as largely static forces that could be predicted over time. The field remains focused on understanding the evolving infrastructure and urban form rather than the direct behavioral impacts of these new technologies. These high-value, high-impact innovations in transportation are coming from the private sector with little coordination or planning, and their collective impact and potential unintended consequences are not being adequately explored (Townsend, 2014). This current, ongoing re-programming of mobility isn't being engineered by planners. As the popularity of on-demand, point-to-point services increases and patterns of mobility change, governments cannot continue to invest heavily in public transport in the future without adequately understanding the changing landscape of urban mobility and user behavior.

Planners need to understand the changes these technologies are causing, in real time, to adapt and embrace newer technologies to effectively plan for a future that is not so distant anymore. Governments need to understand the implications of these technologies to prioritize spending. As these are nascent technologies and their full impacts are still undocumented and not realized, studying the impacts they are causing and monitoring them in real time becomes crucial to be able to adapt quickly. This research aims to study some of those impacts in an Indian city, Hyderabad, by comparing the travel patterns of residents from before the introduction of these technologies to after, to help understand this restructuring.

The historical Indian context:

India is the second most populous country after China. India and China are the world's most important developing countries. Together, they had more than 2.4 billion inhabitants in 2005, accounting for 37% of the world's total population (Central Intelligence Agency (CIA), 2005). While India's per-capita incomes are still quite low, they have risen considerably with rapid

economic growth in recent decades. Between 1980 and 2005, real per-capita income (adjusted for inflation) more than doubled in India. One result of higher incomes has been skyrocketing ownership and use of motor vehicles in the country. Since 1990, the total number of motor vehicles has roughly tripled in India (Ministry of Road Transport and Highways, 2003). That has led to alarming increases in traffic deaths and injuries, air pollution, noise, traffic congestion, and energy use (Gakenheimer, 1999; Vasconcellos, 2001; Pendakur, 2002; Gwilliam, 2003; Silcock, 2003).

From 1989 to 2005 India's population grew at an average annual rate of 1.7%) (United Nations, 2004). The population growth has been concentrated in cities largely due to in-migration from economically depressed rural areas. Urban population rose in India from 160 million in 1981 to 285 million in 2001, an average annual increase of 2.9% (Office of the Registrar General of India, 2001a; Padam and Singh, 2001). However, actual urban population growth probably exceeds these official statistics because there are additional, substantial transient populations in cities (often poor migrants from rural areas) that are not counted by the censuses in the country (Pucher *et al*, 2007).

The rapid growth of Indian cities has dramatically increased demand for land and travel in urban areas, thus putting enormous pressure on transport and other kinds of public infrastructure. The sheer increase in the urban population would be sufficient to generate serious transport problems. In addition, however, motorization rates have skyrocketed, thanks to large increases in average incomes. Real per-capita income has increased slightly more than twofold in India between 1972 and 2002. Income growth has stimulated large increases in private car and motorcycle ownership and use in the country (Pucher *et al*, 2007).

India does not have a national survey of travel behavior that canvasses the entire country. Travel surveys have been conducted for many of the largest cities, but they are not necessarily comparable, since they were conducted independently in each city by different firms using

different methods. Moreover, since the available surveys focus on large cities, they are not representative of the country as a whole. Thus, the information that follows should be considered as rough approximations and not used for exact comparisons (Pucher *et al*, 2007).

Generally, walking and cycling serve the highest percentage of trips in smaller cities and villages where incomes are lower, trip distances are shorter, and public transport is not available. In India, for example, the walk share of all trips falls from 37% in cities with 100,000–250,000 inhabitants to 28% in cities with over 5 million inhabitants. The bicycle share declines more sharply with increasing population size, from 26% to only 9% (Singh, 2005). As city size increases, trip length increases as well, and public transport services become more available. Higher incomes in larger cities make public transport more affordable and also enable purchase of private motorized vehicles (Pucher *et al*, 2007).

Public transport's share of travel usually rises with increasing population size. Using aggregated city-size categories, the Indian Ministry of Urban Development (2001) reported an increase in public transport share of trips from an average of only 16% in cities with 100,000–250,000 inhabitants to an average of 63% in cities with over 5 million inhabitants (Sreedharan, 2003; Singh, 2005). But there are considerable differences even within size categories. For example, public transport serves a much higher percentage of trips in Mumbai and Kolkata than in Delhi, perhaps because of the better road network and higher car ownership in Delhi. Mumbai and Kolkata also had more extensive rail systems than Delhi in 2000, at the time of the travel surveys. The recent opening and ongoing expansion of the Delhi metro will probably raise the public transport share of travel there. In 2000, however, public transport's share of trips was roughly the same level in Delhi as in the intermediate size cities of Chennai, Bangalore, and Hyderabad. For the considerably smaller cities of Kanpur and Lucknow, regular bus services are minimal, typical of the situation

of many smaller cities (Singh, 2005). Consequently, walking and non-motorized vehicles (mainly bicycles and cycle rickshaws) are far more important in those two cities, serving over two-thirds of all trips. In addition, Lucknow and many other smaller Indian cities rely on a mix of paratransit modes such as auto rickshaws, jeep taxis, and tempos (large auto rickshaws). A study by the Indian Ministry of Urban Development (2001) reported that such paratransit vehicles served an average of 30% of all trips in cities with 100,000–250,000 inhabitants, more than four times the 7% share in cities with more than 5 million inhabitants (Singh, 2005) (Pucher *et al*, 2007).

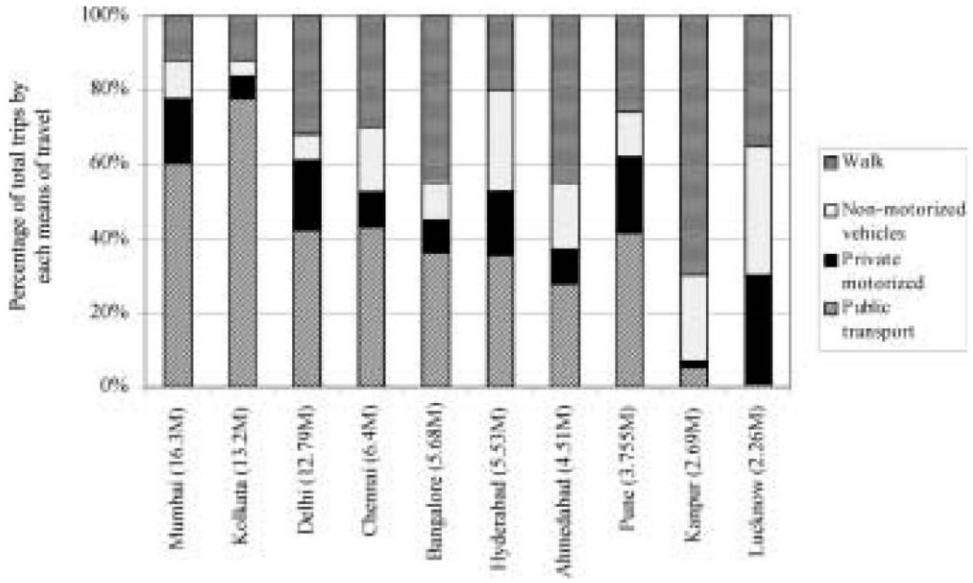


Figure 4. Percentage distribution of urban trips by means of travel for selected Indian Cities, 2002. *Sources:* Pendakur (2002) for Mumbai, Delhi, Bangalore, Ahmedabad and Kanpur; and World Bank (2002) for Kolkata, Chennai, Hyderabad, Pune and Lucknow

Source: Transport Reviews, Jul2007, Vol. 27 Issue 4, p379-410, 32p, 1 Chart, 10 Graphs Graph; found on p385 (Pucher et al, 2007).

The most dramatic transport development in India has been the striking growth in private motorized travel, especially by car and motorcycle. The best available indicator of that trend over time is the level of ownership of such vehicles. In India, the fastest growth has been in motorcycles and motorscooters. From 1981 to 2002, the total number of motorized two-wheelers rose from

fewer than 3 million to 42 million in India—a 14-fold increase (Ministry of Road Transport and Highways, 2003).

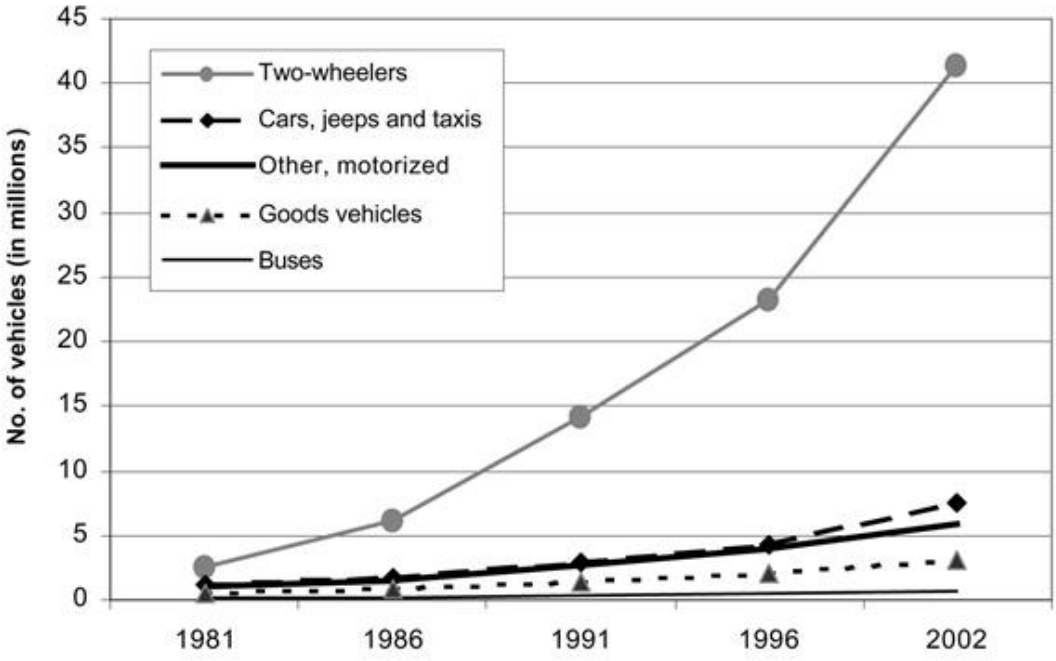


Figure 5. Growth of India's motor vehicle fleet by type of vehicle, 1981–2002 (in millions). 'Others' includes tractors, trailers, motorized three-wheelers such as auto rickshaws and other miscellaneous vehicles that are not separately classified. *Source:* Ministry of Road Transport and Highways (1999, 2000, 2003)

Source: Transport Reviews, Jul2007, Vol. 27 Issue 4, p379-410, 32p, 1 Chart, 10 Graphs Graph; found on p387 (Pucher et al, 2007).

Although motorcycles and motor scooters account for most of the recent growth in motor vehicle ownership, worldwide attention has focused on the rapid growth in private car ownership over the past two decades. From 1991 to 2003, the number of cars per 1000 population in India more than doubled, rising from about three to more than seven (National Bureau of Statistics of China, 2003; Ministry of Road Transport and Highways, 2004). Car ownership was once concentrated among the political and economic elite in India, but it has been increasingly spreading to the middle

classes as well, since the car is a hugely popular consumer item and prestige symbol in the country. However, national aggregate statistics hide the variation in car ownership among regions and cities. Car ownership and use declines in intermediate size cities with lower incomes, and is even lower in small cities and villages, accounting for only 3% of trips in cities with populations between 100 000 and 250 000. (Pucher *et al*, 2007).

The current Indian context:

Ola was launched in India in late 2010 (Tambi, Chauhan, & Kalbalia, 2015) and Uber in 2013. India, the country of 277 million Internet users, which barely registered as a blip in the global market for cab aggregators (in terms of rides) in the first quarter of 2014, grew into the third biggest market after China and North America in the first quarter of 2016, and is continuing to grow (Chakraborty, 2016). India is also Uber's fastest growing market (Chakraborty, 2016).

In India, these services grew rapidly in popularity to include collaborations between the digital platforms and car dealerships, and with banks to provide financing for people to buy cars to ply as on-demand cabs. This is enabling a wider population from lower income groups to be able to afford a car, or to lease one, while simultaneously decreasing people's dependence on private cars and personal chauffeurs. By normalizing its use and acceptance, on-demand cab services are making it socially acceptable to not own a car and to share a ride with strangers, which is not so different from using public transportation in its essence. Owning a car is no longer celebrated as a defining milestone amongst many Indians, especially millennials (Ghosh, 2015). In a country where public transportation is looked down upon as a poor man's mode of transport and owning a vehicle is a symbol of economic and social standing, on-demand cab services are altering the perceptions of ownership and the implicit social stigma associated with public transportation. The digital

platforms are also transforming the notions of work, and this raises questions of what it means to drive-to-work and calls for a re-examination of the basic notions of work and travel.

On-demand cab services in India are fundamentally different from on-demand cab services across the world. Uber, a global digital platform, adapted aspects of its business model and operations to suit the Indian market. In India, driving an on-demand cab does not supplement income, it is the primary source of income for most drivers. Drivers registered on these platforms do not just drive part-time, they do so full-time, as their primary occupation. In India, the cars registered on these platforms are not re-purposed, underutilized assets that people already own, but are newly bought assets to serve as on-demand cabs (Karnik, 2017). This capital investment makes these platforms and the digital market they provide extremely valuable to on-demand cab drivers in India. In India, Uber and Ola accept cash payments which is a significant departure from Uber's global workings. This initiative stemmed from the Reserve Bank of India's (RBI) two-step authentication process required for online transactions, wherein a cardholder enters the card details and has to enter a one-time verification pin sent to their registered phone number to authenticate the transaction. Uber and Ola also allow for requesting a ride by dialing a number on the phone, like a traditional radio-cab; through their webpage (as opposed to the app); and allows a user to request a ride for another person (Deccan Chronicle, 2016). While considering the digital divide, this move makes on-demand cab services accessible to a larger population in India, as a majority of Indians do not own smartphones or credit cards and do not trust mobile payments.

All these factors have helped on-demand cab services gain popularity and momentum in India. This growth was also aided by the lack of any regulations passed to control or steer the growth of these services in India. In India, road transport is included in the State List of the Seventh Schedule of the Indian Constitution, "thereby placing road transport primarily in the [legislative] domain of

State administration." The Motor Vehicles Act, 1988, a central law that regulates road transport vehicles, requires specific permits for transport vehicles, and stipulates various conditions and requirements for holding such permits. In addition, the Act grants state authorities the power to issue rules regulating taxis. In exercising this power, state governments have established radio taxi systems, which regulate the operation of traditional radio taxis. India does not currently appear to have a national law specifically tailored to regulate digital aggregators such as Uber; however, attempts to develop one are underway. In mid-October 2015, the country's Ministry of Road Transport and Highways issued nonbinding guidelines for states to regulate companies such as Uber and Ola, which identify themselves as "on-demand information technology-based transportation aggregators." In addition, draft legislation, the Road Transport and Safety Bill, 2015, which is still in its consultation stage, contains provisions regulating IT-based transportation aggregators, including a statutory definition of such entities (Goitom, 2016). Due to a lack of clear directive from the federal government, states and cities have taken it upon themselves to regulate these services within their jurisdictions as they see fit. This ranges from banning these services in city centers to absolutely no regulation. But the federal government is in the process of finalizing the bill outlining the regulatory framework to legalize these services in India (Bloomberg, 2016). Since India has not yet adopted policies to regulate these services, it is important to study, analyze, and understand the structural changes these services have brought about in Indian cities in formulating regulatory framework.

The current Hyderabad context:

Hyderabad is the capital of Telangana state in southern India. However, currently, it is the joint capital of both Telangana and Andhra Pradesh states. Hyderabad is a city of about 7 million people and 5,000,000 motorized vehicles coexisting in 251 sq. mi. (Didyala, 2016). The city of Hyderabad

is divided into five zones: South Zone, East Zone, West Zone, North Zone and Central Zone. Each zone is further divided into circles, eighteen in total. The circles are subdivided into 150 wards, each with around 36,000 people in 2007 (The Hindu, 2007).

The primary modes of public transportation in the city are a network of buses, which are owned and operated by the state, and a suburban rail system called the MMTS (Multi-Modal Transport System). It is a joint partnership of Government of Telangana and the South Central Railway, a federal body, and is operated by the latter. Buses along some routes, along the main arterial roads ply all night while the others retire from service from 11 pm to 5 am. The MMTS also suspends service from 11pm to 5am. The first phase of an elevated metro rail system is currently under construction and is slated to be operable by 2018.

The primary mode of transportation in the city however, is by private vehicles, either cars or motorbikes. These vehicles are registered by zone, with the regional transport authority. The state does not yet have a category for on-demand cabs and lets them be registered as cabs, with a commercial license. The other cabs that were in existence prior to the introduction of these on-demand cabs are the radio-cabs, which were primarily used for travel between the airport and the city. There are no other special regulations on cabs in the city (excluding taxation). There is also a semi-informal network of three-wheel auto rickshaws.

Hyderabad is currently the joint capital of two states, following their bifurcation in 2014. It will remain so until 2024, while Andhra Pradesh builds its new capital. The responsibility of governing of the city falls on the newly created state of Telangana. However, since it is new, and since most functions and services within the city are still tied to both states' operations, this makes establishing clear ownership of data and accountability difficult. This process is also not helped by the fact that AP state government is constantly in the process of migrating as they try to shift their staff,

administration, and operations to their new capital and surroundings, in their state (Indian Express, 2016). This could also be a reason for the lack of any regulations pertaining to on-demand cab services in Hyderabad. On-demand cab services like Uber and Ola entered this automobile-centric city during a shift of political power and have led to shifts in mobility patterns of the city residents.

Research Questions

This research aims to investigate if on-demand cab services affect public transit ridership and vehicle ownership patterns in Hyderabad, India by comparing the travel patterns in Hyderabad from before the introduction of on-demand cab services to after, and looking for any unanticipated changes in these patterns. This research aims to establish the relationship between public transit ridership and vehicle ownership before the introduction of on-demand cab services, to after and investigate any unanticipated changes in this relationship.

The research is based on the hypothesis that as on-demand cab services gain popularity and increase, vehicle ownership declines. In some cases public transit ridership declines.

The research then aims to investigate how these effects are spatially distributed across the city and compare the spatial patterns of public transit ridership before the introduction of on-demand cab services to after. The research aims to establish the spatial relationship between public transit ridership and on-demand cab services, if any, based on the hypothesis that these effects are distributed unevenly across the city.

Literature Review

Ride sharing technologies, ride sourcing platforms, on-demand cab services are all relatively nascent technologies and new concepts. Their long-term, far-reaching social, cultural, economic, behavioral, environmental, and political ramifications are unrealized yet and thus, undocumented.

The studies on their potential are limited, as are the studies on their workings and its understanding by the world at large. The existing studies, in the first markets these technologies operated in have noticed some patterns and effects on mobility due to these platforms. But these effects are not universal and in different countries the effects have been felt differently, and different countries and different cities have regulated these technologies differently, resulting in even more localized effects.

As these technologies are now ubiquitous, their impacts are also being felt in Indian cities. India lacks up-to-date, in-depth, reliable studies on mobility patterns to begin with, given the extremely complex realities of data collection, high percentage of informal trips made, and the share of the informal economy. The digital technologies phenomenon is relatively new in India, and finding rich data or existing studies on an on-going restructuring is highly unlikely.

The most recent transportation study carried out in Hyderabad was in 2011, titled Comprehensive Transportation Study - Hyderabad Metropolitan Area**,** (LASA, 2011) and was the feasibility study for the elevated metro rail system which is now under construction. This study predicts travel demand up to 2041 and models different scenarios. This study predicts that as population increases, so will land consumption, vehicle ownership and travel demand in the city. The masterplan of the city and development has been based on this study. However, this study does not consider on-demand cab services as these services were not as prevalent in Hyderabad in 2011. The study also

does not consider local residents as stakeholders and with the introduction of on-demand cab services and changing stakes for the residents in developing mobility, this study presents outdated views and stakeholder perspectives. This study, though helpful in understanding the development patterns of the city, is outdated and following the bifurcation of the state, development priorities have changed.

So, this research looks to decade old studies on mobility patterns in India, like Singh, S. K. (2005) and World Bank (2002), which do not factor in these disruptive technologies either, to predict the future of transportation in India, and studies carried out in other cities across the world, which are contextually similar to Hyderabad, and relies heavily on news articles and press releases for updates to the service in India, and to study the impacts of these technologies.

Shontell (2015) reports the vision the CEO of Uber has for the future of urban mobility of the world which is to put an end to the ownership of private vehicles, with everybody riding to their destination in driver-less cars of the future and Burns (2013) offers alternatives to private vehicle ownership to promote sustainable transportation, while Luoma, Sivak & Zielinski (2010) discuss the future of vehicle ownership in 2025 and interesting they conclude that in the Indian cities they studied, there would be an increase in personal vehicles used for leisure traveling. Though this study was carried out before the wide spread introduction of on-demand cab services, it showcase a different anticipated vision for the future. This view is shared by UBS, in their report titled "What Is the Scope of the Sharing Economy?" published in 2016, which believes that due to the societal importance and class privilege associated with owning a car in India, services like Uber may not deter Indians from wanting to own vehicles in the long run. However, there are studies which claim that there has been a decrease in vehicle ownership in cities, especially amongst millennials, and this a view shared by auto manufacturers for the future (Ghosh, 2015). These contrasting views

highlight the lack of understanding of the long-term impacts of these services on cities and ownership patterns amongst residents and the pressing need to study and analyze these patterns and resultant impacts.

With the wide-spread usage of these technologies, their impacts on environment, congestion, pollution, ridership, sustainability have been questioned. However, various studies like that by Wright and Nelson (2014), though discusses the viability of ride-sharing to alleviate congestion and parking problems around large commuter stations in the UK, the article alludes to the fact that these services actually promote public transit ridership by providing last mile trips, like Uber is claiming to in its study in cities across the world (Uber, 2016). This just reiterates the fact that the full potential of these technologies and their impacts are yet unknown. This has also been noticed in cities across the world, by the study carried out by Shared-Use Mobility Center for APTA. It will be interesting to see if the same patterns hold true in the Indian context, and what this could mean for the future of Indian public transit. But there are no recent studies, and this research methodology does not include surveys to gather such data.

The research also looks at other studies carried out using the on-demand cabs data as this potentially informs the data gathering section of the methodology while also looking at studies and news articles that provide information on how the world understands the app to work as this would be critical to collecting data using the app.

Li, Zuh, Gao, Chen, Ren, Yu, & Hu (2013) and Kotzanikolaou, Patsakis, Magkos, & Korakakis (2016) present methodologies to extract location data of users of a location based app, to gather supply side data (number of cars you see on the app) and possible demand data (when a user goes offline). Though this could be a very rich method to gather all required data, the current Terms of

the service provider platforms now explicitly prohibit the extraction of data from their platforms or apps using scripts. The findings from these studies, using these methodologies, and the conclusions drawn informed and validated the methods chosen for data gathering in this research. Similarly, Chen, Mislove & Wilson (2015), extract location data from Uber's platform to explore how surge-pricing works, by running scripts to ping the Uber server to get location data, and counts of cars and users to determine supply and demand volumes in Midtown Manhattan and downtown San Franisco. This study too reinforces the validity of the methods adopted in this research and findings, ultimately. Interestingly, a study by Shared-Use Mobility Center for APTA uses surge pricing as a proxy for demand, the logic being that if the demand volume is high, there will be fewer available cars and longer wait times, thus driving up surge pricing.

Also, the study carried out by Shared-Use Mobility Center for APTA, found that frequent on-demand cab users owned fewer cars and postponed buying a car than their non on- demand cab users' counterparts. A similar study carried out by Sivak and Schoettle (2011, 2012), also supports these findings by comparing the number of new driver's licenses issued each year in the state of New Jersey, the logic being that every year teenagers apply for driver's licenses as they turn sixteen, and this number has seen a steady decline over the years and the authors attribute it to the lifestyle changes associated with using on-demand cab services. Similar studies have also been carried out using surveys as a data gathering tool and the findings are similar. Similar studies have not been carried out in India and this would be an interesting comparison to make if the data is available.

Though there have been claims that the cars seen on the Uber app don't really exist and are just a design gimmick, Heisler (2015), Uber later released a statement clarifying this and dismissing the claims. The claims were also disproved in the study carried out in midtown Manhattan by Chen,

Mislove & Wilson (2015). This is important to this research methodology as the data collection is based on noting the number of cars visible on the app. And finally the study looks at studies and articles that discuss the role of the planner in shaping the technological restructuring in transportation like Goldwyn (2014), which discusses the current and future roles of the government, planning agencies, planners, and private sector in the development of new digital platforms, like apps, to keep up with the changing trends.

Public agencies are inextricably involved in urban transportation and should be involved in the development of technologies that affect how we move through our cities. Cities and states build, repair, and maintain roads, provide bus and rail service, and regulate taxis. Transportation service are critical to cities because they provide access to jobs and schools and take place on crowded city streets. They need careful monitoring. The restructuring of travel patterns and new possibilities of travel and modes are undermining the ability of planners to predict and plan for the future of their cities. By making it cheaper and more convenient to travel by an on-demand cab, these services are undercutting public transit in cities and are also putting more vehicles on streets. On the other hand, these services are acting as gap-fill measures in outer lying areas which are not served by public transit in most cities. However, all these new patterns, densities, frequencies, origins, and destinations cannot be studied by planners to be effectively incorporated into their plans as this data generated is proprietary and is inaccessible to planners and city governments.

Since On-demand cab services are still relatively a new phenomenon in most cities, their effects have not been studied fully. There have been studies on the effects of on-demand cab services on public transit ridership and their effects on vehicle ownership, but there have been no studies yet on the effects of on-demand cab services on both public transit ridership and vehicle ownership.

As the data produced through using these services is proprietary, the studies have employed different methods to gather this data, primarily through user/driver surveys or through scraping and extracting the data from these platforms. There have been some studies carried out by various city governments which were given access to this proprietary data, and had to comply with the company's data non-disclosure policies. There is a clear lack of precedent and immediate need to collect operational data about on-demand cab services to objectively and comprehensively study their patterns and impacts on cities.

To understand how cities and on-demand cab services may work together to better serve city residents, this research looked at the City of Altamonte Springs, FL, and at Philippines as case studies.

After losing Federal funding for a feeder bus system, in March 2016, the City of Altamonte Springs, FL, decided to pilot a one year public-private partnership with Uber by subsidizing its residents' trips in the area by 20%. The city hoped to promote ridership on the local commuter rail, SunRail, and offered 25% discount on trips to or from a railway station. (Woodman, 2016). This is one amongst the many examples of City governments entering into contracts with Uber, a private company, to provide a primary means of transport to their citizens. However, as noted by the author, this move has left many marginalized populations out of the benefits of this partnership, like the digitally challenged or the physically challenged.

In a similar but more nuanced approach adopted by another city in Florida, Pinellas County, offers its poorest residents a certain number of free Uber rides between 9 pm and 6 am, in a move to spread the benefits of such partnerships to marginalized communities.

Philippines was the first country to adopt nation-wide regulations to legalize on-demand cab services across the country. The country created a special category for on-demand cab vehicles requiring a 6 step licensing and permitting process (Alba, 2015). These examples show some of the possible options India could adopt, however, these policies have not been in existence long enough to measure their impacts to help choose the best option moving forward.

Methodology

Hypotheses: As on-demand cab services gain popularity and increase, vehicle ownership declines. In some cases, public transit ridership declines. These effects are distributed unevenly across the city.

The methods adopted in this research were determined by the nature and availability of the data and this has influenced the findings and the conclusions drawn in this research, and subsequent recommendations. This is a limitation of this research.

Data, Methods adopted, and Limitations:

The primary limitation of this research is that the data needed to analyze these relationships either does not exist or is proprietary. The data that does exist is incomplete, either in terms of time or in terms of information. There is also a lack of clear understanding and agreement upon geographic boundaries. No digital formats (shapefiles) of these boundaries are publicly accessible.

In Hyderabad, as previously mentioned, the city buses fall under the purview of the state government, the MMTS under the federal railways body, and city vehicles under the city roads and transport agency. These bodies have different geographic jurisdictional limits, different

funding and budgeting systems, and thus, different ticketing and data collection mechanisms, and at different scales. This is another limitation of this research.

Vehicle ownership: In Hyderabad, vehicles are registered with one of the five zonal Road Transport Offices, based on which zone one's home address falls under. As this was the smallest geographic scale this data could be aggregated at anonymously by the city agency, this is the scale of comparison adopted in this research to be able to compare vehicle ownership, public transit ridership, and on-demand cabs distribution in the city. Though a more granular scale data, at the ward level for example, could shed light on more localized trends, it could undermine the anonymity of aggregated data and could lead to the identification of individual vehicle owners and their personal details. Therefore, this data was not sought after in this research. However, the city agency may work on aggregating just the number of different types of vehicles to provide a more granular view of the city situation while protecting the privacy of city residents. The city agency may also undertake similar studies to eliminate privacy concerns and provide information on the number of vehicles registered.

In Hyderabad, upon the purchase of a vehicle, to register it with the zonal city agency a one-time, life-time road tax is to be paid. So, at any given point in time, the city agency has no idea how many of those vehicles that have been registered are actually functional or how many of them have been destroyed, since there is no system of deregistering vehicles. So, as time goes on, the absolute number of vehicles registered in the city only increases. Therefore, to make sense of the number of new vehicles being registered, this research examines the types of vehicles registered as proportions of all vehicles registered to identify any shifts in the type of vehicles being registered.

Though the absolute number of functional vehicles at any time would be more useful to understand the real number of vehicles on the streets, the city has no system to keep track of these numbers.

The city is however, in the process of debating an automatic deregistration of vehicles that are 15 years or older. However, this method yet again does not account for transfer of registration to another state, or zone, or destruction of the vehicle. This is another limitation of this study.

To overcome this limitation, this research thus examines the proportions of different types of vehicles registered to the total number of vehicles registered in different zones.

Bus ridership: In Hyderabad, on a city bus, a bus conductor goes from passenger to passenger and issues tickets as paper tickets with predetermined fares to the passengers, based on distance or number of stops, by tearing them off a stack of printed tickets. This method does not allow for ridership data at a bus stop scale to be collected. Thus, the bus ridership is calculated as annual occupancy ratio which is the ratio between the amount of money made from ticket sales to the amount of money spent by the agency to run that bus route (assuming that at 100% occupancy the agency breaks even on that bus route).

In Hyderabad, monthly joint bus and MMTS passes are also issued. These bus and MMTS passes are again issued non-digitally. As there is no system of swiping the card to get on the bus or MMTS, there is no record of these frequent users using public transit specifically. This is another limitation of this research. This research and the data available do not take into consideration these most frequent public transit users as there is no way to count or track their usage. This also means that the annual bus occupancy ratios do not present a complete picture of bus ridership in the city.

As there is no system of swiping a card to gain access to the bus or MMTS, non-paying citizens may also ride the public transit for free if the bus is crowded enough and the bus conductor cannot physically reach the passengers to issue tickets. This again prevents these riders from being counted.

This annual bus occupancy ratio is along a bus route so it can be used to along with frequency to plan for more optimized routes. It can be used to determine which areas are underserved by buses and those which are overserved. The bus routes also help in understanding how the bus network is connected and how these connections or the network influence ridership in areas. The annual occupancy ratio along bus routes can help understand the flow of ridership or travel patterns largely at a city scale. However, ridership data at the bus stop scale would have been useful study more localized and granular patterns like popular origins and destinations and their relationship to the on-demand cabs distribution. This granular data may allow for more concrete findings and exploration of causal relationships.

To minimize the skewing of data due to not counting of some populations, this research uses frequency of the buses along different bus routes in addition to annual occupancy ratios to establish a better understanding of the demand for public transit in the city.

MMTS Ridership: In Hyderabad, as the MMTS is under the purview of the federal railways agency, the tickets are issued by the federal body. MMTS tickets are issued electronically at the different MMTS stations, whose fare is based on categories of destinations and not the actual destination itself. This system allows for fairly accurate trip origin data. However, again, there is no system of swiping in to board the train and un-ticketed passengers are only caught if there is a random check. Again, as in the case of buses, there is no record of frequent users holding the monthly joint bus and MMTS pass using public transit specifically. This is another limitation of this research. This research and the data available do not take into consideration these most frequent public transit users as there is no way to count or track their usage. This also means that the MMTS ridership data at stations does not present a complete picture of MMTS ridership in the city.

The MMTS ridership data is from the Hyderabad branch of the federal Railways system. The MMTS trains and the national trains run on the same tracks. The MMTS is not confined to the city boundaries and passengers can travel out of the city on the MMTS but the passenger numbers are only calculated within the city. This is another limitation of this data.

The Hyderabad MMTS is a very localized service and serves a very limited geography of the city. Thus, MMTS ridership numbers do not offer a representative view of the public transit demand in the city.

To overcome these limitations in the data, the research looks at the overall trends in MMTS ridership at the zonal scale and also in conjunction with bus transit ridership.

On-demand cabs availability:

As the data on the availability, distribution, and operations of on-demand cabs is proprietary and unavailable, this research devised a method to collect data about the availability of these cabs in the city. To be able to compare the availability of these cabs to public transit and more importantly, to registered vehicles, this data was decided to be collected based on zones.

As on-demand cabs' availability is dynamic and ever changing, some constants had to be established. These constants were determined to be the sample location and the time of observations. This determination of the sample locations affects all conclusions drawn from this study and this research acknowledges that a different sampling method could have resulted in different conclusions. However, as this research aimed to examine the effects of on-demand cabs on vehicle ownership, and vehicle ownership data was only available at the zonal scale, it was decided to examine the availability of on-demand cabs also at the zonal scale to be able to compare the two.

Truly randomly selected locations could also have been used but this method may have made comparing the on-demand cabs' availability to vehicle ownership by zones less meaningful. However, in the future, if more granular vehicle ownership data is available, truly ransom sampling locations may be employed to identify truly localized and spatially distributed effects. Also, as the bus ridership data is available as annual occupancy ratios along bus routes which cross over zones, this sampling by zones is helpful in comparing these various datasets.

The on-demand cab availability data was collected over a period of 4 weeks and these numbers represent the supply of on-demand cabs available around a sample point. It is not the demand for those cabs. There is no way to determine how many trips have been made, or the origin or destination from this dataset. The zone the cab is registered to is also unknown.

The different mobile apps limit the number of cabs that can be seen on the screen to 8. However, as the data was collected across two platforms and across all variations of the service available, this limitation might not have significantly affected the data collection or the representation of a complete picture.

For measuring the change in on-demand cabs registered in the city, this research uses the number of cabs registered assuming that the majority, if not all, of the new cabs being registered are on-demand cabs. This may not be the case but, since the city does not have a separate category for on-demand cabs or any other means to track these numbers, this method was adopted.

Also, this research acknowledges the fact that there are wider societal, economic, and political factors which influence people's travel behaviors and they have not been explored in this study as they were deemed to be outside the scope of this study. Similarly, there are many more impacts on cities and their residents due to on-demand cab services which are outside the scope of this study.

Methodology:

To test the relationship between on-demand cabs, public transit, and vehicle ownership, public transit ridership numbers from 2010 to 2016, by zone, were compared, through descriptive statistics of the data. Similarly, number of cars, motorbikes and on-demand cabs registered were compared, through descriptive statistics of the data, as percentage changes and as proportions. This data was acquired from the Telangana Road Transport Authority (number of vehicles registered), Telangana State Road Transport Corporation (bus occupancy ratios), and South Central Railways (MMTS ridership data). The relationship between public transit ridership and vehicle ownership, as proportions, before the introduction of on-demand cabs to after was also examined. This comparison resulted in the identification of changes in the trends of the data, though none of those changes can be attributed to the introduction of on-demand cab services.

To test the spatial distribution of these effects, the research collected the number of on-demand cabs data, on site, across platforms for analysis.

Location sampling

Hyderabad is divided into five zones, North, South, East, West, and Central zones. Since on-demand cabs can only travel on roads, the sampling locations will be along roads to eliminate generation of sampling points in physically inaccessible locations like waterbodies. Also, as the research aims to compare the prevalence of the on-demand cabs in relation to transit lines, the location samples would have to be along roads. The extent around each sample point was limited to a mile as the average wait time for an Uber around the world is about 5 minutes and a mile is the average distance that can be travelled in 5 minutes, given normal traffic volumes.

Uber's interface only allows for 8 on-demand cabs to be seen on the screen at any point of time, irrespective of the extent (of zoom). But, over the weeks more than 8 on-demand cabs have rarely been noticed clustered anywhere in the city, and the number of on-demand cabs across two platforms were collected. This should minimize the data collection error, if any.

Upon running the Sampling Design Tool plugin for ArcMap, to generate spatially distributed/ balanced random samples multiple times for each zone, (with the number of samples required was set as 10000 and the tool was run for 5 minutes each time), the maximum number of samples 1 mile apart for the all the zones collectively was determined to be 286 locations. These 286 location samples would allow for the coverage of the entire city at locations that are less than one mile apart. As collecting data at 286 location multiple times a day, over a period of time is not possible given human capacity limitations, these 286 location samples were considered as the population. And at 90% Confidence Level, with 10% margin of error, 55 is the sample size, i.e., 55 sample locations were needed (the confidence and margin of error were determined by limitations on human power at disposal). As the research needs the same number of samples in each zone to measure the differences in availability across the zones, 55/5 = 11 was decided as the number of sampling locations across each of the zones.

But, these 286 spatially distributed random points were not located along roads. So, to randomly select sampling locations along roads, main, arterial roads were selected (as transit is along these roads and on-demand cabs would generally travel along these roads as opposed to smaller roads), and a fishnet of 0.15 mile x 0.15 mile was drawn. All the cells of the fishnet that intersected with any portion of a road were given a value of 1, and those that didn't were 0. Then, locations were sampled through stratified sampling based on whether a road is present in the cell or not. This generated 11 sampling locations, along a road, in each of the five zones. These are the sampled

locations and were numbered 1 through 11 with a prefix of E, W, N, S or C corresponding to East, West, North, South, and Center respectively.

Time sampling

From observed trends in Hyderabad (LASA, 2011) and in cities across the world, (and limitations on human power), peak hours have been determined to be between 8am and 10am, and 5pm to 8pm. During these hours, as surge multiplier varies and demand and supply vary very dynamically, data was be collected every 2 hours (at 8 am, 10 am, 5:30 pm and 7:30 pm). At other hours of the day, between 7am and 11pm, data was collected every 4 hours (12pm, 4pm, and 10pm). Over the weekends, data was collected every 4 hours all day (8am, 12pm, 4pm, 8pm) and every 2 hours between 11pm and 3am (10:30pm, 12:30am, 2:30am). This data collection continued for 30 days, which gave an adequate snapshot of the trends in the city and across both the platforms (Uber & Ola), during holidays, during regular days and any other happenings.

This data was then mapped along with transit lines, with frequency, stations, and transit ridership to explore any relationship between transit and on-demand cabs. Then, the near relationships between these various modes of transit was explored to identify any transit and on-demand cabs deserts and their relationship to each other.

Analysis and Findings

On-demand cabs:

Upon mapping the number of on-demand cabs observed within one mile of the sampled locations at different times over the course of a month, it was noticed that there were a higher number of cars around locations in the center of the city, which is the Central zone and decreased as one moved toward the periphery of the city in all zones.

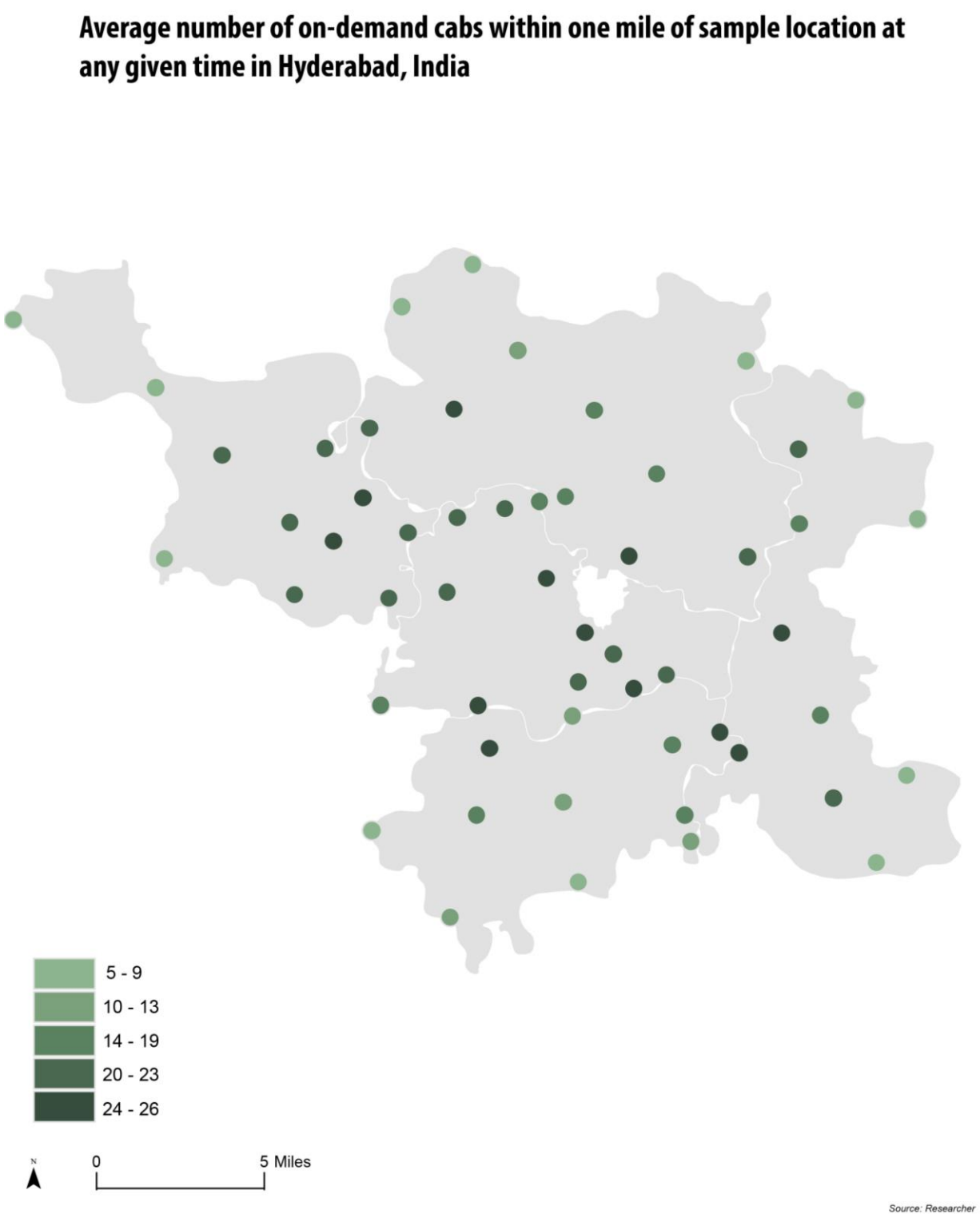
The average number of cabs at any given time, at any given location in the city is 18 cabs.

	N zone	S Zone	E Zone	W Zone	C Zone	City
Monthly	16	16	17	19	22	18
Weekday	19	18	19	21	25	20
Weekend	14	14	15	16	19	16

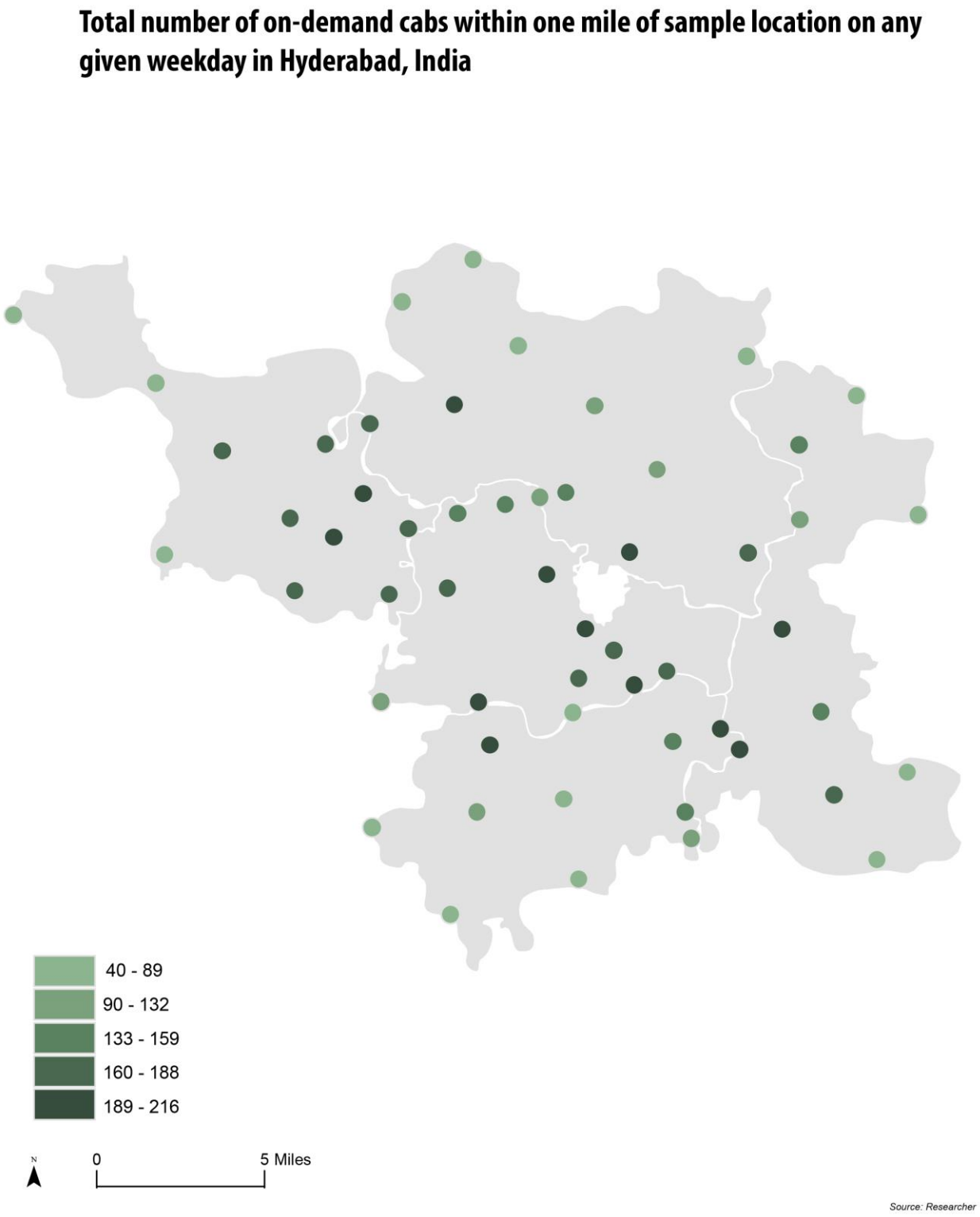
Table 1 – Average number of on-demand cabs within a mile of sample locations on any given day, at any given time by zones

From Table 1, it can be observed that in the Central zone, in all cases, there have been a higher than average number of on-demand cabs. In the West zone too, there have been either the average number or higher than average number of on-demand cabs at any given time, on any given day. However, in the North and South zones, there have been fewer on-demand cabs than average at any given time, on any given day.

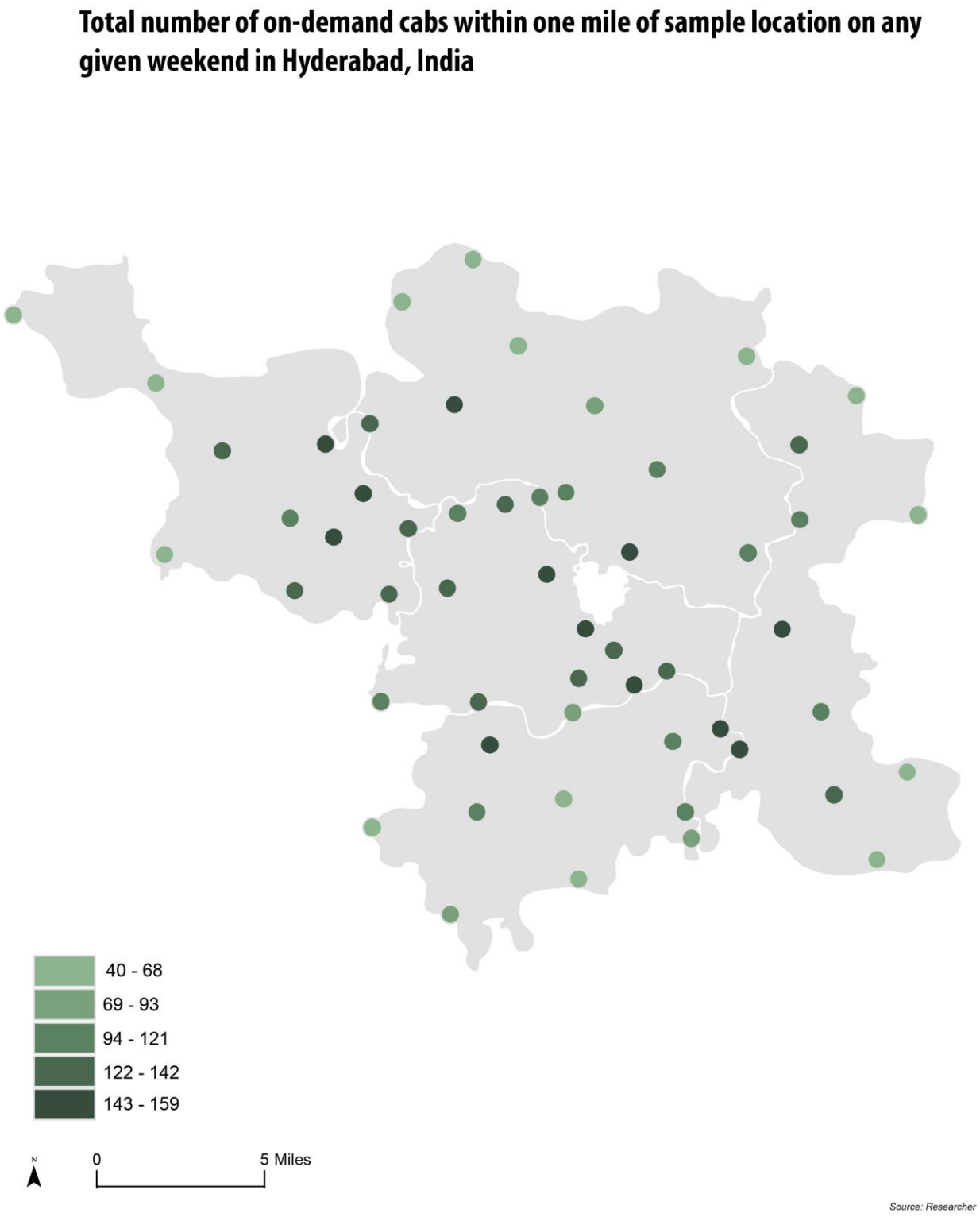
The averages suggest that there are a fewer than average number of on-demand cabs in the South zone and that the Central zone is the most served by on-demand cabs.



Map 1 – Average number of on-demand cabs within a mile of sample locations on any given day, at any given time by zones



Map 2 – Total number of on-demand cabs within a mile of sample locations on any given weekday by zones



Map 3 – Total number of on-demand cabs within a mile of sample locations on any given weekend by zones

From the average number of on-demand cabs around sample locations during week nights (10 pm) in the city, it was noticed that the highest averages were in the North zone and the others in the central zone and in the West zone were also concentrated near the North zone. Lower averages were observed in the South zone. The North zone has experienced the greatest loss in annual bus occupancy ratio from 2014 to 2016. This could suggest that in the night, at 10 pm, people in the North zone would rather travel by on-demand cabs. These higher averages also seem to cluster around MMTS stations in the North and Central zones.

From the average number of on-demand cabs around sample locations during weekend nights at 12:30 am and at 2:30 am in the city, it was noticed that at 12:30 the higher averages were concentrated in the Central zone in the West zone close to the center of the city, and lower averages were observed in all other zones toward the outer edges of the city. This could possibly be explained by the high density of restaurants, bars, and clubs present in the West zone towards the center of the city.

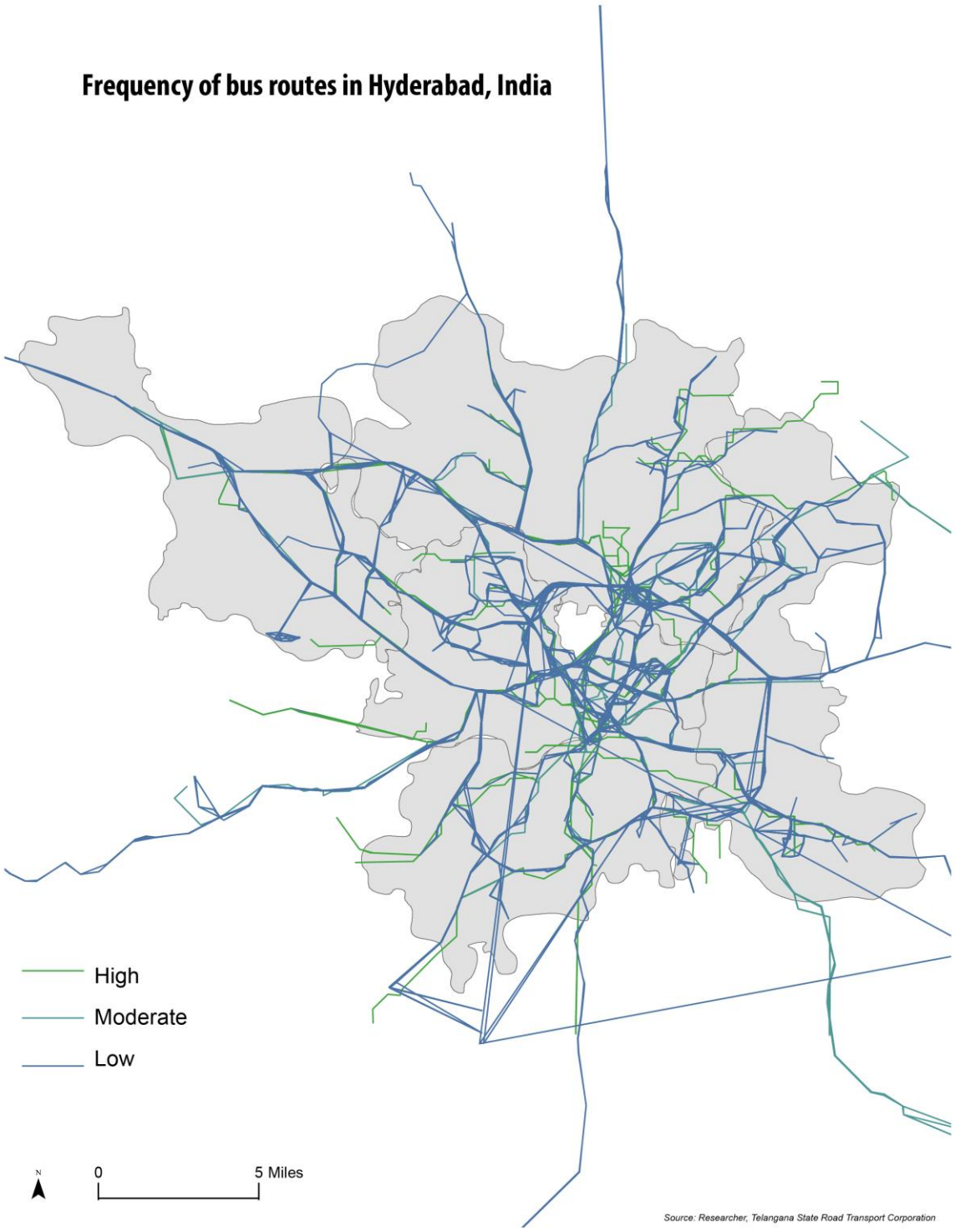
At 2:30 am however, a lone higher average was observed on the outer periphery of the East zone and one in West zone on the periphery of the city. These averages would require further study to understand the high number of on-demand cabs in those location. Given the hour, and the location, one possible explanation could be that these could be the final destinations of on-demand cab drivers, i.e., their homes. But this research has no way of knowing if it is true.

Buses:

In Hyderabad, there are 31 bus depots and over 1500 bus stops. 357 unique bus routes in the city have been identified and mapped. 290 serve the Central zone, 236 serve the North zone, 143 serve the South zone, 161 of these serve the East zone, and 135 serve the West zone. There are a greater number of bus depots toward the east and south of the city.

The 357 bus routes were categorized into high frequency bus routes, with buses every 5 to 10 minutes during peak hours and 11 to 20 minutes during non-peak hours; moderate/mid frequency bus routes, with buses every 11 to 20 minutes during peak hours and 21 to 30 minutes during non-peak hours; and low frequency bus routes, with buses every 30 minutes or greater.

Based on this categorization, there are 60 high frequency bus routes, 41 moderate frequency bus routes, and 256 low frequency bus routes. The high frequency bus routes and the moderate frequency bus routes can be together considered to be frequent bus routes.



Map 4 – Map of bus routes categorized by their frequency

Upon mapping the bus routes based on their frequency it was observed that, out of 60 high frequency bus routes, only 10 routes serve the West zone. Of these 10 routes, 4 only serve the inner edge that is closer to the center of the city. In contrast, 32 high frequency bus routes serve the Central zone, 32 serve the North zone, 27 serve the South zone, and 20 serve the East zone.

Of the 41 moderate frequency bus routes, 35 serve the Central zone, 30 serve the North zone, 21 serve the South zone. 14 serve the East zone, and only 10 serve the West zone.

These patterns suggest that the West zone is less served by frequent bus transportation that the rest of the city, followed by the East zone. On the other hand, it seems that the Central zone is the best served by frequent bus transportation in the city, followed by the North zone.

As the bus ridership data was unavailable at the bus stop level, annual occupancy ratios of the bus routes were analyzed. From the Occupancy ratio data along routes for years 2014, 2015, and 2016, Percentage change in the Occupancy Ratio along a route from 2014 to 2016 was calculated.

From these percentage changes it was observed that between 2014 and 2016, 58 of the 357 bus routes experienced an increase, whereas the other 299 routes experienced a decrease in occupancy ratio. The raise (Percentage increase) in occupancy ratios ranged from 0.01% to 465% while the losses (Percentage decrease) ranged from 0.1% to 469 %. The average percentage change for bus routes in the city from 2014 to 2016 is -1.5% (decrease). The average percentage decrease is 65% and the average percentage increase is 60%.

The average percentage decrease (only the losses) in bus occupancy ratio from 2014 to 2016 in the Central zone is -9.3%, in the North zone is -16.6%, in the South zone is -3.6%, in the East zone is -2.9%, and in the West zone is -12.9%.

These trends suggest that individually each of the zones experienced a greater than city average decrease in occupancy ratio, and the highest changes can be noticed in the North zone, followed by the West zone.

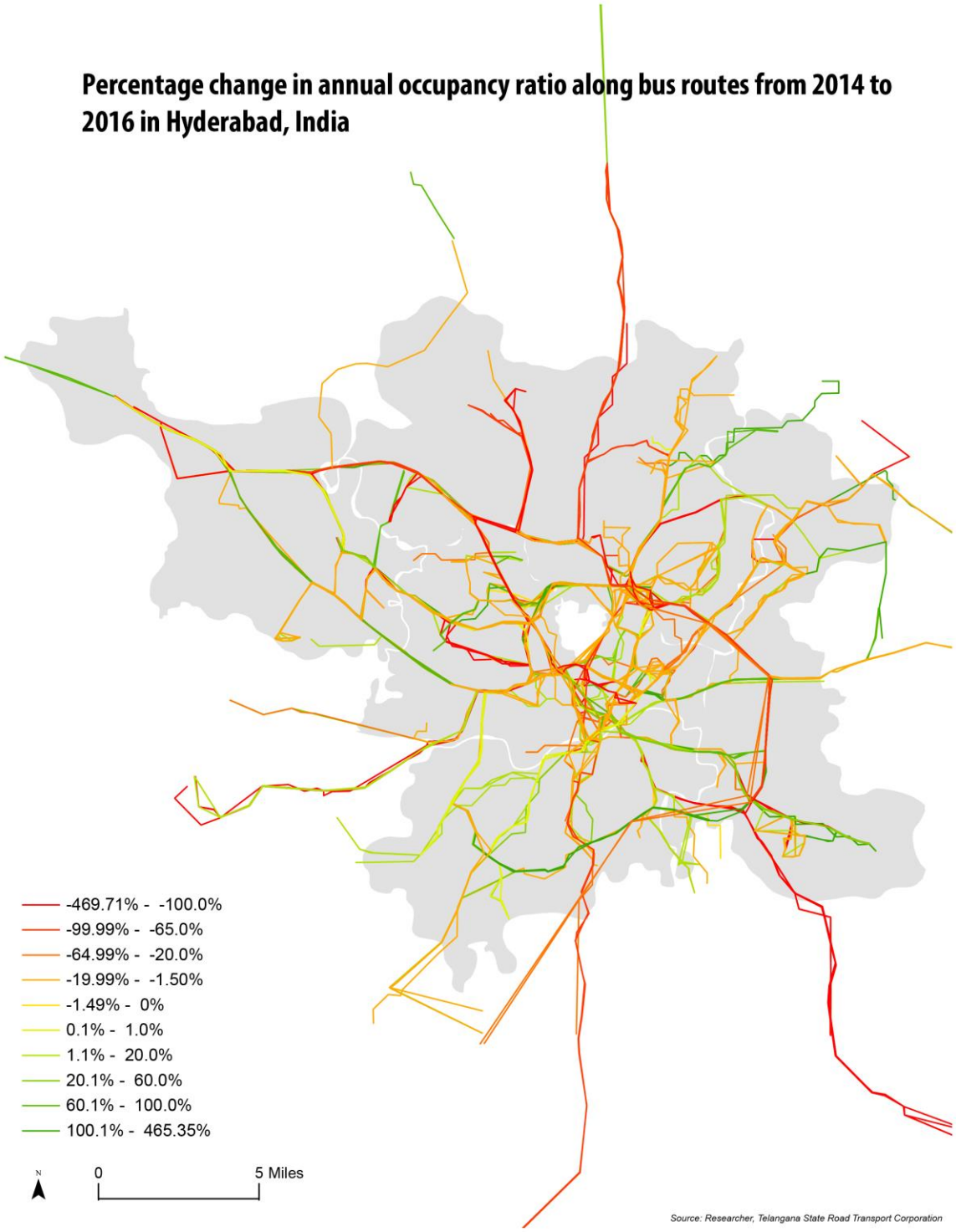
	Central zone	North zone	South zone	East zone	West zone	City
Average Percentage Change	2.01	-30.73	-3.56	14.74	-13.93	-1.5
Average Percentage Decrease (only losses)	-9.3	-16.6	-3.6	-2.9	-12.9	-1.5

Table 2. Average change in annual occupancy ratio along bus routes from 2014 to 2016 by zones

Though the North zone is well served by frequent bus routes, it experienced the greatest decrease in bus ridership. Though East zone is not as well served by frequent bus routes, it experienced the least decrease in bus ridership. This suggests that bus frequency may not influence bus ridership to a great extent.

East zone and Central zones experienced a net percentage increase in annual occupancy ratios. This again suggests that bus frequency may not greatly influence bus ridership as East zone is not very well served by frequent bus routes.

From the average occupancy ratios observed, 10 categories of percentage change in Occupancy Ratio from 2014 to 2016 were established.



Map 5 – Percentage change in Occupancy ratio along route from 2014 to 2016

Greater than 100.1% decrease – this is a much higher change than the average change. The bus routes in this category mostly originate or terminate in the Central zone, or pass through it. Of the bus routes in this category, 1 is a high frequency bus route and 9 are moderate frequency bus routes.

65.1 – 100% decrease – this is a substantial change compared to the average change. 17 bus routes fit into this category, and most of them are longer routes. 6 bus routes in this category are high frequency routes and 4 are moderate frequency routes.

20.1 to 65% decrease – This is slightly higher than the average change but within the average decrease. There are 11 bus routes that fit into this category, and there are fewer bus routes in the North zone and the South zone. 9 of the 11 routes are toward the east of the city. 6 of these routes are high frequency bus routes and 2 are of moderate frequency.

1.6 to 20 % decrease – this range of change is within the average change. These bus routes can be observed in all the zones. There are 52 of them. Most of the routes are shorter routes and can be found toward the east of the city. 15 of these bus routes are high frequency routes and 10 are of moderate frequency.

0 to 1.5% decrease – this range is the no change or average change in the city. There are only 4 bus routes that fit into this category and they are closer to the center of the city. All of them pass through the Central zone. Of the 4 bus routes, 2 of them are moderate frequency routes and 2 are of low frequency.

0 to 1 % increase – this is the no change or very slight increase range. There are only 5 bus routes that fit into this category. All of them pass through the Central zone and none pass through the East zone. Of the 5 bus routes, 1 is a high frequency route and 1 is of moderate frequency.

1.1 to 20% increase – this is the lesser than average increase range. Most of the bus routes in this category originate or terminate in the South zone or in the Central zone. 20 out of the 25 bus routes in this category pass through the Central zone. Of the 25 bus routes, 7 are high frequency routes and 4 are of moderate frequency.

20.1 to 60% increase – this is the average increase range. 5 bus routes fit into this category and can be found in the Central zone, the North zone, and the West zone. There are none in the East zone. These bus routes are closer to the center of the city. Of the 5 bus routes, 1 is a high frequency routes and 1 is of moderate frequency.

60.1 to 100% increase – This is the slightly greater than average range. 13 bus routes fit into this category. Most of them are closer to the center of the city and there are fewer of them in the South zone. Most of them either originate or terminate in the Central zone. 11 of the 13 bus routes pass through the center. 3 of the 13 bus routes are high frequency routes and none are of moderate frequency.

Greater than 100.1% increase – this is the substantial increase range. 10 bus routes fit into this category. Most (8 out of 10) of these bus routes originate or terminate in the East zone. Fewer bus routes serve the North zone and the South zone. 4 of the 10 bus routes are high frequency routes and 3 are of moderate frequency.

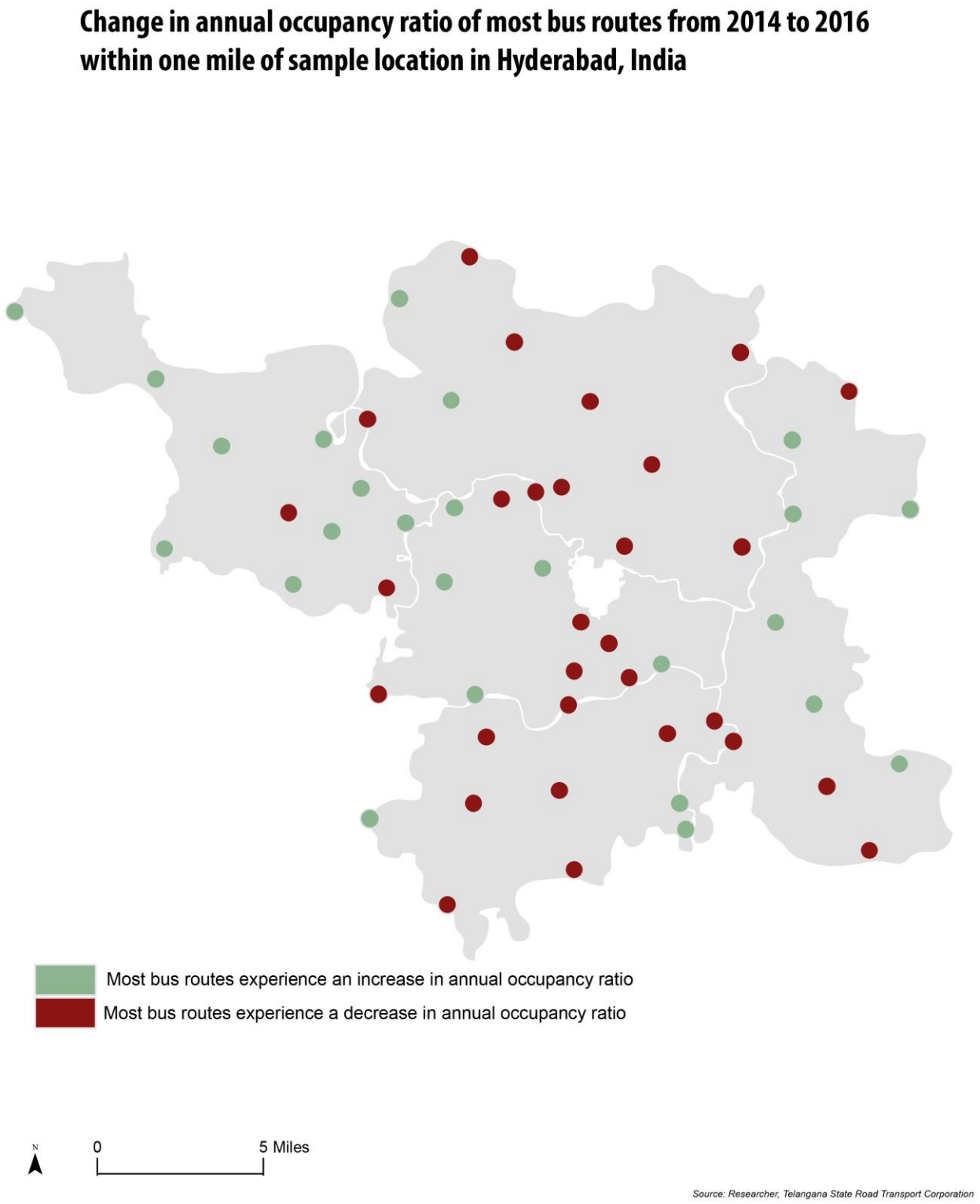
It is interesting to note that the percentage change of the occupancy ratio bus routes in the categories of greater than 100% increase and decrease; and 1 to 20% increase, and 1.5 to 20% decrease, whose ranges correspond to the most variation from the mean change, the average changes, and less than average increase respectively, mostly overlap. The bus routes that fit into

the over 100% categories mostly overlap in the West zone and the Central zone, while the bus routes closer to the averages overlap mostly everywhere.

This could suggest that these routes duplicate each other for the most part and are leading to lower occupancy ratios along those lines.

Buses and on-demand cabs:

The total number of routes within a one mile radius of the Sampling locations were determined. If a greater number of routes within that one mile radius have experienced a decrease rather than an increase in occupancy ratio from 2014 to 2016, then the net bus transit ridership within a one mile radius of that sampling location was considered to have decreased. Conversely, if a greater number of routes experienced an increase, then the net bus transit ridership within a one mile radius of that sampling location was considered to have increased.



Map 6 – Sample points categorized as increasing or decreasing based on the greater number of routes within one mile experiencing an increase or decrease in occupancy ratio

From this categorization, it can be observed that the bus ridership within one mile of 7 out of 11 sampling points in the Central zone decreased. Similarly, the bus ridership within one mile of most (9 out of 11) sampling points in the North zone experienced a loss, within one mile of 8 out of 11 sampling locations in the South zone decreased. Bus ridership within one mile of 7 out of 11 sampling points in the East zone increased, and within one mile of most (9 out of 11) sampling points in the West zone experienced an increase.

These trends suggest that even though routes in the East zone experienced an increase in ridership, it is outweighed by the loss of ridership along other routes in the zone.

A quarter mile buffer, a half mile buffer, and a mile buffer were established around the Sampling points, and within a quarter mile of the sample locations, a higher proportion of the number of high frequency bus routes can be observed in the Central zone and in the North zone.

Within a half mile of the sample locations, a higher proportion of the number of high frequency bus routes can be observed in the Central zone and in the North and South zones close to the center of the city.

Within a mile of the sample locations, a higher proportion of the number of high frequency bus routes can be observed in the Central zone, the North zone, the South zones, and the East zone.

Within a mile of the sample locations, a higher proportion of the number of frequent bus routes (high and moderate frequency) can be observed in the Central zone, the North zone, the South zones, and the East zone, all leaning toward the east of the city. Lower proportion of number of frequent bus routes was observed in the Central zone, in the West zone, and in the South zone, all leaning toward the west of the city.

These observations suggest that there are no real areas unserved by high frequency bus routes that are within the sampling area. However, if frequent buses (high frequency and moderate frequency) are considered, then the lower proportion of number of frequent bus routes that emerge, in Central, West, and South zones occur in the same areas that experience higher than average number of on-demand cabs.

MMTS:

The MMTS runs as two routes within the city. Route 1 consists of 22 stations and Route 2 consists of 5 stations. There is only one interchange station. The MMTS does not serve East zone at all and it only serves the area of the North zone that is closest to the center. 13 of the 27 stations lie in the Central zone.

Map 7 – map of MMTS stations and routes in Hyderabad

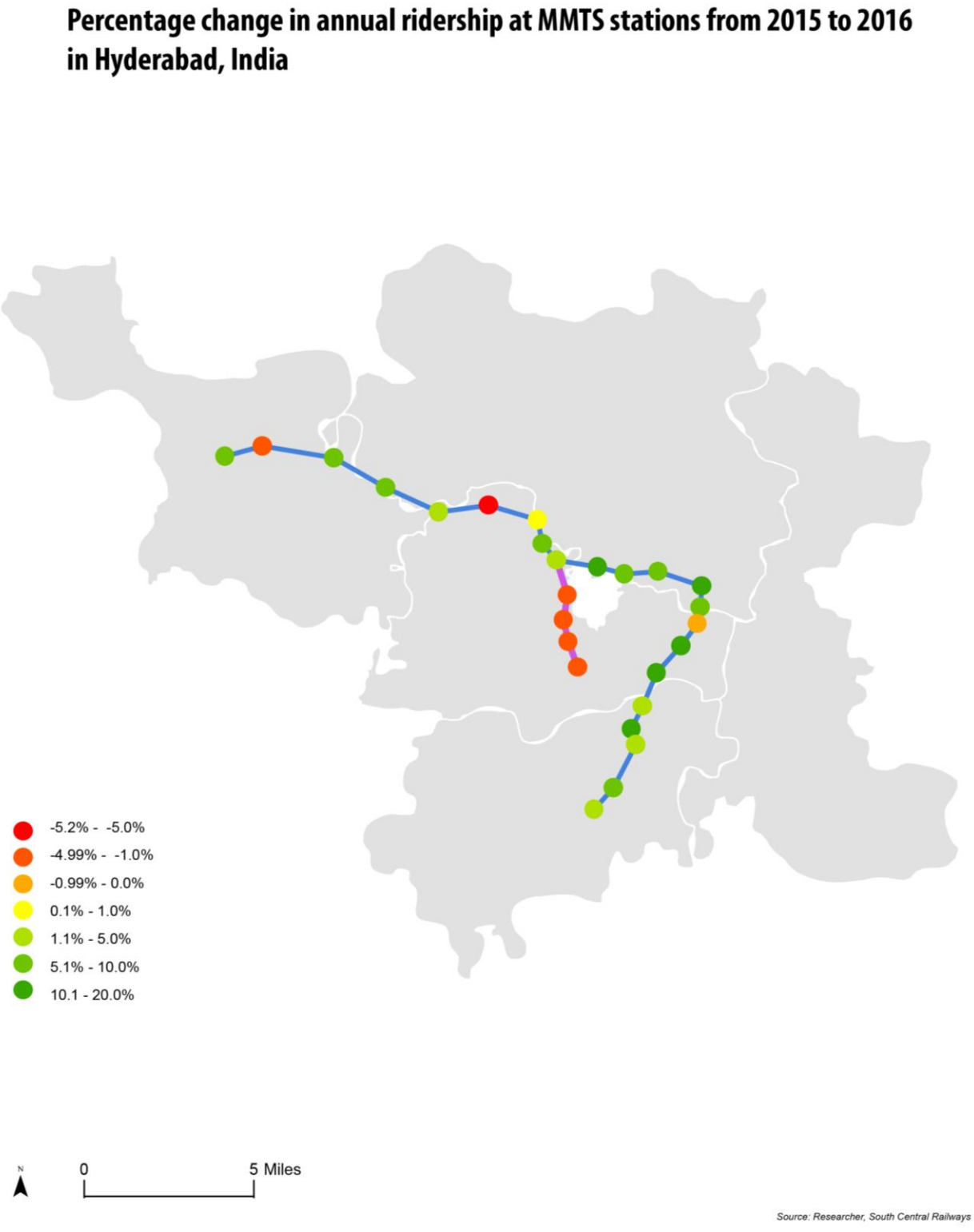
The annual figures show a 4.5% increase from 2015 to 2016.

Financial year	2014_2015	2015_2016	Percentage Change
Number of passengers	39116277	40899407	4.558537102

Table 3 - annual percentage change in number of passengers from 2015 to 2016.

Route 1 consisting of 22 stations experienced an increase in ridership at almost all of its stations. It only experienced a decrease at 3 of its stations. The average percentage change in ridership 4.5% citywide.

Based on the range and citywide average of percentage change in ridership, 7 categories of percentage change were identified.



Map 8 – Percentage change in ridership at MMTS stations from 2015 to 2016

Over 5% decrease – this is the range of maximum change noticed – only 1 station fits into this category. It lies in the Central zone.

1 to 5% decrease – this is the range of slight decrease – 4 of the 5 stations of route 2, which lie in the Central zone fit into this category. One station which lies in the west zone also fits into this category.

0 to 1% decrease – this is the range of very slight change – only 1 station which lies in the Central zone, toward east of city fits into this category.

0 to 1% increase – this is the range of very slight change – only 1 station which lies in the Central zone fits into this category.

1 to 5% increase – this is the range of the average change noticed. 5 stations fit into this category of which, 3 lie in the South zone toward the east of the city, 1 lies in the West zone, and 1 in the Central zone.

5 to 10% increase – this is the range of greater than average increase - 8 stations fit into this category of which, of which only 1 lies in the Central zone, 3 lie in the North zone toward the east of the city, and 3 lie in the West zone.

10 to 20% increase – this is the range of highest increase noticed - 5 stations fit into this category and they toward the east of the city, 2 in Central zone, 2 in the north zone, and 1 in the South zone.

Route 2 consisting of 5 stations experienced a decrease in ridership at 4 of its stations.

One of the stations that is experiencing decreasing ridership in the West zone is not within one mile radius of any of the identified sampling points.

MMTS ridership has increased the most in the Central zone, and all the stations of the MMTS lie along frequent bus routes. The Central zone also experienced higher than average number of on-demand cabs. However, lower proportions of frequent bus route around sampling locations emerged. This could suggest that the ridership has shifted from bus to MMTS. But without bus ridership numbers, the validity or the proportion of this shift, if any, cannot be determined since MMTS serves a very small area of the city and cannot be considered representative of the city's public transit demand.

Vehicle ownership

The proportion of the different types of vehicles from 2010 to 2016 has been analyzed.

Between 2010 and 2016, the city wide proportion of on-demand cabs to all vehicles increased from 0.8% to 1.4%, while the proportion of cars decreased from 19.8% to 17.4%. The proportion of motorbikes increased from 72.5% to 74.1%, and the proportion of all other vehicles combined increased from 6.7% to 7.0%.

In the West zone, during the same time period, the proportion of on-demand cabs to all vehicles increased from 0.9% to 1.4%, while the proportion of cars decreased from 14.0% to 11.7%. The proportion of motorbikes increased from 75.9% to 77.7%, and the proportion of all other vehicles combined stayed nearly the same at 9.0%.

In the East zone, during the same time period, the proportion of on-demand cabs to all vehicles increased from 0.5% to 1.1%, while the proportion of cars decreased from 13.9% to 11.6%. The proportion of motorbikes decreased from 77.9% to 77.1%, and the proportion of all other vehicles combined increased from 7.5% to 10.0%.

In the North zone, during the same time period, the proportion of on-demand cabs to all vehicles increased from 0.5% to 1.2%, while the proportion of cars decreased from 21.4% to 19.1%. The proportion of motorbikes increased from 72.5% to 74.2%, and the proportion of all other vehicles combined increased from 5.4% to 5.3%.

In the South zone, during the same time period, the proportion of on-demand cabs to all vehicles increased from 1.3% to 1.4%, while the proportion of cars decreased from 8.7% to 7.7%. The proportion of motorbikes increased from 75.0% to 78.2%, and the proportion of all other vehicles combined decreased from 14.8% to 12.5%.

In the Central zone, during the same time period, the proportion of on-demand cabs to all vehicles increased from 0.9% to 1.6%, while the proportion of cars decreased from 27.0% to 24.5%. The proportion of motorbikes increased from 67.8% to 69.7%, and the proportion of all other vehicles combined decreased from 4.1% to 4.0%.

Type	2010	2011	2012	2013	2014	2015	2016
Motor Cabs	0.84	0.99	1.03	1.00	0.95	1.06	1.41
MotorCars	19.82	19.12	19.16	18.76	18.33	17.88	17.41
MotorBikes	72.56073	72.82	73.58	72.95	74.18	74.18	74.12
Others	6.772998	7.05	6.20	7.28	6.52	6.86	7.04

Table 4 – Proportions of different types of vehicles from 2010 to 2016

Type	10_11	11_12	12_13	13_14	14_15	15_16	10_16	13_16
Motor Cabs	159.33	63.67	33.09	20.30	37.03	60.00	1390.24	163.78
MotorCars	111.26	58.25	33.82	24.04	20.17	17.26	682.14	74.80
Bikes	119.80	59.51	35.55	29.06	23.21	20.34	809.60	91.37
Others	128.16	38.91	60.33	13.72	29.63	23.62	826.12	82.25
Total Vehicles	119.00	57.86	36.73	26.91	23.21	20.44	790.36	88.33

Table 5 – Percentage change of different types of vehicles from 2010 to 2016

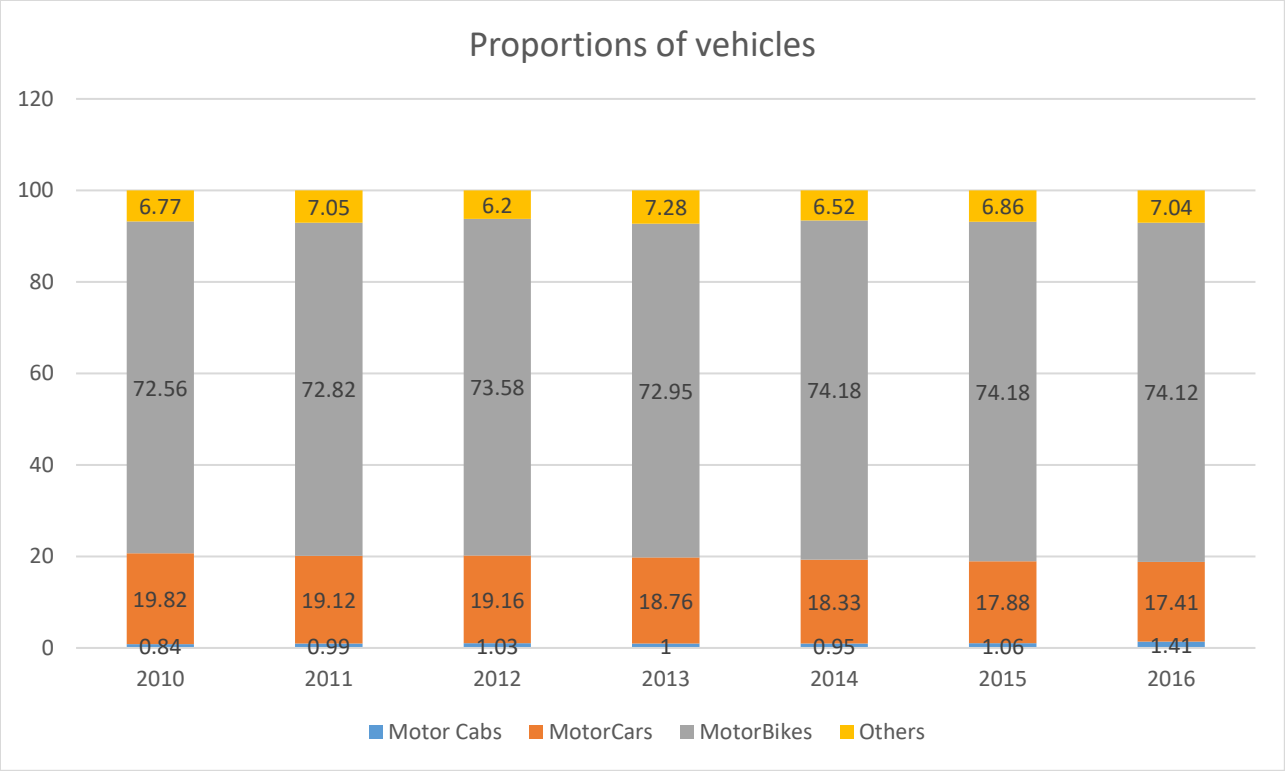


Chart 1 – Proportions of different types of vehicles from 2010 to 2016

% Change	Type	10_16	13_16
	Motor Cabs	1390.24	163.78
	MotorCars	682.14	74.80
	Bikes	809.60	91.37
	Others	826.12	82.25
	Total Vehicles	790.36	88.33

Table 6 – Percentage change of different types of vehicles from 2010 to 2016 and 2013 to 2016

From 2010, when Ola was launched, to 2016, the city experienced a net increase of 1390% in number of motor cabs, accompanied by a 682% increase in motor cars, 809% increase in motor bikes, 826% increase in other vehicles, and a 790% increase in total vehicles registered.

Between 2013, when Uber was launched, and 2016, there has been a 163% increase in motor cabs, 74% increase in motor cars, 91% increase in motor bikes, 82% increase in other vehicles, and a 88% increase in total vehicles registered.

In central zone, from 2013 to 2016, a 0.4% decrease has been noticed in new motor cars registered, and a 0.7% decrease was observed in the West zone. These zones are also the zones that experience higher than average number of on-demand cabs in the sampling areas.

% Change	Type	10_11	11_12	12_13	13_14	14_15	15_16	10_16	13_16
	Motor Cabs	74.02	-24.62	-13.36	0.38	142.50	92.95	433.76	369.71
	MotorCars	13.74	8.96	-8.33	-6.78	2.28	4.36	13.05	-0.48
	Bikes	22.46	6.57	-9.28	10.72	2.33	9.15	46.42	23.68
	Others	17.91	-25.05	73.79	-56.09	79.77	57.15	90.47	24.02
	Total Vehicles	20.42	5.46	-6.69	2.52	5.37	11.70	43.00	20.67

Table 7 – Percentage change of different types of newly registered vehicles from 2010 to 2016 in Central zone

% Change	Type	10_11	11_12	12_13	13_14	14_15	15_16	10_16	13_16
	Motor Cabs	35.22	43.25	-18.83	-41.60	169.86	106.59	411.94	225.60
	MotorCars	8.73	10.93	-2.75	-6.22	-3.65	9.82	16.40	-0.76
	Bikes	21.50	11.60	-3.25	10.00	5.47	12.75	71.64	30.83
	Others	28.72	-54.32	156.69	-33.31	101.90	-2.48	98.14	31.28
	Total Vehicles	20.48	5.49	3.26	2.90	11.93	12.03	69.38	29.04

Table 8 – Percentage change of different types of newly registered vehicles from 2010 to 2016 in West zone

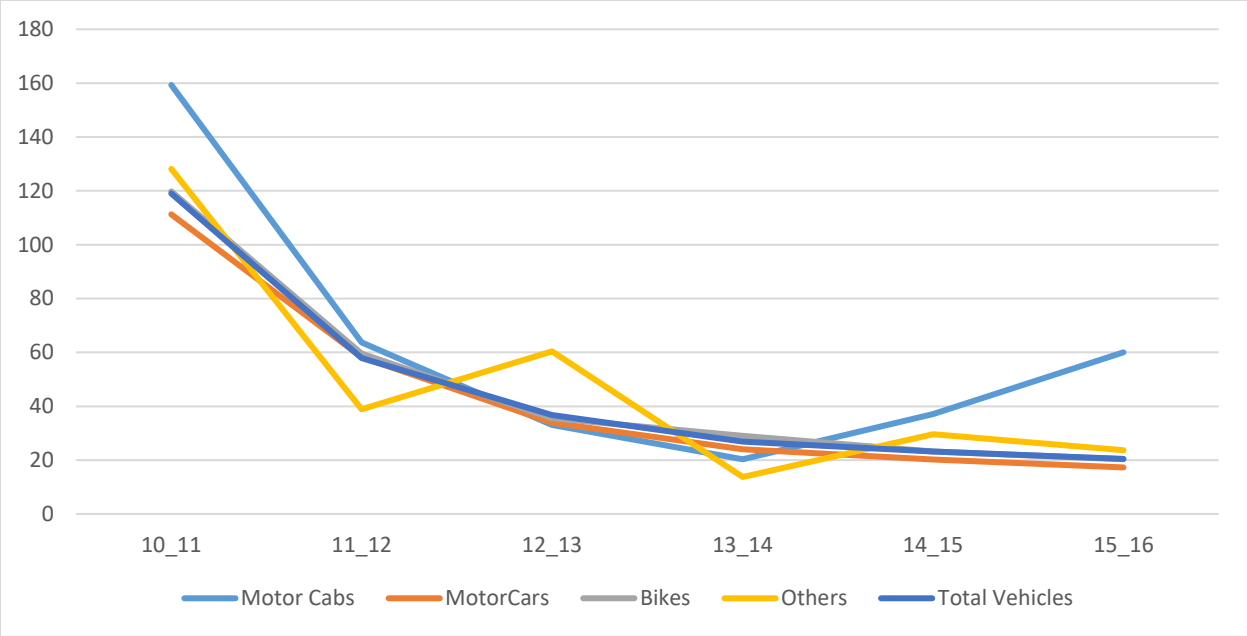
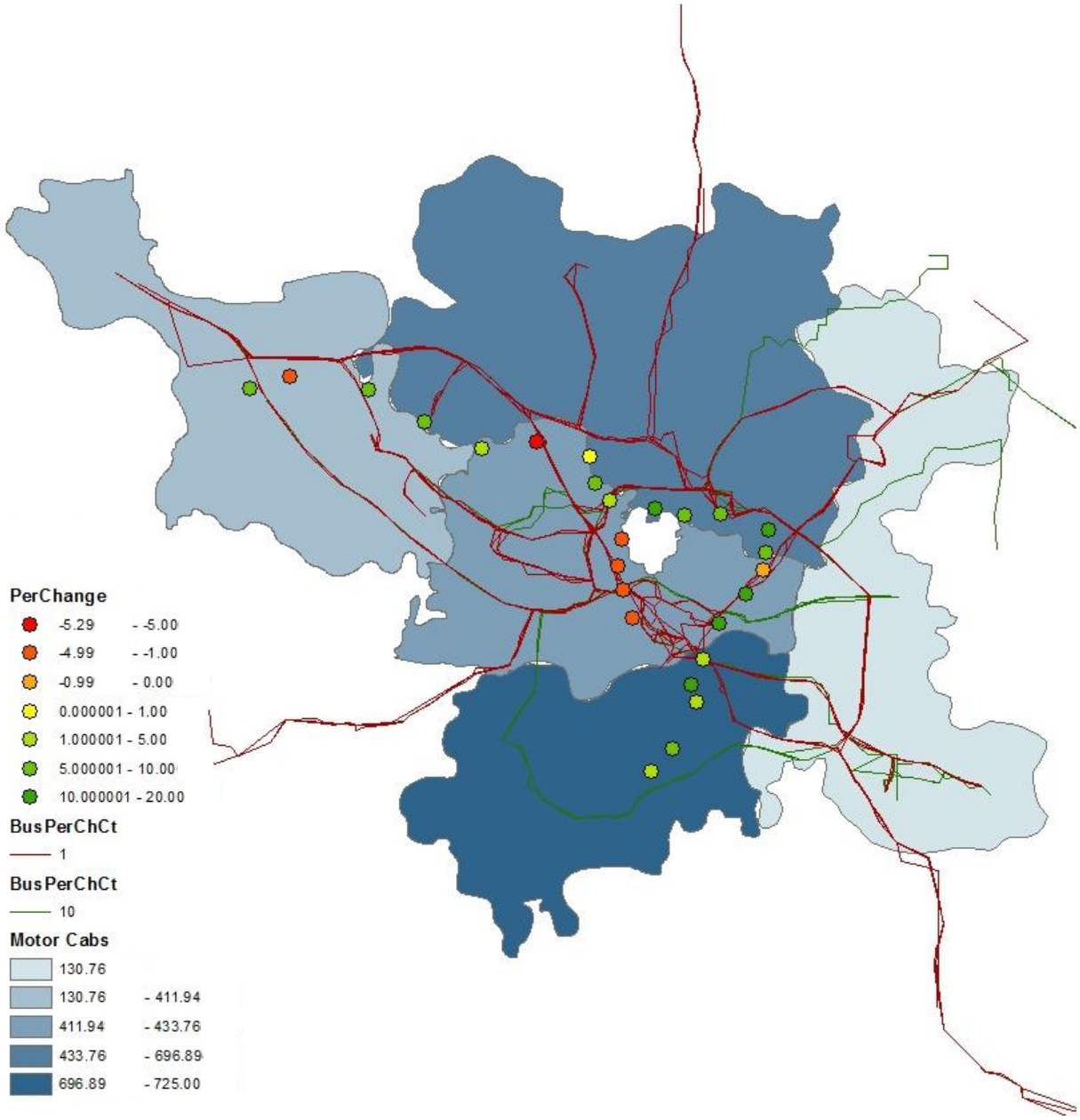


Chart 2 – Percentage change of different types of vehicles from 2010 to 2016 in Hyderabad

Vehicle ownership – Public transit ridership:

Traditionally, in cities across the world, as vehicle ownership increased, public transit ridership decreased or vice-versa. Or, in some cases, bettering public transit and increased public transit ridership did not affect vehicle ownership. This could be attributed to the cultural and social influences on perceptions of wealth associated with car ownership across the world.

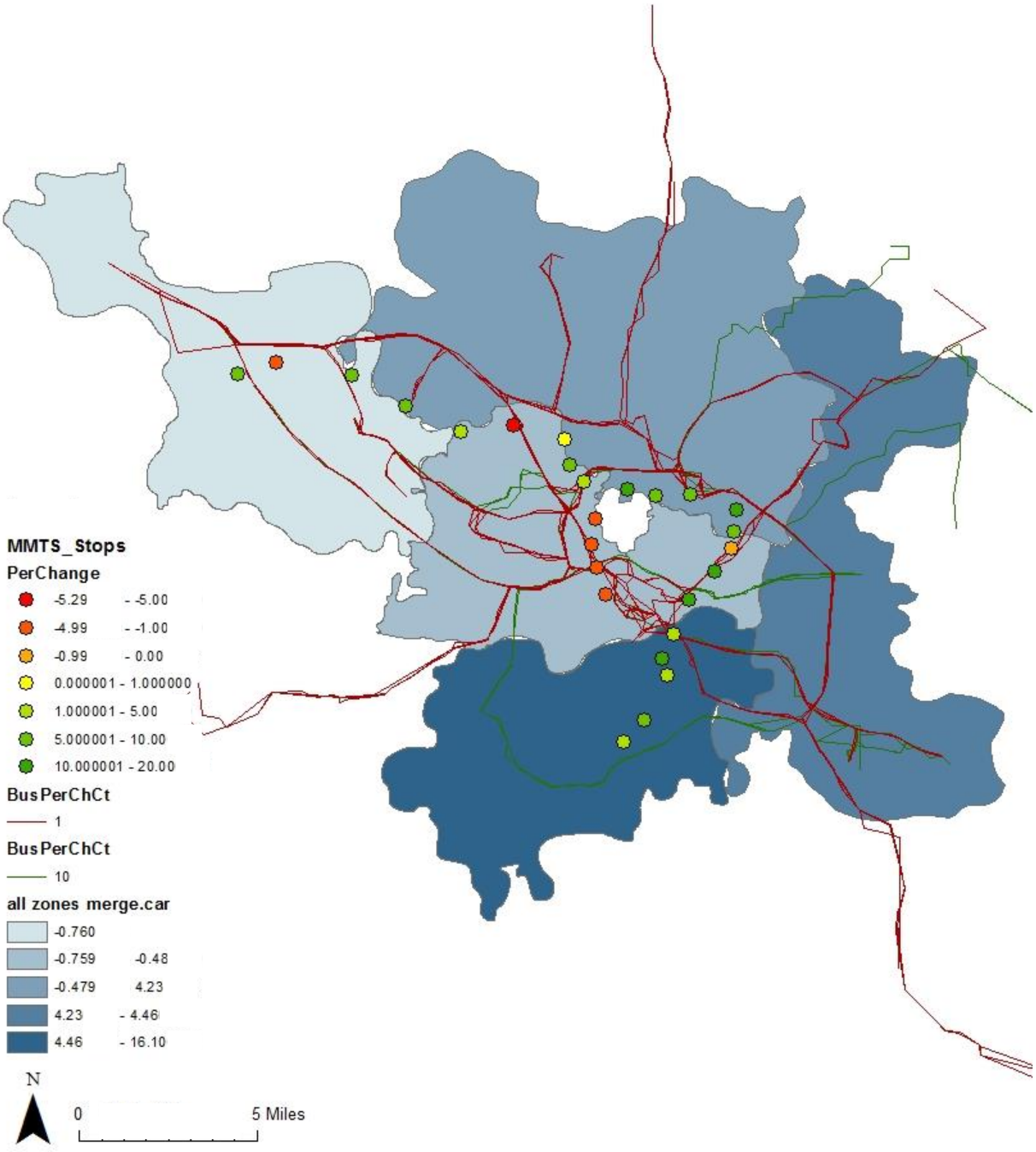
In Hyderabad, upon mapping the percentage change in number of on-demand cabs registered from 2010 to 2016, the bus routes with highest losses and gains in ridership occupancy ratios from 2014 to 2016, and the percentage changes in ridership at MMTS station from 2015 to 2016, it was observed that in the North zone, annual occupancy ratio along bus routes decreased while number of on-demand cabs increased and ridership at MMTS stations increased. Similarly, in the South zone, for a similar change in percentage of on-demand cabs, bus occupancy ratio increased, along with ridership at MMTS stations. These findings are consistent with literature on the topic.



Map 9 – Percentage change in on-demand cabs registered from 2010 to 2016, percentage change in annual occupancy ratio along bus routes from 2014 to 2016, and percentage change in ridership at MMTS station from 2015 to 2016

However, upon mapping the percentage change in number of new motor cars registered from 2013, when Uber was introduced and on-demand cab services become more popular, to 2016, the bus routes with highest losses and gains in ridership occupancy ratios from 2014 to 2016, and the percentage changes in ridership at MMTS station from 2015 to 2016, it was observed that in the West zone, annual occupancy ratio along bus routes decreased while number of cars decreased and ridership at MMTS stations marginally increased. In the South zone, bus occupancy ratio, ridership at MMTS stations increased, accompanied by the highest percentage increase in number of cars from 2013 to 2016, which is much higher than the city average.

These findings suggest that the spatial relationship between vehicle ownership and public transit needs to be studied further to understand these findings.



Map 10 – Percentage change in cars registered from 2013 to 2016, percentage change in annual occupancy ratio along bus routes from 2014 to 2016, and percentage change in ridership at MMTS station from 2015 to 2016

Discussion

Following the findings section, broad conclusions about patterns that developed across geographies can be made. These conclusions and the proposals of this research are discussed below. To understand how these proposals may be implemented (or why not), the discussion also focuses on the various challenges and opportunities that might present themselves in trying to implement these proposals, while examining the implications of this research for developing a regulatory framework for on-demand cab services. The overarching conclusion is that these findings support the hypothesis that vehicle ownership is decreasing in Hyderabad, and so is bus ridership. However, since the MMTS ridership is increasing, the net change in public transit ridership and demand is unknown. (However, it is important to remember that MMTS serves a very small area of the city and cannot be considered to be representative of public transit demand in the city). While these effects cannot be attributed to the introduction of on-demand cabs, the findings suggest that these patterns need to be studied in greater detail, while considering other factors to chart a way forward for the city.

All the studies carried out on mobility in India and in Hyderabad, and all those studies that predict the future demand and modal split of vehicles in India state that the demand for private vehicles in the country will continue to grow as per capita incomes rise due to the societal importance that is associated with vehicle ownership in the country. However, the findings in this research from 2010 to 2016 contradict those predictions. The data and the methods employed in this study have their limitations but the findings and the associated trends suggest that this phenomenon of on-demand cabs and its effects need to be further studied in detail, with appropriate data, at the appropriate granular scale to truly understand the shifts in vehicle demand and modal split, if any. While this study does not prove any causality or state that on-demand cabs are indeed affecting public transit

ridership or vehicle ownership, it makes a case for the necessity of studying these phenomena in greater detail.

The studies on demand on public transit in the country also assume that the demand will continue to rise as population increases. However, in Hyderabad, from the annual bus occupancy ratios, it was seen that the annual occupancy ratio decreased across most bus routes from 2014 to 2016. And as the first phase of the new metro rail is slated to open soon, this occupancy ratio may be further effected, leading to increasing redundancies and waste of tax payers' money. This again highlights the need for a timely study and understanding of the demand for public transit and mobility patterns of city residents, to better plan for the future.

Though this study does not take into consideration other factors such as demographic shifts, migration rates, policy amendments, changes to tax structures etc., it suggests that a phenomena that could potentially cause shifts in predicted patterns does indeed exist and needs to be further understood before it can be regulated or incorporated into future plans.

These suggested shifts in patterns also raises another important factor to be considered in the future – public participation. In Hyderabad, public participation is facilitated through suggestions and complaints to proposed projects rather than as a consensus building process as in most western cities. As the public, and especially some populations, like on-demand cab drivers or peer-to-peer service providers in general, begin to have more at stake due to these new technologies, facilitating meaningful participation during the process, including through the study and research stages becomes important to identify issues that need further exploration to be addressed. In Hyderabad, the most recent study on the mobility and projected travel demand in the city, the CTSHMA 2011, does not list the public or users as stakeholders. It only lists the various government agencies as stakeholders. Moving forward, if new technologies exacerbate societal inequalities and put some

vulnerable populations at more risk, like drivers, there needs to a paradigm shift in how public participation is facilitated in the city to truly plan for equitable outcomes and society.

The CTSHMA also models the future development of the city based on travel demand in the future. Until CTSHMA, Hyderabad only had the existing land uses mapped with little directive for the future in terms of land use. CTSHMA is a comprehensive land use and development plan for the city until 2040. However, as previously mentioned, new digital platforms offering on-demand cab services are slowly restructuring travel patterns in our cities. By making it cheaper, easier and more convenient to travel, on-demand cab services are enhancing the mobility of residents and making it possible to live farther away from public transit options. This restructuring of travel patterns and new possibilities are undermining the ability of planners to predict and plan for the future of their cities. By making it possible to live farther away from public transit, on-demand cab services are undermining the power wielded by transit oriented development to steer development in a city. By making it cheaper and more convenient to travel by an on-demand cab, these services are undercutting public transit in cities and are also putting more vehicles on streets. On the other hand, these services are acting as gap-fill measures in outer lying areas which are not served by public transit in most cities. This restructuring has effectively rendered the CTSHMA outdated and as the first phase of the new metro is slated to open soon, it is vital the city or state invest the necessary resources to understand the restructuring or shifts, if any, and public opinion and stakes involved in a timely manner before investing in any more large infrastructure, and revise the land use and development plan as necessary. This is also a crucial moment in time to plan for the future development of the city following the bifurcation of the state.

Hyderabad can look to other states and other cities in India for successful public participation in development models like Ahmedabad, Bangalore, Delhi, Kerala etc. These cities and states are

also having to address similar issues pertaining to on-demand cab services and new digital technologies in general. Hyderabad Traffic Police already has a strong public presence on social media, like Facebook and Twitter, and this form of public engagement could be explored, in addition to other more traditional forms, to facilitate successful public engagement and outreach.

Conclusions and recommendations:

Electronic issuing of public transit tickets and data gathering: Upon examining all the findings comprehensively, it can be concluded that bus ridership in Hyderabad has decreased over the years. However, this is accompanied by an increase in MMTS ridership. Since the MMTS station wise data that could be procured only spans across two years and the bus ridership was calculated from occupancy ratio, the net demand for public transit in the city cannot be determined conclusively. As these are the two modes of public transit in the city, the net demand for public transit cannot be determined unless there is comparable data for both modes. So the first recommendation is to establish electronic issuing of bus tickets that can track the number of passengers using public transit every day and establish peak hours and peak demand. This data gathering is even more crucial at this point in time as the Metro Rail is slated to open soon and with public transit split three ways in the city, planners need to understand the modal split of passenger demand to optimize service and eliminate what could possibly be duplicating of routes as predominantly noticed in the Central zone and the West zone.

Further study to be carried out to understand factors influencing public transit ridership: The next conclusion is that frequency of bus routes does not affect ridership. As observed, though

the North zone is well served by frequent bus routes, it experienced the greatest decrease in bus ridership. Though East zone is not as well served by frequent bus routes, it experienced the least decrease in bus ridership. This suggests that there are other factors at play that could influence ridership. The next recommendation is to further study what those factors could be to optimize service provision.

Further study the relationship between public transit ridership and on-demand cabs: The next conclusion is that the supply of on-demand cabs in an area is not affected by the area's proximity to high frequency bus routes, since it was observed that even though there are fewer high frequency bus routes than others in the city, there were no frequent transit deserts noticed within a quarter mile of any of the sample locations. This could suggest that those future cab trips could have been fulfilled by a high frequency bus route. So the next recommendation is to further collect data and study this relationship to determine if on-demand cab services are acting as a fill-in measure where frequent transit is scare or if they are just a convenient mode of transportation. This determination could ultimately shape regulatory policy in the city.

Mandate data disclosure: This determination would also depend on the demand of on-demand cabs services in the city and this data is proprietary. Next recommendation would be to incorporate strict data sharing policies into the regulatory framework, to mandate annual data disclosure by these digital platforms to city agencies. In the absence of which, the state government could require stringent licensing and permitting procedures that could include the installation of city monitored GPS devices to glean some demand activity data.

City governments entering into contracts with these private companies, like in the case of the City of Altamonte Springs in Florida, or Melbourne, Washington D.C or Manila, through Uber

Movement, to gain access to their proprietary data also raises concerns of the changing relationship between planners and city residents.

However, to formulate any regulations, the state government would first have to acknowledge the existence of these new entities. The Union Ministry of Road Transport and Highways (MoRT&H) of India, is currently debating the issue on on-demand cab services in Parliament, at the federal level, and the state transport authorities have stated that they are awaiting the result of those proceedings to move forward. However, the central government did issue advisory guidelines for regulation in 2015 and states were free to interpret those guidelines as it suited them (Nair, 2015). There have been some regulations passed in different states that ranged from banning these services to permitting only CNG run vehicles to operate as on-demand cabs. However, Hyderabad as a city, and Telangana as a state have not formulated any policies yet to regulate these services in any way.

Control Variable Pricing: Of the other things being considered at the federal level, the government has decided to examine the variable pricing model employed by these companies to set maximum variations allowable, especially during peak hours. This could potentially mitigate some of the inequity that is inherent in these variable pricing models.

To keep track of this data and to enable a special licensing and permitting process or any other policies regarding the on-demand cab services, the state government should determine if it should treat these on-demand cab services as taxis or establish a new category for them, and establish some regulatory framework to control and plan for the restructuring that is happening or might happen in the future.

Develop digital databases: Hyderabad and the state of Telangana have limited publicly accessible data and to further Open data policies adopted by the state and to facilitate studies such as this and other pertinent and timely research, the state and the city must develop open, accessible, digital databases and datasets. A special department already exists within the government and the capacities of this department must be built up to meet the evolving needs of city residents.

Further study the changes in proportions of cars and on-demand cabs to all vehicles: Next conclusion is that there has been a shift in the proportion of cars and cabs compared to all vehicles registered between 2010, when Ola was launched, to 2016. It was observed that the proportion of cabs to all vehicles is growing while that of cars is decreasing and that of motorbikes has increased. However, the proportion of motorbikes has decreased since 2015. As cars or motorbikes are the primary types of personally owned vehicles in Hyderabad, this trend needs to be explored further and studied to understand if this shift is suggestive of changing attitudes towards ownership and shared modes of transit in the city.

These shifts in proportions have been studied at an aggregated zone scale. However, if these proportions were to be studied at finer resolution, there could be a more nuanced understanding of how and where any major shifts in vehicle ownership are occurring and this may help better understand if on-demand cab services are initiating a cultural shift in the city.

In conclusion, this research recommends further study on all the factors that influence transit ridership and vehicle ownership, and the impacts on-demand cab services are having on them in greater detail and over a larger time span to truly understand the restructuring of urban mobility in the city, if any, and to formulate policies that weigh societal costs against individual gains to promote the development of an equitable society.

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