What do we do When Public Transit Needs a Break?

A Review of Rapid Transit Disruption and Alternative Service Planning Processes in Three Cities

A thesis submitted by

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Abstract

In Boston, New York City, and Washington, D.C., planned rapid transit service disruptions are a necessary maintenance step towards continued safety and efficiency of aging rail systems. These disruptions are viewed negatively by the public due to disruption of routines. Disruptions are also challenging for transit agencies, as they are costly and may lead to sustained ridership loss. Past research on service disruptions largely focuses on modeling travel behavior during disruptions and establishing bus-bridging as the leading form of alternative service during disruptions. This study aims to fill gaps in the literature around organizational processes during disruptions, using a qualitative approach to investigate primary players and decisions made during service planning. Semi-structured interviews with transportation planners in Boston, New York City, and Washington, D.C., identify leading challenges and opportunities for growth in this field, including a need for more streamlined collaboration and clear processes. Through greater role definition, timeline overlapping, and process clarification, planners may be able to apply a 'window of opportunity' theory to disruptions, allowing the negative script around service disruptions to be partially flipped. This study suggests that positive change during disruptions may be possible if periods of disruption and associated planning processes incorporate intentional change around transportation habits, infrastructure improvements, and transit efficiency.

Acknowledgements

This project is largely influenced by the thoughts of the public, with much of the problem definition based in human habit formation and the consequences resulting from habit interruption. Thank you to everyone who has ever talked about transit disruptions in my vicinity – this project would not exist if these conversations (whether complaints or observations) were not a regular part of my life.

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Table of Contents

Chapter 1 - Introduction

Planned service disruptions, while necessary for continued safety and efficiency of aging transit systems, can feel chaotic to transit riders, no matter how much advanced notice they were given. Impacts of transit disruptions can be felt by commuters adding time to their daily journeys, by businesses whose parking may be removed for shuttle stops, by cyclists trying to avoid increased congestion, and certainly by government officials and transportation planners receiving the brunt of the negative feedback.

If these disruptions are intended to improve transit, speed up travel time, and create smoother rides, the positive intentions are at a complete imbalance with the negative perceptions they receive. If service disruptions are proactively planned, is there a step along the way that can help quell dissatisfaction, or at least maximize the results of such disruptive periods?

This thesis takes a qualitative approach to understanding the planning processes behind service disruptions and alternative service provision. By clearly outlining existing processes and identifying current challenges, this thesis posits a potential perspective with which to approach disruption planning. First, a clear understanding must be garnered of disruptions, their causes and purposes, the important players in the processes, and current strategies. Past research forms the base understanding of service disruptions within this thesis. Primarily, service disruption literature discusses travel behavior, various disruption scenarios, and alternative service strategies used during diversions. Much of the challenge of negative public perception around disruptions is solidified through past research on travel behavior changes during lapses in service such as mode shifting, noting potential ridership impacts post-disruption. The literature establishes bus-bridging, or shuttling, as the most common form of alternative service provided during disruptions. Mode shift to car is discussed as a negative impact of service disruptions, and mode shift to active transportation is rarely discussed apart from bikeshare

programs, as researchers note a lack of available data on active transportation usage[1]. Bus-bridging wait time and in-vehicle time has been found to be perceived more negatively than reciprocal times in the initial transit service[2]. However, without ridership data due to free-charge policies for replacement shuttle buses (and therefore the lack of an automated fare collection) it has remained difficult for past research to tie these negative perceptions to any real observed changes in ridership. While studies repeatedly refine travel behavior models for disruption scenarios, research focused on institutional challenges, managerial strategies, policy barriers, and budget shortcomings related to disruptions are lacking. Similarly, little research has been done to date around the service disruption planning priorities or goals of transit agencies and cities. It is possible that the goals of disruption planning are considered too obvious to deeply study – those of maintaining a safe and efficient transportation service. However, as the field of transportation planning continues to face economic, environmental, and social pressures, it is useful to take a closer look at how these processes are planned, and what the underlying motivations are. Better understanding these goals, as well as the processes and challenges that currently exist, may lead to opportunities for further transportation improvement. The findings of this thesis will provide policy makers, planners, and advocates a clearer path towards flipping the dialogue around disruption planning, and working towards disruption plans that may serve a larger purpose in the overall transportation planning field.

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[1] Arslan Asim et al., "Transit Users' Mode Choice Behavior During Light Rail Transit Short-Term Planned Service Disruption"; Nguyen-Phuoc et al., "How Do Public Transport Users Adjust Their Travel Behaviour If Public Transport Ceases?"; Zhu and Levinson, "A Review of Research on Planned and Unplanned Disruptions to Transportation Networks."

[2] Noureldin and Diab, "Impacts of Long-Term Transit System Disruptions and Transitional Periods on Travelers"; Yap, Nijënstein, and Van Oort, "Improving Predictions of Public Transport Usage during Disturbances Based on Smart Card Data."

Research Questions

This thesis leads with the central question “how do transit agencies and their local counterparts plan for service disruptions?”

Within this general question, a few sub-questions emerge as follows:

- How do transit agencies organize alternative service provision during disruptions, and what factors contribute to decisions around alternative services? (RQ1)
- How do planning processes differ place to place? What impacts do organizational structures, infrastructure, environment, policies, and budgets of different jurisdictions have on service disruption plans? (RQ2)
- How do transit agencies work with cities or other jurisdictional partners on disruption and alternative service planning, and who else is involved in these processes? (RQ3)
- What barriers currently exist, and what key opportunities exist for continuing to improve the process of planning for transit disruptions? (RQ4)

Chapter 2 - Literature Review

This thesis will begin with a literature review of travel behavior, focusing on behaviors in relation to periods of service disruption. The literature review will then discuss strategy around planned service disruption and alternative service provision. Discussion of service disruption definition, and the three main behaviors associated with service disruption - mode shift, route changing, and destination shift - will follow. Mode shift will be most heavily discussed, as mode shifting may lead to sustainability impacts – either negative or positive – depending on the mode that is ultimately selected. The literature review will also include further detail around alternative service strategies, focusing on bus-bridging as the primary mode, with discussion of bikeshare programs as an alternative service not directly provided by the transit agency. To conclude, the

literature review will discuss challenges recognized in past research around transit disruptions, constructing a clear basis for what is currently understood, and where gaps exist in literature around transit disruption and alternative service planning processes.

Transportation provides connections for most urban functions, including housing, employment, commerce, and recreation. Thus, understanding the mechanics, costs, and behaviors related to transportation can aid city and state welfare, and improve accessibility of city functions. Transportation is a well-researched field, with public transit held in high regard for its ability to offer high volume service with relatively low cost and energy per trip, compared to personal vehicles. While public transit is considered to be sustainable, equitable, and relatively efficient, public transit networks are inflexible and require continuous infrastructure maintenance. Public transit systems rely on multiple transportation components - within a system, bus lines fill in gaps rapid transit rail lines are not able to serve, and outside of the system, bike lanes and shared-use paths allow pedestrian and bicycle first-last mile accessibility. A system with a high variety of options for transportation can be called a multimodal system, benefitting from the provision of choice for locals to decide which mode best fits their personal preferences and needs [3].

Service Disruptions

Studying service disruptions allows us to generate a deeper understanding of current processes and potential improvement, while also investigating the idea of disruptions as a window of opportunity for testing new transportation solutions. The need for broadening our understanding of service disruptions lies in past research identifying negative impacts from service disruptions. Transit disruptions have been found to have lasting negative effects on ridership and led to

[3] Noureldin and Diab, "Impacts of Long-Term Transit System Disruptions and Transitional Periods on Travelers"; Arslan Asim et al., "Transit Users' Mode Choice Behavior During Light Rail Transit Short-Term Planned Service Disruption."

lower public trust in transit in some cases, while also increasing operating costs for transit agencies and local jurisdictions[4]. These negative impacts position service disruptions as a lose-lose situation, but one that is necessary for continued transit success. However, through deepening our understanding of these processes, we come to an opportunity to flip the way we look at disruptions while creating positive change. Service disruptions are short, controlled periods of time in which transportation alternatives can be tested – policy windows and trial-periods for more sustainable transportation modes and multimodal solutions[5]. Looking more closely at what happens during disruptions can be a way not only to improve disruption experiences, but also to investigate what might be possible for the future of transportation. Previous studies identify that transportation habits are not easily changed, but that large events or disruptions may function as catalysts for such changes[6]. This theory then positions transit disruptions as windows during which transportation habits may be influenced – an opportunity for transportation planners and policy makers to flip the dialogue around disruption planning.

Before investigating service disruptions and what they may offer to transportation planning and policy, it is important to investigate how service disruptions are currently understood and categorized. Service disruptions, or periods of time during which public transit service is interrupted, can occur for various reasons. Planned service disruptions – the focus of this study – are typically the product of aging infrastructure requiring routine maintenance and improvements that cannot occur on the tracks while service is running. Unplanned service disruptions on the other hand, are typically the result of distinct and unpredictable events. Zhu and Levinson suggest that most unplanned service disruptions are related to one of the following four types of

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[4] Arslan Asim et al., "Transit Users' Mode Choice Behavior During Light Rail Transit Short-Term Planned Service Disruption."
[5] Younes et al., "How Transit Service Closures Influence Bikesharing Demand; Lessons Learned from SafeTrack Project in Washington, D.C. Metropolitan Area."
[6] Kent, Dowling, and Maalsen, "Catalysts for Transport Transitions."

major events: transit strikes, bridge closures, special events, and earthquakes[7]. Event type and magnitude can lead to varying impacts on larger transit networks. One specific difference in impact to transit networks between planned and unplanned disruption is the 'period of chaos' following an unplanned disruption, as phrased by Christoforou et al. This is an apt description for the time following an event causing an unplanned disruption to transit service, as the details and magnitude of the disruption are often unknown, along with the likely duration of the disruption. Not only is this information unknown to transit agencies and operators, but to riders and the public as well – meaning communications regarding the disruption are often challengingly vague[8]. Planned service disruptions benefit from avoiding these periods of chaos. Instead, transit agencies can strategize prior to the disruption, creating a service plan that can ideally maintain capacity and demand for transit services. With the benefit of advanced notice, planned disruptions are typically scheduled outside of peak hours, impacting weekend and evening service rather than peak commuter weekday service[9]. While transit agencies can avoid periods of chaos by planning in advance, proper communication around disruptions is necessary for ensuring customers can also avoid experiencing chaos. Without effective communication, the public may feel little difference between planned and unplanned service disruptions.

Travel Behavior

Travel behavior is a well-researched area in the field of transportation planning, lending framework to service disruption planning by informing likely public reactions to reduced service. A leading principal of travel behavior is that travel decisions are largely informed by prior knowledge and experiences, along with available information[10]. This understanding is the

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[7] Zhu and Levinson, "A Review of Research on Planned and Unplanned Disruptions to Transportation Networks."
[8] Christoforou et al., "Managing Planned Disruptions of Mass Transit Systems."
[9] Arslan Asim et al., "Transit Users' Mode Choice Behavior During Light Rail Transit Short-Term Planned Service Disruption."
[10] Christoforou et al., "Managing Planned Disruptions of Mass Transit Systems."

foundation of the idea that service disruptions may present windows for individuals to become familiar with new transportation modes due to their typical modes being out of service. Increased familiarity may then contribute to higher likelihood of future use[11]. The idea of available information shaping travel behavior also emphasizes the necessity of strong communication in public-facing diversion plans – particularly when communication is used as a tool to encourage certain modes over others. It is also understood that transit customers value regularity over punctuality, meaning that riders would prefer to be unsure the exact timing of their train but that they would have an option shortly, as opposed to knowing exactly when the train would come, but not having another option for some time[12]. Frequency of service will be further discussed in the context of bus-bridging later in this paper.

Differences have also been observed in the travel behaviors of various demographic groups. As higher income is associated with fewer cost-barriers for transportation modes and increased flexibility, higher income groups are less likely to take transit when compared to lower income groups – specifically so in the case of bus ridership. Similarly, if there is a delay or disruption in typical travel patterns, higher income groups have been found to cancel their trips more often than lower income groups. Age and gender are also associated with travel behavior, with younger age groups being more prone to driving than older age groups, and women being more likely to avoid long travel times – and thus cancel or reschedule trips – than men. Overall, women typically report shorter travel times when compared to men[13]. While transit agencies serve all of the groups discussed above, it is important to understand that travel behavior is not monolithic,

[11] Younes et al., "How Transit Service Closures Influence Bikesharing Demand; Lessons Learned from SafeTrack Project in Washington, D.C. Metropolitan Area."
[12] Schmöcker, Cooper, and Adeney, "Metro Service Delay Recovery."
[13] Arslan Asim et al., "Transit Users' Mode Choice Behavior During Light Rail Transit Short-Term Planned Service Disruption"; Mihailova and Vance, "Promoting Active Transportation"; Noureldin and Diab, "Impacts of Long-Term Transit System Disruptions and Transitional Periods on Travelers."

and transportation planners should be aware of varying preferences, tendencies, and experiences.

Much of the literature related to service disruptions focuses on how travel behavior changes during periods of disruption. This body of work has developed a hierarchy of behaviors occurring during disruptions: route switching, mode shifting, and destination shifting. This hierarchy suggests that in the case of a disruption riders will first assess whether other routes to their destination are available without changing their transportation mode (a bus rider might consider an alternative bus route, a train rider might transfer to another train line to reach their destination). If this is not a possibility, riders will then consider switching to another transit mode (a bus rider might walk to a train station and take the train to their destination, a train rider might find a bus with a similar route). If mode shifting does not present a viable or preferable option, riders will then resort to shifting their destination, including trip cancellation (a shopper might choose a store in a different location that they could get to despite the service disruption, a commuter may cancel their trip and decide to work from home) [14]. These behaviors are crucial building blocks for service disruption planning and policy, as they indicate the types of replacements riders might first look towards. Similarly, when thinking of disruptions as opportunities for the public to become familiar with other transportation modes, this hierarchy can help to inform what types of behaviors may be most easily encouraged.

While the hierarchy outlined above suggests a general behavior model, varying demographic factors, available modes, and urban layouts multiply the complexity of predicting how riders will react to service disruptions. Trip importance and wait time tolerance are two factors largely impacting this behavior hierarchy. Trip importance, if low, impacts the likelihood of engaging in

[14] Noureldin and Diab, "Impacts of Long-Term Transit System Disruptions and Transitional Periods on Travelers"; Younes et al., "How Transit Service Closures Influence Bikesharing Demand; Lessons Learned from SafeTrack Project in Washington, D.C. Metropolitan Area."

trip cancellation. Especially following the COVID-19 pandemic, flexibility to work from home has allowed many commutes to be considered trips of relatively low importance. While this is not the case for everyone, in the instance of a short-term transit disruption, trip cancellation may rise in the behavior hierarchy especially if coupled with long wait-times[15]. Wait-time tolerance is a major consideration when deciding whether to mode or route shift. Past literature suggests a 20-minute wait time cut off before riders change their habitual behavior. This cut off may vary based on typical wait times in the area (for example, if a transit system has 4-minute headways, wait time tolerance may be lower compared to a system with 15-20-minute headways)[16]. Literature also suggests that wait time tolerance may be impacted by customers' level of trust of the information provided by the transit agency (with higher levels of trust leading to increase wait-time tolerance)[17]. In the case of longer service disruptions (6 months or longer), riders may start to look to new alternatives rather than following the outlined hierarchy – making major changes such as purchasing a car or moving to a location that is not disrupted[18].

Mode Shift

Within the previously mentioned travel behavior hierarchy, mode shift stands out as having the highest potential for negative environmental impacts (or positive, if shifting to active transportation). Mode shift likelihood is influenced by available alternatives, which according to general travel behavior research, are correlated with income level, with higher-income groups more likely to have access to alternative modes (such as personal vehicles or ride share)[19].

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[15] Zhu and Levinson, "A Review of Research on Planned and Unplanned Disruptions to Transportation Networks."
[16] Zhu and Levinson; Arslan Asim et al., "Transit Users' Mode Choice Behavior During Light Rail Transit Short-Term Planned Service Disruption."
[17] Rahimi et al., "Analysis of Transit Users' Waiting Tolerance in Response to Unplanned Service Disruptions."
[18] Nguyen-Phuoc et al., "How Do Public Transport Users Adjust Their Travel Behaviour If Public Transport Ceases?"
[19] Liu et al., "A Social Equity Lens on Bus Bridging and Ride-Hailing Responses to Unplanned Subway Disruptions"; Noureldin and Diab, "Impacts of Long-Term Transit System Disruptions and Transitional

Available alternatives can largely impact the way the travel behavior hierarchy is followed, as drivers need not follow pre-defined routes, and bikers need not consider long-wait times, to list a few examples.

Available alternatives do not guarantee mode shifting. Mode shifting is more likely if riders are experienced and comfortable using the available alternatives. Typically, transit riders prefer direct service, short wait times, and reliability – if a rider has experience with an available alternative and knows what type of service to expect, shifting to that mode during a service disruption may be desirable. If riders do not know how frequently another service runs, how reliable it is, or what their experience would be like, they may be more hesitant to elect an available alternative as opposed to taking the replacement service provided by transit agencies[20]. Service disruptions are situations where multiple factors increasing mode shift likelihood are aligned. Thus, these are scenarios where the public may be more easily influenced to try new travel behaviors than during times of standard service.

Mode shifting is also given significant attention in literature due to potential environmental implications related to mode shifting to car or bike. Whereas mode shifting from public transit to bike is considered a net-zero or positive impact, mode shifting to car is tied only to negative externalities. In Nieuwenhuijsen and Khreis' study of plans for car-free cities, they explained the potential impacts for public health associated with reducing and even removing cars from a city. They predicted significant decreases in NO2 levels, increased street space due to minimized parking, allowing for more green and social space, and a higher mode-share of active transportation modes[21]. Each of these benefits becomes less attainable the more mode-shifting

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Periods on Travelers"; Zhu and Levinson, "A Review of Research on Planned and Unplanned Disruptions to Transportation Networks."

[20] Arslan Asim et al., "Transit Users' Mode Choice Behavior During Light Rail Transit Short-Term Planned Service Disruption."

[21] Nieuwenhuijsen and Khreis, "Car Free Cities."

to car occurs. Mode shift to car during transit disruptions has also been linked to sustained transit ridership losses, meaning that riders may have grown to prefer driving as an alternative during the duration of the shutdown[22]. In addition to car ownership, trip importance is a leading factor influencing likelihood of mode shifting to car during service disruption, with mode shift being more likely the higher the trip's importance. Other influential factors include accessibility to public transit stations (the closer one lives to a public transit station, the less likely they are to mode shift to car) and travel time and cost (the more additional time a trip by car would add compared to a trip by transit, the less likely one is to mode shift to car) [23]. Some urban layouts may be more conducive to transportation by car than others - Zhu and Levinson noted that their mode-shift study conducted in Los Angeles may be limited by the city's high mode-share of cars compared to public transit[24]. Understanding factors impacting likelihood of mode shifting to car may help discern how to dissuade this behavior, especially during 'trial period' windows, where riders may instead familiarize themselves with other modes.

Encouraging mode shift to active transportation during service disruptions has been suggested as a way to improve transit network's sustainability, with the perspective that this strategy may lead to permanent increases in active transportation usership. Active transportation is lauded in the literature for its sustainability, potential physical and mental health benefits, and for its low infrastructure costs in comparison to infrastructure for other transportation modes[25] . Though it is viewed positively, active transportation is typically mentioned in the context of service

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[22] Arslan Asim et al., "Transit Users' Mode Choice Behavior During Light Rail Transit Short-Term Planned Service Disruption"; Nieuwenhuijsen and Khreis, "Car Free Cities"; Zhu and Levinson, "A Review of Research on Planned and Unplanned Disruptions to Transportation Networks."
[23] Nguyen-Phuoc et al., "How Do Public Transport Users Adjust Their Travel Behaviour If Public Transport Ceases?"
[24] Zhu and Levinson, "A Review of Research on Planned and Unplanned Disruptions to Transportation Networks."
[25] Mihailova and Vance, "Promoting Active Transportation"; Younes et al., "How Transit Service Closures Influence Bikesharing Demand; Lessons Learned from SafeTrack Project in Washington, D.C. Metropolitan Area."

disruptions only following discussions of mode shifting to car. Limited focus in past literature may be due to data deficiencies, given private bike usage numbers and pedestrian counts are less readily available compared to public transit ridership and vehicle count data.

Likelihood to mode shift to active transportation is related to access to public transportation, perceived safety of walking/biking, time and cost constraints, and existing infrastructure and policies. Perceived safety can consist of bike and pedestrian infrastructure in the area, lighting and driver behavior, as well as the individual's own perception of their surroundings and their identity. Time and cost constraints are important when discussing active transportation, as these modes are typically slower than motorized transportation modes. The difference in trip time when taking active transportation modes compared to motorized modes can impact likelihood that mode-shift will occur. Cost constraints do not necessarily refer to monetary costs, but also energy, convenience, and comfort[26]. With increasing focus as rates of active transportation have declined over the past few decades, some research studies policy levers that may increase likelihood to mode-shift to bike [27]. Mihailova and Vance suggest that changes such as increased bike infrastructure and introduction of carbon taxes on fuel could help flip observed decreases in active transportation[28]. Understanding these influential factors can provide transportation planners with a toolkit of strategies to encourage mode shifting to active transportation rather than car during service disruptions.

Bikeshare programs are the main focus of any discussion in service disruption literature around active transportation. This is likely due to the data accessibility these programs provide. Past research finds that bikeshare has been used as an alternative to transit during disruptions, with a few limitations. Bikeshare is mainly used as a disrupted service alternative only when the

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[26] Nguyen-Phuoc et al.
[27] Zwald et al., "Network Influences on the Development and Implementation of Active Transportation Policies in Six U.S. Cities."
[28] Mihailova and Vance, "Promoting Active Transportation."

intended transit trip was relatively short. A study of dockless bikeshare usage in Cologne found that bikeshare use was higher in areas close to transit stations, suggesting bikeshare was largely used as a first-last mile transportation solution Bikeshare ridership increased during a rail disruption, signifying that it was an attractive alternative service option for transit riders, likely related to the area's already high ridership and familiarity with the mode[29]. A study conducted by Younes et al. identifying bikeshare as a first-last-mile solution in Washington, D.C. during a Metro closure found that those using bikeshare to bypass closed sections returned to transit once they had passed the impacted segments. Younes et al. then identified that for longer segments (an entire line closure, for example), it was more common to mode-shift to car or bus, suggesting shifting to bikeshare may be a popular solution only for shorter trips[30]. Bikeshare as an alternative was also found to be limited by station and bike availability, unlike in Schimohr and Scheiner's Cologne study, where the dockless bikeshare model made availability less of a barrier.

Various studies identify bikeshare as a utilized alternative to transit during service disruptions, even if just for short trips. Some literature even begins to suggest the potential for sustained mode-shift to active transportation through familiarizing transit riders with bikeshare during service disruptions. However, data around mode shifting to other modes of active transportation such as walking or use of a personal bike is understudied. This leaves holes in the literature's overall understanding of mode shifting during service disruptions, which could pose challenges for transportation planners when planning for disruptions.

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[29] Schimohr and Scheiner, "Spatial and Temporal Analysis of Bike-Sharing Use in Cologne Taking into Account a Public Transit Disruption."
[30] Younes et al., "How Transit Service Closures Influence Bikesharing Demand; Lessons Learned from SafeTrack Project in Washington, D.C. Metropolitan Area."

Planning for Service Disruptions

A significant portion of service disruption literature also focuses on service replacement strategies typically used during disruptions. Mainly, this research focuses on bus-bridging practices and modeling shuttle success. This is still a fairly new field, and suggestions for future research include increased focus on alternative service planning optimization[31].

Alternative Service Planning

Planning for service disruptions generally focuses on service replacement through an alternative mode, matching the capacity of the original service as closely as possible. Past research identifies two transit network characteristics that might make disruption planning and alternative service provision less challenging. First, systems with few physical barriers and unconstrained environments may be more flexible to non-standard service provision. Second, systems with more technological advancement may be able to better plan for and execute diversion strategies[32]. Assessments of a transit network's ability to execute diversion strategies are often based on the reliability of their replacement services. As transit reliability has been linked to increased ridership, researchers suggest that regularity should be a priority when planning transit replacement services. Maintaining regularity is a large focus of disruptions where service is diverted onto parallel rail tracks rather than to alternative service. However, parallel rail diversions are quite rare, with only 11% of the transit systems studied by Pender et al., and 20% of systems studied by Christoforou et al. having parallel rail networks [33]. Most transit systems are without the benefit of parallel rails, necessitating mode shift and more complex alternative service provision plans.

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[31] Christoforou et al., "Managing Planned Disruptions of Mass Transit Systems."
[32] Schmöcker, Cooper, and Adeney, "Metro Service Delay Recovery."
[33] Pender et al., "Planning for the Unplanned: An International Review of Current Approaches to Service Disruption Management of Railways"; Christoforou et al., "Managing Planned Disruptions of Mass Transit Systems."

The most common strategy for planned transit disruptions is bus-bridging, or shuttling, often provided at no cost to riders[34]. Widely recognized as the standard for alternative service provision during diversions, past research on bus-bridging includes route planning and prioritization analyses, as well as studies of public perceptions of shuttles service. Bus-bridging is intended to provide an above-ground service mirroring that of the closed rapid transit line, using buses to carry passengers from station to station, as a train typically would. The next few sections of this literature review focus on the complexities of bus-bridging strategy and summarize suggestions for improving the efficiency and customer perceptions of shuttle services.

Public Perception and Rider Experience

Past research around perceptions of and satisfaction with shuttle service shows that shuttle service is poorly regarded by transit riders. When comparing wait-time for shuttle service compared to standard transit service, riders overestimated the wait time for shuttles, showing a tendency to have shorter patience for unfamiliar service[35]. It is also possible that expanded perceptions of wait times may be due to the conditions of waiting, if standard service includes a sheltered station and seating, and shuttle service requires passengers to wait in an un-sheltered, outdoor location without seating. Some past research also points out that replacement services lose the benefit of standard service's typical real-time information equipment, which helps riders predict their wait time[36]. Station infrastructure is certainly not the only factor that may impact perceptions of shuttle services, as passengers also tended to overestimate in-vehicle time and report more negative in-vehicle perceptions compared to

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[34] Schmöcker, Cooper, and Adeney.
[35] Noureldin and Diab, "Impacts of Long-Term Transit System Disruptions and Transitional Periods on Travelers"; Yap, Nijënstein, and Van Oort, "Improving Predictions of Public Transport Usage during Disturbances Based on Smart Card Data."
[36] Yap, Nijënstein, and Van Oort, "Improving Predictions of Public Transport Usage during Disturbances Based on Smart Card Data."

standard service, showing a general negative opinion of replacement shuttle rides[37]. Noting that more frequent disruptions are associated with higher levels of customer frustration, Sarker et al. identify factors that may reduce frustration related to service disruptions, including high quality service, good network coverage, and staff and operator behavior (accommodation and courteousness)[38].

Various shuttle strategies have been implemented to reduce negative riding experiences, including adding direct, or express routes, and providing varying frequency depending on the time of day. As transit riders prefer a direct route with short wait times and reliable service, converting a typically underground service to above-ground undeniably faces barriers. However, offering various route options including local routes (stopping at each regular service station) and express routes (stopping only at terminals or large transfer stations) is a strategy many agencies implement to try to provide more choice and agency over a rider's transit journey[39].

Recognized Barriers

Capacity has been found to be a leading challenge for shuttle buses as a replacement service, as planners must reach an important balance between providing enough capacity for riders, when trains typically hold many more passengers than a typical bus can, and the cost and congestion resulting from too many buses. Some researchers suggest varying service provision throughout the day to meet different levels of demand and reduce costs[40]. Others suggest that increasing frequency is not a valuable adjustment, and only the pairing of shuttles with additional replacement services and mitigation strategies will meet demand and improve

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[37] Noureldin and Diab, "Impacts of Long-Term Transit System Disruptions and Transitional Periods on Travelers."
[38] Sarker et al., "Applying Affective Event Theory to Explain Transit Users' Reactions to Service Disruptions."
[39] Arslan Asim et al., "Transit Users' Mode Choice Behavior During Light Rail Transit Short-Term Planned Service Disruption."
[40] Jin, Teo, and Sun, "Disruption Response Planning for an Urban Mass Rapid Transit Network."

satisfaction with service during disruptions[41]. Modeling is also used to better gauge frequency levels that will build capacity while remaining cost-efficient. By modeling various shuttle routes, planners can select the best routes and test various operating differences on these routes to optimize route efficiency[42].

Frequency and capacity rely on the procurement of buses – a less studied corner of diversion planning. While some transit systems use regular service buses for shuttling purposes, shutdowns can sometimes require so many buses that additional resources must be procured. In a study of diversion strategies, Pender et al. found that around 40% of the transit agencies in their sample borrowed buses from existing service for shuttling purposes[43]. Some past research identifies an equity issue in the notion that disruptions may pull regular service buses from their standard routes to shuttle for diversions, disrupting the typical bus riders' experience for the sake of the rapid-transit riders' experience[44]. Other transit agencies use contracted services rather than procuring buses in-house, with a small fraction of transit agencies reporting a stock of reserve buses for disruption response. Keeping reserve buses is a proactive strategy more commonly used for quick response to unplanned service disruptions. Along with procuring a fleet of reserve buses, storage locations must also be coordinated. Predicted convenience is often used for optimizing storage locations – using an analysis of disruption type likelihood along with passenger volume at nearby stops and the travel time to other modes of transportation. While this is a rare strategy, some transit agencies like WMATA chose to keep reserve fleets – in

[41] Yap, Nijënstein, and Van Oort, "Improving Predictions of Public Transport Usage during Disturbances Based on Smart Card Data."
[42] Jin, Teo, and Sun, "Disruption Response Planning for an Urban Mass Rapid Transit Network."
[43] Pender et al., "Planning for the Unplanned: An International Review of Current Approaches to Service Disruption Management of Railways."
[44] Liu et al., "A Social Equity Lens on Bus Bridging and Ride-Hailing Responses to Unplanned Subway Disruptions."

this case, 25 buses – for strategic support in times of additional service needs, whether those needs are planned or unplanned[45].

Shuttling during disruptions, while studied in past literature, remains burdened by resource procurement and scheduling challenges. Researchers have begun to chip away at challenges by using modeling and analyses of shuttle bus systems in various transit networks, but shuttling has rarely been studied in partnership with other mitigation strategies during service disruptions. Considering the widespread dissatisfaction with shuttle service compared to standard service, it is crucial to consider alternatives that may provide more positive perceptions, or at least additional options better fitting transit riders' needs and schedules. While some past research uses a ranked-choice scenario survey to assess preferences for transportation during service disruptions, few feasible options other than various forms of bus bridging are imagined in the current universe of disruption planning[46].

Active transportation is often overlooked as a viable replacement service. Younes et al. studied bikeshare during transit shutdowns in Washington, D.C., suggesting that promoting bikeshare as an alternative service encourages low-carbon transportation options and can increase the amount of choice travelers have in their impacted transportation journeys. Station capacity was a major consideration in this study, as bikeshare station capacity is a fraction of the capacity of transit services, meaning that reevaluation of bikeshare station spacing and capacity may be necessary prior to increasing the promotion of bikeshare during service disruptions[47].

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[45] Pender et al., "Planning for the Unplanned: An International Review of Current Approaches to Service Disruption Management of Railways."
[46] Arslan Asim et al., "Transit Users' Mode Choice Behavior During Light Rail Transit Short-Term Planned Service Disruption."
[47] Younes et al., "How Transit Service Closures Influence Bikesharing Demand; Lessons Learned from SafeTrack Project in Washington, D.C. Metropolitan Area."

Alternatively, dockless shared micromobility may have an opportunity to evade capacity-restraints and make active transportation increasingly available as a service alternative[48].

Another challenge complicating bikeshare as an alternative service during disruptions is that bikeshare systems are often operated and owned separately from transit agencies. While this may make encouraging bikeshare usage during disruptions a disjointed process due to different governing bodies, it also poses an opportunity for private bikeshare companies to profit off of transit agencies' lapse in service. Profits would primarily result from the increase in demand for alternative transportation, as well as the window of opportunity to gain new riders. Many bikeshare systems, including the Boston BlueBike system, provide promotional codes offering a limited number of free or discounted rides during transit shutdowns[49]. Offering free ride codes not only makes using bikeshare a desirable alternative, but also requires that new users sign up for an account, making usage post-disruption a higher likelihood. However, this is a strategy that requires collaboration between privately owned bikeshare companies and transit agencies. Past research encourages partnership between transit agencies and shared micromobility, not only to capitalize on alternative service opportunities, but also to increase spatial equity of transportation options[50]. In other words, active transportation can help to fill in gaps in rapid-transit systems, whether due to disruptions or a lack of fixed service in the area.

While these partnerships are encouraged, minimal research has been conducted to identify the processes and actors with the power to begin increasing active transportation's role in service disruptions.

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[48] Liouta et al., "Can Shared Mobility Compensate for Public Transport Disruptions?"
[49] "Bluebikes Offers Free Rides During Red Line Shutdown - Streetsblog Massachusetts."
[50] Gao and Li, "Synergizing Shared Micromobility and Public Transit towards an Equitable Multimodal Transportation Network."

Communication

Communication of changes is a crucial aspect of planning for service disruptions, as all types of riders need to be informed that their daily commutes, or the routes they had mapped out, will no longer be viable, and an alternative will be in place. Past research has begun to look into communication and messaging campaigns around disruptions, identifying the need to better assess the relationship between the plans and the public reactions, as satisfaction is often low. Through semi structured interviews, Pender et al. identified communication challenges as a consistent challenge across transit agencies when trying to understand disruption situations and relay information to riders quickly and accurately[51]. While the understanding aspect may be more relevant to unplanned disruptions, the communication of disruption information and alternative service to riders who are used to a standard commute remains a challenge, especially as disruptions can elicit negative responses from the public. One way to deal with these negative responses is to try to begin to explain the need for the changes in place. Washington, D.C.'s transit agency, WMATA, branded their long-term rail safety and rehabilitation project "SafeTrack" for this reason[52]. Naming a project something recognizable, with a title that bears positive associations, may begin to indicate to riders that the disruptions are for good reason, rather than immediately generating frustration. Communicating disruptions bridges technical, operational, and socio-emotional sides of this work, and remains an under-studied subfield in disruption research, though challenges persist.

Past research identifies leading barriers in diversion planning to be related to transit network structures, technology and communications, and resource and staff limitations. Though identified, the literature lacks discussion on how these challenges are addressed in current

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[51] Pender et al., "Planning for the Unplanned: An International Review of Current Approaches to Service Disruption Management of Railways."
[52] Younes et al., "How Transit Service Closures Influence Bikesharing Demand; Lessons Learned from SafeTrack Project in Washington, D.C. Metropolitan Area."

planning practices, or whose responsibility they are to overcome. Identifying the parties and players who have the power and agency to address these challenges is an important next step in disruption planning research. Additionally, past research lays the foundation for the theory that disruption-related mode shifting could act as a 'test period' for transportation modes with which transit riders were not previously familiar. If this is indeed an implication of disruptions, then understanding how diversion planning processes can take advantage of this mindset is a crucial next step for the field.

Chapter 3 – Methods

As past transit disruption research focuses largely on analyzing and predicting travel behavior during lapses in service, this thesis instead studies the decisions made behind the scenes by transit planners involved in disruption planning. Data availability is a limiting factor for studying some forms of mode shift, therefore making the conversation around transit disruption mode shifting incomplete. If this conversation is incomplete, transportation planners must then resort to other sources of information or strategies by which to plan for service disruptions. This key gap begs the question of what other barriers exist in the planning process – a question which would be difficult to tackle through quantitative means. In order to answer this question and understand the current barriers in the service disruption planning process, a qualitative approach is the most appropriate. As Gaber and Gaber advise, questions seeking out an "insider perspective" are often better approached qualitatively[53].

The population of interest for this study is transportation planners working on service disruption planning. This population has hands on experience planning for past service disruptions, and a

[53] Gaber and Gaber, *Qualitative Analysis for Planning and Policy*.

first-hand perspective on challenges and possible changes in the planning process. To gather qualitative input, this study used semi-structured interviews with transportation planners working in Boston, New York City, and Washington, D.C. Transportation planners from various parties were interviewed, aiming to gather perspectives from both transit agencies and local jurisdictional planning partners, as these parties often share responsibility for planning service disruption mitigation strategies. Such a partnership can be exemplified by shared messaging and alerting approaches (for example, on November 14th, the MBTA and the City of Boston both published updates and information about the Redline shutdown occurring from November 18th to November 24th, 2024th[54]). Therefore, speaking with multiple parties depending on role relevance was a crucial step in triangulate the research approach of this thesis and painting a complete picture.

This study focuses on Boston, New York City, and Washington, D.C. as its study areas due to their regional proximity, multi-line transit systems, and 'in-network' statuses. Regional proximity avoids vast environmental or climate factors that could differentiate transportation conditions (extreme heat, snow, etc.). Cities were considered 'in-network' if I had contacts in my extended professional network working in the city. Past literature was also referenced to support study area selection. Specifically, I referenced a table constructed by Pender et al. to display similarities between the selected cities' transit networks. Pender et al.'s study included interviews with 48 different transit agencies, for which they created a table to tag different network characteristics impacting management such as transit mode, bus network operation, minimum of two tracks (no single-track sections), agency responsibility for track maintenance, and below zero temperatures in operating area. I categorized my selected study areas with these same characteristics prior to initiating recruitment, to ensure that the cities had relatively

[54] "Red Line Closure Travel Options | MBTA"; "Boston MBTA Shutdowns 2024 | Boston.Gov."

similar pretext for diversion planning, and to gain some background information on each transit network. The table, modeled after Pender et al.'s, can be found in Table 1[55].

Table 1: Characteristics of the three transit agencies included in the study area sample, modeled after Pender et al[56].

Operator	City	Transit Mode	Operate Bus	Min. 2 Track	Track Maint.	Temp <0°
MBTA	Boston	Light-Rail Rapid, Rail-Rapid Transit, Suburban Rail	Yes	Yes	Yes	Yes
MTA	New York City	Rail-Rapid Transit	Yes	Yes	Yes	Yes
WMATA	Washington DC	Rail-Rapid Transit	Yes	Yes	Yes	Yes

Sample identification for interview participants was mainly a matter of recruitment (availability and willingness to participate), though I aimed to interview at least two planners from each city, ideally from at least two different teams or organizations involved in disruption planning. Recruitment occurred by way of email, aided by existing connections from my professional network and relevant research on city and transit agency websites. A sample recruitment email is included in Appendix A. Participants were informed of how their input would be used, and that they would have a chance to review any findings tied to their name or role once written. Once participants confirmed their understanding and willingness to continue, participants were asked a series of interview questions developed based on existing literature and gaps. Similarly to Pender et. al's methodology, interviews were semi-structured, as this format provided flexibility for respondents to speak from their own perspectives and define concepts in ways which may not have been previously understood. Semi-structured interviews also allowed for a flexible

[55] Pender et al., "Planning for the Unplanned: An International Review of Current Approaches to Service Disruption Management of Railways."
[56] Pender et al.

question order and relevant probing to explore issues most relevant to the particular interviewee[57].

Eleven interviews were conducted, with a total of 17 participants (three group interviews were conducted). Interviews lasted between 30-60-minutes, nine were conducted virtually, two were conducted in person. Multiple interview participants also aided in the recruitment process, connecting me to additional stakeholders following their interviews and thus contributing to a snowball sampling strategy. A list of the 17 interview participants is below, organized by the interview participants' organization. In addition to the role of each participant, this table includes the citing mechanisms used in the findings section to indicate from which interview information originated. Multiple individuals having the same citation code means that the individuals participated in a group interview.

Table 2: Interview participants by organization

Organization	Name (if applicable), Role, and Citing Mechanism
MBTA	• Laura Riegel, Senior Director of Alternative Service (MBTA) • John Savino, Director of Contracted Bus Operations (MBTA) • Alexander Anhwere-James, Director of Alternative Service Planning (MBTA) • Aria Wong, Transport Planner, Alternative Service (MBTA2) • Scott Yard, Manager of Contracted Bus Operations (MBTA2)
Boston Transportation Department (BTD)	• Amanda Caparoso, Diversion Coordinator (BTD)
MTA New York City Transit	• Allyson Bechtel, Senior Director of Rail Planning (MTA) • Joshua Rosenberg, Director of Track Access Forecasting (MTA) • Harry Beck, Director of Short Range Track Access (MTA) • Alan Foster, Acting Director of Rail Network Planning (MTA)

[57] Pender et al.

	• Buckley Yung, Director, Bus Service Planning (MTA2)
NYCDOT	• Chris Hrones, Director of Transit Planning and Policy (NYCDOT)
Department of City Planning (DCP)/MTA	• Senior Transportation Planner (former MTA planner) (DCP)
WMATA	• Juwhan Lee, Service Director, Street Operations (WMATA) • Charley Dingboom, Planning Manager, Bus Service Planning and Scheduling (WMATA2) • Raka Choudhury, Director, Bus Priority (WMATA3)
DDOT	• Micromobility Coordinator, Sustainable Transportation Programs (DDOT)

A list of questions or prompts guiding the interviews and the more detailed interview guide creation, along with the research questions addressed, can be found below in table 3.

Table 3: Questions and prompts driving interviews, along with the research questions addressed

Question/Prompt	**Research Question Addressed**
How are you involved in the service disruption planning process?	RQ1, RQ3
What does the planning process for service disruptions look like? • What types of alternatives/replacements are typically planned for, and why? • What does the planning process for those alternative services look like?	RQ1
How are service disruption plans unique in your city? How might they be different in other cities?	RQ2
How do the following factors impact the alternative service possibilities available in your city? How do these factors impact the overall diversion planning process? 1. Your city's infrastructure 2. Local and state policies 3. Your city's environment	RQ1, RQ2

4. Your city/transit agency's budget	
What data sources are considered when planning for service disruptions? What type of information, if any, are missing or difficult to collect?	RQ1, RQ4
Who are the primary decision makers and contributors to service disruption planning? Who else is involved? • How do you collaborate with other teams or organizations when planning for disruptions and alternative service provision?	RQ1, RQ3
In a world with unlimited resources, what would planning for service disruptions look like? • What barriers currently exist preventing this vision from becoming a reality? • What changes or resources would be necessary to overcome these barriers?	RQ4

The research proposal for this thesis, as well as all participant-facing-stimuli (recruitment materials and interview guides) underwent an expedited IRB review and received a letter of exemption determination prior to initiating recruitment.

Analysis

Interview analysis and coding consisted of a multi-step note organizing and coding process. Notes were taken during interviews or while listening back to recordings of any interviews that were agreed to be recorded. Next, findings were pulled from notes into a Google Sheet, where each finding was tagged with one, or multiple themes. This way, findings were organized both by interview, and also by theme. Next, categorized findings were pulled into a Master sheet, allowing findings to be filtered by theme, allowing for analysis of which parties spoke to each theme, and the range of details within each theme. Organizing by theme also aided organization for the findings section of this thesis.

Themes were identified by doing close readings of interview transcripts and notes and identifying similarities and differences, along with ties to previous literature[58]. A comprehensive list of the themes used to tag findings can be found below, and further detail around how findings were tagged by theme can. Be found in the appendices.

- Data Sources and Justification
- Proactive Planning
- Resource Procurement
- Accessibility
- Travel Behavior
- Service Provision
- Interagency Collaboration
- Challenges and Barriers
- Management and Operations
- Street Infrastructure
- Shuttle Operations
- Messaging
- Routing
- Costs
- Active Transportation
- Creative Alternatives and Strategies
- Customer Satisfaction
- Troubleshooting

It is important to note that while a qualitative approach is appropriate for the identified research questions and semi-structured interviews allowed the most specific and anecdotal data, there are still limitations to this approach. First, internal validity could not be assured as interviewees may have felt compelled to discuss only what they wanted to be cited on, and interviews as a method cannot realistically represent the entire universe of service disruption planners, given

[58] Gaber and Gaber, *Qualitative Analysis for Planning and Policy*.

the timeline of this project. As a student researcher, obtrusiveness may be less of a threat to the internal validity of this project than as a researcher with higher standings or alternative agendas. Interviewing individuals from multiple teams or agencies within each city helped to increase this project's sampling validity, as it was clear when pieces of the process were commonly understood by multiple parties, or when there were experiences unique to only one team, agency, or city. A thorough literature review also supports the interpretation of results, increasing the likelihood that data processing was conducted accurately and in a way that reflects existing understandings of transit service disruptions[59].

Chapter 4 - Findings

Stakeholders and Management

It was clear from all interviews that disruption planning is a process involving a wide array of agencies and teams, requiring careful coordination to minimize the adverse impacts from the closure. Ownership is a large contributor to this need for collaboration – streets are typically owned by the local jurisdiction, whereas train lines, bus stops, and transit vehicles are usually owned by the transit agency. Further, some roads might be owned by the local jurisdiction, whereas others may be owned by the state Department of Transportation (DOT), and some transit systems span multiple municipalities and states, adding further complexity. As maintenance and operations cannot be conducted on infrastructure not owned by the acting party without permission, a high level of coordination and communication is paramount in these processes. Any suggested alternative service will likely interact with infrastructure owned by

[59] Gaber and Gaber.

another party, and various players will have a stake in the ways that the alternative service impacts existing infrastructure, traffic, and surroundings.

Relationship management here is key. Each interview discussed the need for frequent collaboration, along with mention of either a team or a point person who has existing relationships with entities relevant to the process. The City of Boston had one point person from the city's transportation planning department who processes requests from the transit agency and delegates to other appropriate teams and agencies. New York City and Washington D.C. operated on more of a team-basis, where some requests were transmitted through their government relations teams, and some to their counterpart teams at various departments of transportation. The approach in these cities is likely less streamlined than Boston's approach due to their need to coordinate with multiple different jurisdictions and DOTs, whereas the MBTA operates only in one state, and its main service is within, or catering to only one jurisdiction, the City of Boston. The tables below depict the involved parties for diversion planning in each city, along with their main roles and responsibilities within the transit disruption planning process. These lists are certainly not comprehensive and includes only the parties and processes discussed during interviews.

Transit Agency Teams

Table 4: Transit agency teams involved in disruption and alternative service planning in Boston, New York City, and Washington, D.C.

MBTA		MTA		WMATA	
Team	*Primary Role*	*Team*	*Primary Role*	*Team*	*Primary Role*
Alternative Service Planning	Planning alternative service for shutdowns, metrics assessments	**Operations Planning (OP)**	Overarching department comprising of various track access and planning teams	**Street Operations**	Management of street- level operations, coordination for shuttling

Contracted Operations	Execution of shutdown plans, adjustments and documentation	**Track Access Forecasting**	Long-term planning of track access for construction and maintenance	**Bus Operations**	Primary planning and execution of shuttle operations
Bus Operations	Coordination around fixed bus routes and operator scheduling	**Short Term Track Access**	Creation of service plans for upcoming construction and maintenance requiring track access.	**Bus Service Planning and Scheduling**	Coordination on fixed route service, advising on shuttle routes
Technology Innovation Department	GTFS deployment for shuttle services, data collection.	**Rail Network Planning**	Analytical support and planning for service during track outages	**Bus Priority**	Coordinating bus lanes and priority measures for shuttles
Transit Facilities	Prints, installs, and maintains signage	**Department of Subways (DOS)**	Coordination around subway work/track closures	**Transit Police**	Enforcing street-level changes, intersection control
Transit Priority	Collaborating on bus priority initiatives	**Service Delivery**	Team within the Department of Subways, partially responsible for signage and information	**Special Events**	Coordination on detours and closures during special events
Transit Ambassadors	Contracted service for providing information	**Department of Buses**	Coordination of available buses for shuttling	**Government Relations**	Public interfacing
Transit Police	Enforcing street-level changes, intersection control	**Construction and Development**	Coordinate track access and schedules	**Sign and Shelter Team**	Signage decisions and installation
Customer Experience	Messaging and information around shutdowns	**Government Relations**	Public interfacing	**MetroAccess**	ADA service assistance
		Customer Experience	Messaging and information	**Customer Experience**	Messaging and information

			around track outages (in collaboration with DOS and OP)		around shutdowns
		Metro North Railroad, Long Island Railroad	Communicate potential ridership changes		

Jurisdictional Partners

Table 5: Jurisdictional partners involved in disruption and alternative service planning in Boston, New York City, and Washington, D.C.

Boston		New York City		Washington, D.C.	
Team	*Primary Role*	*Team*	*Primary Role*	*Team*	*Primary Role*
Boston Transportation Department (BTD)	Key point of contact for MBTA, Diversions Coordinator manages delegation of tasks and requests to various parties	**NYCDOT Transit Development**	Collaboration on alternative service plans, permitting for street work and infrastructure changes	**District Department of Transportation (DDOT)**	Owner/responsible for street right-of-way, close collaboration on street-level implementations, road closures, events and construction, etc.
Boston Permitting	Requesting permits for road work, curb space, etc.	**NYCDOT Bus Stop Management**	Coordination of changes to bus stops, layover needs, etc.	**DDOT Traffic Team**	Collaboration on traffic mitigation during shutdowns
Special Events Department	Coordination on potential conflicting events	**NYCDOT Signals Unit**	Signal modification implementations and analysis	**DDOT Permitting Team**	Permitting for street, curb, and sidewalk usage during shuttling events
Disabilities Commission	Coordination around shuttle accessibility	**NYCDOT Borough Commissioners**	Collaboration on borough-specific street changes	**DDOT Bus Priority Team**	Collaboration with WMATA Bus Priority team

Boston Police Department	Enforcing street-level changes, intersection control	**Borough Engineering Departments**	Collaboration on street and infrastructure adjustments	**DDOT Freight Team**	Collaboration around parking removal/ changes to freight access during shutdowns
Boston 311	Public interfacing	**Port Authority**	Coordination around train closures near the airport	**Montgomery County DOT (MCDOT)**	Coordination on MCDOT owned ROW
Office of Neighborhood Services	Public interfacing	**New York Police Department (NYPD)**	Traffic enforcement and intersection assistance	**Maryland DOT (MDOT)**	Coordination on MDOT owned ROW
Parks and Recreation	Tree trimming at shuttle stops	**New York State DOT (NYSDOT)**	Coordination on NYSDOT owned ROW	**Virginia DOT (VDOT)**	Coordination on VDOT owned ROW
Public Works	Coordination around street construction and repairs			**Jurisdictional Police Departments**	Enforcing street-level changes, intersection control
BlueBikes Team	Discount codes for bikeshare during shutdowns			**DC Department of Public Works**	Parking enforcement, collaboration on some street-level implementations
Traffic Management Center (TMC)	Oversees traffic signals and adjusts signals for diversion plans				
Parking Enforcement and Tow & Hold	Enforcement of no parking zones during diversions				
Other Municipalities (Cambridge, Quincy, etc.)	Ad-hoc coordination with DPW/Head Transportation Planner, etc. at other cities on diversions needs				

MassDOT	Coordination on MassDOT owned ROW				

Other Collaborators

Table 6: Other collaborators involved in disruption and alternative service planning in Boston, New York City, and Washington, D.C.

Boston		New York City		Washington, D.C.	
Party	*Primary Role*	*Party*	*Primary Role*	*Party*	*Primary Role*
Contracted Bus Service	Primary contracted bus service	**Public Transit Union**	Coordinate route entry into Union picks, labor laws for operators	**Other Private Shuttle Companies**	Communicating potential conflicts at stops/along routes
Keolis	Commuter Rail closure management	**NYC Economic Development Corporation**	Collaboration for use of Ferry Services during shutdowns	**Contracted Bus Companies**	Contracting for buses and operators
Transportation Advocates	Messaging around shutdowns, diversion mitigation strategies, alternative service, etc.			**National Parks Service**	Coordination on NPS owned areas (National Mall, Tidal Basin)
EZShuttle, other private shuttle companies	Communicating potential conflicts at stops/along routes			**Montgomery County Bus Service, other regional transit services**	Communicate potential ridership changes
Boston Public Schools	Coordination on communicating shutdown impacts to students				
Tent Supply Contractor	Supplies tents for shuttle stops				

Traffic Mitigation Equipment Contractor	Supplier of traffic mitigation equipment (cones, signs, etc.)				
Consultants (Bowman, Nelson\Nygaard, HSH)	Assist on transportation management plan creation, workstream organization, timeline management				

Existing Planning Processes

Interviews with transit agency employees and city or DOT transportation planners revealed complex, meticulous processes that happening behind the scenes. While there are many similarities between the cities' planning processes, there are of course differences based on the structures of the teams working on these initiatives, as well as unique characteristics of each city, which play a role in challenges and areas for improvement as well. By comparing processes of each city, we are also able to learn best practices or ideas implemented by one system that may be beneficial for another city to apply in future diversion plans.

Justification for Shuttling as the Core of Diversion Planning

Below, the findings section outlines disruption planning processes as detailed in interviews with transportation planners and transit agency employees in Boston, New York City, and Washington, D.C. All three cities and transit agencies use shuttle buses as the primary means of alternative service replacement for longer term shutdowns (with the exception of New York City's ability to divert service onto parallel tracks for shutdowns in Manhattan, as discussed towards the end of this findings section). Thus, these three cities reflect standard procedures described in literature of shuttling, or bus-bridging.

When discussing shuttling, planners spoke of the service as a given during shutdowns, especially in transportation networks where shuttling is a necessity due to a lack of other existing alternatives (such as parallel rail service, in New York City). Shuttling offers continued provision of mass public transportation by the transit agency, with operational levers available to bring standards and capacity as close to those of the ordinary subway service as possible (MBTA2). For these reasons, it is rare to find a transit agency that does not employ shuttle services during disruptions. Charley Dingboom, the Planning Manager for WMATA's Bus Service Planning team, reiterated the central role shuttling plays in any rapid transit diversion project, sharing:

> *"It's still bus bridge. Bus bridge is a fact of life if you're running a rail system anywhere. Even if you're running a light-rail system, you've got bus bridges that you've still got to manage when you have disruptions. It's flavors of the same thing, it can be more intense, but again, when you get down to it, it's essentially doing the same thing and it's just degrees of that same management program."*

In New York City, shuttling is not as much of a given for every shutdown, due to the redundant quality of the subway network. As riders can be diverted onto parallel tracks or lines when one track needs repairs, shuttling is typically only a necessity when major work is being done, or towards the ends of lines in the boroughs, where the subway network is sparser and cannot rely on rail redundancy (MTA). However, this means shuttling is a part of all three cities' approaches to diversion planning and alternative service provision. Shuttle buses are a core component of diversion planning processes and a predominant service strategy of disruption planning in the three studied cities. Additional service provision models will be discussed in more depth at the end of the findings section, along with some major differences and challenges that may make shuttling more or less efficient as a sole strategy.

Initial Planning

The first step in the diversion planning process is assessing whether the maintenance that needs to be done is something that can be done in a short span of time and can be scheduled for only weekends or overnight, or if it is a bigger need that requires track work for multiple weeks or even months – leading to full shutdowns. Commonly, separate teams handle the shorter-term diversions that can go without largescale plans for alternative service, and the longer shutdowns requiring extensive planning. The longer shutdowns will take up the majority of this paper's findings.

Once the vague scope of the maintenance and associated closure time has been decided upon, Service Planning teams begin drafting initial service plans around 90 days or 14 weeks prior to the intended start of the shutdown (MTA, WMATA). The initial plan includes collecting data from stations and route timing, fleet calculations and availability, station closure needs, staff availability, and supplemental schedule creation. The service plans then go through reviews and edits and are approved around five weeks prior to the start of the shutdown. These plans require substantial collaboration, as they often involve maintenance and construction schedules involving multiple capital groups and also have to take into account union rules if applicable and staffing and resource availability. These plans are typically called service plans, though in New York city the staff-facing instructions are called General Orders, or G.O.'s (DCP, MTA).

Data Sources and Justification

Service plans include details about how service will continue to be provided to passengers, whether via alternative modes like shuttle buses, or in a limited capacity on the same line with diverted traffic to parallel lines, in the case of New York City. This planning takes into account travel patterns and data to calculate the level of service needed to meet demand and also uses data from past shutdowns to aid predictions. Ideally, service plans would be fully constructed based on data from past shutdowns, but such examples are lacking – especially with similar

timespans, impacted stations and routes, and schedules. Rather than using transit propensity analysis, service planners will conduct ridership analysis based on train ridership to predict demand (MBTA2). In New York City, standard service is planned to follow Passenger Loading Guidelines, a formal policy outlining how frequently subway and bus service need to run in order to meet demand, along with vehicle capacity and safety standards (MTA). No such standard guidelines exist for replacement services, so planning is based off of service planners' evaluations of capacity based on what has been observed of guidelines and associated ridership during standard service.

Ridership analysis for diversions is also called a displacement analysis, using ridership peaks to calculate the maximum number of shuttle buses needed to provide enough capacity during peak transit periods (MBTA2). These analyses will also take into account yearly ridership increases if using ridership data from the previous year – a practice that has been important since ridership patterns changed during COVID-19 and have been steadily increasing every year since (WMATA). Modeling may be used for larger shutdowns to predict hourly loads and ideal routes. Washington D.C. benefits from its rail transit system being tap-in tap-out, providing linked pairs for route modeling. For bus routes, WMATA follows a similar analysis to systems with only tap-in, linking repeated morning origin locations with repeated evening origin locations to form origin-destination pairs (WMATA2). New York's Metropolitan Transit Authority has a modeling group that is pulled in to help with this work, looking at potential displacement caused by an outage, and indicating the level of need to service planners (MTA, MTA2). For shorter shutdowns, service plans are less likely to use modeling, and operations teams will instead rely on the institutional knowledge to provide an estimate of how many displaced passengers are likely to ride provided shuttles (WMATA2). No matter how low the projected ridership might be, a baseline level of service must still be provided, as noted by MBTA service planners (MBTA2).

Ridership analysis is also crucial for seeing whether a diversion is feasible as currently planned. In New York City, where diversions may mean thinning service on the subway rather than completely stopping service, ridership analysis is crucial for analyzing whether trains will be overcrowded. If overcrowding is a likely possibility, the planners will iterate with the capital group requesting the outage to see whether they can break the work up another way, or at a different time. If the previous plan had been to take two of four tracks out of service, they might push for only taking one track out of service, but over the course of a longer period of time to still allow ample service provided (MTA). As the MTA aims to conduct most track work on the weekends to avoid commute rush hour, this might mean increasing the number of weekends during which work occurs to avoid overcrowding on weekdays. In these situations, compromises must be made to keep everything moving while still getting work done. One such compromise is having a higher crowd tolerance on the weekends than usual – often a crowd level akin to that on weekdays (MTA).

Boston and Washington, D.C. do not have the benefit of multiple tracks on which they can run thinned service in most areas of their transit networks. Instead, their ridership analysis deals with the challenge of providing a level of service meeting the demand for a train, yet with smaller vehicles – thus increasing the fleet and frequency requirements. Ridership analysis for shuttling also takes into account self-diversion, which planners are able to assess by examining ridership changes for nearby bus routes and other rail lines during past diversions (MBTA2).

As diversion shuttles typically do not require fare payment, ridership is not collected in the same way as it is on trains, making shuttle ridership analysis a challenge. However, data on shuttle routes, timing, and ridership is still collected through various means. First, GPS trackers are installed on all buses, including contracted shuttles, to collect data around route run times. When using contracted buses, both the MBTA and the contractor collect this data for their records as a source of accountability and cost-monitoring (MBTA2). In both Boston and

Washington, D.C., diversions will use a mix of in-house buses (from the local transit agency's fleet), and contracted shuttle buses. While in-house buses typically have Automatic Passenger Count (APCs) to record ridership data, contracted buses may not. Currently, the only way to collect ridership data for contracted buses is by manual counting. Manual counts are conducted by stationing staff at each shuttle stop to count the number of passengers boarding and alighting each shuttle, and the time that each shuttle departs (MBTA, WMATA). This is a more common practice in Washington, D.C., than Boston, and is less than ideal as it requires more staff time and coordination.

Another way to estimate shuttle ridership is by studying tap-in numbers at the first open station along the detoured route – where passengers would logically transfer between the shuttle and regular train service to continue their journey. By comparing the tap-in numbers to typical numbers outside of shutdown periods, planners can calculate the difference and attribute the increase to individuals coming directly from the shuttle bus. Using this method, MBTA service planners have found that around 70% of passengers use provided shuttles in off-peak times, compared to around 50% during peak times. This type of information helps with fleet estimations, as the MBTA can plan to provide fewer shuttle buses than they might initially assume during peak times (MBTA). As Juwhan Lee of WMATA noted, although shuttle ridership is typically lower than standard rail ridership, it is a careful balance between providing too many and too few buses. Too many buses will be costly and may lead to additional congestion, whereas relying on lower shuttle ridership and providing too few buses can raise issues with public approval (WMATA).

Lastly, planners must also conduct speed and station capacity analyses. If work is being conducted on the tracks that will cause parallel service to slow, it is crucial to understand how this might impact capacity for the rest of the rail network (MTA). Similarly, roadway speeds will impact fleet requirements, as the slower a vehicle moves, the fewer people can move through

space at a time (BTD). Station analyses are mainly conducted when a station that is not typically a terminal will become the end of a line, or a turnaround point. In these scenarios, the space must be assessed to ensure it can hold the capacity of passengers typically expected of a terminal station, which may impact the need for increased frequency of service to reduce crowding at stations (MTA).

Shuttle Planning

Route Planning

Shuttle Routes are typically planned to mimic the route of the original train service as closely as possible with the existing road network. The first step to route planning is typically a rough sketch of a shuttle route in Google Maps or another similar platform, highlighting the stations that need to be serviced. Route planning also involves identifying 'problem areas' on the road and avoiding them if possible. These are areas with high congestion or bottlenecks, often already identified by Bus Service Planning or Transit Priority teams within the transit agency (MBTA, WMATA2). Route planners also aim to avoid residential neighborhoods, as the goal is to limit impacts on local communities. Once an initial plan is drafted, it will be passed from one team to the next for review – in Washington, D.C., this would be the Bus Operations team formulating the shuttle route (specifically design for the shortest possible distance and run time) and passing it off to the Bus Service Planning team, who will review the plan and identify necessary revisions based on their experiences with existing bus service (WMATA2). Charley Dingboom of WMATA Bus Service Planning described the process as follows:

> *"They'll take that first stab at [drafting a route], and they'll have put together an idea that says 'well we're considering the two local services and one express service.' And then we'll come back and say 'well actually, you might want to do a second express that does this instead.' And we're looking at that because of travel patterns, and we're looking at that because we know the way people are trying to get to and where they are trying to end up and this makes most sense for it."*

It is also crucial to assess how planned shuttle routes may impact other, existing service. Typically, keeping shuttle stops aligned with fixed route stops is easiest in terms of infrastructure, but part of route planning is seeing whether regular service will be too heavily burdened by additional vehicles stopping at bus stops, or using regular service route roadways. If shuttle routes do not align with regular service routes, then the new routes must be scouted out to ensure they will have proper infrastructure, stopping, and layover areas available (MTA).

Route Scheduling and Testing

Much of route planning involves determining how to get from stop A to stop B in the shortest possible amount of time. When calculating drive time, planners will choose a date with predictably high traffic – in Boston, this is typically a Tuesday in Autumn (MBTA2). After getting a predicted drive time for a given route, a buffer of around 25% of that time is often planned in, as accidents, construction, or other various delays may slow down predicted timing. Part of the need for added time is that by adding 50-100 buses to the road, additional congestion will be added that typical travel time calculations do not account for (MBTA2). The more shutdowns that occur, the more data that is collected specifically on shuttle route runtimes, making timing predictions easier and less reliant on conservative timing buffers (MBTA2). Calculated runtimes allow service planners to calculate the required shuttle frequency to meet demand, allowing the creation of service schedules. Service schedules indicate the number of buses needed and can thus be translated into costs. Shuttles are the largest item in the Rail Shutdown budget in Washington D.C., so this process is an important step in budget calculations (WMATA).

Once routes are planned, they are tested. Most routes are tested around two weeks in advance if they are only for weekend or off-peak shutdowns for shutdowns impacting peak transit periods, routes will be tested closer to two months in advance, to provide time to plan for additional considerations, as discussed later (MBTA2). A major consideration here is layover locations, for which parking spaces often have to be removed – requiring coordination with the

local jurisdiction (WMATA2). Route testing can also lead to observations around turn feasibility, as some contracted coach buses are less maneuverable than typical service buses and cannot perform some of the tighter turns on the route. This will either lead to route revisions, or potential roadway modifications like stop bar adjustment to allow for a larger turn radius (WMATA2). If routes are not tested with an actual bus, service planning engineers will conduct turn analyses to assess maneuverability. Service planning then writes up the final routes as turn-by-turn directions to provide to operators, along with announcements detailing each stop on the route (MBTA2).

In New York City, another important part of route planning is determining whether the route will be eligible for the union pick. If the shutdown is long enough, and the route is planned out far enough in advance, the shuttle route can be entered into the bus operator's union pick, where operators pick which routes they want to drive. The pick happens four times a year, with operators picking their route for the next three months. If a shuttle route does not make it into the pick, it can only be driven as volunteer overtime, which is very costly to the MTA. This makes shuttle route planning and scheduling a strategic process, where having a shuttle route long enough, and timed correctly to make it into the pick can save a large amount of budget for the project (MTA2).

Local and Express Routes

Often, route planning involves more than just one shuttle route. Many transit agencies have taken up the practice of offering various routes to better match travel patterns and demand. For example, due to the high percentage of MBTA riders who take the Red Line only within Cambridge, Red Line shuttles often run a turnback route (turning around prior to the typical end of the route – in this case, turning back to continue servicing Cambridge rather than heading into Boston) (MBTA2). When determining which routes to run, service planners will assess ridership patterns and travel time, determining which stations are more or less popular, and would be

better served by multiple route options. The most common offerings are a 'local' route and an 'express' route. Local routes are the most common offering, stopping at every standard service station. This option seems to be the one that is least confusing to riders, as it is most similar to the service they are used to taking. (WMATA, WMATA2). Express routes typically run straight to the end of the rail disruption/detoured segment, or stop at a few major stations along the route, skipping smaller or less popular stations (WMATA). Express routes can take advantage of a less prescribed path of travel, allowing them to take highways or faster roads that could cut off travel time (WMATA, WMATA2).

In some systems, express routes are not always planned ahead of time but may be a day-of decision by operations managers noting that there is significant backup impacting shuttle routes. In these scenarios, an operations manager would radio in to contacted operators, informing them of the switch to an express route instead (MBTA2). Other times, express routes are already running, but more vehicles may be needed for either a local or express route, and a certain vehicle may be asked to switch to another route. For this reason, route assignments are left fairly flexible, and some agencies do not advertise turnback loops (like the Cambridge example mentioned previously) to give operations management flexibility to reassign routes as needed, and to avoid customer confusion (MBTA2). Turnback routes, while potentially confusing for customers, can be efficient solutions for avoiding congestion in bottleneck areas. For example, a Cambridge turnback shuttle helps to avid bus congestion over the Longfellow bridge going into Boston (MBTA2). In New York City, where shuttling is largely done only at the ends of lines where there is less rail redundancy, one route is typically sufficient to address ridership demand (as planners determine through origin-destination analyses) (MTA2). Offering only one route in these cases also helps to avoid public confusion that multiple route variations can bring.

Potential Route Improvements and Efficiency Boosters

Route Implementations

With route efficiency being crucial for both meeting public demand and reducing costs and congestion, various analyses and implementations are considered by both transit agencies and city or department of transportation staff. These are largely street-level adjustments to help shuttles along and avoid increasing congestion. In Boston, the city transportation department conducts several analyses including signal timing analyses and intersection analyses to see whether there are changes that could be made to ease shuttle routes. In particular, identifying any areas where shuttle buses could get priority signals or queue jump signals, or just by extending a green light in areas that tend to experience intersection-related congestion (BTD). Similarly, if turn radius analyses show that a bus may struggle to turn through an intersection, the city would assess whether they are able to move back a stop bar or alter the street design slightly to create a wider turn radius available for shuttle buses coming through that intersection (BTD, MTA2). These implementations are often most crucial when shuttle routes are along roads that do not have standard bus service, as intersections will not always be pre-designed to accommodate large vehicles (NYCDOT).

In New York City, the Department of Transportation can quickly recommend areas for queue jumps based on a list of locations they had already determined as good candidates for queue jumps due to typical traffic and congestion levels (NYCDOT). The MBTA Transit Priority team has a similar workbook of areas in need of intervention and potential implementations, which the alternative service team consults when planning for shuttle routes (MBTA). This avoids new analyses shuttle planning teams have to do and instead uses shuttle routes as a justification for moving forward with these temporary implementations. Some recommendations can be more easily accommodated, whereas others, like traffic signal changes, can require advance planning and collaboration. Signal adjustments are typically managed by the local jurisdiction (either the

city or the city's DOT), and time for these changes and associated analyses of related impacts to the area need to be built into the shuttle planning timeline.

Another leading street-level implementation for shuttle efficiency service planning teams will consider is the pop-up bus lane. Pop-up bus lanes can either be completely new, using cones or flex posts to section off a lane reserved only for shuttle and standard service buses, or they can extend the hours of part-time bus lanes and increase bus lane enforcement for shuttle efficiency. If considering a bus lane use for shuttle routes, city or DOT planners would assess the number of travel lanes in the area and whether one could be turned into a bus lane without having largescale traffic impacts (BTD). Sometimes, a bus lane already exists along the shuttle route, and small changes will be made to enhance the bus lane prior to the shutdown, like repainting it to make it more noticeable, lining it with cones, or increasing enforcement (MBTA). While shuttles will take advantage of existing bus lanes if available along their route, shuttle routes will rarely be rerouted just to use existing bus lanes, as this would typically have a net-zero efficiency change (MBTA).

Shuttle Stop Implementations

Street-level changes are also necessary for accommodating shuttle stops along routes, as shuttles often stop in locations that do not typically accommodate large idling vehicles. The most common implementation for shuttle stops is the removal of parking spaces to make room for shuttles to wait. Service Planning teams request parking spot removal from local jurisdictions, who can fulfill these requests. In New York City, the Bus Stop Management unit of NYCDOT fulfills these requests from the MTA, sometimes completing additional work like extending an existing bus stop to create a new layover zone for shuttle buses or updating and replacing signage (NYCDOT). In Washington, D.C., 'emergency no parking' permits are used for parking removal, whereas any parking removals requested in Maryland for shuttles will be fulfilled by bagging parking meters (WMATA3). Parking is also sometimes removed for better

shuttle turn radii. These requests typically originate from MBTA service planners' pasts experience and test run data and are sometimes confirmed by BTD engineers through a turning movement analysis (MBTA, BTD). Boston Transportation Department also consults Boston's Office of New Mobility to monitor outdoor dining locations, as these locations typically use parking spaces, and may pose potential conflicts for shuttle bus stops, or remaining parking availability if parking has been removed for both shuttle stops and outdoor dining. Coordination between these two offices helps ensure that outdoor dining is not approved in the same locations where shuttle stops will be requiring parking spaces within the coming year (BTD).

Accessibility

Shuttle buses and their routes are held to the same accessibility standards as typical service is, meaning that additional considerations and adjustments often need to be made to ensure temporary service locations are ADA accessible. As most shuttle stops are adjacent to the standard service stations, the shuttle stop's distance from the original station is a primary consideration, especially if it is the first shuttle stop of the closure (and passengers will be coming from the train to the shuttle, or vice versa). Ensuring an accessible path of travel between the two is crucial, and if the shuttle stop is too far or encounters any barriers, it is common that the transit agency will have an ADA van parked at the station to transport people between the station and the shuttle stop if they are not able to make the journey themselves (MBTA). ADA vans are also provided for any areas that are intentionally not shuttled. For example, shuttle routes in Boston typically cease between North Station and Back Bay, as bussing in the downtown core leads to heavy congestion, and parallel subway lines can typically make up for closed service. However, if there is anyone who is unable to walk to a substitute line, an accessible van will be available to transport them to their desired destination (MBTA). Washington D.C. has a similar offering, with WMATA's ADA service, 'MetroAccess' available to provide accessible support during shutdown, though advanced arrangements are required (WMATA).

Accessibility is also considered in the bus procurement process, as low floor buses (typically used for standard service) are more regularly accessible and ADA compliant, but due to limited resources, coach buses are often contracted for shuttling as well. However, MBTA and WMATA ensure they only procure fully accessible vehicles, meaning that any contracted coach buses used for shuttling are equipped with wheelchair lifts, which are regularly checked for function. Additionally, wheelchair accessible vehicles (WAVs) are available for backup as needed (WMATA, MBTA). The MBTA works to identify any mobility deficiencies in Boston infrastructure that may lead to accessibility challenges during shuttling and notifies the City of Boston's diversions coordinator to coordinate accessibility improvements. This process involves collaboration with the Boston Public Works department and the Disabilities Commission to ensure ADA compliance at stops and avoid removing any existing infrastructure implemented for individuals with ADA accommodations (BTD).

Route Conflicts and Permitting

Avoiding Route Conflicts

Other considerations when planning shuttle routes include conflicts with bike lanes, school bus routes, special events, and construction. Bike lanes are sometimes impacted by shuttle routes due to the need to park and wait in the bike lane, or the need to borrow some bike lane width for shuttle bus maneuverability. Flex posts lining bike lanes may be removed for both of these reasons, impacting the standard infrastructure devoted to bike lanes (BTD). The impacts of removing bike infrastructure for shuttle maneuverability are not thoroughly documented, and Amanda Caparoso, BTD's Diversions Coordinator, wonders about how severely these street-adjustments impact local community, and would be interested in collecting further data around bike lane usage in areas where flex post and other bike infrastructure has been removed for shuttle routes (BTD). Other recognized considerations include shuttle routes conflicting with school bus routes, where shuttling in an area that has school pickup/drop-off may lead to

increased congestion and safety issues. Thus, MBTA service planners aim to keep shuttle routes away from schools, and BTD addresses any remaining conflicts with school zones (MBTA, BTD). This may look like closing streets to any vehicles other than buses (both school and shuttle) or removing parking for more space for buses to move around each other (BTD).

Special events can impact shuttle routes by bringing uncharacteristic foot and vehicle traffic to the area. Washington, D.C., stands out as a locale with many special events impacting street traffic – whether the event be a parade, State of the Union Address, a protest, or a standard baseball game (WMATA2). DDOT (District Department of Transportation) will inform WMATA's service planning team of any special events that may impact typical transportation patterns, as these could lead to increased run times or varying ridership levels (WMATA, DDOT). In Boston, the Special Events Department similarly notifies BTD about any potentially conflicting events. Sometimes, this leads to further necessary collaboration. For example, a farmer's market in Back Bay at the time of an Orange Line diversion meant that BTD had to coordinate with the Office of New Mobility on where farmers could park to pick up and drop off produce that would not interfere with the shuttle routes or stops (BTD). Similarly, coordinating with the office of the Parking Clerk to ensure moving occupancy permits are not administered in shuttle stop areas helps to avoid moving trucks or other unusual traffic interferes with shuttle routes (BTD).

Construction and Permitting

Construction is another type of special event that route and service planners keep an eye out for. When planning routes, service planners will contact the city or local DOT to check whether there are any planned construction projects or conflicting permits along the routes during the scheduled time period. Often, this not only involves checking the roads the shuttle routes run down, but also any connecting roads (BTD). Touching base on construction and permits early on is important, as the transit agency can then request that the DOT or city try to prohibit any construction along the shuttle route during the prescribed time period, by putting a hold on any

construction or special permits, unless absolutely necessary (BTD, WMATA). Street occupancy permits, like those for utility work or moving trucks, may still be granted, so long as route planners confirm that shuttles will be able to use the road at the same time (BTD).

Shuttle planners not only ask for permits to be held but also request permits from the DOT or city for certain street modifications necessary for shuttling (parking space removal, etc.). Permitting for shuttle route implementations becomes more complex the larger the shutdown, as shutdowns with a greater impact area typically involve more permitting bodies and jurisdictional partners. Countless street-level projects occur simultaneously to shuttling projects, and in for large cities like New York City, massive agencies mean multiple layers of input and approval are needed even to make small changes (MTA2). After permits are issued by the DOT or jurisdiction, they sometimes also require a verification step. For example, in Washington, D.C., a shuttle planner picks up issued permits and installs them as needed, followed by a step of taking pictures of the permits and having them verified by DDOT before they can be enforced (WMATA).

Resource Procurement

Shuttle Buses

Planning for transit shutdowns and alternative service offerings is dependent on the ability to procure necessary resources. When planning for diversion shuttling, bus and operator availability and procurement is a key step. In Boston and Washington, D.C., shuttle operations teams use buses from their standard service fleets when available, and will use contracted buses (often coach buses) to meet additional need. In New York City, shuttle operations only use in-house vehicles, as contracting buses would lead to a slew of issues involving union contracts (MTA2). Each city's transit agency has worked out a slightly different system for bus procurement. In Boston, the MBTA has an agreement with a contracted bus vendor for a reserve of around thirty low-floor buses. This means that the MBTA has first priority to use these thirty

contracted buses, aiding in bus procurement during large shutdowns (MBTA2). While the low-floors are preferred for accessibility reasons, the MBTA often requires more buses than the available low-floors, leading to contracting additional coach buses. When possible, the MBTA will try to reduce bus counts by running express routes or using efficiency tactics as previously discussed, to try to reduce the costs that a higher shuttle count incur (MBTA2). While the MBTA has a typical contractor, in Washington, D.C., WMATA plans the bus contractor proposal and bid process into their timeline if requiring more buses than available in their Metrobus fleet (WMATA). Contracting adds another layer of collaboration and monitoring to the planning process, with bus operations planners in Washington D.C. and Boston managing contracts and keeping track of service level agreements, which ensure contractors are abiding to the transit agency's standards for service and accessibility (MBTA2, WMATA2). If shutdown shuttling is managed in-house and contracted operations are not involved, WMATA works with various bus divisions to figure out how many buses each division can spare to be used as shuttle buses, and which routes each of those buses will drive (WMATA).

In New York City, union contracts make contracted buses a non-option. Instead, MTA uses buses only from their fleet to shuttle. As the MTA typically runs shuttle routes towards the ends of subway lines rather than in the core due to the dense subway network's provision of alternatives, the required number of buses for shuttling is typically contained to a manageable amount. With just under six thousand buses in the MTA fleet, almost every bus is in service during weekday morning and afternoon peak periods. However, shutdowns are typically planned for nights and weekends, so borrowing fifty to one hundred buses is not usually a challenge (unless numerous shutdowns occur in one weekend, all requiring additional buses and rail service adjustments). The MTA also keeps a 'spare factor,' around ten to fifteen percent of their fleet which is reserved for emergencies, breakdowns, or other similar situations. This is where shuttles are typically pulled from if needed on weekdays or during peak hours (MTA2). When planning for a major shutdown that required more buses than the spare factor could account for,

as in the case of the planned 2019 L train shutdown, bus planning contacted the Department of Buses to procure additional shuttles. The Department of Buses handles bus retirement – sending buses away and putting them out of use after their lifespan of twelve years. In preparation for the L train shuttle, the Department of Buses planned to hold around one hundred buses off from retirement or to speed up bus repairs to meet the L train shuttle quota (MTA2).

Operators

Coordinating operator availability is just as, if not more, important than bus procurement. Again, transit agencies approach this process slightly differently. When shutdowns occur on weekends or during off-peak hours, there is higher likelihood that in-house operators will be available to operate routes on overtime. For midweek and peak hour shutdowns, there is often less operator availability, and the MBTA and WMATA may ask for additional operators from the contracted bus lines. When working with contracted operators, the transit agency has to plan in at least 1-2 weeks prior to the shuttle commencement to train operators on agency standards and policies, as well as briefing them on the routes. In Washington, D.C., this process usually involves bringing in contracted drivers that are not from the area, so additional training may be needed to become familiar with the street network (WMATA). In New York, service planning has to be aware of whether a shuttle will run for long enough (at least 3 months) and is well timed to be entered into the union route pick, in which case operators would drive the route as their regular daily work. If the shuttle route is too brief to be entered into the pick, they can only be driven by operators doing 'volunteer' or overtime hours, making operator procurement for shuttling very expensive for the MTA (MTA, MTA2). Union contracts also prevent the MTA from contracting operators, differing from the process in Boston and Washington, D.C. (MTA2)

Shutdowns often involve other staff as well, with transit ambassadors or customer service agents available at stations to help move operations along smoothly. This might consist of bus operations workers stationed at each stop telling shuttles when to depart and counting how

many passengers get on each bus or might be more customer-facing representatives walking around stops to answer customer questions and clarify routes. WMATA has a separate contract for customer service, with these workers primarily responsible for shuttle data collection. These contractors are also joined by a WMATA supervisor at each station, who is available for any necessary troubleshooting (WMATA).

Communicating Shuttle Services to the Public

When planning for a shutdown, service planners must ensure that the public is aware of upcoming disruption plans. This often means running alternative service plans by leadership, public officials, and local representatives. In Boston, BTD holds biweekly meetings with the Office of Neighborhood Services to discuss shuttle plans and other changes to the road to discuss unforeseen impacts, especially those which may fall on disadvantaged communities (BTD). The MTA notifies elected officials and community boards of proposed changes several months in advance of the shutdown's start. Community boards do not have veto power in this process, but are involved for information and feedback, which the MTA usually takes into account and accordingly makes adjustments. After all, the goal of these plans is to provide a service that the public will like and use (MTA2).

Messaging during diversions can help quell frustrations of transit riders whose routines have been disrupted. Juwhan Lee of WMATA noted that customer satisfaction is a main goal of service planning, and Alexander Anhwere-James of the MBTA further detailed this commitment by explaining "we really put ourselves in the mind of the customer and think 'how are you experiencing this and how can we navigate'" (WMATA, MBTA). Much of transit agency's communications efforts involve coordination with their Customer Experience teams, who manage signage and digital communications (MBTA, MBTA2, MTA). To determine what types of signage and instructions will be needed, service planners will go on site walks with the Customer Experience team and sometimes representatives from Systemwide Accessibility,

noting any potential areas of confusion or difficulty (MBTA). For flyers and signage, a service planner collects the relevant information and puts together a bus detour map detailing the shuttle routes and service changes and then passes this information to customer experience. Customer experience then works on public-facing language and design to best relay this information to customers (MBTA2, MTA2). Information is translated to multiple languages, specifically focusing on languages spoken in nearby neighborhoods. Fliers are typically dispersed in stations, on the way to stations, and distributed electronically as well. Automated announcements in trains can be difficult to change, and shuttles typically are not equipped to have automated announcements. Therefore, train conductors may have to make special announcements to inform passengers of limited service, and shuttle operators will typically read announcements and upcoming stops from a script provided by service planning (MBTA2).

After service planning drafts the information and customer experience revises it for public comprehension, it is typically a third team, like the MBTA's Transit Facilities team, who does the actual printing, installation, and maintenance of signage (MBTA). For larger shutdowns, WMATA may decide to contract out the messaging and signage work, in which case a service planner would still relay necessary information and locations for messaging, but the contractor would do the design, printing, and installation (WMATA). The MBTA similarly contracts service for station support, with Transit Ambassadors wearing red shirts with the MBTA logo to clearly signify they are available to provide information as needed (MBTA). Signage installation typically occurs the night before the shutdown (for any specific directional, station signage, rather than general information signage like fliers or website information which would go up further in advance), requiring employee availability from the signage teams the night before the shutdown (WMATA).

Transit riders typically find out about changes through the transit agency's website, newsletters, navigation platforms like the TransitApp, fliers, and through customer ambassadors stationed at shuttle stops for assistance (DCP, MTA2). It is also common for transit agencies to work closely

with their Government Relations teams, especially for bigger shutdowns. These teams can help interface with the public, as well as with business districts and other parties impacted by the shutdown. The goal is to get this information across clearly and well in advance, so no one feels blindsided (WMATA). However, communicating changes to the public also relies on the assumption that people read or listen to the information that is provided. Even if passengers are aware of the changes, emphasizing that routes will take extra time, and to prepare accordingly, can be a challenge. The MBTA has started to provide estimated route times along with their messaging and press releases to set expectations about journey times (MBTA). The proactive sharing of this information is an attempt to prepare passengers and reduce frustration.

Performance Evaluation and Post-Shutdown

Live Adjustments and Assessments

While much of the work involved in planning for a shutdown and coordinating alternative service is done weeks or months in advance, there is a significant number of live adjustments and collaboration involved, as well as post-shutdown evaluation and lessons learned for future shutdowns. Buckley Yung of New York City's MTA noted that short, straightforward shutdowns typically encounter few issues, but the more complex a shutdown is, the more careful and thorough planners must be about implementation, and the more the public wants to be involved in evaluation and discourse around the implementations (MTA2). The MBTA's contracted operations team, consisting of four full time staff, is in charge of monitoring diversion success and responding to any issues that arise. It is contracted operations' job to assess whether the distribution of shuttles need to be reassigned across multiple routes (i.e. express or local), replace and monitor sign accuracy, and communicate with operators about any other changes that need to be made (MBTA2). Often, transit agencies will hear about customer complaints or confusion through transit ambassadors stationed at stops, or through social media or the customer service portal (MBTA). They aim to address these as quickly as possible, especially if

the issue pertains to safety or transit efficiency. Most agencies will have a group chat hosted on a communication platform like Microsoft Teams with all the relevant stakeholders in planning for and executing shutdowns. They can then send any updates, necessary changes, or lessons learned to this chat to delegate work and document the process for next time (MBTA). In Washington, D.C., rovers drive along the shuttle routes to supervise and provide assistance as needed, conveying any issues to the daily briefings held twice a day for internal WMATA shutdown coordination (WMATA). Juwhan Lee of WMATA noted that daily briefings and documentation of shutdowns is much more difficult when multiple shutdowns are happening at the same time, as staff time and resources are spread thin (WMATA).

The MBTA's Systemwide Accessibility team performs shuttle audits during shutdowns, an extra check during the process to ensure accessibility is consistently upheld under alternative service (MBTA2). The audit team will perform covert audits, riding shuttle buses to observe accessibility functions, and also performing less covert checks like ensuring ramps and lifts are working, and that operators properly secure wheelchairs (MBTA). The Contracted Operations team also has the authority to inspect shuttles as they make their rounds during shutdowns, testing accessibility features and announcement systems. Any non-compliance will be noted, and operators driving noncompliant vehicles are questioned about whether they tested features before taking the bus out of the yard that morning (MBTA2). This level of continued inspection emphasizes the MBTA's commitment to maintaining standards for accessibility, even when running alternative service.

Performance Evaluation

During shutdowns, data is collected to record shuttle efficiency and document other aspects of the shutdown. This data can be used to help improve planning for future shutdowns, as well as justify the need for certain implementations that can help shuttle efficiency and overall satisfaction with the provided alternative service. Service and operation planners will use

collected ridership data to conduct ridership analyses on shuttles, reporting findings during shutdown post-mortems, where the involved teams review the details of the shutdown, its efficiency, and its overall success (WMATA). WMATA's Bus Priority team assist with performance evaluation, collecting data on shuttle speed increases when using pop-up bus lanes, as well as ridership change and throughput. This type of data can be useful for justifying future use of implementations like bus lanes, both to service planners as well as the public (WMATA3). The MTA's post-mortem always includes discussions of what worked well, along with the biggest public complaints, to see how those might be quelled for the next shutdown (MTA). Service planning keeps well-documented notes from any post-mortem or evaluation meetings, so that they are able to reference these when planning for future shutdowns (MBTA). Executing a shutdown exactly as planned is unlikely due to the number of moving pieces and parties with which to collaborate, but a sound plan will make bumps in the road far smoother. WMATA's Juwhan Lee reflected this sentiment, explaining:

> *"What you plan and what happens - they're never the same, but as long as you can get them close…" (WMATA).*

Additional Forms of Alternative Service and Mitigation Strategies

Although shuttle buses are the standard for transit disruption service planning in most cities, planning for disruptions in Boston, Washington D.C., and New York City also includes other planned services and mitigation strategies that must be mentioned.

Diversion to Existing Service

The most notable strategy to discuss, as it differs largely from the processes in Boston and Washington, D.C., is New York City's ability to divert ridership to parallel tracks and lines. The New York City subway has three or four tracks in most locations, a feature that allows multiple trains to pass through the same station. Often, this will look like local tracks and express tracks

running right next to each other. Similarly, in denser areas of Manhattan, it is easy to walk a block to another line and find a similar route that adds little additional travel time. Boston and Washington, D.C. have sparser rail networks, and few locations have multiple tracks, meaning that maintenance and construction on tracks forces a shutdown, and necessitates alternative service.

The MTA's diversion planning process, therefore, differs from that of the MBTA and WMATA. The MTA's first step is determining the severity of maintenance or construction work that needs to be done, and whether service on that track can still run, or if the entire track needs to be shut down. This will help determine whether planning will involve shuttling at all, or if traffic can mainly be diverted to other tracks and lines (MTA). The MTA aims to schedule most track work for overnights and weekends, when thinned service is more feasible than during the week when service needs to accommodate weekday rush hour (MTA). However, track work being done with continuing service comes with additional planning steps. For example, when tracks are being replaced, the process spans two weekends with resulting slow zones for weekday service, even if all tracks are running. This results from tracks being skeletonized the first weekend (concrete removed), and new concrete poured the second weekend, meaning that slower service must run during the week when tracks are skeletonized (MTA). The MTA also must generally be careful not to schedule track maintenance on parallel lines, as they want to ensure passengers have a feasible alternative should they be looking for a substitute for a reduced service route (MTA). Lastly, sometimes diverting traffic to service on other tracks means asking passengers who would typically elect local routes to take express routes. This means that some passengers will have to back ride; in other words, the express will take them past their destination, and they will need to ride back in the opposite direction to reach their destination, all of which still allows them to get to their final destination using the subway, just adding time to their journey (MTA). When service planners assess track work, they aim to ensure that passengers never have to back ride more than once in their journey to/from the Central Business District (Midtown and lower

Manhattan), as tracks are often undergoing maintenance in various parts of the subway network at once (MTA). Coordination and detail-oriented scheduling of this work, as a result, is key.

Other transit agencies are aware of the possibility that riders may self-divert from shuttle routes to other existing transit routes, sometimes even encouraging these behaviors (MBTA2). As shuttle buses are constrained for capacity and congestion, the more people who self-divert, the less shuttle buses may encounter overcrowding issues. A second benefit of self-diversion is the familiarity it can build for local residents' understanding of the overall transit network in their city. Navigating alternative routes provides individuals with the experience and information to take an alternative route in the future, or to opt for a transit route rather than driving a personal vehicle (MBTA2). For example, shutdowns may encourage transit riders to try the commuter rail, bus, or even ferry as an alternative, even if they have never tried these modes before (MBTA2). The MBTA has encouraged self-diversion for shutdowns where existing service made sense as an alternative, like during shutdowns of segments of the Orange Line that are parallel to the Green Line. While shuttles are still made available, the MBTA recognizes that taking the Green Line instead will be a faster journey and encourages this switch, but note that many riders are set in their transportation habits and take the shuttle rather than learning a new route (MBTA). Sometimes, encouraged diversion is effective. One way that diversion is often encouraged is by making the suggested alternative service fare free, similar to the lack of payment for shuttles during shutdowns (MBTA). During another Orange Line shutdown, the Haverhill line of the commuter rail was made fare free, and many commuters found this to be a more convenient, and faster way to commute (MBTA). The MBTA even saw an increase in ridership on the Haverhill line post-shutdown, meaning that new riders liked the route enough to continue taking it even once fares were reinstated (MBTA).

Sometimes, service planners will make the decision to increase service on a transit line that may be absorbing ridership from a shutdown, like increasing Orange Line service during Green Line

shutdowns (MBTA2). The MTA noted running more frequent service on some subway lines when others are shut down to ease crowding, like increasing service on the 1 train when the A train is down (MTA). Charley Dingboom of WMATA noted that this type of service increase, and even the decision to advertise existing service for self-diversion, is dependent on the resources and staffing available to support increased ridership (WMATA2). Prior to promoting a bus route as an alternative to a subway line under maintenance, service planners would assess whether the peak bus load occurs in close proximity to the segment of the route that could be an alternative for the closed subway line. If the peak load is within this range, they would not promote this line as an alternative without increasing service, which could be a challenge in terms of bus and operator availability (WMATA2). Similarly, if advertising another route as an alternative, planners must think about the impact to the regular riders of that route. If their route is suddenly packed and less efficient than before, this may not be a benefit to the overall transportation system (WMATA2). Without advertising of alternative routes, Dingboom shared that only the more experienced transit riders who know the network well would elect an alternative route, making ridership impacts more manageable (WMATA2).

Sometimes, transit agencies will collaborate with other transportation agencies in the area that might be able to assist with diverted passengers. As New York City and Washington, D.C. are both adjacent to other cities and states, there are other transit agencies or sub-department operating nearby that they have collaborated with in the past during shutdowns. For example, MTA service planners work with the MTA's Long Island Railroad and Metro North Railroad planners, promoting these lines as alternatives if a subway outage parallel to these lines is upcoming (MTA). The MTA has also coordinated with New York City's ferry service, sponsored by the New York City Economic Development Corporation, as the ferry may be a fast and effective, yet unknown alternative service to many New York commuters (MTA). In Washington, D.C., WMATA transit service runs past the D.C. borders, into Maryland and Virginia. WMATA can make use of overlaps; for example, the bus service planning team coordinated with

Montgomery County bus service during shutdowns, as the separate bus service might be a useful alternative to some passengers, even though operated by a separate agency (WMATA2). Even if not an advertised alternatIve, communicating with other bus providers to let them know of a potential increase in ridership is an important part of maintaining an efficient and capable transportation network (WMATA2).

Active Transportation

Passengers choosing to forego provided shuttles may instead choose a form of active transportation for their route, though most transit agencies are not involved in promoting active transportation as an alternative. Lack of active transportation promotion is mainly due to organizational separation and bandwidth. In other words, service planners have limited time and resources to promote alternative forms of transportation and can most easily advertise and adjust services operated by their agency. Active transportation is its own being, with the vehicles being individuals themselves, personal bicycles or scooters, or bikeshare/shared micromobility. The former examples are individually owned, and the later, bikeshare and shared micromobility, are typically operated and owned by private companies, often collaboratively housed within the city or local Department of Transportation's planning office. While transit agencies do not directly work on active transportation measures for shutdowns, they are also aware of impacts to bikers and pedestrians. Service planners aim to minimize shutdown-related pedestrian impacts as much as possible, providing alternatives wherever construction or shuttle routes obstruct sidewalks or pathways (BTD, MTA2). In New York City, shutdown planning relies on the city's walkability, often understanding that passengers will easily be able to walk a block to another subway line, or to make a walking transfer where they might otherwise make a transfer on a subway line (MTA, DCP).

In Boston, New York City, and Washington, D.C., the city's bikeshare programs run discount codes during major shutdowns to promote bikeshare as another possible alternative

transportation option customers can select (NYCDOT, BTD, DDOT). However, these codes and bikeshare promotion is typically completely separate from the transit agency's work around shutdowns. In Boston's case, the MBTA coordinates with BTD's Diversions Coordinator on shutdowns, and the BTD Diversions Coordinator then interfaces with the BlueBikes team, also housed within BTD. The BlueBikes team then creates the code to be used for MBTA shutdowns, even though BlueBikes and the MBTA are separate entities that do not directly interface (BTD, MBTA). Funding for BlueBike codes comes from the City of Boston, so these initiatives are separate from shutdown project budgets, and are part of the city's goal to maintain a healthy and efficient transportation network during transit outages (BTD). Additionally, discount codes can be beneficial for the overall program, as an uptick of new members often occur during shutdowns, with a rise in users maintained even following shutdowns (BTD). Because of Boston Transportation Department's role in diversion planning, as well as their partnership with BlueBikes, bikeshare is well-integrated into the city's approach to diversions. Not only do they provide bikeshare codes, but they also integrate these bikeshare codes into flyering and messaging around the diversion that the city conducts. Bikeshare codes are included in materials distributed in local neighborhoods and passed around to local businesses, and specific 'bike cards' are produced by BTD including the BlueBike codes and suggested bike routes for shutdowns (BTD). Amanda Caparoso, Boston Transportation Department's Diversions Coordinator, elaborated on the goal of BlueBikes partnership during diversions, explaining:

> *"We communicate closely with our Bluebikes team here. In 2024 we emphasized providing free BlueBike discount codes to really try to shift people out of their cars and using alternate transportation modes, especially during diversion, because we want to minimize traffic impacts as much as possible." (BTD)*

Washington, D.C., a city with the second largest bikeshare program in the United States, also adds dockless, shared micromobility to the available options for customers during transit

shutdowns (DDOT). Dockless or shared micromobility refers to electric scooters or bikes that re available for rides at a cost, but do not require initiation or return to a set dock, as most bikeshare systems do. Free from being tethered to prescribed areas, this model allows dockless devices to populate in origins and destinations of high demand (DDOT). While shared micromobility is typically owned by private companies (Lyft or Lime, for example), and in The District, the dockless program is managed by DDOT's micromobility team, the model's ability to respond and adapt to customer demand allows dockless shared micromobility to become a good option for transit shutdown alternatives. DDOT's shared micromobility planners do not interface with WMATA on plans around shutdowns, nor do they create their own plans for adjusting shared micromobility fleets and availability to better serve needs during shutdowns (DDOT). As previously mentioned, WMATA does not currently have the time, resources, or authority to adjust dockless or bikeshare availability, and DDOT understands the dockless service's tendency to fill needs as they come due to their lack of tethering to one location (WMATA, DDOT). While a partnership for planning micromobility usage during shutdowns does not currently exist, DDOT Shared Micromobility does plan for other special events that could disrupt or impact typical transportation patterns. For example, Shared Micromobility works to organize extra parking for dockless devices outside stadiums during sports seasons, in an attempt to discourage car use and promote alternative options (DDOT). Similarly, during the 2025 Presidential Inauguration, many transit stops and bikeshare stations were impacted or temporarily closed. DDOT Shared Micromobility recognized this as an opportunity to see what role dockless micromobility could play in filling transportation gaps and meeting any displaced demand (DDOT). A main goal of the Shared Micromobility team is to anticipate negative transportation-related impacts to the community and mitigate them, providing alternative options when needed. Similarly, the DDOT Shared Micromobility team sees dockless services as a way to get people out of cars and into active commutes, with the intention of decongesting streets, improving air quality, and even public health (DDOT).

Washington, D.C., similar to both Boston and New York City, has robust bike infrastructure, making active transportation a safe and viable option (DDOT). However, the existence of bike infrastructure may contribute to less intentional planning for active transportation during shutdowns, as it can be assumed that the infrastructure is there for anyone who wants to use it. For example, in New York City, some shutdown plans receive public requests for active transportation options, but the general discourse remains that bike lanes already exist on most streets in the area (NYCDOT). Boston has begun to take initiative to improve the experience for active transportation users during shutdowns, recognizing that shuttling can impact bike routes, and publicity around active transportation may encourage more willingness to mode shift (BTD). Apart from bikeshare promotion, BTD and the MBTA have worked on a number of initiatives to encourage active transportation and specifically biking. While BTD mainly leads active transportation initiatives during diversions, the MBTA has also played a role by increasing messaging and information on Pedal and Park locations (bike storage at transit stops) and noted a large increase in pedal and park usage in the southwest corridor during an Orange Line shutdown (MBTA2). Similarly, the MBTA collaborates with BTD on creating a map for suggested bike and pedestrian pathways during shutdowns. The map is a collaboration between the MBTA, BTD, and the various transportation advocacy groups BTD works with for diversion planning, including Bikes not Bombs, Boston Cyclists Union, TransitMatters, and WalkMassachusetts (BTD). After receiving shuttle routes from the MBTA, BTD and transit advocates develop an alternative bike route, fulfilling the role of getting bikers into downtown for a commute, but avoiding shuttles for a more pleasant path of travel (BTD). BTD's Diversions Coordinator, Amanda Caporoso, describes this process as follows:

> *"We provide an alternate route for biking because bikes can be impacted and it's not the most pleasant ride to ride next to a shuttle… and sometimes the Boston cyclist's union, all the volunteers will bike to work riding along our planned route."*

As mentioned above, bike advocates will go a step further than just planning the route, organizing 'bike buses or group bike rides following the planned route, to encourage others to do the same (BTD, MBTA). Planned initiatives to encourage active transportation during shutdowns, whether by using bikeshare, micromobility, or personal bikes, is a way to go beyond simply providing the infrastructure for active transportation to be an alternative during shutdowns. If transit riders are forced to find another way around during a shutdown, encouragement, discount codes, and increased messaging around active transportation may well help people make the temporary, or even permanent, switch to using active transportation.

Roadway Modifications

Shuttles, the standard diversion practice, rely on roadways to provide service to customers. As discussed in the *Route Implementations* section, service planners have adopted a toolkit of potential modifications to roadways they can implement to improve service. This section discusses creative strategies developed to augment alternative services during shutdowns, providing specific cases as examples.

Pop-up bus lanes are a leading strategy for boosting shuttle efficiency and were discussed by planners in all three cities examined in this study. To plan pop-up bus lanes, service planners ask city or DOT counterparts to assess bus lane feasibility for the shuttle route. In some areas with high levels of congestion, bus lanes can be highly effective. However, in less trafficked areas, bus lanes may not be worth the laborious installation procedure, requiring crews to put up cones, paint, flex posts, or other configurations to identify the lane as bus-only. To make these determinations, planners assess traffic patterns, analyzing current speeds and studying whether traffic impacts would be proportional with the benefits to the shuttles (WMATA3). The right-of-way (ROW) also needs to be closely examined for bus lane implementation. Many locations in Boston are unsuitable for bus lanes, where the ROW is so narrow that an additional foot of width

required to place cones delineating a bus lane would not leave enough space for the parallel travel lanes (MBTA).

WMATA's Bus Priority team is fairly selective about the shutdowns they work on, due to the level of work involved in planning for them. To date, the team has worked on bus priority lanes for three different shutdowns. Bus lanes are most easily implemented in areas that would already benefit from bus priority lanes, even without shuttle traffic. Pop-up bus lanes can then be used as a test period for potential permanent implementation of a bus lane, with the Bus Priority team analyzing the impacts of the bus lane on the rest of the transportation network (WMATA3).

Pop-up bus lanes also require coordination with the local jurisdiction, who has to complete permit applications and review, and often is in charge of signage changes and enforcement of the bus lanes. Juwhan Lee illustrates one challenge crucial to consider of pop-up bus lanes, saying "Bus lanes exist... whether people follow it, that's a different story" (WMATA). Lee refers to the fact that bus lanes can be ignored by drivers and rendered ineffective, especially in the case of an existing bus lane that has had its hours extended for a shutdown. In these cases, many regular travelers will follow their typical travel patterns in the bus lane without knowledge that the bus lane hours have been extended (WMATA, MBTA). Protected bus lanes are one way to avoid the need for constant enforcement of driving and parking in bus lanes (MBTA). Signage, while helpful for informing drivers of new changes, is often ignored, torn down, or made otherwise illegible. Where signage is ineffective, enforcement officers are often stationed to replace signage as needed and to regularly patrol, ensuring the shuttle implementations can be used as intended (WMATA).

In many cities, bus lanes can also be a contentious subject to broach with the public due to the perceived negative impacts on traffic, leading to temporary bus lanes either being a way to compromise with the public, or to demonstrate the potential benefits of bus lanes. Th cases below demonstrate the interplay between public perception and bus lane implementation.

⇒ For a shutdown occurring on the Dekalb/Lafayette Avenue corridor in Brooklyn, NYCDOT planned and implemented two temporary bus lanes to move shuttle buses along. Acknowledging that the public deserved more extensive outreach, NYCDOT made it clear that the bus lanes would only be in place for the duration of the shutdown. However, NYCDOT was able to collect data from the temporary installation that they are using to plan permanent bus priority on the corridor.

⇒ In preparation for the L Train shutdown, NYCDOT assisted with various mitigation strategies that would help the efficiency of such a large shuttling project. Though the full shutdown was cancelled, plans for bus priority on 14th Street evolved into New York City's first permanent busway, and one of the most successful bus priority implementations in the city (NYCDOT).

⇒ A pop-up bus lane on Georgia Avenue in Montgomery County was made permanent following its success during D.C.'s Red Line closure (WMATA2, WMATA3).

Signal Modifications are another common implementation used to boost shuttle success during times of diversion. As mentioned in the *Route Implementations* section, service planners inquire with local jurisdictions (city or DOT departments) whether any signals could be modified to help move shuttles along. Signal modifications can benefit shuttle routes by prioritizing buses, extending green lights in bottlenecked areas, or even allowing manual light changes in high congestion intersections (MBTA2, WMATA). A complication to this strategy is that signals are planned in accordance with surrounding signals, so modifying one signal can impact regular vehicular traffic and consecutive intersections (BTD, MBTA2). Signal modifications can also require intensive signal analyses necessitating time and advanced planning from DOT or city partners (MTA2).

Sometimes, unique roadway modifications and shuttling strategies are necessary to address local challenges. For example, Boston service planners deal with extremely constricted

roadways, few options for diversion to existing service, and the threat that shuttle buses will worsen existing high levels of traffic. John Savino, MBTA's Director of Contracted Bus Operations, notes Boston's unique struggle:

> *"We're all competing at not a lot of access points to get into the core and trying to transport people through. That's what makes Boston different. It's the oldest city, and there's not much planning for trains or buses to traverse the streets in the 1800s or 1600s."*

Several unique, tailored strategies for making alternative service during shutdowns more efficient are discussed in the cases below, many of which occurred in Boston.

⇒ Due to bottlenecks leading in and out of Boston's downtown core, the MBTA decided to forego shuttling the core, in an attempt to reduce negative impacts to the surrounding community. The BTD team suggested this approach, suggesting streets that would be easier to shuttle down. In this approach, shuttling does not serve Park Street, as past shuttling of this station led to extensive congestion. Due to the small size of Boston's downtown and the higher rail line density in the core, passengers can either walk to connections (making use of the Downtown Crossing – Park Street concourse) or take an alternative subway line that is not shutdown. As shown in Figure 2, Red Line shuttles serve the Haymarket Green Line station and the State Street Blue Line station instead of Park Street, resuming the normal Red Line shuttling route at Downtown Crossing.

This creative strategy, while sometimes confusing to passengers, provides the unique benefit of a Red-Blue Line connection, which does not exist otherwise in the MBTA system. MBTA's Alexander Anhwere-James speaks to this balance, explaining:

> *"But there are also benefits too. So in that same example, we serve State Street, which you know - red and blue never connect with each other. And I will never forget the complaint that we got saying 'Why didn't you tell us?'"*

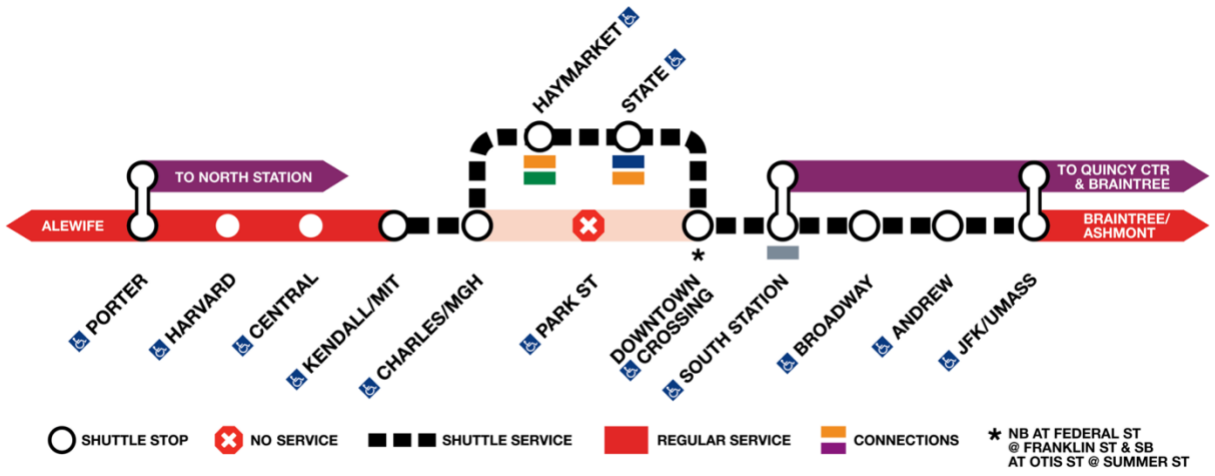

Figure 1: Depiction of shuttle routing to avoid the downtown core in Boston. Source: MBTA

⇒ During an MBTA Red Line Braintree branch shutdown, service planners decided to bus Braintree passengers to Ashmont rather than shuttling from North Quincy to JFK/UMass (Figure 3). While JFK/UMass is the next stop on the Braintree branch, the journey time during peak hours on the shuttle would have taken far longer than bussing to the nearby Ashmont station and sending passengers on the subway from there (MBTA2).

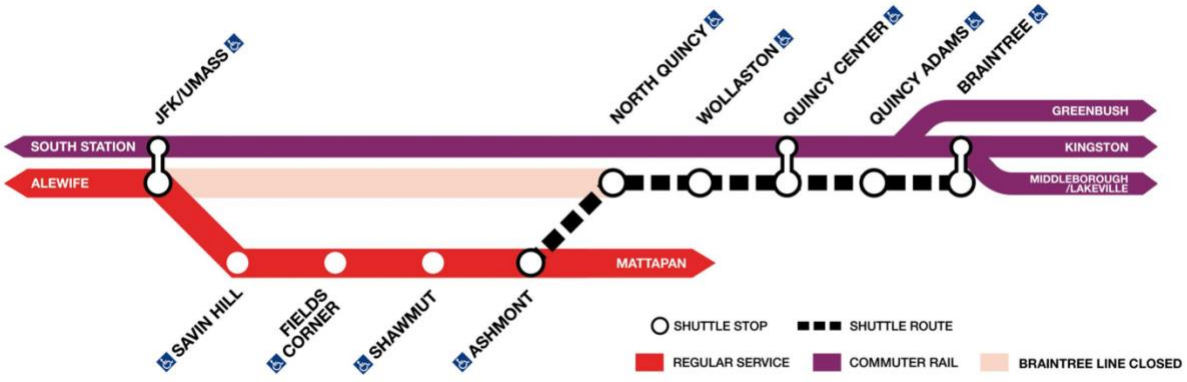

Figure 2: Depiction of shuttle routing bussing riders to the Ashmont branch. Source: MBTA

⇒ Though an Orange Line shutdown was originally planned to span from North Station to Wellington, the MBTA extended the closed segment to Oak Grove. The reasoning

behind this extension was that Oak Grove (the end of the Orange Line) is only two stations from Wellington, so passengers starting from Oak Grove would be forced into a two or even three-seat ride in the original shutdown plan. Similarly, the Oak Grove station is built with a higher parking capacity than Wellington due to its status as a terminal station, making Oak Grove a more suitable initiation point for shuttling (MBTA2). Lastly, the extended shutdown opened an opportunity for additional maintenance work to be completed on the additional segment of track, all during the same shutdown (MBTA).

⇒ During an outage on the Lowell Line of the MBTA Commuter Rail, service planners got creative with frequency adjustments to make up for the fact that shuttles would never be able to accommodate the capacity of a commuter rail. Typically, the Lowell Line runs every two hours, which would require a significant bus fleet running consecutively to mirror service of the train. Instead, service planners decided to reduce the bus count but run more frequent service – every hour rather than every two. By increasing options but decreasing bus count, the MBTA was able to manage costs, while maintaining a good customer experience, as additional options for their commute was a benefit for many passengers (MBTA).

⇒ The MBTA identified a partnership with the Postmaster General that could help boost shuttle efficiency through shuttle use of the Post Office Road. While the roadway is typically reserved only for Postal Services, the MBTA worked on an agreement with the Postmaster General to use the road as a route to mitigate congestion (MBTA). As Postal Service is typically heaviest in the morning and early afternoon, shuttles only use the route during the PM peak, leading to route time decreases of five minutes in each direction. When using this road, a dispatcher will assign operators to use either the standard route or to turn down the Post Office Road as needed, dispersing shuttle-related congestion. The MBTA recognizes the politics involved in this type of partnership and is sensitive to the possibility of needing to pull shuttles off the Post Office Road if

posing too much of a disruption to Postal Service. However, identifying potential partnerships like these that may provide opportunity for increased efficiency is a crucial aspect in alternative service planning, and affords service planners with high reward for creativity (MBTA).

⇒ Prior to a shutdown on Manhattan Avenue in Brooklyn, service planners were concerned about overall traffic volume and corresponding impacts on shuttle route times. NYCDOT was able to assess the corridor and implement strategic turn restrictions, where specific turns were banned for regular vehicles, and only buses were permitted. Other areas of the corridor would instruct non-bus traffic to turn off the corridor, leaving the following stretch bus-only. This allowed shuttles, along with regular bus service, to get through a typically high-congestion area quickly (NYCDOT).

While pop-up bus lanes and signal modifications are fairly standard items in service planners' toolkits for increasing shuttle route efficiency, planners have begun to get creative with other implementations that can benefit both alternative service efficiency, and passenger satisfaction. These opportunities begin to suggest potential for growth and optimization in the future of diversion planning.

Chapter 5 – Discussion

Based on existing diversion and alternative service provision planning processes, this discussion will point out opportunities for improvement partially based on identified barriers in the process. The section integrates themes from findings by comparing challenges and intended outcomes. Ultimately, this discussion asserts a potential relationship between the strength of having a defined collaborative process for diversion planning and cultivating opportunities for encouraging various transit modes and street implementations during diversions. Each barrier in this section is tied to a potential opportunity for improvement, drawing out central themes of collaborative structure and creating windows of opportunity for implementing positive change.

Technology, Modeling, and Analysis

Many stakeholders spoke to the complexity of planning for transit diversions, specifically pointing out the need for more technical tools that could help ease the process. Technical tools may refer to organizational and scheduling software, modeling, or adapting current technical uses to better fit shuttling structure. Transit agencies typically use scheduling and asset management software for their regular services. For example, WMATA recently switched from using a software called Trapeze to a software called HASTUS. Within these programs, WMATA stores digital data of their assets, routes, and schedules. While there are optional HASTUS packages that may make temporary changes easier, the base software package is not designed for the fast-moving and sometimes unpredictable disruption planning process (WMATA2). Multiple planners specifically desired a software designed for planning diversions or temporary transit changes (MTA, WMATA2). Organizing assets involved in the process, many of which have differing ownership, would be a large benefit to planners, who note it can be hard to keep track of all of the moving pieces in diversions and ensure nothing slips through the cracks. WMATA noted using Remix for route planning and scheduling in small batches (groups of 2-3 routes), which has been useful for planning shuttle routes especially if detached from the rest of the transit system (WMATA2). This platform is limited and gets more challenging as more routes are added but could be a good model to serve as a basis for diversion planning software that could be used to interface with contractors and various planning partners. A transportation planner in New York City reiterated that digital tools would be useful for checking for all trackwork needing to be done on a specific segment, aiding in the piggybacking process and avoiding repeat shutdowns as much as possible (DCP). Thus, a diversion-based software could help streamline data and crucial information to all partners, allowing for decreased shutdown redundancy and increased opportunities for overlap and consecutive work. This barrier ties directly to the development of technology providing structure, boosting efficiency and streamlining processes for overlapping work and cost-cutting.

Another technological-related constraint is the lack of modeling capabilities for overall mode-shift during disruptions as well as shuttle ridership. While some transit agencies, like MTA, have dedicated modeling teams, other agencies, like the MBTA, more frequently complete manual comparisons of predictions and reality to fill this gap (MBTA). While comparing field data and expectations helps service planners improve their predictions over time, a lack of more advanced modeling technology is a recognized barrier to continuing to improve the understanding of public behavior during shutdowns.

More advanced modeling capabilities was also noted as a way for planners to compare various routes, as well as better predict required fleet sizes and runtimes (WMATA, MBTA). While planners have current processes for estimating fleet sizes and runtimes, advanced models would speed up the process and increase accuracy. This is another opportunity to streamline processes with more advanced analytical capabilities, with increased prediction accuracy leading to reduced congestion and smaller project budgets. Modeling specifically could help save money by providing justification for reducing shuttle counts if modeling showed low passenger loads. Multiple planners spoke to this idea of modeled data being used as justification for various requested changes. Modeling runtimes with and without a bus lane could similarly boost the tolerability of temporary bus lanes if modeled data showed minimal impacts to standard traffic (MBTA, WMATA2, WMATA3). To increase modeling capacity, transit agencies should look to other agencies with specified modeling teams (like the MTA, for example). Another required step will be dedicating resources to improved data collection. As modeling requires a basis for building off of, data deficiencies around pedestrian patterns and personal bike usage limit modeling accuracy. Investigating partnerships with journey mapping applications may be an area of opportunity for increasing data in these fields, along with committing staff time and funding towards manual counts not only for shuttle ridership but also bike and pedestrian patterns during shutdowns. As maintenance requirements persist and

shutdowns continue, improving efficiency and minimizing costs may rely on updating technology used in these practices, and focusing on a comprehensive range of data sources.

Active Transportation

Active transportation remains a relatively untouched form of alternative service for shutdowns, with the exception of bikeshare discount codes being fairly common. With benefits to active transportation use as a substitute to vehicle use like reduced CO2 emissions, integration of active transportation into diversion plans works towards building a more sustainable transportation system (DCP). Bikeshare program ownership is a recognized barrier to full integration into diversion strategies, though Boston's structure has shown that housing the bikeshare team within the same department as a diversion coordinator or planner may make this partnership more plausible.

In Boston, we see incorporation of active transportation into service plans through alternative, suggested bike routes developed during shuttling, which advocates encourage the use of by leading commute bike-buses. Bike infrastructure is also part of the planning process conversation, noting that flex posts and other bike-centric infrastructure removal for shuttles may have larger impacts on active transportation safety and popularity (BTD). While New York City and Washington, D.C. did not discuss similar strategies for encouraging personal bike usage during shutdowns, both cities are equipped with ample bike infrastructure and largely successful bikeshare programs. Washington, D.C., also benefits from shared micromobility presence, widening the pool of non-fuel powered vehicle options to use during shutdowns (DDOT). A DDOT Shared Micromobility planner suggested that other cities looking to grow shared micromobility presence, and overall active transportation usage, should try to get ownership of micromobility programs to increase partnership opportunities with transit agencies (DDOT). Thus, bikeshare and micromobility program ownership is an immediate goal that municipalities can work towards when aiming to increase their sustainable transportation efforts, as well as

improve accessibility and availability of additional transportation options during transit shutdowns.

Overall, each city has the potential to increase active transportation usage during shutdowns, whether by initiating new programs and partnerships, increasing advertising and advocacy for active transportation, or by folding in active transportation infrastructure conversations into the planning process. A throughline here is that active transportation integration relies on partnership and collaboration, as this work is typically not spearheaded by transit agencies, but rather by jurisdictional partners and even advocates.

Collaboration and Partnership

As detailed in the *Stakeholders* section, diversion planning requires collaboration between numerous teams, jurisdictions, agencies, and representatives. These processes not only require multi-party collaboration, but they also rely on frequent and clear communication. Multiple planners referred to the many collaborative intricacies of the process, the goal of ensuring nothing slips through the cracks described as “a complex puzzle” by Juwhan Lee (WMATA, BTD). Frequent meetings during diversions are a common practice. Daily meetings keep planners on track and provide space for those involved in the project to provide updates, relay public commentary, or to workshop adjustments. Clearly, collaboration takes up lots of time, and it can be difficult to stay on top of all of the moving pieces. However, without a high level of collaboration, the process would be disconnected and lead to less efficient routes, higher costs, and a dissatisfied public. The following cases provide clear examples of the necessity of collaboration and partnership in the diversion planning process.

Case 1: WMATA Bus Service Coordination

⇒ Adding shuttles to the road means additional vehicles that create congestion on roadways and at bus stops – making coordination with standard bus service paramount. Standard service may experience longer run times due to shuttle bus congestion or

regular bus stops being blocked, so service planners make sure to analyze impacts to regular service when planning shuttle routes. In Washington, D.C., shuttles are typically assigned to the bus bay closest to the rail station entrance to ease passenger confusion as they transfer from the subway to a shuttle bus. However, this means that buses that normally use these central bus bays must be reassigned to other bays. Bus bay reassignment requires the Bus Service Planning and Scheduling team to work on bus bay reassignment, including creating a messaging plan to inform riders of these changes and monitor for any confusion (WMATA2).

Case 2: Curating Parking Removal by Business Type

⇒ Public and business relations can require a high level of coordination, as diversion planners aim to create a plan with as few impacts to local communities as possible. BTD carefully assesses which businesses might be impacted by their diversion plans, especially when parking is to be removed in front of a business. BTD has developed a step in the planning process where the diversions coordinator considers businesses impacted by added shuttle stops. When a shuttle stop is added along a route, the diversions coordinator looks for areas to remove parking from that are in front of quick-stop businesses (such as a takeout pizza restaurant) rather than a business associated with longer parking times (such as a hair salon) (BTD).

As indicated by both of these cases, collaboration can help decrease the impact that shuttling has on the local community and existing services. Another way to reduce this impact is by consolidating rail-related work to the fewest possible periods of time. This concept can also be called ‘piggybacking’. Ideally, if a line is being closed, workers can piggyback multiple maintenance needs during one shutdown, necessitating fewer closures. This allows more work to be done in a shorter time period - leading to less disruption of the public, and often large cost savings. However, if all parties are not informed of line closure schedules, planners may find out after the line is reopened that another party also had work to do in that area, requiring the

planning of another shutdown (DCP). We again find that streamlined processes and enhanced collaboration have potential to lead to cost savings and efficiency, especially in the case of piggybacking. Streamlining processes and coordinating between multiple parties may be easiest done by one point-person or team, who is responsible solely for this work, and has a deep knowledge of the involved parties and guidelines. Using Boston's structure of a diversion coordinator housed within the City of Boston's Department of Transportation, responsible for coordinating with the MBTA and delegating tasks to various city departments, there is a clear indication that such a role may be useful in streamlining diversion planning processes. Especially in the case of piggybacking, a point person can identify potential overlaps due to their enhanced understanding of the process, timelines, and existing budgets. For the clarity of future planning processes, other cities should identify within which agency and department a point-person would be most impactful, and push for funding for a new position supporting diversion process organization, collaboration, and management.

Street Ownership and Infrastructure

Large scale diversions also face the challenge of collaboration with and reliance on approval from various street-infrastructure owners for any street-level implementations. Based on where cities are situated, planners viewed this challenge at varying levels of difficulty. The MBTA mainly deals with right-of-way (ROW) ownership changing by municipality but benefits from being relatively far from state lines. While individual cities in the Greater Boston area own most roadways, MassDOT also has ownership over some segments of roadway, requiring MassDOT permits for any adjustment to those segments. Sullivan Square, a major Orange Line station, is located partially on Boston property, partially on Somerville property, and also partially on state-owned property. Thus, requesting permits for adjustments can be challenging, as Alexander Anhwere-James puts it, "we're playing Guess Who" (MBTA).

New York City and Washington, D.C. both deal with the challenge of being adjacent to municipalities in other states, requiring more external collaboration and jurisdictional relationship management. New York City deals with this issue less for subway work, as its subway system runs only within the city. The city's Department of Transportation, NYCDOT, has management over street-level infrastructure, and has complete domain over changes. The Commissioner of NYCDOT is directly appointed by the mayor, making these relationships political (MTA). In planning for shuttle routes, the MTA has a similar process to the MBTA of requesting permits and changes from the city (NYCDOT) prior to implementing. This challenge is eased because most shutdowns are able to be managed through diversion to other tracks, and NYCDOT is mainly involved for longer shuttle routes planned in the boroughs (NYCDOT).

Jurisdictional and state collaboration becomes a more prominent challenge in Washington, D.C., where WMATA runs service into both Maryland and Virginia. Both states have their own state and county DOTs, with county DOTs owning around 80% of the ROW, and some larger roadways owned and maintained by the state DOT. This quickly results in numerous different partners with which to coordinate for street requests (WMATA2). Not yet mentioned are DDOT, Washington D.C.'s Department of Transportation which manages most of the roadways in The District; the National Parks Service, which holds control of the entire National Mall and Tidal Basin area; and other Federal stakeholders (WMATA). As standard bus service already runs to Maryland and Virginia, Bus Service Planning and Scheduling is aware of which contacts to reach out to for street-level requests, but the challenge is more a concern of various opinions, perspectives, timelines, and resources aligning to the visions of WMATA's service planners (WMATA2). Awareness of the prominent players in requesting permission to alter street infrastructure is a first step to streamlining this process. These findings support the recommendation to designate a point-person in charge of managing collaboration and timelines in diversion planning, where the role relies on the individual's knowledge of relevant contacts in the area and their associated approval processes. This level of streamlining could also simplify

processes by clearly delegating documentation responsibilities, allowing for improved planning for future shutdowns, and increased bandwidth to innovate during shutdown planning processes.

Timelines and Process Clarity

Time limitations emerged as another leading challenge in diversion and alternative service planning. While all cities and transit agencies mentioned timing stress, New York City stood out as having unique timeline challenges resulting from some of their subway system's strengths. First, the New York City subway runs all day every day, meaning that there are no natural breaks during which maintenance or construction could be scheduled without interrupting service (DCP, MTA, NYCDOT). Second, as the city's dense transit network and parallel lines allow most Manhattan-based subway closures to occur without shuttling plans (often relying on diverting service to other tracks and lines), work is typically limited to the weekends and overnights, when slower service will be less impactful. However, this leads to a large challenge noted by the MTA of only 52 weekends in a year, some of which are blocked off from construction work due to holidays or other staffing shortages. This limited number of windows for trackwork makes coordination, scheduling, and sticking to timelines imperative (MTA). Further, this challenge adds to the importance of successful piggybacking, in order to get the most work done in the least possible amount of time.

Last minute requests arose as another time-related challenge, where new information leads to additional requests for the alternative service plan shortly before the shutdown is scheduled to begin, with little time for the jurisdiction or DOT to fulfill requests. For example, service planners may be aware of upcoming construction scheduled to end right before a shutdown begins. Then, the construction schedule may change due to weather, material delivery schedules, or scope changes, leading to late complications with shuttle plans (MTA). Last minute requests from the community often result from later press releases or messaging circulating about the shutdown.

Typically, the city or DOT attempts to make requested last-minute changes but may be unable to fulfil the request due to limited time for requesting permits, receiving approval, and implementing changes all before the shutdown begins (NYCDOT). Many of these timeline-related challenges were stressed by those working in New York City, where large shuttling projects are not as frequent as in Boston and Washington, D.C., and where timelines uniquely revolved around rail-diversion scheduling on weekends. This challenge clarified that more time to plan would help smooth out some of these timeline-related bumps. However, if additional time is not possible, process standardization, with deadlines communicated to each stakeholder, may help avoid stressors of last-minute changes. A kickoff meeting held at the start of the shutdown planning process could be an efficient, and effective way to clue all stakeholders in on intended schedules and relevant deadlines. This could also provide a reference point to refer to when last minute changes are requested and provide clarity around changes that may still be achievable, and which may have missed the window for accommodation.

Staff availability is directly related to timeline challenges in that operators have their own schedules limiting their availability to operate shuttles, and union laws may add to budget constraints and operator availability in certain cities. Some transit agencies deal with existing operator shortages, like Washington D.C., making contracted staff a necessity especially during longer shutdowns requiring WMATA staff at every shuttle stop (WMATA). Shortages can also clash with situations where more operators may be needed than regularly expected, especially in systems that do not use contracted operators. For example, if the MTA closes a segment of a subway line mid-route, the running sections on either side will run turnback loops (turning around prior to the closed segment) and require more train operator and conductor crews as when the route runs normally (MTA).

In New York City, union laws put strict rules on operator availability to work overtime and operate shuttle routes, making careful planning of staffing and timelines key to cost savings.

Because shuttle routes must run for at least three months to be entered into the union pick, staffing can be a costly investment for the MTA for shorter diversions, when staff operate on 'volunteer' or overtime hours. In the example of a five-month shutdown, planners will strategically aim for the last three months of the shuttle to be a part of the pick, allowing the MTA to budget standard pay for operators driving this route. However, the first eight weeks of the shutdown would still need to be operated on overtime, as shutdowns rarely align perfectly with the pick schedule (MTA2). This is another example of an area for large cost-cutting opportunities, if enough advanced planning and cross-sectional collaboration is executed. Scheduling shutdowns around the union pick, and ensuring work is piggybacked during that time, can save both operator time and transit agency budget. This is an example emphasizing the need for local, specified knowledge in planning processes, and especially for a point-person or coordinator who may be spearheading timeline creation.

Consistent struggles with timelines, as discussed above, could be aided by process clarity resulting from detailed debriefs and documentation of each shutdown and the steps leading up to it. In New York City, where shuttle planning occurs less frequently due to rail diversion ability, there are less defined steps to diversion planning processes, leading to a high level of adaptation and step retracing (NYCDOT). In Washington, D.C., a lack of time and bandwidth makes shutdown post-mortems a 'nice-to-have' rather than a routine (WMATA2). Service planners expressed a desire for improved documentation of issues and fixes during shutdowns so that they are better able to anticipate challenges and plan for future shutdowns (WMATA2). Here, Boston's model stands out as well-coordinated, and benefits from a high volume of shutdown plans, requiring a routine to be established. The partnership between the MBTA and Boston's Transportation Department, assigning a Diversions Coordinator to keep track of moving pieces and collaborate with relevant parties helps to continue clarifying these processes. A diversions coordinator or point person reduces lack of clarity around roles and increases comprehension of specific tasks or processes each party should undertake. The less confusion

involved in processes, the fewer chances work is duplicated or forgotten, and the more room there is for squeezing in additional innovation and positive change in diversion planning processes.

Budget Capitalization

Throughout interviews and past literature, many challenges in diversion planning tied back to budget constraints. Often, budget was cited as a hinderance to further creative implementations or analysis around alternative service possibilities. Typically, diversion planning budgets are managed by the transit agency. In New York City, MTA usually serves as the project sponsor for shutdown projects, meaning that NYCDOT work done in relation to shutdown efficiency (pop-up bus lanes, signal modifications, turn restrictions, etc.) are typically part of the MTA project budget (NYCDOT). Budgeting structure can be a challenge when the budget has already been outlined, but additional changes are requested for NYCDOT to consider implementing. NYCDOT will make some temporary changes through their own budget (outside of the contract), but there is a limit to how much they can do, as their budget cannot account for all changes that the MTA may be interested in for a given shutdown (NYCDOT).

In Washington, D.C., budgeting for shutdowns is mainly managed by the street operations team who manages shuttles, as shuttles are the single largest budget line item for shutdowns (WMATA). Specific budget prescription can also be a barrier, as budget is meticulously outlined, making it difficult to work towards additional analyses or partnerships that might benefit shutdown services, as this would not have designated funding. For example, the DDOT Shared Micromobility has done little analysis of micromobility use during transit shutdowns. While this is a subject of interest, DDOT has a limited budget and must focus first on its responsibility to purchase more ebikes and build more stations in order to expand systemwide capacity. As budget dictates priority, analysis of the role of micromobility in transit shutdowns is unlikely to be further examined until it is designated in the budget breakdown (DDOT).

In Boston, The MBTA's service planners note that alternative service provision is expensive, but they continuously work on identifying creative solutions to reduce costs while decreasing congestion and customer inconvenience (MBTA). BTD also has its own budget for diversions, separate from the MBTA's diversions budget. The BTD diversions budget is split into capital and operational budget items, with any consultant, contractor, advocate, or other involved compensated parties' time split between these budgets as best fits with their responsibilities (BTD). Managing the BTD budget can be challenging, as the city is constrained by sticking to an allotted budget for all of the shutdowns for the year (BTD). Designating jurisdictional budget towards diversion planning can allow for greater focus on creative street-level implementations that reduce impacts to the local community, rather than this goal being a second priority to service provision in transit agency budgets. If transit agency service planning teams feel budget constrained with little opportunity to implement street-level changes to benefit the community, looking into opportunities for local jurisdictional partners to take over some of this work under their own budgets could allow for further innovation from both parties. Through the challenge of constrained budgets, we see that one of the largest opportunities to reduce costs while also reducing impacts to the local community is by creating strong partnerships and collaborations between departments. Budget constraints are also eased by piggybacking, for which opportunities are identified more clearly when planning processes are streamlined and stripped of confusion.

Politics, Public Opinion, and Communication

Potentially the most complex challenge in diversion planning is balancing politics and public opinion, as the goal of alternative services are to continue serving the public in times of disruption. Juwhan Lee of WMATA succinctly describes the challenge of balancing public desires with feasible service provision, saying "What's being requested and what we could deliver… that expectation, there's always a gap. But how do we minimize that?" (WMATA). The core challenge with public interfacing is the fact that customers' routines are disrupted or

burdened. The challenge service planners face here is getting customers comfortable with a different mode of transit, or a different route than they are used to. Laura Riegel, MBTA's Senior Director of Alternative Service explains,

> *"Their typical trip is disrupted, they're going to have to do something different, they're used to their train, they want to get on their train, they don't want to have to get on a bus. It's going to take longer because buses that are in traffic go slower than trains that are on fixed headway." (MBTA).*

It is easy for the public to perceive transit agencies as large organization with endless funding to make changes that would please the public, but the findings above suggest this is certainly not the case. Service planners go to great lengths to make shutdown services more palatable to passengers, aware that most riders will already be displeased with a disruption to their transit routines. For example, service planners work closely with Customer Experience teams to provide clear information around shutdowns, but there is only so much that can be done to encourage customers to read and absorb what is provided. Information provision includes translated materials, so that all customers receive relevant information. The MTA typically translates to twelve different languages, and BTD works with specific neighborhood representatives to identify the most common languages in the neighborhood for flier provision (MTA, BTD).

Communication and public perception are also barriers to the level of creativity that alternative service can take on, as service differing largely from standard will likely be more confusing and unfamiliar to the public. Laura Riegel explains the balance between creative strategies and comprehension, saying:

> *"There's a lot of stuff I think we would like to do more of but it's hard to communicate it to everybody and make sure people get the information in advance because most people just aren't paying attention. So we really have to balance how creative we can be to make a really good experience, but if people don't know about it, or don't know to do that thing - like if people don't know to*

show up on that other hour, it wouldn't matter that we did that. And we have a lot of customers who speak other languages, so all this information has to get translated, so a lot of work has to go into communication the changes, and if people don't pay attention, then it doesn't matter how much planning you put into it" (MBTA)

In essence, planners sometimes have to forego innovative solutions because they want to avoid adding extra comprehension difficulty onto passengers' journeys.

Negative public perception is quickly garnered during diversions, especially due to the high visibility of shuttle buses. The issue of having too many or too few buses is not only an issue of cost and resource procurement, but also of public perception. WMATA service planners spoke to the balance of determining the right number of buses, as lines of buses waiting around the block can sometimes be necessary to accommodate rush hour loads but may be perceived by the public as wasteful and a catalyst for congestion (WMATA). Service planners must be practiced in determining when customer complaints are just expressions of frustration around route changes, and when there is a legitimate operational or safety issue that should, and feasibly can, be fixed. In the case where complaints are addressable (largely those related to safety, efficiency, and messaging), service operations planners or supervisors stationed at shuttle stops will make the decision to implement the change, calling in the relevant parties and documenting the changes in daily meetings (MTA, MBTA).

Political collaboration is an added challenge to public perception, where political figures typically hold power to reflect and nudge public opinion. Sometimes, elected officials may request additional shuttle buses or more augmented existing services than what service planners propose. However, service planners have carefully estimated service needs based on ridership data and behavior during past shutdowns, settling on a number that will provide adequate service while keeping cost down. Buckley Yung of MTA explained that public officials sometimes over-ask for service, and that community boards and councilmembers can "underestimate the

resiliency of the bus customer" (MTA2). The service provision balance relies on careful planning, as well as the ability for transit riders to make their own decisions and adapt to the provided services. However, it is also a balance that public officials will usually try to sway towards being more customer-centric, and therefore incurring more costs (MTA2, MTA). Amanda Caparoso of BTD summarizes the challenge of balancing politics, public opinion, and service planning, sharing:

> *"...We have to try to make our leadership happy, while also making sure pedestrians are happy and transit riders are happy, and even people driving are happy. It can be very hard to balance all the interests, especially because they often conflict with each other. So a lot of the time it's hard because you're choosing between the lesser of two evils." (BTD)*

Continuing to work towards clear, accessible, and frequent communication of service changes is an opportunity for growth that transit agencies are actively working towards. Multiple planners spoke to wanting to expand outreach plans and streamline communication, working towards the public being better informed of diversions. One way to continue improving communication is to increase the robustness of outreach plans, with communications delegated from a central coordinator to various specific contacts representing impacted populations. Specifically, BTD's diversion planner mentioned wanting to increase collaboration with the disabilities commission to do more personal outreach to potentially impacted individuals, as well as working more closely with local business and school representatives to further mitigate shuttle-related impacts (BTD). Initiating the planning process for outreach at an earlier point in the overall timeline may allow for greater collaboration with various commissions and parties. This is a careful balance however, as initiating collaboration too early may lead to invitation for co-creation when this is infeasible, but initiating coordination too late can leave out certain stakeholders or make the public feel blindsided. To toe this line, planners should outline which groups should be pulled in

and at what point, at the beginning of the planning process, and aim to stick closely to this timeline.

Another opportunity related to public interfacing is increasing and improving digital communications during diversions. Planners spoke to various ways that customers could be provided with more information around diversions, including connecting shuttles to real-time trackers allowing for live shuttle tracking, and increased station countdown clock accuracy during diversions (WMATA, MTA). Both of these improvements would make trips more predictable and reduce frustration. Lastly, increasing the amount of information on transit agency websites was a common goal among various service planners (BTD, MTA). BTD's diversions planner specifically noted wanting more time to be able to provide explanations of changes happening as well as *why* they were happening. Additionally, more frequent service advisories and earlier start dates for information dissemination may help reach a greater population (BTD). By increasing information and decreasing public frustration, planners may also be able to work on more creative implementations and encourage mode- or route-shifts without being met with as much confusion or frustration.

Diversions as Windows of Opportunity for Transportation Improvements

It is clear from what has been gathered about the process of planning for diversions and alternative service provision that changes to the local street infrastructure are often made, and transit riders are often faced with new transportation routes or modes. Sometimes, these changes become permanent additions to the street infrastructure, or new, permanent transportation routines. These findings pose the opportunity that diversions may be opportunities to accomplish goals for the local transportation network – whether by pushing along infrastructure changes that would otherwise be slow to implement, or by familiarizing the local community with new routes and modes. Already, there are situations where service planners identify infrastructure deficiencies under standard conditions and are able to complete

improvements through diversion implementation work. Amanda Caparoso of BTD summarized this strategy as follows:

> *"When we're taking a closer look at these roads for shuttle operations, and because we have to do all these analyses, we do recognize that certain areas are underperforming and if we can and if we have the budget we really want to improve them, because, why not? We might as well make it better - we're here, we're implementing stuff, we're spending money on it, so we might as well make it a better space for all." (BTD)*

NYCDOT has also approached shutdowns as an opportunity to try out new implementations and respond to community requests. An NYCDOT transit planner compared the window of opportunity shutdowns provide to COVID-19, which although a tragedy with countless negative impacts, was a window of time where things operated differently than usual, spurring change and innovation (NYCDOT). Sometimes, these opportunities for fast-tracked, positive change may just be simple fixes that can be covered under the diversions budget, due to their relation to the project and work area. The following cases exemplify this idea.

- ⇒ In 2024, BTD made seven shuttle stops (and thus the curb space they occupied) ADA compliant through sidewalk repairs, improving both shuttle stops and the standard pedestrian experience. (BTD).
- ⇒ Through site visits and turn analyses, BTD identified an intersection that posed potential issues for shuttles getting through. They were able to permanently add a yield sign that had been missing and reconfigure the intersection to push the stop line back and repaint the roadway's center line (BTD). These changes not only aided diversions by easing shuttle turns in the intersection, but also permanently improved turning safety for passenger vehicles (BTD).
- ⇒ NYCDOT was able to improve congestion along the Manhattan Avenue corridor by creating eight truck loading zones on the street as part of a diversions plan, decreasing

the presence of double-parking during loading. While this was a change implemented for the shutdown, it was advertised to the public as a permanent change and continued to decrease congestion even post-shuttling (NYCDOT).

Pop-up bus lanes emerged as one of the larger-scale opportunities for positive, sometimes permanent change that could result from diversion planning. The cases below provide further details around bus lanes resulting from diversion planning.

- ⇒ After exhibiting the benefits and minimal negative impacts of a bus lane on Georgia Ave that was initially planned for a shutdown, WMATA was able to push for conversion to a permanent bus lane (WMATA2, WMATA3). WMATA's bus priority team collected data on the bus lane, related traffic speeds, travel time, and safety implications during the shutdown collecting justification for permanent implementation (WMATA3).
- ⇒ NYCDOT collected substantial data on a pop-up bus lane implemented as part of a diversion plan. While they removed the bus lane following the shutdown due to promises to the public, NYCDOT now has data that can form the basis for a permanent project development plan (NYCDOT).

As illustrated by these examples, transit disruptions are unique periods where more drastic transportation measures may be accepted to fulfill demand not being met by standard means. This provides a 'test-run' of sorts, where planners and public alike can observe how well an implementation works, and any related negative impacts. These are particularly useful trial periods if the main resistance to an implementation is fear of change, in which case a situation like a transit disruption may be the perfect opportunity to showcase the benefits of roadway implementations like bus lanes.

As exemplified by the cases below, this perspective can also be used to encourage more sustainable and efficient transportation options that customers may never consider if not for a transit shutdown.

⇒ The MBTA advertised fare-free commuter rail service as an alternative to the Orange Line during a 2022 shutdown, which quickly gained immense popularity as an alternative option. So much so that additional commuter rail service to Forest Hills was added to meet the new demand, which was sustained even after the shutdown ended (MBTA).

⇒ Bikeshare programs have experienced increased business during transit disruptions, often introducing new users to the service. Boston's BlueBikes program documented 16,000 trips taken using one of the diversions discount codes that BTD publicized, with a significant number of riders being new users registering for the service for the first time during the shutdown (BTD).

Thus, diversions are not only opportunities for planners to push through infrastructure changes but are also windows where transit riders may become familiar with new transportation modes or routes. Sometimes, transportation offerings advertised during these periods may be more convenient than customers' previous routines, leading to a permanent switch. Typically, encouraging different travel habits can be slow due to the tendency for people to continue using travel modes and routes with which they are familiar. However, windows of transit irregularity may provide the stimulus for people to try new transportation modes or routes that they would not otherwise experience. In this vein, diversions can be thought of as effective periods for building familiarity with new modes or routes and should be used as such by transportation planners. While shutdowns can be used as opportunities to encourage new transportation habits or to implement permanent infrastructure changes, these innovations rely on a certain level of process clarity and streamlining in order to realize the appropriate windows of opportunity in the first place.

Chapter 6 – Conclusion

Through a comprehensive outline of the diversion and alternative service planning processes in Boston, New York City, and Washington, D.C., this thesis identifies opportunities for rapid transit

diversions to be used as catalysts for change in the field of transportation planning. Literature largely paints transit disruptions as problems to solve, with little focus on the steps involved in planning for diversions and alternative service, or how processes could become more streamlined. Through qualitative interviews, this study identified that planning for transit disruptions requires a high level of collaboration, along with timeline and budget management. These findings reinterpret the sentiment of transit disruptions as the public and previous literature typically view them. It is true that disruptions are costly, inconvenient, and require long, arduous planning processes. However, it has also become apparent that there may be opportunities for transportation planners to implement positive change by way of transit disruptions. Multiple examples from interviews pointed to clear moments where street infrastructure improvements were made possible through diversion assessments and implementations. Similarly, planners spoke to ways in which transit customers must adapt to new routes or methods during disruptions. Borrowing what is known from previous travel behavior literature – individuals will continue to take the route or mode with which they are familiar – diversions offer a test period for new modes and routes, with which individuals may then become more familiar.

The clear theme of transit diversions as windows of opportunities for street infrastructure implementations and new travel behaviors may be seen as an idealistic one if not paired with clear planning processes and streamlined collaboration. Highlighting the finding that those planning for diversions and alternative service provision are largely limited by time, money, and resources, it would be a disservice to suggest that all planners immediately adopt the 'window of opportunity' perspective around diversions. Instead, the ability to work creatively with a positive outlook towards potential improvements requires alignment earlier in the process. This thesis points to various opportunities for transit agencies to increase their collaboration and streamline work through a specific point-person or team, ideally within or with connections to local

jurisdictions. Similarly, clarifying roles, timelines, and processes can help align work needs, increasing the frequency of piggybacking and reducing costs as well as community impacts.

While this study highlights opportunities for diversion planning process growth and allows for the comparison of processes between cities, it was also limited by the timeframe and scope of a thesis project. Cognizant of the complications that wildly different environments or transit systems would have added to this study, three relatively similar transit systems and city study areas were used. However, this study lacks discussion around the overall transportation and rail density of all three cities, compared to other transit networks the country. Future research may benefit from comparing newer transit networks and their diversion planning processes to some of the older systems focused on in this paper, especially as newer systems reach the age where maintenance-related shutdowns become necessary.

The timeline of this study also limited interviews to primarily transit agencies and jurisdictional partners. As displayed in the Stakeholders section, there are numerous teams from transit agencies, local governing bodies, and other organizations involved in disruption and alternative service planning processes. Future research may be able to uncover additional, less transit agency-centric opportunities for diversion planning. Speaking to stakeholders who less frequently collaborate with transit agencies may also shed light on necessary changes for improving communication processes between parties.

Appendix I

Additional Methodology Details

An example of how findings were tagged by theme can be found below. This process utilized google sheets.

Note	Theme
Finding 1	Proactive Planning, Service Provision
Finding 2	Challenges and Barriers
Finding 3	Routing, Creative Alternatives and Strategies, Active Transportation
Finding 4	Data Sources and Justification, Resource Procurement

Appendix II

Interview Guide Note: this document serves as a guide for all interview possibilities. As the length of this document would take longer than the proposed interview time of 60-mintues to complete, questions will be prioritized prior to the interview based on the participant's role and experience (collected from background research). Other questions within the guide may be selected or passed depending on the flow of conversation. The guide is. Not meant to be a full script.

ROLES & RESPONSIBILITIES

1. **Tell me about your current role at** [CITY/TRANSIT AGENCY]
2. **At** [CITY/TRANSIT AGENCY], **who is involved in plans for service disruptions?** [PROBE: who oversees this work? Which teams are involved?]
3. **How are you involved in planning for service disruptions?** [PROBE: what is your role/responsibility in this process?]
    a. Tell me about a recent service disruption you were involved in planning for. What were your daily tasks? Who did you work with? What challenges did you encounter? How did you assess the success of your plans?
4. **What requirements, if any, exist for service disruption plans?** [PROBE: service must be replaced in some way, at least X% of typical capacity must be provided, etc.]

MITIGATION STRATEGIES

5. **I'd like to hear about the interventions** [CITY/TRANSIT AGENCY] **typically planned during service disruptions. I know a leading strategy for continuing service is by providing shuttle busses. Could you tell me more about what goes into planning shuttle bus replacement service?**
    a. What factors are considered when planning the routes, schedules, and fleet sizes for these replacement shuttle buses?
    b. What are some of the common challenges in this process?
    c. Who is involved in planning for these replacement shuttle buses?

d. If you had all the resources and time in the world, is there anything you would do to change the way that shuttle buses are planned for?

6. **What other strategies does** [CITY/TRANSIT AGENCY] **implement to provide continued service and ensure people are able to get where they need to go?** [PROBE: Free charge for buses, free charge for blue bikes, express buses, etc.]
    a. What factors are considered when planning the routes, schedules, and demand of [mentioned strategy]?
    b. What are some of the common challenges in this process?
    c. Who is involved in planning for [mentioned strategy]?
    d. If you had all the resources and time in the world, is there anything you would do to change the way that [mentioned strategy] is planned for?
7. [IF NOT MENTIONED] **Does** [CITY/TRANSIT AGENCY] **ever form service disruption plans centered around bike or pedestrian mobility? If so, what do these plans consist of?** [PROBE: Are these plans focused on mitigating negative impacts to preexisting bike/ped infrastructure? Or are these plans focused on increasing bike/ped infrastructure capacity during shutdowns to accommodate greater demand?]
    a. [IF YES] Who is in charge of bike/ped-planning during service disruptions?
        i. How does bike/ped planning interact with other aspects of service disruption planning, if at all?
        ii. If you had the power/ability to, would you change anything about the way that bike/ped-focused planning is conducted for service disruptions?
    b. [IF NO] Why do you think [CITY/TRANSIT AGENCY] does not engage in bike/ped-focused plans during service disruptions?
        i. In your opinion, would bike/ped-focused plans during service disruptions be useful?
        ii. What would be needed in order to incorporate bike/ped-focused plans into service disruption planning? [PROBE: what barriers exist? What types of resources would be needed to overcome these barriers?]

COMMUNICATION

8. **Who is in charge of communications around service disruptions?**
    a. What does this process look like? [PROBE: are the disruptions communicated in the same way that the replacement services/alternatives are?]

9. **What communication methods are used to provide information around service disruption plans and alternatives?** [PROBE: communication channels, language and wording used, engagement, etc.]
    a. Do you think these methods are effective? Why/why not?
    b. What, if anything, would you change about the way that service disruptions and any associated plans are communicated to riders and the wider local community?

BARRIERS, RESTRICTIONS, AND LOCATION-SPECIFIC PLANNING

10. **I'd like to hear a little bit more about the current barriers, restrictions, and limits to planning for service disruptions. When you hear limits to service planning, what's the first thing that comes to mind?**
    a. [IF NOT MENTIONED] How does [insert any of the below] play a role in planning for service disruptions?
        i. Infrastructure
        ii. Scheduling/capacity
        iii. Budget
        iv. Environment
        v. Policy
11. **How do you think planning for service disruptions in [CITY] might differ from planning for service disruptions in other cities or regions? Why?**
12. **What type of data or information do you, or others at [CITY/TRANSIT AGENCY] use to inform plans for service disruptions?**
    a. Are there any additional data or information sources that you think would benefit this process? How so?

VISION & IDEAL PLANNING PROCESS

13. **In a perfect world, what would the process for service disruption planning look like to you?** [PROBE: additional alternatives offered, modes shifted to, other mitigation strategies, etc.]
    a. Do you think this is a common vision? Why/why not?
14. **What would you change about the current service disruption planning process? Why?**

CLOSING

15. Before we end, is there anything else you would like to add about your involvement in service disruption planning, current mitigation strategies, or what you would like to see changed in disruption planning processes?

Thank you so much for your participation!

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