Increasing Bicycles' Share of Commuter Trips in Atlanta through Improved Trip Routing Methodologies

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Abstract

The paper investigates some of the many elements required for successful bicycling. It gives some suggestions to encourage people to choose bicycle as their trip mode. Due to limited data, the paper considers only bike-to-work trips. The report is split into three major sections: workplace incentives and facilities, land-use and bike facilities, and suggestions for bicycle trip routing. For workplace incentives, the analysis found that even though many employers generally offer showers and/or incentives for biking to work, this type of data is not being stored and is thus not widely available. For land-use and bike-facilities, the analysis found that, while multi-use paths and bike lanes generally serve destinations and origins equally, protected facilities are located in more destination- heavy areas. For the third section, the paper puts forward suggestions based on bicycle trip experience, aimed at producing reasonable results. Further, this section lays out the required process for routing bicycle trips. Finally, considering the current special Covid-19 situation, the paper includes some speculations about the future of bicycle use resulting from the epidemic conditions.

Introduction

Policies about Bicycle Infrastructure in Atlanta

The Atlanta Regional Commission's Walk. Bike. Thrive! Plan (WBT Plan), approved in 2016, is designed with the objective of creating a connected, safe network. Its goal is improving the safety, mobility, and economic competitiveness of the Atlanta region under the framework of active transportation. The plan highlights the fact that only 5% of Atlanta region residents currently walk, bike, or take transit for their daily trips and identifies three key needs: safety, mobility, and economic competitiveness.[1] As part of the long-term regional plan and through federal and other funding, the Atlanta Regional Commission (ARC) plans to inject over one billion dollars by 2040 to improve bicycle and pedestrian friendliness of the region. The plan departs from traditional pedestrian and biking plans in Atlanta: instead of simply specifying bicycle paths on major thoroughfares, this new version provides a policy framework for integrated, comprehensive bicycle and pedestrian infrastructure projects for the 20 counties in Atlanta region.

Emergence of Active Transportation on the Public Agenda

Active transportation in the US can be traced to the 1970s, when enthusiasm for cycling grew with environmentalist sentiments and as a reaction to the automobile-centric development in the previous few decades. Atlanta was no exception; planners brought biking to the planning agenda during that period. In fact, in 1973 the ARC, Georgia Department of Transportation (GDOT) and MARTA commissioned the first regional bicycling facilities plan in the country, The Bicycle: A Plan and Program for its Use as a Mode of Transportation and Recreation.[2] The plan made several suggestions including calling for local jurisdictions to take on the responsibility of providing biking facilities and for a regional bicycle committee. It also recommended a specific review process for identifying project potentials and suggested that "local development ordinances should

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[1] Atlanta Regional Commission. 2016. *Walk, Bike, Thrive! Part 1*, 2.
[2] Hurley, J. 2018.

provide incentives for bicycle facility development". The conceptual plan included design recommendations for placement of bike paths, typologies, and specific networks and locations for demonstration projects. [3]Since then, the ARC has continued to produce plans and proposals on the topic of bicycling. In 1974, the Decatur Parkway Preliminary Engineering Design Report proposed bike lanes near the Candler Park Station along Decatur Street/DeKalb Avenue.[4] The 1977 Comprehensive Development Plan recommended the addition of "bike paths within the rights-of-way of major streets and highways" during renovations and additions.[5] This plan also included an official map showing 15-year bikeway plan showing location and type of bike paths (see Figure 1).[6]

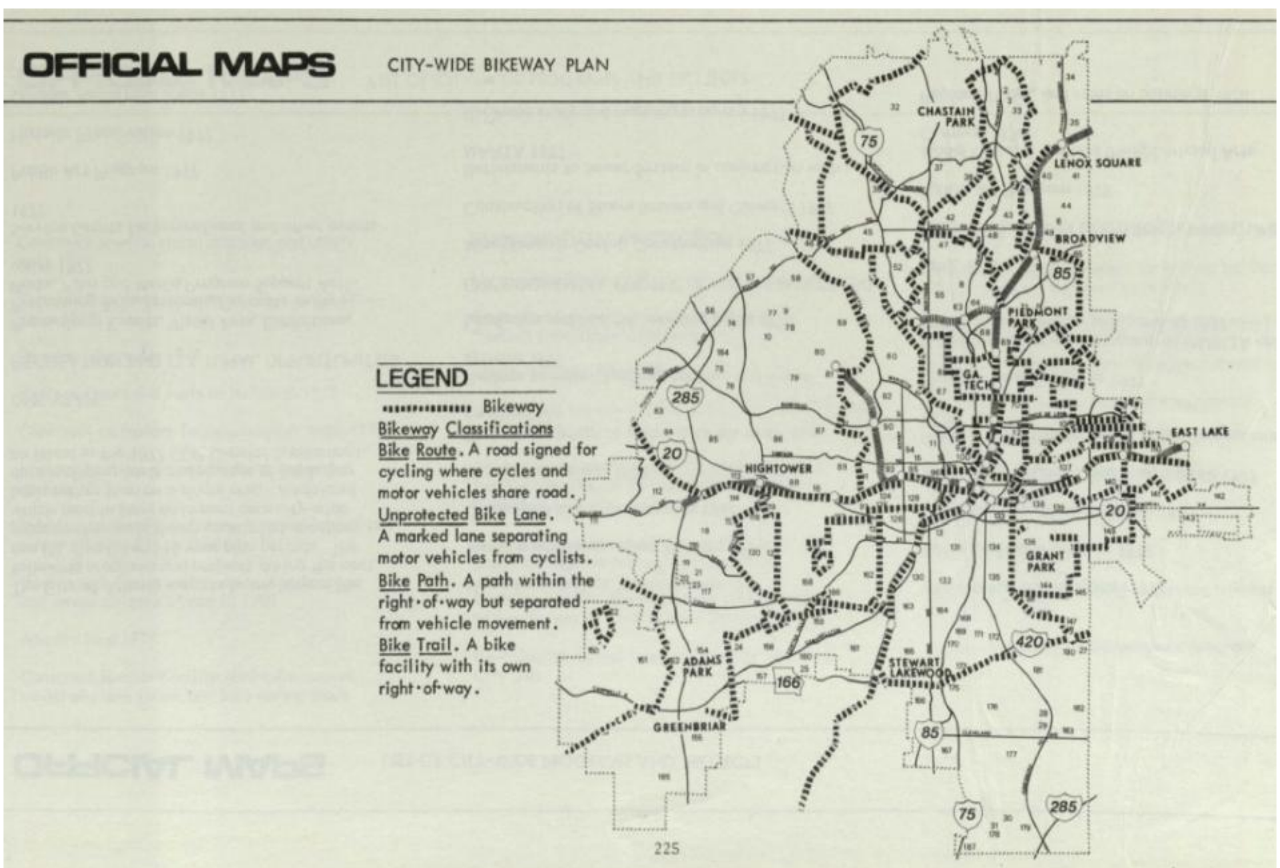

Figure 1. Regional bike path map from 1977 Atlanta Comprehensive Plan

[3] Barton-Aschman Associates. 1973. 65-68.
[4] Gustafson and Associates. 1974.
[5] City of Atlanta. 1977. 110-112.
[6] Ibid., 225.

Perhaps due to the legacy established by these early plans, the updated regional bicycling plans have focused on publishing maps with bike paths, and on making a regional connector bike network by adding bike lanes to major thoroughfares.

However, the added bike paths along the major regional connectors did not always attract riders, which led to political opinions that resources have been wasted on ineffective biking programs.

Current status of bicycle use of Bicycle in Atlanta

Bicycles can provide a low-energy, active, alternative to single occupant vehicle trips.[7] Compared to other American cities, the City of Atlanta has lagged in bicycle mode share at less than 1% for the City of Atlanta[8] and 6.3% for the City of Portland (2019), 1.8% for Sacramento Metro Area. Recent literature suggests that a lack of protected infrastructure and low-traffic-stress biking routes might be the reason for this discrepancy.[9] As the City of Atlanta invests in bicycle infrastructure and expansion, planners and engineers require an analytical approach that helps better place and justify bicycle infrastructure.[10]

Not all trips can be completed by bicycle. Due to physical constraints such as distance to destinations, elevation change, individual stamina, existing infrastructure, and limited carrying capacity, planners and engineers must focus on trips that are short enough to be easy for biking. Additionally, due to the low mode-share of bikes currently, getting data for more nuanced bike trips like a shopping trip provides additional difficulty. Therefore, trying to predict mode shift from single-occupancy vehicles to bicycles for short distance commute-to-work trips should be a more reasonable objective. Single-occupancy vehicles are chosen since that individual is not predicted to be driving others, such as children to school.

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[7] Grava, S. 2003

[8] Farris, Jen. 2019

[9] Furth, 2012

[10] Dill, 2013

For an individual to bike to work, certain requirements must be met such as bike parking, close proximity, and comfortable route. Without these conditions, an individual will likely choose a different mode.

Purpose of Project

The purpose of this project is to understand some of the factors that would need to be considered in a bike trip routing and develop recommendations for improving transportation infrastructure of bike-to-work trips.

The infrastructure requirements for travel can differ significantly across different trip purposes, such as commuting, shopping, dining out, social, and recreational travel. However, planning for bicycle infrastructure does not typically separate planning by trip purpose. Compared with other travel, commuting travel has a certain temporal and spatial stability. The schedule of commuting travel directly affects the arrangements of other activities of urban residents. Especially with the acceleration of the urbanization process, the employment scope of urban residents is continuously expanding, the distance of commuting trips is increasing, and the time is continuously prolonging, making commuting trips increasingly complicated and diversified. Therefore, it is necessary to conduct a comprehensive analysis and study on the commuting behavior of urban residents, to master the regular pattern of commuting travel, and to improve the traffic environment for residents traveling.[11] So, this study considers only commute-to-work trips.

This report is broken down into three sections. The first section is about employer incentives and amenities. This includes showers, bike parking, and/or incentives for biking to work. This information is useful because it is suspected to influence the likelihood of a person biking to work, and these incentives/amenities likely vary from location to location. This information can be coded into a bike travel demand routing model to determine mode choice. The second section of this report is about the connection between land-use and existing bicycle facilities. This information is useful

[11] Li Zhang. 2011

because it could inform decision makers on how to appropriate funds for projects, and it is suspected that some facilities are more effective than others. In the third section, a rudimentary trip routing experiment was made to demonstrate how cyclists would deviate from the shortest route based on commonly agreed upon route impedance found in literature. Lastly, some thoughts on the future of bicycle use under the influence of the epidemic.

Stakeholder Assessment

There are several stakeholders that would be interested in or benefit from developing bicycle infrastructure and routing method. Since this paper's analysis is limited to the City of Atlanta, many of the key stakeholders are local to the Atlanta region. Identified stakeholders include four distinct categories: government and governmental agencies; advocacy groups; businesses; citizen groups and individuals.

Under government and governmental agencies, key stakeholders include the City of Atlanta, the ARC, Georgia Department of Transportation (GDOT), and National Association of City Transportation Officials (NACTO). The ARC would be required to put in the most resources out of any of the mentioned organizations in order to actually develop a bike travel demand model. The City of Atlanta would find a bike travel demand model useful for appropriating funds and determining where new biking facilities would be best placed. Most of the city's bike facilities are on city owned roads as opposed to GDOT owned roads. However, GDOT could use this model to predict bike travel on their own corridors.[12] And it would likely be interested in having more resources to justify guidelines.

For advocacy groups, key stakeholders include the Atlanta Bicycle Coalition (ABC), League of American Bicyclists, and Georgia Bikes. These organizations already advocate for new bike facilities but may not have the data to argue about the impact new facilities might have on bicycle connectivity.

[12] GDOT. 2019

Under businesses, key stakeholders include transportation coordinators, or those working in a similar function doing transportation demand management (TDM). Transportation coordinators typically manage commuting facilities at worksites, such as bicycle parking and showering facilities, and can also manage programs aimed at incenting other forms of commuting. At large employment buildings that are not wholly owned by one company, this work could fall to the property management team, which may decide to include facilities mentioned above for the benefit of all tenants in the building.

For citizen groups and individuals, key stakeholders include community improvement districts (CIDs), neighborhood planning units (NPUs), and cyclists. These are the individuals that would ultimately be paying for the model and any facilities constructed because of it.

Practical Issues

Technical

Technical issues include available data, Transportation Analysis Zone(TAZ) size, and computational limitations. Currently, an inventory of cyclist amenities such as available public parking, employer amenities, and employer incentives are not available for Atlanta. Having an inventory of these amenities and incentives is critical to determine the impacts each has on mode choice. The section on employer incentives/amenities will go into more detail about these.

Additionally, as distance increases away from downtown Atlanta, the size of TAZs decrease. Having TAZs with small areas throughout the model would increase the computational strain, however this project addresses this issue specifically for cyclists. This issue will be expanded upon the routing model section.

Policy

No detailed performance measures to continually track cyclist infrastructures ridership and impacts currently exists in Atlanta. While this project does not directly suggest performance metrics, it provides a reference to analyze infrastructure relationship to land use and creating bicycle trip routing model.

Political

Presently, the placement of Atlanta bicycle facilities is largely a political decision. The City of Atlanta funds the project, and therefore, decides where the project will go. While this project does not suggest changes to this structure, it provides decision makers with insight into where future facilities should be placed.

Literature Review

Many literatures in this field provide support and inspiration for this study. Based on the objectives of this project, the literature review was split into two components: To understand current employer incentive programs and facility options to accommodate bikes and to make recommendations on how to make bikes as a mode of transportation have a reasonable routing model.

Employer Incentive Programs and Facility Availability

When modes like the automobile dominate, it might be best to provide incentive programs and high quality end of trip facilities to encourage less used modes. Several studies examine commuter programs and employer benefits but most also include the transit and walking.

The first thing to consider is all the possible benefits an employer can offer. These benefits can be the presence of canceling parking charges for parking, transit passes, bike parking, showers, and lockers. Free-parking for cars not only not an incentive to bike to work but also have an negative impact on the probability of employees biking to work.[13] From this study it is clear that it is important to consider all commuter benefits.

Most studies in this area approach incentive programs from a travel demand management perspective (i.e. reducing congestion and pollution by reducing single occupancy vehicle mode share). Additionally, some benefit programs work on a game system where employees can work towards rewards for taking alternative modes.[14]

Another factor to consider in the effectiveness of employer incentive programs is the context of the workplace and residential built environment. One study found that the built environment around the workplace mattered more than the residential built environment. Additionally, they found that trip chaining was not a significant deterrent to different non-auto modes.[15]

Ultimately, from the literature review, several large employers in Atlanta should be contacted to understand the local availability of these employer incentive programs.

Bicycle Modeling

It is of interest to create a bicycle trip routing model because there has been a lot of growth in both the number of bike facilities and bike mode share in the City of Atlanta. Trip demand models can often be used for planning and justifying infrastructure investment. Until bikes are successfully implemented into the model, planners and investors will be unable to forecast long term planning outcomes for bicycles.

At the turn of the century, the FHWA put out a guidebook on modeling non-motorized modes of transportation. It outlined some key issues that prevent bikes from being included into existing models: insufficient ridership data, insufficient level of detail with traffic analysis zones (TAZs), and no way of distinguishing between recreational and utilitarian cyclists.[16] It also served as a useful jumping off point in that it looked at how

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[13] Hamre. 2014
[14] Piatkowski, D., et al. 2014
[15] Dong et al. 2016
[16] FHWA, 1999

other cities modeled bikes. In general, this document made it clear that travel time, cost of travel, and shortest path were not adequate measures for modeling bicycles. Most regional travel models at the time only predicted automobile and transit travel.

In 2006, Roger Geller came up with a 4 tiered classification scheme for identifying cyclists by confidence and comfort with traffic decisions. While it is useful to acknowledge the existence of this classification system, this report is going to try and come at trip modeling primarily from the perspective of the primary trip purpose. However, there have been follow up studies that have tried to verify these classifiers by survey data successfully through surveys and phone interviews. As such it might be a useful method of determining the propensity to bike as each classification would have different requirements that would need to be met before they would feel willing to bike.[17]

NCHRP Report 08-36, Task 141 evaluates walk and bicycle demand modeling practice. Key challenges in incorporating bicycle and walk trips into travel demand model include spatial constraints, data constraints, modal choice, and land use, among other factors. Currently, TAZs are too large to accurately consider biking and cyclist trips which may often be inter-modal. While GPS data makes it easier to analyze cyclist and pedestrian trips, the details of the data on the type of trip and data on the person making that trip are usually more difficult to come by. The mode choice breakdown also creates issues when considering the availability of the mode may not be equal in certain locations. In addition, there is a relationship between both routing and mode choice with land use and transit. All these factors will need to be overcome to robustly include both walking and bicycling into travel demand models.

In addition, a disconnect between the research and MPOs/DOTs and researchers exist. Currently, a majority of route choice research is occurring at the university level, however, detailed zone data may be limited for their research. MPOs and DOTs are also limited in terms of budget and the number of hours their modelers can work on these projects. Different regions, however, have had some success in bicycle research and integration into their travel demand model.

[17] Dill, 2013

In certain geographic regions, the number of cyclists justifies incorporating both cyclist mode choice and routing choice into the travel demand model. Three peer cities which have completed research on cyclist routing include San Francisco, Sacramento, and Portland.

Research has occurred in both Portland and San Francisco to adjust current routing assumptions using only shortest distance methods. Sacramento, however, does not adjust the full routing, but adds specific cyclist routes that previously did not exist in TAZs.

Research completed by Broach, Gliebe, and Dill in 2007 instrumented cyclists in Portland in order to develop a route choice model. This study collected 1,000 individual, non-recreational trips, and linked GPS data to the existing roadway and bicycle network. Trips were broken down into both commute and non-commute categories. In Portland, this study found that distance remained the largest factor in cyclist mode choice, but other factors such as slope, facilities, and adjacent traffic affected cyclists route choice. The largest negative facility impacts came from lacking of off-street paths and bicycle boulevards. In addition, this study also found that work commute trips will likely have a shorter distance, while non-commute trips seek out better facilities, which forces them to travel additional distances. This route choice algorithm with its associated factors was successfully implemented into the Oregon Metro’s travel demand model. Portland, however, has not completed a follow-up study since 2007, and therefore assumes the factors found remain accurate. The Oregon Metro does continuously update their bicycle facilities in their model.

In 2011, Hood and Charlton performed a similar study in San Francisco. Rather than instrumenting bikes, however, this study used cellular GPS data. Unlike Portland, bike lanes had the largest positive impact in routing, while distance and slope were still the largest factors. This study, however, failed to adequately relate adjacent traffic to their route choice model, and have severe undersampling of women and lower-income communities.[18]

Sacramento ,while incorporating bikes into their model, did not do any type of survey or rider study. Instead they just used anecdotal data and assumed cyclists would perceive paths with less traffic and more bike facilities as shorter than the actual shortest path.[19] To accomplish this they used weights to modify distances. They also included bike only paths to the transportation networks and took out any roads that bicycles were not allowed on like interstates. Finally they attempted to use distances between census blocks rather than TAZ's for short <1 mile or interzonal trips.

Overall, these findings suggest the impacts of different factors on route choice likely varies by region. While cyclist facilities have a positive impact in routing, the impact for each facility type would vary by region. Plus, common sense suggests that the rapid rise of motorbikes, scooters and e-bikes may definitely negatively impact the use of bicycle. To accomplish a route choice model for cycling in the Metro Atlanta region, a similar study to the one in Portland should be conducted.

Bicycle Amenities and Mode Choice

Background

It is well documented that certain behavior can be encouraged and discouraged, and this is the case as well for bicycle commuting. The literature points towards different actionable items at the employer level that can persuade employees to bike to work. On one side, employers can provide facilities that facilitate an active commute, such as covered and protected bike parking for storage and shower and locker facilities for work preparation.[20] On the other side, employers can provide financial incentives for both

[18] Hood, J., E. Sall, B. Charlton. 2011
[19] SACOG, 2015
[20] Piatkowski, 2014

transit and biking to increase the occurrence of bike commutes.[21] It is also important to note that in either case, the presence of free motor vehicle parking at the work place can undermine all other amenities and policies and decrease bike commuting.[22] These main factors are summarized in Table 1 on the following page.

Table 1: Primary Factors at the Work Place

Factor	Influence	Description
Bike Storage	(+)	availability of safe and covered bike parking is of significant importance
Shower Facilities	(+)	availability of shower facilities is important for employees to refresh and prepare after an active commute
Incentives	(+)	presence of financial incentives can encourage a mode shift to active transportation
Free Motor Vehicle Parking	(-)	presence of free automobile parking can detract from all other benefits and promote driving

Methodology

I began collecting information from many employers in the Atlanta metropolitan core to inventory the presence and quantity of amenities at their work places. A uniform questionnaire was distributed to each major employer surveyed. Questions for each work places are as below:

- How many employees are assigned to the location?
- Is there off-street, covered bike parking for employees? If so, how much?
- Are there showers or lockers available for employees?
- Does the worksite conduct tracking for bicycle commuters?
- Does the worksite provide any financial incentives for bicycle commuters?
- Does the worksite provide free motor vehicle parking?

[21] Dong, 2016
[22] Hamre, 2014

The geographic scope of the inventory is limited to the Atlantic Station, Midtown, and Downtown areas. This process aimed to collect information from large towers with approximately more than 1000 employees assigned to it. I began the facility inventory by reaching out to large employers directly. The responses are shown in Table 2 in the following section.

Analysis

The responses to the questionnaire are shown below in Table 2. Unfortunately, all respondents did not have exact answers for the those questions. In the end, I collected information from 17 employees around the city. For simplicity, their companies are anonymitied.

Table 2. Facility Information by Building

Respondents	Area	Bike Parking	Shower Facilities
1	Atlantic Station	Y	Y
2	Atlantic Station	Y	Y
3	Atlantic Station	Y	~
4	Atlantic Station	Y	Y
5	Atlantic Station	N	N
6	Downtown	Y	Y
7	Downtown	Y	Y
8	Downtown	Y	Y
9	Downtown	Y	Y
10	Downtown	Y	Y
11	Midtown	Y	Y
12	Midtown	N	N

13	Midtown	Y	Y
14	Midtown	N	N
15	Midtown	Y	N
16	Midtown	Y	Y
17	Midtown	Y	Y

Y - yes, facility is present | N - no, facility is not present | ~ - facility is available to specific employer

Respondent companies are located in buildings that can accommodate thousands of people, so their feedback is the current status of the bicycle infrastructure in 17 buildings. There are 14 buildings have available bike parking. Only one building, in Downtown, provides financial incentives for its bike commuters, though it is important to note that there is one forward-thinking individual employer in a building in Atlantic Station that provides similar financial incentives. This is the same company shown in the table above that constructed showering facilities on their floor to specifically give their employees access to showering facilities. At the city-wide level, Georgia Commute Options provides monthly raffles and cash incentives for employees to switch to alternative commutes, including bike commuting. Since the inventory is not robust nor exhaustive, further analysis of facilities and incentives impacts for Atlanta are required.

Bicycle Facilities and Land Use

Background

The current ARC Plan lays out a local framework for cities and counties to implement bike/ped infrastructure. The Plan defines a 20-minute neighborhood, in which all the key needs of a community are provided through a careful mix of land uses in a connected street grid with bike/ped-friendly infrastructure and access to transit. The Plan urges local communities to update land use and development codes, rethink parking requirements and design guidelines, and work to reduce vehicle speeds, among others.[23] Understanding how bicycle facility placement relates to land use in Atlanta can

[23] Atlanta Regional Commission. 2019. *Walk, Bike, Thrive!*

help inform planners and engineers of the best type of locations to place new facilities. Because of its wide variety of activities and its high density, mixed-use areas possibly encourage more walking and biking trips. In addition, those interested in biking and walking may move to mixed-use areas, so they can use those active modes.[24] Additionally, as a transportation network the bicycle network must connect origins and destinations for individuals to use it.

Analysis

Loading the ARC's bicycle facility inventory shapefile into ArcGIS displays the entire network for the Atlanta region. Using ArcGIS's clip function and the City of Atlanta's geographic boundaries, the bicycle facilities in the City of Atlanta were found. Within Atlanta, three different types of bicycle facilities exist: bike lanes; protected bike lanes; and multi-use paths. Table 3 below displays the mileage breakdown for each facility type. Overall, Atlanta has 106 miles of bike facilities with a majority of those facilities being bike lanes.

Table 3. Atlanta Bike Facilities by Mileage and Percent

Facility Type	Miles	Percent
Bike Lanes	62	58.5%
Multi-use Path	40	37.7%
Protected Bike Lanes	4	3.8%

After finding the bicycle infrastructure within the city of Atlanta, each facility type's relationship with land use is examined. To encourage bicycling to work trips, bicycle facilities must connect origins and destinations. Connecting existing facilities to land use also examines if the more impactful facilities like protected bike lanes are currently placed in the most impactful areas.

To understand the breakdown between origins and destinations within Atlanta, TAZ's are examined. Ideally, TAZs are homogeneous within and heterogeneous throughout

[24] NCHRP, 2019

which means an individual TAZ has similar land-uses while different TAZs can have vastly different land-uses . The TAZs file have attributes which include the number of businesses, houses, and population, among others.

From the model outputs, the number of home to work and work to home trips for each TAZ can be calculated. Based on the percentage of home to work trips, individual TAZs can be examined on how origin or destination oriented they are. The equation below depicts the calculation used to see the percent origin of a TAZ.

$$\%\ Origin = \frac{Home\ to\ Work}{(Home\ to\ Work + Work\ to\ Home)}$$

A TAZ which has no work to home trips is a 100% origin TAZ. Conversely, a TAZ which has no home to work trips is considered 0% origin or 100% destination. The code used to calculate the number home to work and work to home trips is in Appendix A. Figure 2 below depicts the percent origin for all Atlanta TAZs and Atlanta bike facilities.

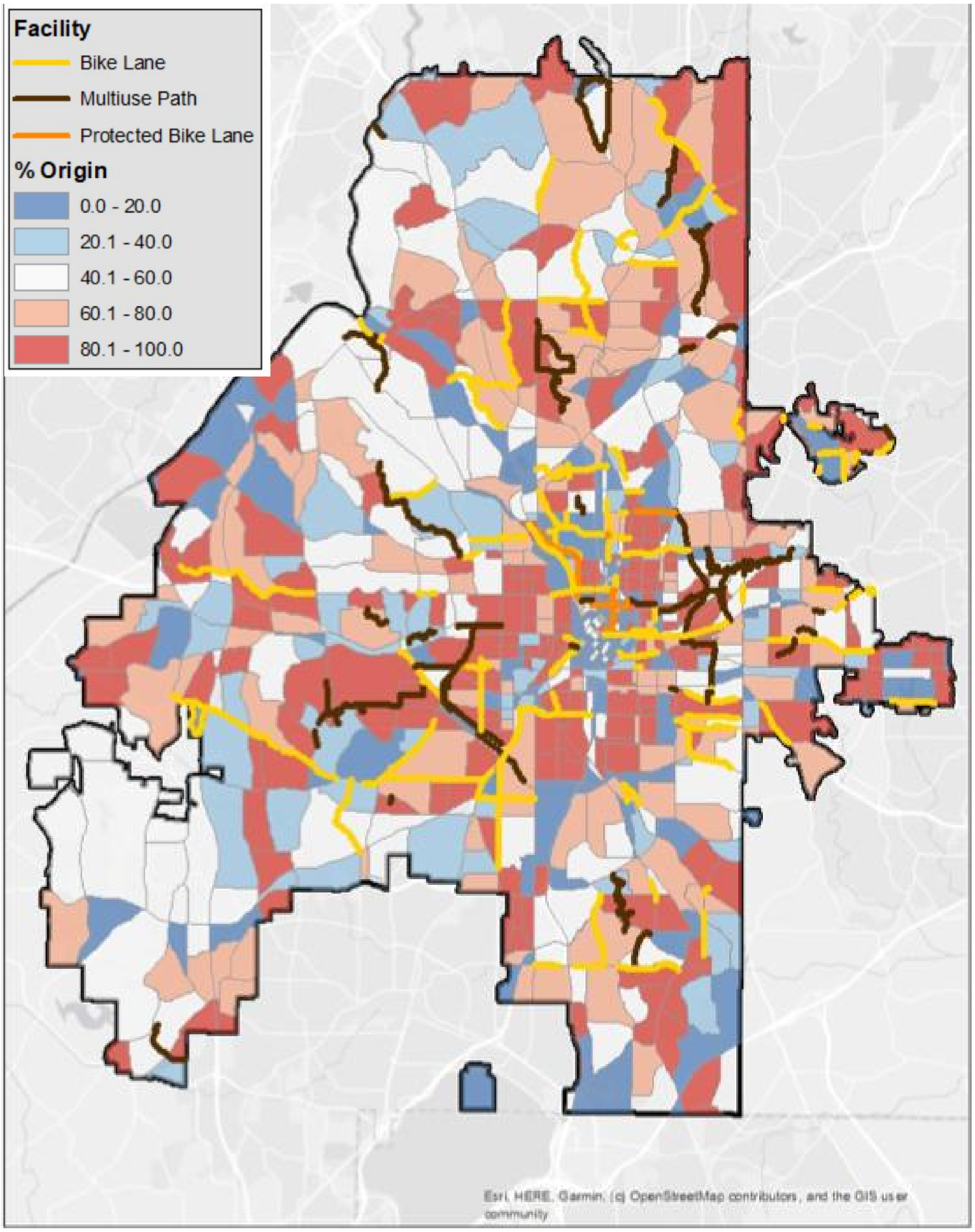

Figure 2: Percent Origin for each Atlanta TAZ

The red TAZs mean the TAZ is primarily origin based, while the white TAZs means the TAZ is mixed between origin and destination trips. Conversely, the blue TAZs are primarily destinations. Using the intersect feature of ArcGIS, Atlanta's bicycle facilities are analyzed to see whether they are currently located in origins or destination centric TAZs.

From the map we can observe how the three bike facilities distribute trips in different oriented TAZs. Basically, protected bike lanes located primarily in destination centric TAZs, they currently do not serve many origin-destination pairs. Looking at Figure 3 below, big gaps in the cycling infrastructure are noticeable. Currently, protected bike lanes, seen in orange, are primarily located in downtown Atlanta and fail to connect origin TAZs to the west and northeast.

Figure 3: Downtown Atlanta Gaps in Cyclist Infrastructure.

Along with examining origins and destinations, analyzing bicycle facilities and their relation to mixed-use TAZs also demonstrates current gaps in Atlanta's cyclist infrastructure. Using a mixed-use entropy equation from NCHRP 08-36 listed below, Atlanta TAZs mixed-use indexes are calculated.

$$Mixed\ Use = \frac{2*(Households*Employment)}{(Households + Employment)}$$

Figure 4 below depicts the mixed-use levels for Atlanta TAZs. Darker purple means that an individual TAZ has a higher mixed-use level. These TAZs are located primarily in Northeast Atlanta near Lenox Mall.

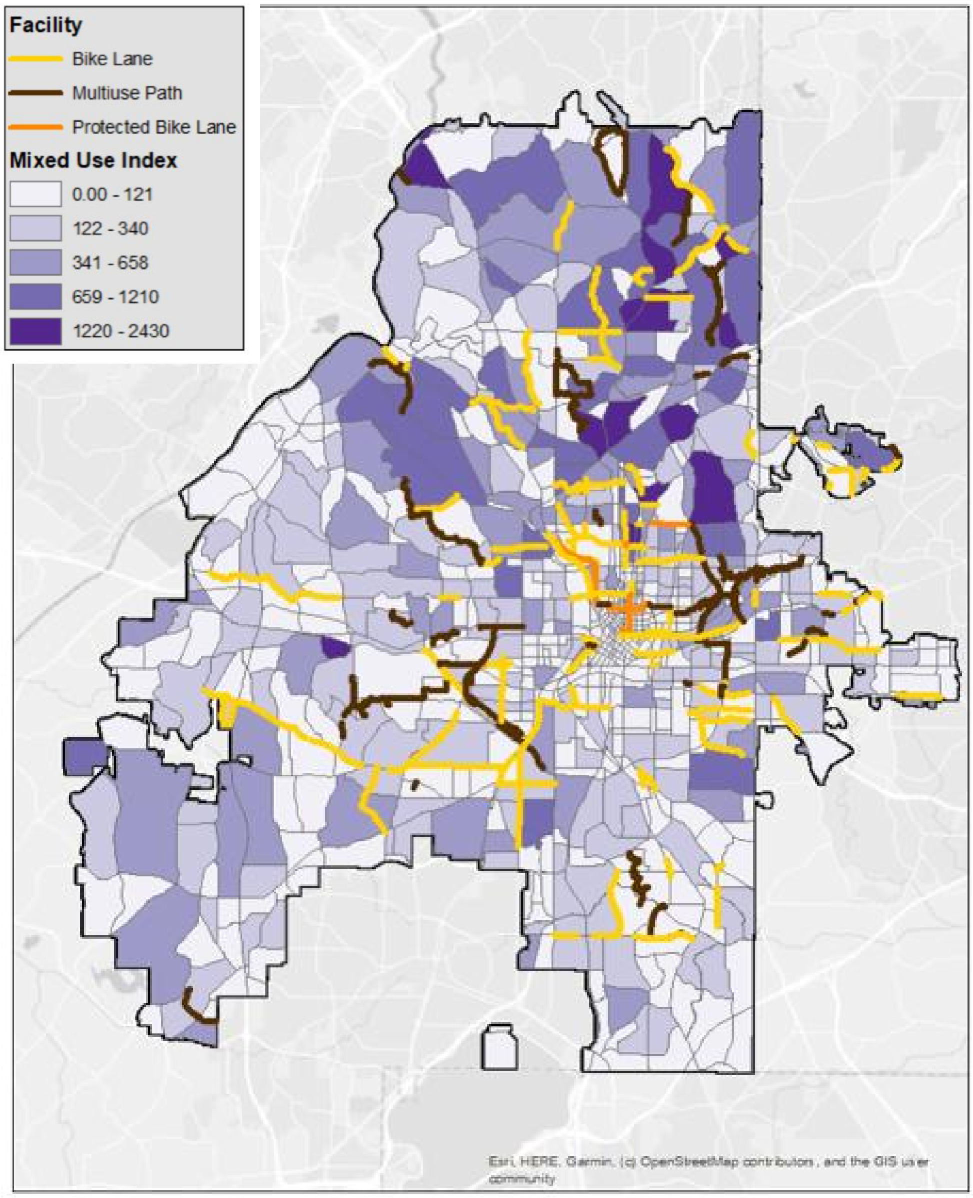

Figure 4: Mixed-Use Index by TAZ

Ideally, more protected facilities such as protected bike lanes and multi-use paths would be located in the more mixed-use areas compared to its overall facility share. In reality, by observing figure 3 we can know that bike lanes are slightly disproportionately located in more mixed-use TAZs when compared to multi-use paths and protected bike lanes.

Analyzing Atlanta’s bike facilities both in terms of origin-destination and mixed-use depicts that Atlanta’s more protected cyclist facilities are not currently located in areas that encourage cyclist trips.

Bicycle Trip Routing

Background

There are several reasons for why bikes need a separate routing method than automobiles. The first is that routing models for autos generally only consider distance and time. While bike travel is limited by distance and time, it has been shown that cyclists will deviate from the shortest past as much as 30% on average in Atlanta.[25] This may be due to detours to avoid busy roads, big hills, or take a bike facility.

The second reason is that the traditional method for routing autos does not include bike specific network links. In Atlanta, an example of this would be the Beltline. It is shared use path that, for the most part, do not parallel any roadways. Additionally, bike facility presence is also not considered. As stated earlier in the introduction, there is a lot of evidences that point to people preferring facilities with more separation from automobile traffic.[26] Where the conflicts between walkers, joggers, scooters, and cyclists diminish the experience for all. To accurately reflect observed bike trips, the bike routing model must account for the bike specific network.

The last reason is that the Traffic Analysis Zone and the road network may not be spatially precise enough to accurately route bikes. As mentioned above, people prefer to avoid sharing the road with automobiles, but it is not possible in Atlanta to get from every start point to every end point while only on dedicated bike infrastructure. As such, people might elect to take smaller neighborhood streets with a lower traffic stress.[27] To

[25] Misra. 2016
[26] Clark. 2018
[27] Furth. 2012

make routing less computationally intensive, these smaller neighborhood streets are likely not considered in the traditional automobile routing. Additionally, any intrazonal trips or trips to adjacent zones do not yield useful routing information (NCHRP 2019). Because of these issues, other cities use micro-analysis zones (MAZs) to model bicycles.

Latent Factors that Influence Routing Decisions

Since not all people take the shortest distance network path when biking to work, it would be of interest to know more about these factors that cause cyclists to detour. The more obvious ones may be bike facility preference or avoiding steep hills, but there are also other less obvious factors like the number of turns or presence of traffic signals.[28]

These factors that influence routing behavior are normally captured using instrumented bikes and/or GPS traces. The City of Atlanta had an app a couple years ago that crowdsourced the recording of bike trips. The app was based off a similar app used for San Francisco.[29] It was found that participants of this app would have an average 30% detour rate from the shortest path.[30] Participants would generally deviate from the shortest path if there was an alternate route with higher proportion of bike lanes, and participants would generally deviate from the shortest path if the shortest path had steep elevation grades or higher traffic. Although these factors (bike facility availability, grade, and traffic volume) were found to be significant, there is not a clear way of transferring these findings into a cost comparison.

Other cities largely found similar trends with bike facilities and grade, but they differed on the degree of significance. San Francisco found bike lanes to be the most significant factor that impacted routing decisions in contrast to Portland that found bicycle boulevards to be most significant.[31] Leading off of that, some cities have facilities that Atlanta does not have. Portland's used instrumented bicycles to determine bicycle

[28] NCHRP. 2019
[29] Zorn. 2011
[30] Misra. 2016
[31] Hood. 2011/Broach. 2011

boulevards's significance, but Atlanta does not have any designated bicycle boulevards.[32] It is unclear if the development of bicycle boulevard in Atlanta would lead to a change in routing behavior.

The NCHRP Task 141 report summarizes a list of factors that affected routing behavior. This list was converted to Table 6 below and given a "+" or "-" depending if it caused cyclists to not detour or if it caused them to detour respectively.[33]

Table 4. Factors Considered by Peer Cities

Factor	Generalized Influence	Source
Road Grade/Elevation Change	(-)	San Francisco
Number of Turns	(-)	Portland
Bike Facilities	(+)	Portland/Monterey
Unprotected Left Turns	(-)	Portland

Even though there is fairly consistent consensus on what factors cause cyclists to deviate from the shortest path or adhere to it, there is no agreement on how to convert these factors into a cost function that would work for every city. Additionally, every city network is different, and might have a different amount of biking facilities. Sacramento, despite not doing its own instrumented bicycle study, came up with weights based on engineering judgment and finding from others, and they used these weights to adjust routing behavior simply based on facility availability.[34] The important takeaway is that results from these models need to be verified, but trip routing factors can be estimated based on previous studies.

[32] Dill. 2011

[33] NCHRP. 2019

[34] SACOG. 2015

Creating MAZs for Atlanta

In the bicycle trip routing process, there is a need for more spatially precise unit than a TAZ. The method used for creating these units, called micro-analysis zones, comes from the NCHRP Task 141 Report. This method involves intersecting TAZs with census blocks. Like TAZs, census blocks are bounded by roads; this makes it so the general structure of a TAZ can still be used. Additionally, census blocks should have the same sort of information that TAZ's provide. If a census block is in two different TAZs, then there will be two different MAZs that both represent that census block.

When this process is done for the city of Atlanta, there is a noticeable increase in spatial detail as seen in Figure 5. There are 745 TAZs within the city of Atlanta, but there are 5566 MAZs. Even though we don't know how exactly does the math change when all of these new MAZs are added, now there are many more network links or road segments that need to be used for inclusion of bike facility presence, number of lanes, and so on. This output result will likely not agree with every road network in reality. However, even if not every link can feasibly be used in the bike trip routing model, there is still useful information in knowing that the street exists in the first place. This is because certain trips might actually be shorter distance because of the added street network.

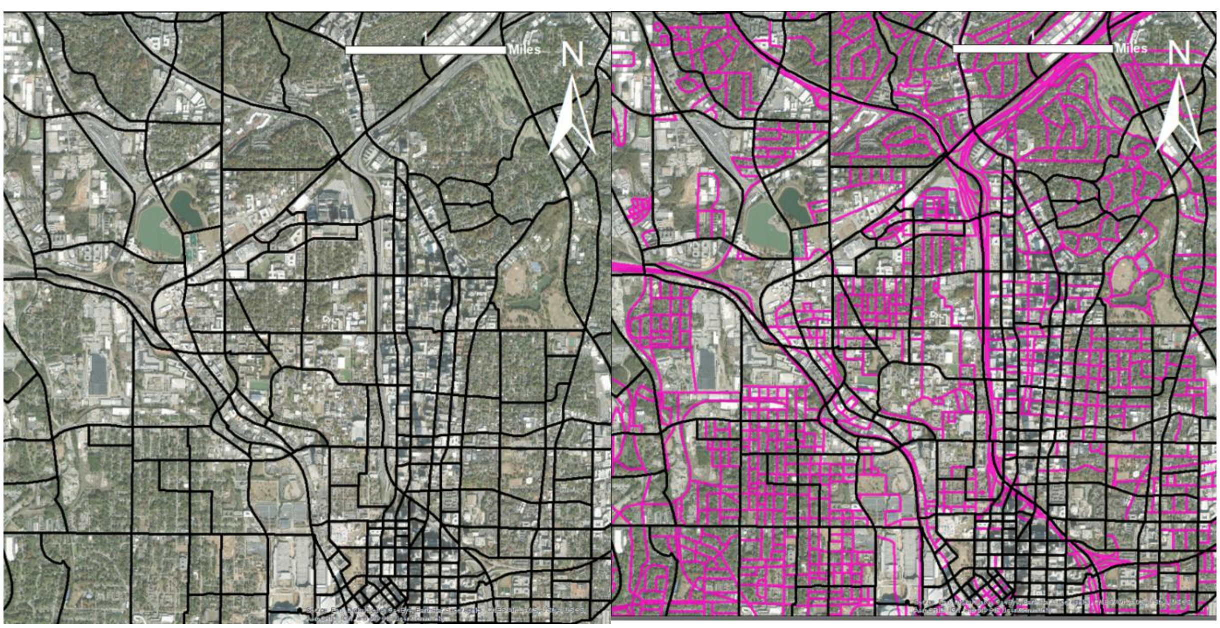

Figure 5: Left, with just TAZs & Right, with MAZs

Bicycle Trip Routing Experiments

A field trip was conducted by the author on March 3rd, 2020. Two routes were chosen to compare the bike experiences. I had experience getting to the start location to the end location by bike, and I think the detour route is the less stressful way of getting to end place. The first route is a coffeehouse Barista commuting from Home Park to Octane Coffee.

In each commute experience, two routes were tried by me. One is controlled route that generated by navigation model and another is alternative route which I preferred to use. I assumed that after analysis with more weighted factors, the alternative one would be chosen by the routing model other than the less-distance one.

As seen in Figure 6, the shortest path involves taking a major arterial, 10th St. The alternative route went to the Barista through Georgia Tech Campus, utilizing as many bike facilities as possible. Figure 7 show the field trip image on the control route and figure 8 show the field trip image on the alternative route. Through the comparison of the bicycle facilities and road conditions, it seems reasonable that a person would rather take dedicated bike facilities than a busy arterial, even though the estimated time difference between the two routes came out to be about 3 minutes.

Table 5. Distance and Time Differences for Coffeehouse Barista Trip

<table>
<tr><th></th><th>Straight-line distance</th><th>Control Route</th><th>Alternative Route</th><th>Time Difference</th></tr>
<tr><td>Distance</td><td>0.78 mi</td><td>1.41 mi</td><td>1.62 mi</td><td rowspan="2">3 mins</td></tr>
<tr><td>Time</td><td>-</td><td>9 mins</td><td>12 mins</td></tr>
</table>

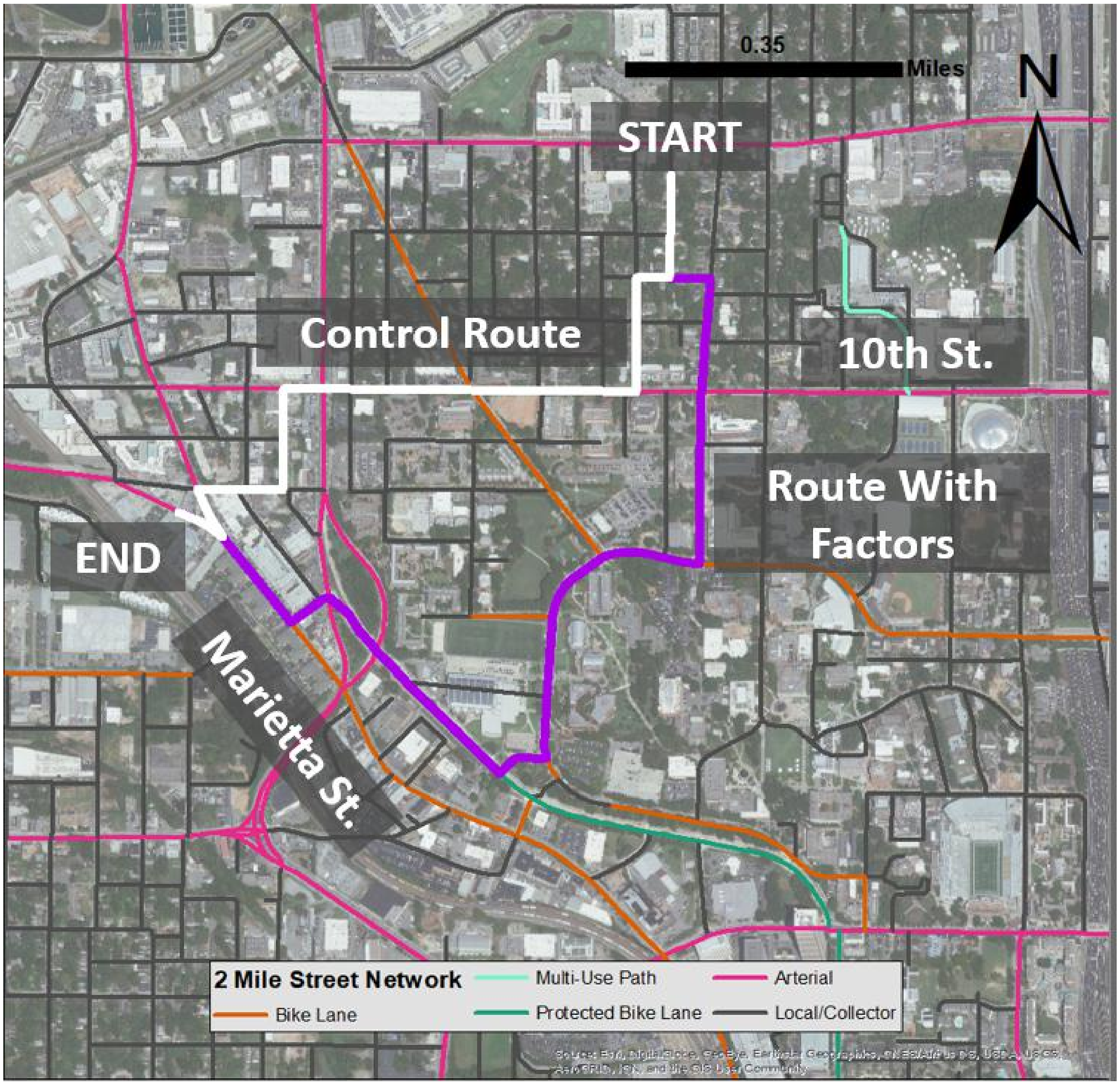

Figure 6: Trip Routing for Coffeehouse Barista Scenario

Figure 7: Field Trip image on the Control Route for Coffeehouse Barista Scenario

Figure 7: Field Trip image on the Alternative Route for Coffeehouse Barista Scenario

The second trip is a Park Groundskeeper commuting from Home Park to Piedmont Park. The shortest path involves taking a busy arterial all the way to Piedmont Park. The alternative route takes a route with more bike facilities and local streets.

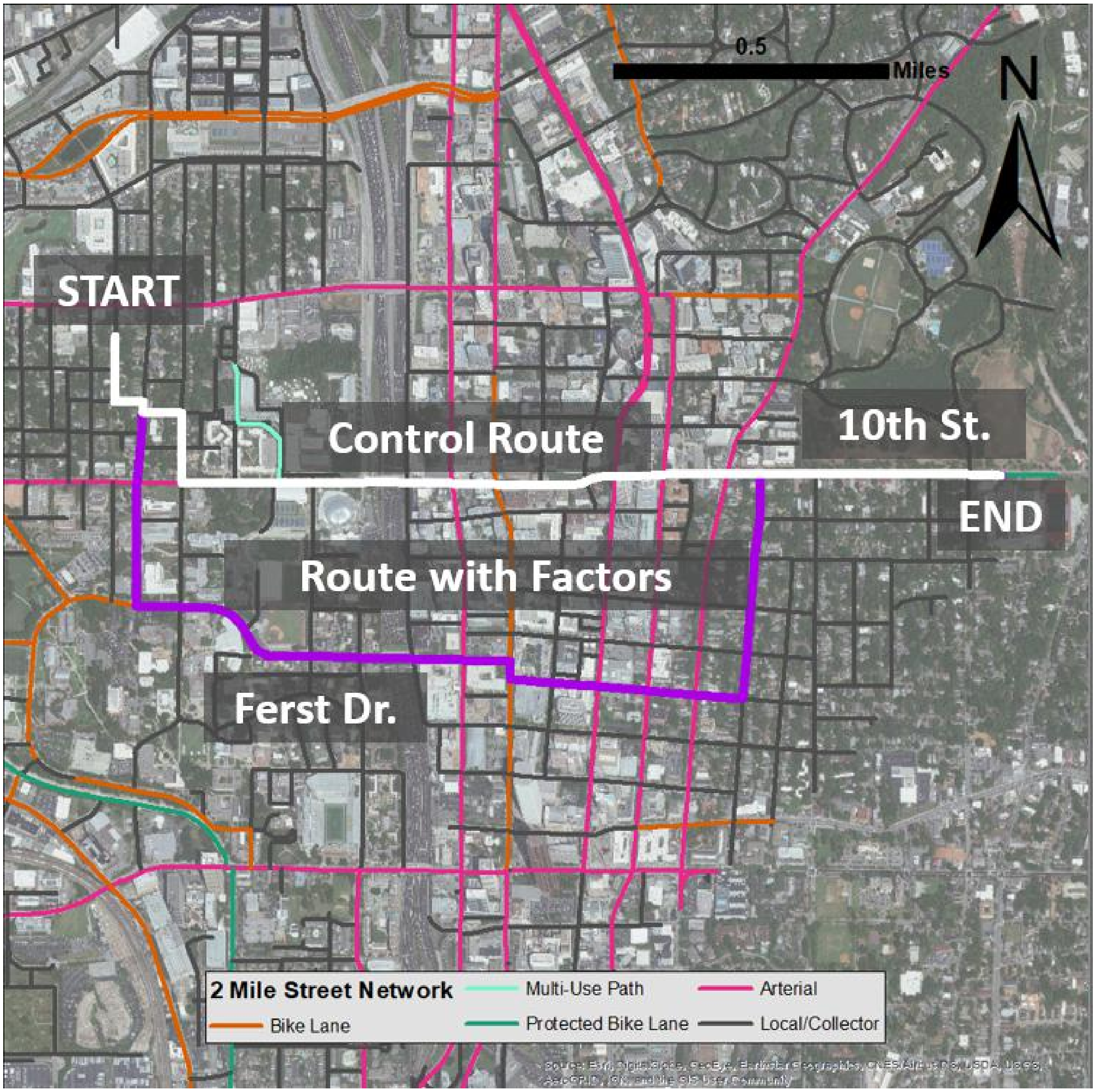

Figure 8: Trip routing for a Park Groundskeeper Scenario

Table 6. Distance and Time Differences for Park Groundskeeper

	Straight-line distance	Control Route	Alternative Route	Time Difference
Distance	1.65 mi	1.88 mi	2.57 mi	5 mins
Time	-	14 mins	19 mins	

The time difference for the second route came out to 5 minutes. Again, it’s difficult to know if an individual commuter would consider that trade-off worth it. At the very least, these routes seem like reasonable decisions.

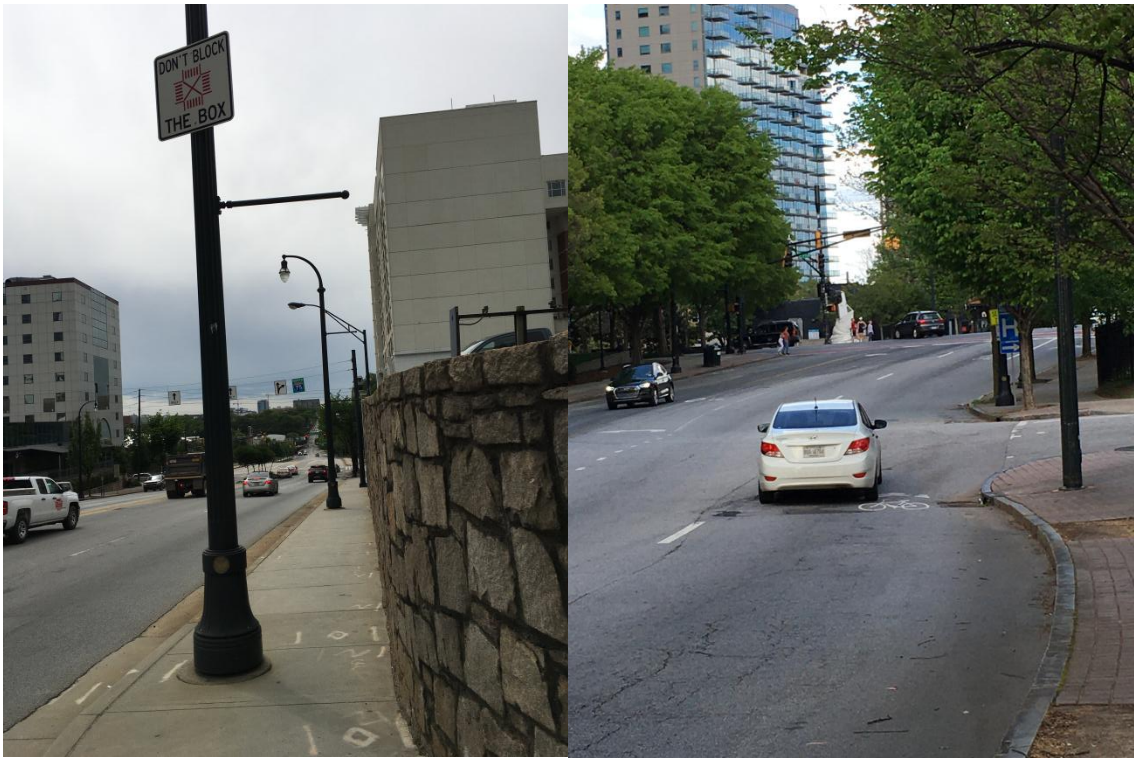

Figure 9: *Field Trip images on the Control Route for* Park Groundskeeper Scenario

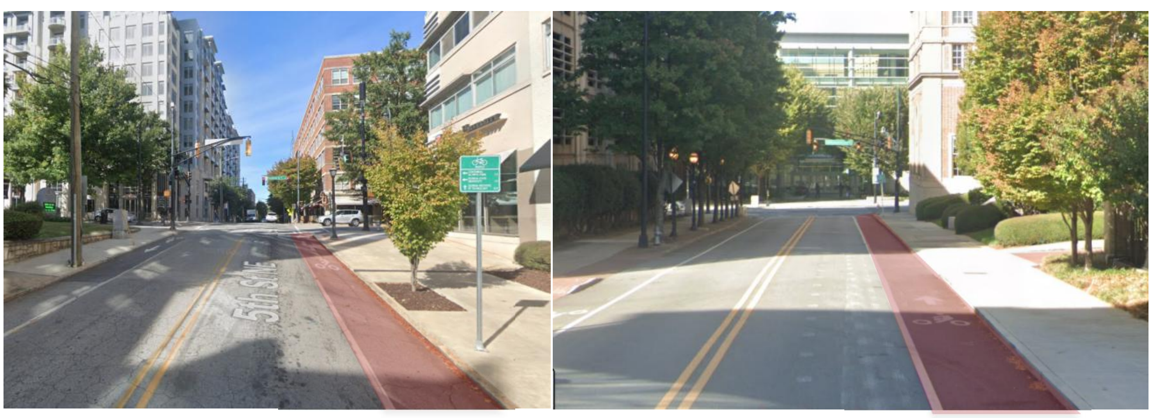

Figure 10: *Field Trip images on the Alternative Route for* Park Groundskeeper Scenario

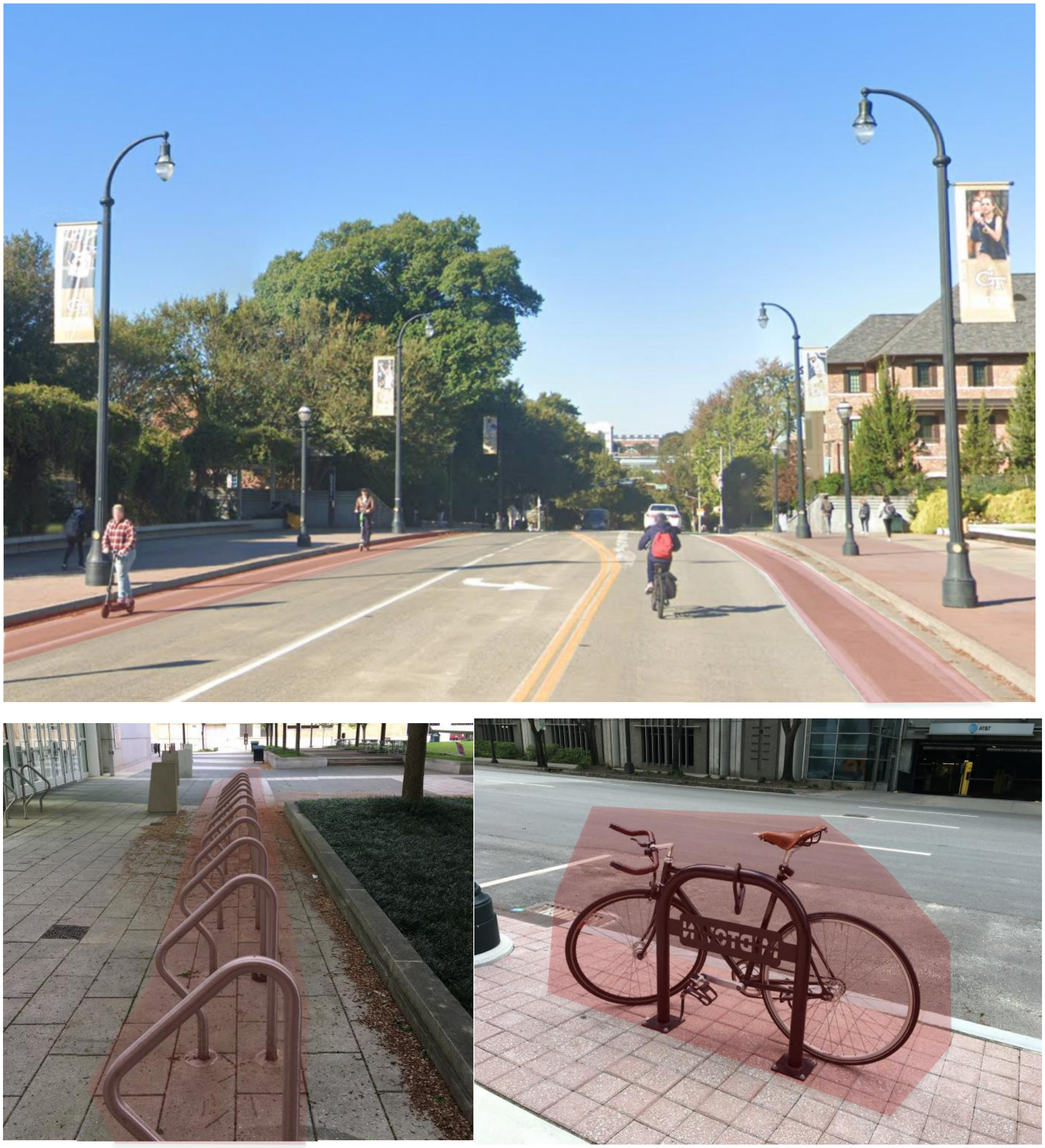

Figure 10: *Field Trip images on the Alternative Route for* Park Groundskeeper Scenario

Figure 9 show the field trip images on the control route and figure 10 show the field trip images on the alternative route. Through the comparison of the bicycle facilities and road conditions, it seems reasonable that a person would rather take dedicated bike facilities than a busy arterial, even though the estimated time difference between the two routes came out to be about 5 minutes.

Despite the simplifications of data and and the limited technology skill availability, the alternative routes seem reasonable. For full implementation of a routing modal, however, there will need to be much more work done. For one, all bike facilities will need to be included into the bicycle routing model network. If MAZs are to be used, then all of the smaller roads will need to be included into the network. Lastly, some guidelines need to be set on how far commuters would detour to get to a destination. A detour rate is needed to be calculated based on those considerations. If taking the least stressful route requires a detour rate less than for example 30% or just is not available, then there might not be a feasible biking route to work. This method could still be used to distribute funding for new bicycle facilities.

Speculations About the Future of Bicycle Use

Background

Covid-19 is having tremendous impacts on how cities, geographic spaces, behavioral patterns and information are organized, and how urban designers and planners practice in future. Some values behind how bicycle path/facilities should be designed and planned seems to be more problematic and questionable.

Speculations

Firstly, for density matters, for many urban systems to function properly, density has been the goal, not the enemy. The high-density living environment offers proximity and intimacy of social relationship that is becoming problematic in pandemics. Cities like New York and New Orleans are now having the serious outbreak. Discourse of “anti-urbanism” might be arising that is threatening contemporary urbanity. People's dependence on commuting tools would increased after more spread urban development. But as we can see in figure 11, many modes of public transportation are confined spaces, which poses a threat to people's health. In this situation, the utilization rate of bicycles and other light transportation will increase.

Figure 11 Subway Passengers Affected by the Covid-19.

For accessibility, we advocate walkability, accessibility and connectivity in designing physical urban environment. In the context of post-corona cities, do people still “reach” their surrounding resources by the walkshed? People do not necessarily “walk” to their adjacent locations for schools, groceries and medical facilities. How important it is the travel cost to measure “closeness” between origin and destination? By designing a coherent and complete bike lane/facilities, travel cost will be greatly reduced and the accessibility criteria will be relatively changed. More city facilities can be activated, and even have unexpected effects.

For diversity and mixed uses, when the segregation and social distancing is a new norm, how will the proximity of various uses and diverse social groups still function as a community? What urban systems would physically accommodate the diversity measure in the new context? If the convenience of bicycles can be used to bring the communities together, this problem may be solved initially. We also need to consider how different groups of people in the community can realize the participation of the elderly, lowincome groups and other socially disadvantaged groups in this process, which will be challenging.

Cities are now both digital and physical. Social networking operates in augmented environment. When we develop bicycle facilities, phasing planning is necessary in this process to achieve the maximum utilization of them. We may consider more about complete existing bicycle paths which connecting relate land use. Not only home-to work, but also some new modes such as working and learning, collaborating and sharing, and living and entertaining.

Suggestions

Currently, the City of Atlanta does not have an inventory on public bike parking or employer amenities. While other studies have demonstrated that incentivizing bicycling increases mode share, I recommends that the City of Atlanta inventory both public parking and employer amenities. In addition, the City of Atlanta require annual reporting from employers on types of cyclist oriented incentive programs and number of bike commuters an employer has. This annual report from employers will allow for comparison of incentive's effectiveness.

Obviously, we need to further decouple bike analyses from methodologies developed for cars and even transit. We need to moderate bike routing method with using data-driven analyses and qualitative factors to get a fuller and more inclusive picture. Also more fluid to account for ever-changing behaviors and technologies – there is not "a final solution" for dealing with the subject. Sacramento seems to reflect such an approach. Somewhere, we need to take into account whole populations, not just cater to the largely upper middle class, more highly educated folks who now make up the preponderance of cyclists – in other words how does transportation serve the needs of the poor, the minorities, the seniors and what roles can bikes play to meet those needs.

Given the sparse information on employer facilities and incentives in the city area, the city of Atlanta should work towards developing an exhaustive inventory. With a robust inventory, and subsequent knowledge that commuters have access to these facilities, a way will exist to analysis the facility and financial impacts into the mode choice decisions. Worksite facilities such as bike parking and showers would appear as additional positive impacts to increase the utility for biking. Similarly, financial incentives would decrease the costs associated with biking, and thus increase the utility as well. Combined with MAZ network, the bicycle routing model should be applied to all possible bike trips throughout the entire city.

Conclusion

This article mainly encourages bicycles to become the mode of choice for more people to travel by improving the Atlanta bicycle routing method. The article draws on the success stories of other cities, such as Sacramento,Portland and San Francisco. The paper concludes that Atlanta should improve the bicycle infrastructure inventory to facilitate the use of route planning; bicycle lanes should connect the starting point and end point of the trip, and the mixed uses of land in order to increase the bike usage; in the bicycle route planning process, the positive influencing factor for encouraging bicycle travel is not just distance, people usually choose a more bicycle-friendly route. Finally, under the influence of the Covid-19, the paper considers the future use of bicycles and hopes to inspire readers.

The article has many shortcomings, especially the lack of data leads to limited analysis.To more accurately determine routing factors, planners and engineers should complete an instrumented bike study for the Atlanta region. While this project uses factors from other cities, the bike study result will determine whether other cities' factors can be used. Also, this paper failed to create a model like bicycle trip routing model, so users cannot really use it to navigate for their bike trips now.

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